И. Д. ЛЕПЕШОВА, Т. И. САВОЩЕНКО

# УЧЕБНИК АНГЛИЙСКОГО ЯЗЫКА ДЛЯ СТУДЕНТОВ СТАРШИХ КУРСОВ ФИЗИЧЕСКИХ ФАКУЛЬТЕТОВ

*Допущено Министерством высшего и среднего специального образования СССР в качестве учебника для студентов физических специальностей высших учебных заведений*

ИЗДАТЕЛЬСТВО МОСКОВСКОГО УНИВЕРСИТЕТА
1973

Печатается по постановлению
Редакционно-издательского совета
Московского университета

Под редакцией Л. Ф. Парпарова



Л $\frac{0714-009}{077(01)-73}$ 79—73

## ОТ РЕДАКТОРА

Предлагаемый учебник предназначен для студентов-физиков старших курсов и ставит перед преподавателем цель научить студентов речевым умениям и навыкам, необходимым для чтения и понимания оригинальной литературы по специальности, а также для выражения своих мыслей в монологической и диалогической форме в пределах тематики по специальности.

Для достижения этих целей в процессе обучения английскому языку следует исходить из следующих положений:

чтение и устная речь — это виды речевой деятельности, являющиеся как целью, так и средством обучения иностранному языку;

перевод и письмо — вспомогательные средства обучения, входящие в систему упражнений при объяснении или контроле лексического и грамматического материала; перевод, кроме того, — одно из средств контроля понимания прочитанного.

Главное внимание в процессе преподавания уделяется развитию разговорных навыков.

Учебник построен на неадаптированных текстах научно-публицистического характера, связанных со специальностью студентов. Отдельные статьи несколько сокращены, что было вызвано методическими задачами, стоящими перед авторами. В материалах учебника, взятых из американских источников, сохраняется американское написание.

Учебник состоит из 36 уроков, имеющих в основном одинаковую структуру. Исходя из практических возможностей, авторы сочли необходимым выделить строгий минимум слов (около 370 лексических единиц), подлежащих обязательному запоминанию. Список слов, подлежащих запоминанию, помещается в начале урока, в разделе Active Vocabulary. В этом разделе даются определения значений этих слов, приводятся примеры их употребления, а также там, где авторы сочли необходимым, даются производные синонимы и антонимы к вводимым лексическим единицам.

Для закрепления лексических единиц, предназначенных для активного усвоения, дается ряд предтекстовых упражнений.

В каждом уроке имеется основной текст, предназначенный прежде всего для развития навыков чтения и перевода.

После основного текста помещены задания: упражнения на активное усвоение лексики, на перевод, вопросы к тексту и по теме, пересказы, устные сообщения и др. Задания (перевод с листа, на слух, письменный) даны ориентировочно. Преподаватели могут, исходя из конкретной обстановки, видоизменять их.

Тематика бесед и сообщений увязана с темой основного текста урока.

Грамматический материал дается в порядке повторения и систематизации, так как прохождение его уже закончено в основном курсе английского языка. Грамматические упражнения включают лексику данного урока и всего предшествующего курса обучения. Работа над закреплением грамматических явлений не есть самоцель: она играет подчиненную роль и направлена на овладение важными грамматическими формами и явлениями, свойственными устной и письменной речи научно-технической литературы.

Часть послетекстовых заданий учебника может использоваться для повторения учебного материала в конце семестра и учебного года.

Работа над каждым уроком учебника должна проводиться в течение 2—4-х часов аудиторных занятий и 2—4-х часов самостоятельной работы. При недостаточной языковой подготовленности групп могут использоваться не все упражнения урока.

Деление упражнений и послетекстовых заданий на «аудиторные» и «домашние» в учебнике не дается. Оно осуществляется преподавателем в зависимости от индивидуальных условий работы с учебной группой.

Как показывает опыт, очень эффективной является работа в лаборатории устной речи. Поэтому целесообразно широко использовать ее при выполнении рекомендованных учебником упражнений.

Уроки 1, 5, 6, 8, 9, 10, 11, 12, 13, 17, 18, 19, 21, 22, 23, 24, 28, 29, 33, 34 и 35 составлены И. Д. Лепешовой, уроки 2, 3, 4, 7, 14, 15, 16, 20, 25, 26, 27, 30, 31, 32 и 36 — Т. И. Савощенко.

Всем товарищам, которые пожелают высказать свои замечания и пожелания по данному учебнику, просьба направить их по адресу: МГУ, кафедра английского языка для физического факультета.



## ОТ АВТОРОВ

Авторы приносят глубокую благодарность зав. кафедрой английского языка физического факультета МГУ, доценту Л. Ф. Парпарову за большую помощь в работе над материалом учебника, зав. кафедрой иностранных языков Московского физико-технического института, доценту М. В. Круть, старшему преподавателю этой кафедры Н. А. Маклецовой, зав. кафедрой английского языка Московского энергетического института, доценту В. М. Макеевой, доценту кафедры английского языка гуманитарных факультетов МГУ Т. А. Абрамкиной, преподавателю кафедры английского языка физического факультета МГУ Т. Г. Сеидовой за ценные советы и указания, сделанные в рецензиях, а также всем преподавателям кафедры английского языка физического факультета МГУ, принявшим участие в обсуждении рукописи.

# LESSON ONE

## Active Vocabulary

### skill, *n.*

1. Skill is the ability to do something well; expertness.
2. Skills disappear when we don't put them to work.
3. He showed a certain skill in carrying out this experiment.

*Derivatives:* skilled, skillful, skillfully.

E. g. skilled work (i. e. work which can be done only by trained and experienced men).

*Synonym:* art.

### opportunity, *n.*

1. Opportunity is a convenient or favourable time or occasion; a good chance.

To find (to make, to afford) an opportunity to do something; to have no (not much, little, not any) opportunity for doing (to do) something.

2. I'm glad to have this opportunity of speaking (to speak) to you.

*Synonyms:* occasion; chance.

### demand, *n.*

1. Demand is asking for something as a right; need; wish to get.
2. It is impossible to satisfy all their demands.

*To be in (great) demand*

3. These goods are not much in demand just now.
4. He is always in great demand as a speaker at public meetings.



### demand, *v.*

1. To demand is to ask for boldly, as if one has a right.
2. He came to my house and demanded that I should help him.
3. He demanded to be told everything (=said that they must tell him everything).
4. This sort of work demands great patience.
5. This letter demands an immediate answer (=it's necessary to answer it at once).

*Synonym:* to require.

### appreciate, *v.*

1. To appreciate is to judge the value of; understand or enjoy fully in the right way.
2. You can't appreciate English poetry unless you have a good knowledge of how English is spoken.
3. We all appreciate a holiday after a year of hard work.
4. I greatly appreciate your kindness.
5. We want students to appreciate the significance of these experiments.

*Derivative:* appreciation.

*Synonyms:* to value; to prize; to understand.

### consume, *v.*

1. To consume is to destroy; to waste; to use up.
2. The flames consumed the whole building.
3. He was so hungry that he consumed everything that was put before him.
4. Some experiments are technically impractical, others too time-consuming.

*Derivative:* consumption.

E. g. energy consumption; heat consumption; power consumption.

*Synonyms:* to waste; to use up.

### encourage, *v.*

1. To encourage is to give hope, confidence, courage or help; to urge on; to cheer; to support.
2. The conversation was skillfully encouraged by him.
3. The example of the Great October Socialist Revolution encouraged struggling peoples to fight for their liberty.
4. The boy felt encouraged by his progress.
5. The teacher should encourage his students in their studies.

*Derivative:* encouragement.

*Synonyms:* to support; to stimulate.

*Antonym:* to discourage.

### propagate, *v.*

1. To propagate is to spread from one person to another; to pass on, as to propagate news; to send on; transmit, as to propagate heat.
2. Radio waves are propagated over long distances by alternate reflections at the ground and in the ionosphere.
3. This research was also the beginning for the whole new technology of electromagnetic-wave propagation.
*Derivatives*: propagation, propaganda.
*Synonym:* to spread.

### suit, *v.*

1. To suit is to satisfy; to be convenient to; to meet the needs of; to fit; to be in accordance with.
2. The seven o'clock train will suit us very well.
3. Will that time suit you?
*To suit with*=to agree with
4. The position suits with his abilities.
*Derivatives*: suitability, suitable.
E. g. Food suitable for human consumption.
*Synonyms:* to satisfy; to fit.

### verify, *v.*

1. To verify is to test the truth or accuracy of; to check; to confirm; to show to be true by results; to fulfil; to bear out.
2. Experimental data verified the theory.
3. He verified the details of the case.
*Derivatives*: verifiable, verification.
*Synonym:* to confirm.
*Antonyms:* to deny; to reject.

### brief, *adj.*

1. Brief is short; lasting only a short time.
2. He made some brief remarks on the subject.
3. They mentioned the fact in a brief summary of the day's news.
*In brief*=in a few words.
4. Say it in brief!
*Derivative:* briefly.
*Synonym*: short.
*Antonym:* long.



## Exercises

### 1. Give the English for:

a) умение, мастерство; удобный случай, благоприятная возможность; требование, запрос; требовать, предъявлять требование; оценивать, высоко ценить; потреблять, расходовать, поглощать; ободрять, поощрять, поддерживать; распространять(ся), передавать на расстояние; удовлетворять требованиям, быть удобным, устраивать; быть полезным, пригодным; подтверждать; короткий, краткий, сжатый;

b) квалифицированный рабочий; найти благоприятную возможность; пользоваться большим спросом; поглощение тепла; распространять электромагнитные волны; подтверждать теорию; краткое замечание.

### 2. Give the Russian for:

a history of physics laboratory; to appreciate the significance; precision measurement; a television tube; a tape recorder; a laboratory experiment; time-consuming; experimental skill; electromagnetic-wave propagation; brief life; high-frequency electromagnetic-wave trains; to verify the relation.

### 3. Give derivatives of the following words:

skill; to consume; to appreciate; to verify; to encourage; brief.

### 4. Give synonyms of the following words:

chance; to value; to waste; to fit; to spread; to confirm; to require; short.

### 5. Read the following words:

vehicle ['vi:ikl]
ingenuity [,indʒi'nju:iti]
series ['siəri:z]
essence [esns]
essential [i'senʃəl]
essentially [i'senʃəli]
controversy ['kɔntrəvə:si]
technique [tek'ni:k]
viable ['vaiəbl]
quantity ['kwɔntiti]
quantitative ['kwɔntitətiv]
to designate ['dezigneit]
designation [,dezig'neiʃən]
to appreciate [ə'pri:ʃieit]
appreciation [ə,pri:ʃi'eiʃən]
particular [pə'tikjulə]
particularly [pə'tikjuləli]
to sophisticate [sə'fistikeit]
sophistication [sə,fisti'keiʃən]
endeavo(u)r [in'devə]

## A HISTORY OF PHYSICS LABORATORY

*A laboratory in which students can reproduce historically significant physics experiments provides them with a useful change of viewpoint.*

by Samuel Devons and Lillian Hartmann

During the past few years we have been developing, at Columbia and Barnard Colleges, a somewhat unorthodox vehicle for teaching physics, a combination laboratory and library designated a history of physics laboratory. In it some of the experiments that have played a major role in the development of physics, for example those of James Joule, Heinrich Hertz, Michael Faraday and Charles Coulomb, are being reconstructed, with proper attention to their significant historical features. The methods and materials used in these experiments are essentially those used originally. We want to provide students with an opportunity to repeat these experiments and to appreciate the significance of each in its historical context.

Not all (nor even most) historically interesting experiments are suitable for a history of physics laboratory. Some experiments are technically impractical, others too time-consuming. Many do not, in their historical setting, particularly illumine the logical structure or context of the subject. (Technical scale elaboration as well as conceptual sophistication are, incidentally, factors that mitigate against the choice of many important contemporary experiments for instructional purposes, and so lead one to seek illustrative material from the past.) But many of the experiments important in the development of physics are suitable. They range from the most elementary to the quite sophisticated. We have chosen some 25-30 experiments or groups of experiments that were of major importance in advancing the physics of this day.

Consider, for example, the significance of Hertz's experiments for their own time. Few physicists have equaled the outstanding combination of experimental skill and ingenuity and great analytical power that Hertz brought to his researches. This research was not only decisive in placing James Clerk Maxwell's electromagnetic theory beyond the range of controversy, but was also seminal for the whole new technology of electromagnetic-wave propagation. In his brief life (1857—1894), Hertz set out to test Maxwell's theory and its major prediction, free electromagnetic waves with velocity equal to that of light. He succeeded at this task in a remarkable series of experiments, but first he developed the essential techniques for generating and detecting very high-frequency electromagnetic-wave trains. Making quantitative measurements, inferring frequencies (in the range $10^9$ cycles/sec), measuring wavelengths and ...rifying the relation $\lambda\nu = c$ were quite spectacular accomplishments ...ve time when techniques for quantitative measurements were com- at a ... nly at frequencies many, many orders of magnitude lower. mon o...



Another experiment we have chosen to reproduce is Cavendish's demonstration of the inverse-square law of force, now commonly known as Coulomb's Law. Cavendish did his investigations more than a decade before Coulomb's but, because they were largely unpublished, their significance was not fully appreciated. More than 100 years later (1879) this remarkable series of experiments became known through a publication edited by Maxwell. Cavendish's method of investigating the law of force between charges is, although less direct, capable of far higher precision than Coulomb's.

In each case the equipment is more or less a copy of that described in the original publications, although not with all the minutiae that might be considered important for museum exhibits. We have tried, however, not to err by modernizing techniques or materials to the extent that a historically essential feature could be misrepresented. Where small, but not physically trivial, changes must be introduced, for example to reduce the time (or skill) demanded of the student, we have drawn attention to these changes and their purpose. More importantly, one cannot in most cases expect a student to retrace all the actual steps, the whole sequence of searching, probing, trial and error to which so often, the «historic» experiment was a crowning climax. Here we rely on documentary material to provide the necessary setting.

What evidence we have of the value and viability of our approach is meager but encouraging. It does seem possible that one can, through a history of physics laboratory, make a modest contribution to the better understanding of both physics itself and its significance as a part of human endeavor. For some students, at least.

*Physics Today*
*February 1970.*

### Exercises

**I. Translate into Russian paying attention to Nouns used as Attributes:**

1. Radio-wave propagation velocity was the next major problem for him to solve.
2. Four-element theory developed by ancient philosophers was of interest for the later scientists.

3. It can provide an introduction to the art of experimentation, a training in precision measurement, an opportunity to develop skill in observation or to gain familiarity with the properties and limitations of actual materials and techniques.

4. He succeeded at this task in a remarkable series of experiments, but first he developed the essential techniques for generating and detecting very high-frequency electromagnetic-wave trains.

5. A laboratory in which students can reproduce historically significant physics experiments provides them with a useful change of viewpoint.

6. We have developed a somewhat unorthodox vehicle for teaching physics, a combination laboratory and library designated a history of physics laboratory.

7. Technical scale elaboration as well as conceptual sophistication are, incidentally, factors that mitigate against the choice of many important contemporary experiments for instructional purposes, and so lead one to seek illustrative material from the past.

8. This research was also seminal for the whole new technology of electromagnetic-wave propagation.

9. In each case the equipment is more or less a copy of that described in the original publications, although not with all the minutiae that might be considered important for museum exhibits.

## II. Translate into English using the active vocabulary of the lesson:

1. Мы хотим предоставить студентам возможность повторить эти эксперименты.

2. Студенты должны оценить историческое значение каждого из этих экспериментов.

3. Вас устраивает это время?

4. Одни эксперименты являются технически трудно осуществимыми, другие занимают слишком много времени.

5. Каждый физик должен обладать мастерством экспериментатора.

6. Исследование Герца положило начало созданию новой техники распространения электромагнитных волн.

7. За свою короткую жизнь он сумел сделать очень много.

8. Результаты эксперимента подтвердили теорию.

9. Они не смогли полностью оценить значение этого эксперимента.

10. Опыт потребовал от студентов определенного мастерства.

11. Молодой ученый был воодушевлен своим первым успехом.

12. Это было для нас подходящим случаем еще раз подбодрить этого способного студента.



## III. Catch the meaning of the text and retell it:

*The instructional laboratory*

As a supplement to other physics courses, the laboratory offers a means of illustrating physical principles and their application in "real" situations. It can provide an introduction to the art of experimentation, a training in precision measurement, an opportunity to develop skill in observation or to gain familiarity with the properties and limitations of actual materials and techniques. It might be a place simply to observe interesting and unusual physical phenomena. There are, however, limitations to all these opportunities.

Consider first the art of experimentation. This should include the conception of an experiment as well as design of the apparatus that materializes the concept; in the instructional laboratory the apparatus usually must be set up beforehand. Presicion measurement? Potentialities of the apparatus are limited, and even these cannot usually be fully exploited in the time available. Critical observation? The student must be told what he should observe, or too much is left to chance. Properties of materials and instruments? The equipment is ready-made, and the student does not usually know how or why.

## IV. Give the situations from the text in which the following words are used:

skill; opportunity; to appreciate; to consume; to encourage; propagation; to verify; suitable; brief.

## V. Give questions to which the following statements might be the answer:

1. The methods and materials used in these experiments are essentially those used originally.

2. Not all (nor even most) historically interesting experiments are suitable for a history of physics laboratory.

3. Some experiments are technically impractical, others too time-consuming.

4. Few physicists have equaled the outstanding combination of experimental skill and ingenuity and great analytical power that Hertz brought to his researches.

5. In his brief life Hertz set out to test Maxwell's theory and its major prediction, free electromagnetic waves with velocity equal to that of light.

6. The evidence we have of the value and viability of our approach is meager but encouraging.

### VI. Translate the following Russian questions into English and answer them:

1. Какие эксперименты являются наиболее подходящими для лаборатории истории физики?
2. Имеют ли студенты возможность повторить исторические эксперименты?
3. Как мы можем оценить экспериментальное мастерство Герца?
4. Проводил ли Герц эксперименты по распространению электромагнитных волн?
5. Какой эксперимент был в свое время оценен не полностью?
6. Можно ли с помощью лаборатории истории физики лучше понять собственно физику и ее значение?

### VII. Render in English:

В качестве постулата Кулон принял, что сила взаимодействия двух электрических зарядов пропорциональна произведению этих зарядов. Сформулировав этот постулат, Кулон исследовал распределение электричества на проводниках. Он установил, что электричество распределяется по поверхности проводника (чтобы убедиться в этом, он повторил, в частности, опыт Кавендиша с двумя полусферами). Основываясь на законе обратных квадратов, он доказал это свойство теоретически. Далее он показал, что электричество распределяется равномерно по поверхности изолированной проводящей сферы; исследовал распределение на нескольких проводящих сферах, примыкающих друг к другу, а также показал, что наэлектризованное тело индуцирует на проводнике равные количества электричества противоположного знака.

### VIII. Answer the following questions:

1. What is the aim of creating a history of physics laboratory?
2. Are all historically interesting experiments suitable for a history-of-physics laboratory?
3. Why are some of these experiments not suitable for a history of physics laboratory?
4. How many experiments that were of major importance in advancing the physics of this day have the scientists chosen?
5. What is the significance of Hertz's experiment for his own time?
6. What experiments were the first confirmation of James Clerk Maxwell's electromagnetic theory?
7. What did Hertz set out in his brief life?
8. Why has Cavendish's demonstration of the inverse-square law of force between charges been chosen to reproduce in the history of physics laboratory, but not Coulomb's experiment?





9. What is the significance of Hertz's experiment for technology of electromagnetic-wave propagation?
10. Why was the significance of Cavendish's demonstration not fully appreciated?

### IX. Review the article «A History of Physics Laboratory».

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. Hertz's experiments.
2. Cavendish's experiments and the nature of electric forces.
3. The aim of physics practicum.

## LESSON TWO

### Active Vocabulary

**account, *v*.**

1. To account means to give a report on something; to give a justifying analysis or explanation.
2. The students accounted satisfactory for their work.
3. It is a consistent theory which accounts for the facts.

*Derivatives:* accountable, accountably.
*Synonyms*: to consider; to explain.

**bind, *v*.**

1. To bind means to confine with or as if with chains or other bonds so as to deprive of freedom.
2. Heat causes clay to bind.
3. This problem is bound up with others.

*Synonyms:* to connect; to unite.

**conceive, *v*.**

1. To conceive means to take into one's mind; to form a conception of something; to imagine.
2. The building was badly conceived and carelessly constructed.
3. Who first conceived the idea of using gas to fill the balloons and so moving through the air?
4. I can't conceive of your allowing a child to go such a long way.

*Derivative:* conceivable.
*Synonym:* to think.

**found, *v*.**

1. To found means to take the first steps in building something; to set or ground on something solid.



2. Moscow was founded in 1147.
3. The winds blew and beat upon the house but it did not fall because it had been founded on the rock.

*Derivatives:* foundation, founder.
*Synonym:* to establish.

**infer, *v*.**

1. To infer means to derive as a conclusion from facts; to carry or bring into.
2. An unknown fact can be inferred from a known fact.
3. Task of physical science is to infer knowledge of external object from a set of signals passing along our nerves.
4. The child infers the existence of an environment which is not part of itself.

*Derivative:* inference.
*Synonyms:* to conclude; to judge.

**offer, *v*.**

1. To offer means to present for acceptance or rejection.
2. He offered himself as a candidate for going to Leningrad.
3. Candidates for the degree may offer English as one of their foreign languages.

*Synonyms:* to present; to suggest.

**provide, *v*.**

1. To provide means to supply with what is needed for support; to supply for use; to equip.
2. People living in the North of the U.S.S.R. are regularly provided with everything they need.
3. He was provided with an excellent education.
4. The children were provided with all necessary books.

*Synonyms*: to supply; to furnish.

**put, *v*. (forward)**

1. To put forward means to propose; to start out.
2. He was put forward as a spokesman for the party.
3. The shortage of qualified people gave him the opportunity to put himself forward.
4. Any single fact must be put forward in support of this idea.

*Synonym:* to propose.

**arbitrary, *adj*.**

1. Arbitrary means according to one's own wishes or ideas.
2. They are discussing such arbitrary items as clothing, room furnishing, travel.

3. He was a man of iron will and arbitrary decision.
*Synonym:* absolute.

**in terms of, *prep.***

1. In terms of means with respect to; in comparison with.
2. One can describe how matter interacts with matter in terms of its location in the fixed space-time.
3. Faraday recognized that Newton's gravitational force need not be viewed in terms of this model.

## Exercises

**1. Give the English for:**

a) объяснять; связывать; представлять себе; основывать; подразумевать; предлагать; предоставлять, давать; выдвигать; произвольный;
b) объяснить с точки зрения; предлагать план работы; предлагать помощь; обеспечивать всем необходимым.

**2. Give the Russian for:**

to account for the behaviour; to bind matter together; to conceive a concept; to found a scientific school; this is what must be inferred; to offer an explanation; to provide the inspiration for; to put forward a theory; arbitrary invention; to be explained in terms of forces.

**3. Give derivatives of the following words:**

to account; to conceive; to found; to infer; to provide.

**4. Give synonyms of the following words:**

to explain; to connect; to think; to establish; to judge; to suggest; to supply; to propose.

**5. Read the following words:**

to postulate [ˈpɔstjuleit]
postulate [ˈpɔstjulit]
to conceive [kənˈsi:v]
conceivable [kənˈsi:vəbl]
philosophy [fiˈlɔsəfi]
philosopher [fiˈlɔsəfə]
anonymous [əˈnɔniməs]
mechanism [ˈmekənizm]



species [ˈspi:ʃi:z]
finite [ˈfainait]
regular [ˈregjulə]
irregular [iˈregjulə]
to rarefy [ˈrɛərifai]
rarefaction [ˌrɛəriˈfækʃən]
alternative [ɔ:lˈtə:nətiv]
to incorporate [inˈkɔ:pəreit]
incorporation [inˌkɔ:pəˈreiʃən]
precipitation [priˌsipiˈteiʃən]
phenomenon [fiˈnɔminən]
phenomena [fiˈnɔminə]

## EARLY VIEWS ON FORCES BETWEEN ATOMS

*Greek philosophers first conceived an atomic theory of matter and scientists after the Renaissance speculated on interatomic forces. More detailed theories awaited 12th-century experimental results.*

by Leslie Holliday

Is matter continuous or is it made up of discrete fundamental particles? If it is particulate, is there one kind of fundamental particle or are there many? What are the forces that bind matter together? Can the properties of matter be explained in terms of forces? Is there one kind of force or more than one? Mankind first began to ask some of these questions more than 2,500 years ago. We are still trying to answer them today.

The story begins about 600 B. C. with the speculations of the Greek philosophers Thales, Anaximander and Anaximanes, who founded the world's first scientific school in the Ionian city of Miletus in Asia Minor.

Thales put forward the theory that the underlying principle of matter was matter, a ubiquitous substance that could exist as a vapor, a liquid or a solid.

Anaximander of Miletus also postulated a single substance, something anonymous and indetermined that could exist in four forms: Earth, Mist, Fire and Water. Anaximenes, the last Milesian philosopher of note, offered an alternative explanation: that Mist or Air (pneuma) was transformed into various forms of matter by the twin processes of rarefaction and condensation. Rarefied pneuma is fire; condensed pneuma becomes first Water and then Earth. Note that Anaximenes' theory represented an advance beyond the earlier theories in that it incorporated a mechanism to account for variety by explaining the change of pneuma into different forms.

These three theories, put forward between about 600 and 550 B. C., had in common their reliance on a single fundamental substance. About 100 years later Empidocles suggested that there were four basic types of matter: Earth, Air, Fire and Water. These four elements were combined to form familiar things through the agency of two universal powers, Love and Strife. The four-element theory of Empidocles survived in one form or another for about 2,000 years, and provided the inspiration for generations of alchemists. And Empidocles' twin concepts of Love and Strife were the first hint of what are now called interatomic forces.

The first atomic theory was put forward by the Greek philosophers Leucippus and Democritus between 450 and 420 B. C. and was elaborated by Epicurus some 150 years later. It represented a radically different point of view, and it had the merit of explaining such processes as expansion and contraction, solution and precipitation and a wide range of other phenomena. Our detailed knowledge of the theory is based on a later source: the long Latin poem «De rerum nature» (On the Nature of Things), written in the first century B. C. by Lucretius, the great Roman poet and philosopher.

Lucretius set out to abolish superstitious fears about the arbitrary intervention of the gods in the affairs of men, maintaining instead that the world is governed by the laws of nature. All things, Lucretius wrote, are made up of invisible, indivisible particles called atoms (from the Greek word for "indivisible"). Atoms exist in a ubiquitous void, a void must be inferred because one can have no direct experience of it. Atoms are small but are finite in size. They are in constant motion. There are various species, or shapes, of atoms. Although the number of species is finite, the number of atoms of each species is unlimited. Atoms are capable of combining, but the number of combinations is finite.

Atoms of various shapes, moving and combining in various ways, fall at last into certain arrangements of which the world of things is created. Solids exist because certain atoms unite, "entangled by their own close-locking shapes". Substances that are hard and compact (diamond, iron, flint and brass, for example) must have particles that are more tightly hooked together than others. Comparing the flowing of wine and of olive oil, Lucretius concluded that the oil must be made up of particles that are larger or "more hooked and entangled one with the other" than the atoms of wine. Substances with a pleasant taste have smooth, round atoms; those that are bitter or harsh have particles that are more irregular.

*Scientific American November 1969.*

## Exercises

**I. Translate into Russian paying attention to the word «most»:**

1. We are still trying to answer most of these questions today.
2. Most Greek philosophers supposed that there was a single underlying principle behind all matter, a universal substance from which all things were made.



3. The most important question that still occupies us is as follows: what is matter?
4. Those were most important and interesting theories.
5. They spent most of the time discussing the results obtained.
6. The different densities of substance could be explained by assuming that they contained most different proportions of solid and weightless matter, but no void.
7. This theory represents a most orthodox development of previous concepts.
8. Most theories of early philosophers were used by later scientists.
9. Most of the investigations largely unpublished, their significance was not fully appreciated.
10. Most of his report is concerned with such processes as expansion and contraction.

**II. Translate into English using the active vocabulary of the lesson:**

1. Континуумная теория предполагает, что частицы материи должны сохранять все ее свойства.
2. Для того чтобы понять свойства тел, необходимо было допустить возможность существования более чем одного вида материи.
3. Различные плотности веществ объясняются тем, что они содержат различные количества твердой и невесомой материи, а не пустоты.
4. Предположение, что материя состоит из дискретных атомов, постоянно подтверждалось начиная с 17 века.
5. Бор предложил заменить модель атома Томпсона.
6. Многие поколения ученых занимались изучением сил, которые соединяют атомы.
7. Первая в мире научная школа была основана около 2500 лет назад.
8. Решение проблемы, обсуждающейся на симпозиуме, зависит от успеха целого ряда экспериментов.
9. Подобное явление не может быть объяснено только действием магнитного поля.
10. Такие эксперименты являются практическим подтверждением всей теории.

**III. Catch the meaning of the text and retell it:**

It is an assumption, but surely a reasonable one, that these early Greek theories were continuum theories, since it was not specified, that the basic element or elements were subdivided into fundamental particles. In essence, a continuum theory of matter assumes, that as matter is divided into smaller and smaller pieces these pieces — no matter how small — will retain the properties of the bulk material. A continuum theory is conceptually difficult because one must imagine that the continuum exists in different states of attenuation in order to account for the various manifestations of matter, such as hard solids and thin fluids. The alternative to a continuum theory is a theory that sees matter as being ultimately composed of discrete, indivisible particles: an atomic theory.

The continuum theory of matter, which continued to be advanced in opposition to the atomists, was reasserted by René Descartes. Like Plato and Aristotle and the Scholastic school that followed them, Descartes could not accept any part of space as being empty. To account for the properties of bodies it was therefore necessary to assume that more than one kind of matter existed. One kind, "subtle" and "etheral", was virtually weightless; the other kind, of which material objects were made, had weight and was subject to gravitation. The different densities of substances could be explained by assuming that they contained no void. Although the theory of Descartes had many supporters, such a theory is much more difficult to handle than an atomic theory, and gradually it lost support.

### IV. Give the situations from the text in which the following words are used:

to bind together; properties; underlying principle of matter; variety; alternative explanation; intervention; direct experience; Renaissance; exclusively; scientific school.

### V. Correct the false statements:

1. Speculations on interatomic forces began only in the 19th century.
2. All the questions concerning matter have already been answered.
3. The Milesians regarded matter as something that could exist in one form only.
4. All the theories of Greek philosophers are acceptable now.
5. Lucretius wrote that all things were made of visible particles which are at constant rest.
6. According to the poem "On the Nature of Things" atoms are of the same shape and keep one and the same arrangements.

### VI. Translate the following Russian questions into English and answer them:

1. Интересовал ли древних философов вопрос о том, что связывает материю воедино?
2. Какое значение для развития философии и точных наук имело основание первой в мире научной школы?



3. Как вы можете объяснить происхождение сил, связывающих атомы?
4. Что общего было в теориях, выдвинутых представителями Милетской школы?
5. Почему Лукреций считал, что пустота, в которой существуют атомы, должна подразумеваться?
6. Произвольное объяснение явления, о котором только что говорилось, невозможно с точки зрения молекулярной физики, не так ли?
7. Какая теория оказалась наиболее приемлемой для алхимиков 15—16 веков?

### VII. Render in English:

Несмотря на оппозицию Декарта (1596—1650), идея о том, что материя состоит из дискретных атомов, постоянно получала подтверждения начиная с 17 века. Сначала модель атома была подобна модели атома, описанной Лукрецием: бесконечно твердое крошечное взаимосвязанное целое. Однако попытка описать атом с точки зрения, которая лучше бы объясняла поведение макроскопических тел, была сделана позднее. Сэр Вилльям Петти (1623—1687) считал, что материя состоит из корпускул (самых маленьких видимых тел), а корпускулы составлены из атомов — самых маленьких тел природы. Как указание на размеры атомов он предполагает, что корпускула содержит по меньшей мере миллион атомов. Атомы, в отличие от корпускул, неизменны, хотя они все разных размеров и имеют различную форму. Как Земля, атом имеет два магнитных поля и центр гравитации; он может вращаться вокруг своей собственной оси и, кроме того, вращаться вокруг других атомов, как Луна вокруг Земли. Взаимодействие атомов между собой обусловлено наличием масс, и они притягиваются к центру Земли вследствие гравитации; они имеют тенденцию выстраиваться в линию в магнитном поле Земли, но от этого их предохраняет собственное движение. Они могут иметь различные скорости. Атомная концепция Петти явно подверглась влиянию Вильгельма Гильберта (1540—1603), чья книга по земному магнетизму была опубликована в 1600 году. Аналогия, проводимая между атомом и Землей, интересна потому, что она указывает на единство законов природы, несмотря на огромную разницу в масштабах.

### VIII. Answer the following questions:

1. Who was the first to conceive the atomic theory of matter?
2. What were the first questions concerning matter?
3. Who founded the first scientific school and what were the consequences?
4. What was the main idea of Anaximenes' theory?

5. What did the three theories have in common?
6. What are the main concepts of Empidocles' four-element theory?
7. Did the first atomic theory have any merits as compared with the previous ones?
8. What are the main concepts of Lucretius' poem?
9. What were his conclusions based upon?
10. What inspired Greek philosophers to speculate on the problems of matter?

**IX. Review the article «Early Views on Forces between Atoms».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. Structure of an atom.
2. Elementary particles.
3. Theory and experiment — what is more important for a physicist.

## LESSON THREE

### Active Vocabulary

**respect, *n.***

1. Respect is a relation to or concern with something usually specified.
2. The final question had respect to the present political situation.
3. Some remarks having respect to an earlier plan were made.
4. The magnetic field can't drift with respect to the stellar surface.

*Derivative*: respective.
*Synonym*: regard.

**threshold, *n.***

1. Threshold is a boundary; the point or place of entering or beginning.
2. The 19th century was the threshold of an era of scientific and technological development.
3. Many African countries are on the threshold of great social and economic changes.

**create, *v.***

1. To create means to bring into existence; to produce through imaginative skill; to make.
2. A new administrative post was created some years ago.
3. Modern science, which created this dilemma, is also capable of solving it.
4. They created an opportunity to talk to him.

*Derivative*: creative.
*Synonym*: to invent.

### estimate, *v.*

1. To estimate means to determine approximately the size or nature of something; to conclude.
2. It is one of the methods to estimate deuterium.
3. Any work should be estimated according to its merits.
4. This theory was estimated to be at least ten years late.

*Derivative*: estimation.

*Synonyms*: to evaluate; to value.

### include, *v.*

1. To include means to take in as a part of a large aggregate or principle.
2. I was in search of a formula which should cover everything even if it included more than I wished.
3. He was included in the list of candidates.
4. There are fifty maps in the atlas, including six of North America.

*Synonyms*: to imply; to involve; to comprehend.

### neglect, *v.*

1. To neglect means to give little attention or respect to something.
2. College authorities neglected the real needs of the students.
3. Don't neglect writing to your mother.
4. Some boys neglect their behaviour.

*Synonyms*: to omit; to ignore.

### permit, *v.*

1. To permit means to make possible; to give an opportunity; to allow.
2. He had to permit others to use his patent.
3. Permit me to offer my congratulations.
4. If time permitted I could go on with my speech.

*Derivative*: permission.

*Synonym*: to let.

### explicit, *adj.*

1. Explicit means characterized by full clear expression; something fully developed or formulated.
2. In each of the equations $y=10^x$, $y=\tan x$, $y=\frac{a+b}{a-b}$, the value of "y" is known when that of "x" is given. Such functions are called explicit.



3. A function is called explicit when expressed directly in terms of variable or variables.
4. A lecturer was quite explicit about the matter, so there were no questions.

*Derivatives*: explicitly, explicitness.

*Synonyms*: definite; specific.

*Antonyms*: implicit; indefinite.

### intermediate, *adj.*

1. Intermediate means lying or being in the middle place or degree; between extremes or limits.
2. Intermediate frequency is a relatively low frequency to which a signal is converted before demodulation in heterodyne reception.
3. The intermediate state is a photon which can then decay into any particle-antiparticle pairs.

### internal, *adj.*

1. Internal means existing or situated within the limits or surface of something; situated near the inside of the body.
2. By having greater resource of our internal reserves we could have shown a higher figure for the year.
3. The internal combustion engine was really the forerunner of a gas engine.
4. He could not understand the internal mechanism of the process.

*Synonym*: inner.

*Antonym*: external.

## Exercises

### 1. Give the English for:

a) отношение; порог; создавать; подсчитывать; включать; пренебрегать; позволять; явный; промежуточный; внутренний;

b) что касается этого явления; промежуточное состояние; запасы внутренней энергии.

### 2. Give the Russian for:

with respect to the fact; to be above a threshold; to create a certain number of electrons; to estimate the constant; to include various types of experiments; to neglect an opportunity; to permit an arbitrary decision; an explicit manifestation; intermediate state; internal structure.

**3. Give derivatives of the following words:**

to respect; to create; to estimate; to permit; explicit.

**4. Give synonyms of the following words:**

regard; to invent; to value; to involve; to omit; to let; definite; inner; to comprehend; to ignore; specific.

**5. Give antonyms of the following words:**

to discourage; long; to depriciate; implicit; external; to exclude; to destroy; to loose; to reckon; to ruin.

**6. Read the following words:**

| | |
|---|---|
| comparison [kəm'pærisn] | to decelerate [di:'seləreit] |
| to compare [kəm'pɛə] | deceleration [di: selə'reiʃn] |
| coaxial ['kou'æksiəl] | quadrupole ['kwɔ:drə,poul] |
| threshold ['θreʃhould] | polarization [,poulərai'zeiʃən] |
| to occur [ə'kə:] | to motivate ['moutiveit] |
| to inject [in'dʒekt] | motivation [,mouti'veiʃən] |
| virtue ['və:tju:] | to annihilate [ə'naiəleit] |
| virtual ['və:tjuəl] | annihilation [ə'naiə'leiʃən] |
| to assume [ə'sju:m] | to contribute [kən'tribju:t] |
| assumption [ə'sʌmpʃən] | contribution [,kɔntri'bju:ʃən] |

## POSITRON BEAMS

*These particles are now made with an intensity and energy approaching those of primary electron beams; their applications include scattering experiments, colliding-beam experiments and annihilation photon production.*

by David E. Yount

Positive electrons, which offer interesting comparisons with negative electrons and can be a useful source of photons, may be made by pair production in a target placed in the electron path of a linear accelerator. Greater intensity can be achieved by acceleration, by a coaxial solenoid, with magnetic quadrupoles or by solenoid-quadrupole combination.

### *Collision and pair production*

Electron-atom collisions produce positrons in a two-stage process. An energetic electron that collides with an atom in a lump of heavy metal (the "converter") is decelerated by the electric field



of the atomic nucleus or one of the atomic electrons. As a result of this deceleration, the electron emits a photon with energy that may be as high as the initial electron energy or as low as a few electron volts. In the second stage, those photons that have sufficient energy (greater than 1.022 MeV, the combined rest mass of an electron and a positron) interact with either atoms in the same converter to create secondary electrons and positrons in equal numbers by pair production. If the initial electron energy is well above this threshold, a cascade occurs in which successive generations of positrons and electrons radiate additional photons that in turn produce positrons and electrons.

Because positrons and electrons have opposite charge, the crests of the "electron" sine wave decelerate positrons while the valleys accelerate them. Positron acceleration can therefore be achieved by changing the phase of the travelling wave by 180° with respect to the positron bunches. If positrons can be produced and injected into a linear electron accelerator with the proper phase, they can be accelerated just as efficiently, and can reach just as high an energy, as electrons injected at the same initial energy and direction.

### *A two-photon process*

The first experiment carried out with the new beam was a precise (to 1% at some points) comparison of positron-proton and electron-proton scattering at 200 and 300 MeV. This experiment provided the first direct test of certain assumptions made in analyzing the extensive data obtained by Robert Hofstadter and his collaborators in the same laboratory. More explicitly the electron-proton interaction was assumed to proceed by means of the exchange of a single photon, and the exchange of two or more photons was neglected. The difference in positron-proton and electron-proton scattering provides a direct measure of the two-photon contributions. These were estimated to be of order Z where $Z=1$ is the charge of the proton in units of the electron charge and $\alpha={}^1/_{137}$ is the "fine-structure constant"; however, deformation of the proton (polarization) by the interaction of one photon can in some models enhance the interaction of the second photon in the two-photon process. The Hofstadter experiments, in which electrons were used in a systematic study of internal proton structure, were of such fundamental importance that Hofstadter himself was awarded the 1961 Nobel prize for physics.

### *Storage rings*

Although the initial development of intense positron beams was otivated by these scattering experiments, a second and very recent pplication may ultimately be of great importance. Specifically, positrons as well as electrons are now being injected at high energies into storage rings. For relativistic reasons, the available energy in such a collision is higher than can be achieved when positrons of far greater energy interact with electrons in a stationary target. This technique not only permits an extension of the positron-electron scattering experiments to very high effective energies, but allows the more important study, at these energies of a variety of annihilation reactions. There is a reasonable probability that instead of annihilating into the usual pair of photons, the colliding positron and electron will produce pairs of mesons and baryons. The intermediate state is a virtual photon — a "ball" of pure energy — which can then decay into any particle-antiparticle pair with rest-mass energy up to the combined energy of the two beams.

*Physics Today*
*February 1969.*

## Exercises

### I. Translate into Russian paying attention to Degrees of Comparison:

1. The reduced angle ensures an enhanced capture efficiency twice as higher. It is twice as high as the initial one.
2. Quadrupoles are normally located farther downstream.
3. We have got further information on this matter.
4. There are many more books now in our library.
5. The difference between these two phenomena is much greater than one could suspect.
6. The curves obtained yesterday are far better.
7. It was the least suitable reason to be mentioned.
8. I have spent here today half as much time as yesterday.
9. The remarks made by the second opponent were less remarkable than those of the previous one.

### II. Translate into English using the active vocabulary of the lesson:

1. Аннигиляционные фотоны дают частично монохроматический фотонный пучок.
2. Еще одно применение позитронных пучков включает в себя сравнение позитрон-протонных и электрон-протонных рассеяний.



3. Позитронные пучки, созданные в линейных ускорителях, отличаются от других вторичных пучков.
4. Эксперименты, которые проводились для более подробного изучения внутренней структуры протонов, дали возможность подсчитать величину $\alpha$.
5. Никогда нельзя пренебрегать мнением своих товарищей.
6. Это новое оборудование позволяет сокращать время проведения эксперимента вдвое и, кроме того, оно более удобно, чем старое.
7. Позитроны и электроны ускоряются от 250 MeV до 550 MeV, то есть выше порогов образования пар мюонов, пионов и катонов.
8. Эту величину следует изменить по отношению к другим величинам.
9. Студенты не знали, как объяснить этот вид промежуточного состояния частиц.
10. В данном случае внутренние различия гораздо более важны, чем внешние.

### III. Translate at sight:

In the earliest annihilation-photon beams, developed in the late 1950's by Stanley Fultz and his collaborators at the University of California, Lawrence Radiation Laboratory and by C. Tzara and his colleagues at Saclay, the photons were produced at zero degrees to the incident positron direction, thereby enhancing the photon yield near the incident positron energy. These early annihilation beams were used to study photonuclear reactions at energies below 50 MeV — an area of research that is complementary to electron or positron scattering from nuclei and is also active today. The Stanford and Lawrence Laboratory groups, working some 40 miles apart, evolved the positron acceleration technique independently. They used their positron beams in two rather different applications (scattering and the production of annihilation photons) simultaneously and for a considerable period either group became aware of the other.

### IV. Give the situations from the text in which the following words are used:

secondary; scattering experiments; to be above; positron bunches; study of; to be assumed; exchange of more than two photons; direct measure; to be estimated.

### V. Correct the false statements:

1. Positive electrons can't be a useful source of photons.
2. Electron-atom collision produces secondary electrons and positrons in different numbers.

3. The initial electron energy is always less than 1.022 MeV.
4. Relative theory has nothing in common with the concept of storage rings.
5. The initial development of intense positron beams cannot be motivated by scattering experiments.

## VI. Translate the following Russian questions into English and answer them:

1. Как может быть увеличена интенсивность пучка положительных электронов?
2. Какие процессы включает создание позитронов?
3. Как и где создаются вторичные электроны и позитроны?
4. Каковы условия эффективного ускорения позитронов?
5. Что дал эксперимент, в котором сравнивались позитрон-протонные и электрон-протонные рассеяния?
6. Чем можно объяснить большую ясность в электрон-протонном взаимодействии при обмене одним фотоном?
7. Каким образом была подсчитана постоянная тонкой структуры?
8. К чему может привести поляризация протона фотоном?
9. Почему эксперименты Хофштадтера были оценены так высоко?

## VII. Render in English:

Первый позитронный пучок был получен на третьем Стэнфордском ускорителе Джоном Пуарье, Давидом Бернштейном и Джереми Пином в 1958 году. Позитроны получались с помощью электронов с энергией порядка 350 MeV, падающими на тонкий медный преобразователь, расположенный около средней точки ускорителя, причем позади этой точки частицы не испытывали ускорения. Из-за того, что преобразователь был очень тонкий, частицы в лавине не расходились по фазе намного от среднего значения и часть позитронов, произведенных по большей мере электронами со значительной энергией, достигали конца ускорителя. Эти позитроны коллимировались и сразу же использовались для получения хорошо сформированного пучка электронов с энергией 200 MeV в экспериментальном пространстве. Относительно низкая максимальная интенсивность нескольких сотен позитронов в каждом импульсе ускорителя хорошо согласовывалась с требованиями эксперимента в камере Вильсона, в которой наблюдалось рассеяние позитронов электронами атомов бериллиевой пластинки.



## VIII. Answer the following questions:

1. What is annihilation?
2. What are the processes in which electron-atom collisions produce positrons?
3. What are the results of an energetic electron-atom collision in a lump of metal? (Heavy metal is meant).
4. What principles are used in linear accelerators for positron beams production?
5. Describe the phase of travelling wave with respect to the positron bunches.
6. What was the first experiment with the positron beams?
7. What was estimated in the experiments with the positron-proton and electron-proton scattering?
8. What do you know about positrons?
9. In what experiments can pairs of mesons and baryons be produced?
10. What can you say about Hofstadter's experiments?

## IX. Review the article «Positron Beams».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. Electron-positron annihilation.
2. Working principles of linear accelerator (of charged particles).
3. Particles and anti-particles.
4. Classification of elementary particles.
5. Structure of nucleus.

## LESSON FOUR

### Active Vocabulary

**entity, *n.***

1. Entity means being; existence, especially independent, separate or self-contained existence.
2. The "observer" is an entity with meaning only in relation to the "observed".
3. In the relativistic view it is the relation that is the elementary entity.

**space, *n.***

1. Space is the limitless expanse in which everything exists; area; the distance between two or more objects.
*Derivative*: spatial.
2. Spatial is something that exists in space.
3. A test particle can be placed at any spatial location.
4. The time coordinate incorporation with the spatial ones implies some interesting consequences.
5. Einstein incorporated the time coordinates with the spatial ones.

**abandon, *v.***

1. To abandon is to give up completely; stop doing.
2. Don't abandon the attempt (i. e. don't stop trying).
*Derivative*: abandonment.
3. Abandonment means giving up with the intent of never again claiming a right or interest.
4. The abandonment of the destroyed ship was carried out in two hours.



**adopt, *v.***

1. To adopt is to take into a relationship; to take as one's own; to choose for required study.
2. Some customs are usually adopted from neighboring countries.
3. If we adopt the realist view that there are fundamental objective elements underlying the laws of nature, then what does relativity theory imply these to?
*Derivatives*: adoption, adoptable.

**distribute, *v.***

1. To distribute is to hand, give or send out among a number of persons or to a number of places.
2. The teacher distributed the examination papers to the class.
*Derivatives*: distribution, distributive, distributable.
3. Distribution is the position, arrangement, or frequency of occurence (as of the members of a group) over an area or throughout a space or unit of time.
4. He was specifically interested in the distribution of summer isotherms over certain parts of Africa.
5. Frequency distribution depends on different conditions.
*Synonym*: division.

**imply, *v.***

1. To imply means to involve or indicate by inference, association or necessary consequence rather than by direct statement.
2. He concluded that to exploit this theory fully, the principle of relativity must imply that the laws of nature are invariant in form.
3. We cannot say it, such things should be implied.
*Derivative*: implication.
*Synonyms*: to include; to suggest.

**reveal, *v.***

1. To reveal is to make publicly known.
2. He has never revealed himself for these long years.
3. The quantum theory was discovered to reveal a formalism that explained atomic phenomena.
4. Several serious mistakes were revealed by the close examination of the papers.
*Derivative*: revealable.
*Synonym*: to discover.

### 'signify, *v.*

1. To signify is to make known; show by a sign; mean; have importance.
*Derivatives:* significance, significant, signification.
2. Significance is something that has special meaning; importance.
3. The Programme of the Communist Party of the Soviet Union is of great significance for the whole progressive mankind.
4. What he thinks about our remark is of no significance.
5. Time has objective significance, it is a thing in itself.

### suspect, *v.*

1. To suspect is to have doubts; to imagine to be true, or probable.
2. I suspect you once thought otherwise.
3. They suspect him to be a clever person.
4. He is suspected of making a mistake.
*Derivatives*: suspectable, suspicion.

### in'trinsic, *adj.*

1. Intrinsic is internal; belonging to the essential nature of a thing; situated within the body.
2. By intrinsic value of a coin the value of the metal in it is meant.
3. When at rest, the body has an intrinsic energy that depends on the product of its rest mass and the square of the speed of light.
*Derivative*: intrinsical, intrinsically.
*Synonyms*: inherent; essential.

## Exercises

### 1. Give the English for:

a) сущность; пространство; пространственный; отказываться, прекращать; принимать; распределять; предполагать; выявлять; означать; подозревать; внутренний;

b) философская сущность; принимать точку зрения; иметь значение; подозревать в чем-либо; пространственные координаты.



### 2. Give the Russian for:

to neglect a philosophical entity of the problem; special meaning of the separate spatial points; to abandon the attempt; abandonment of the principle; to adopt smb's point of view; to distribute the literature; distribution of the curves; to imply different methods; it was revealed by means of analysis; to have objective significance; to suspect smb. of smth; intrinsic inseparability.

### 3. Give derivatives of the following words:

space; to abandon; to adopt; to imply; to reveal; to signify; to suspect; intrinsic.

### 4. Give synonyms of the following words:

division; to include; to discover; meaning; inherent; to suggest; importance; essential.

### 5. Read the following words:

| | |
|---|---|
| to unify ['ju:nifai] | identification [ai,dentifi'keiʃən] |
| unification [,ju:nifi'keiʃən] | to recognize ['rekəgnaiz] |
| spatial ['speiʃəl] | consequence ['kɔnsikwəns] |
| to define [di'fain] | consequent ['kɔnsikwənt] |
| definite ['definit] | simulaneity [,siməltə'niəti] |
| definition [,defi'niʃən] | simultaneous [,siməl'teinjəs] |
| further ['fə:ðə] | to generalize ['dʒenərəlaiz] |
| product ['prɔdəkt] | generalization [,dʒenərəlai'zeiʃən] |
| explosive [iks'plousiv] | to substantiate [səb'stænʃieit] |
| to identify [ai'dentifai] | environment [in'vaiərənmənt] |

## SPACE, TIME AND ELEMENTARY INTERACTIONS IN RELATIVITY

*To express in a unified formalism all the interactions of matter, ranging from the elementary particles to astronomic bodies, we should begin with a simple study of the concepts of Einstein's space-time.*

by Mendel Sachs

Einstein recognized that the time coordinate must also necessarily be incorporated with the three spatial coordinates in one relativistic space-time to describe the laws of nature correctly. This discovery was made when Einstein recognized that the laws of electrodynamics, in the form that they were originally discovered by Michael Faraday, and James Clerk Maxwell, have the same form to all observers, independent of their states of motion relative to each other, only if it can be assumed that the time coordinate is included with the spatial coordinates in the relativistic sense that to describe an observation, all four coordinates must be specified only to the space-time point of a given observer. At this stage, the theory of special relativity was born.

### *Unification of space-time*

Incorporation of the time coordinate with the spatial coordinates implied many interesting consequences, not predicted previously. First, to be able to convert the time coordinate of one observer to a combination of time and space coordinate of another (who is in motion relative to the first) one must express time and length in the same units — in all frames of reference. Thus the time coordinate had to be multiplied by a universal constant with the dimension of length divided by time — a constant speed. Indeed, the identification of the laws of electrodynamics with this number revealed it to be the speed of propagation of the electromagnetic interaction between matter and matter in a vacuum — numerically determined from the speed of light in a vacuum. This determination of the universal speed $c$ then fixed it for all other applications. A further implication here was that the speed of light in a vacuum is independent of the speed of its source. That is, according to this theory, if light is emitted from a moving train or from a fixed position next to the tracks, a fixed observer will measure the same speed in each case.

Another new consequence of relativity theory was that no longer could we speak of the absolute simultaneity of events. If two events are simultaneous to one observer, they are not generally so to a different observer in motion relative to the first one. A third interesting consequence of special relativity came from the modification that results when we pass from classical mechanics of point particles (where time is absolute) to relativistic mechanics of point particles (where the time, along with the spatial coordinates, is relative to the point of observation). It turns out in this generalization that the inertial mass of interacting body is constant when the body is at rest, it increases in a definite way as the body moves relative to a fixed observer. Further, when at rest, the body has an intrinsic energy that depends on the product of its rest mass and the square of the speed of light — an explosively large amount of energy that was not suspected until relativity theory appeared! These and other implications of special-relativity theory in regard to wave motion, for example, that were not predicted by preceding theories were impressively substantiated by experimental facts.



Thus we see that the rules of special-relativity theory refuted the previous laws of mechanics by requiring that the time coordinate must be incorporated with the three spatial coordinates as a fourth parameter, to be specified only relative to the observer. But this change was not too much of a revolution! It was rather a natural extension to a more general way of expressing the laws of nature with a space-time coordinate system. In this case, then, what was the real revolution that came with Einstein's theory? It was the abandonment of the idea that the space-time coordinate system has objective significance as a separate physical entity. Instead of this idea, relativity theory implies, that the space and time coordinates are only the elements of a language that is used by an observer to describe his environment. However, the conventionalist view is not fully adopted since it is further asserted with this theory that the relation between the points of the space-time language of any observer is in fact a representation of the intrinsic interaction within the matter distribution that comprises the physical system. It then follows that if there should be no matter in the universe, there would be no space-time to talk about! It implies that if the matter distribution should be variable, then the relation between the points of the space-time (that is, the geometry) that is used to describe the environment of any point would be correspondingly variable. This view takes space-time as a passive entity that is used to describe nature — perhaps for want of a better language!

*Physics Today*
*February 1969.*

## Exercises

**I. Translate into Russian paying attention to the usage of the words «much», «many», «little», «a little», «few», «a few»:**

1. Incorporation of the time coordinate with the spatial coordinates implied many interesting consequences.
2. This change was not too much of a revolution.
3. Many scientists did not even try to understand the foundations of this theory.
4. There are many people in the conference hall today.
5. The main concept of the article given above cannot be explained in a few words.
6. Before Faraday there was little doubt in any physicist's mind that the fundamental description of the material world must be in terms of bits of matter.

7. Their remarks were of little importance, let's say of none.
8. I have little money, I can't buy this book just now.
9. Second-year students have very few exams in winter.

### II. Translate into English using the active vocabulary of the lesson:

1. Обсуждение таких проблем предполагает понимание теории относительности.
2. Все четыре координаты должны быть указаны только относительно пространственно-временной точки данного наблюдателя.
3. В те годы можно было только подозревать о том огромном значении, которое будет иметь теория Эйнштейна для человечества.
4. В данном случае удобно взять произвольное распределение точек в пространстве.
5. Для того, чтобы выявить природу этого явления, нужно было провести серию экспериментов.
6. Постоянство скорости света во всех системах отсчёта является сущностью теории относительности.
7. Сначала работам в этой области не придавали большого значения.
8. Это относится только к внутренним особенностям некоторых веществ, о которых мы знаем еще очень мало.
9. Отказ от старых мировоззрений еще не означает переход к новым.

### III. Catch the meaning of the text and retell it:

Had Einstein stopped with special relativity, although it was eminently successful in explaining and predicting experimental facts not previously understood, no too much of a revolution would have occured. For, as in the previous "classical" theories, the relation between points in space-time in special relativity is the same everywhere, and it is independent of the matter content of the physical system that is described. Fully to exploit the idea that the space and time coordinates serve only as a language used to represent the matter content of a physical system, it becomes necessary to extend from the flat (Euclidean) space-time geometry of special relativity to a curved (non-Euclidean) space-time of general relativity. The variable curvature of the geometrical system in the general description is indeed a function of the variation of the mutual interaction within the physical system. According to this view, if the matter content of a system was depleted the curvature of space-time would correspondingly diminish. In the limit, where the system is emptied



of matter (corresponding to no mutual interaction of matter), the curvature would be zero, thereby yielding a Euclidean geometrical system and special relativity. The particular non-Euclidean geometry that has this property of asymptotically approaching a Euclidean geometry is that discovered by Georg Riemann. Thus Einstein looked for a relationship between the field of mutual interaction of the matter content of a physical system and the field of properties of a Riemann space-time.

### IV. Give the situations from the text in which the following words are used:

independent of; numerically determined; objective; significance; representation; distribution; entity; explosively; consequence; universe; abandonment.

### V. Give the questions to which the following statements might be the answer:

1. In the elementary-particle theory the world is made out of things — indestructible bits of matter that move along space-time trajectories.
2. With relativity theory one must take the "observer-observed" relation as a fundamental starting point.
3. The valid laws of electrodynamics have the same form to all observers.
4. All four coordinates must be specified relative only to the space-time point of a given observer.
5. We cannot speak of the absolute simultaneity of events.
6. If two events are simultaneous to one observer they are not generally so to a different observer.

### VI. Translate the following Russian questions into English and answer them:

1. Для чего Эйнштейн объединил временную координату с тремя пространственными?
2. Какие последствия имело это объединение?
3. Одинаков ли закон сложения скоростей в механике Эйнштейна и механике Ньютона?
4. Каково отношение механики Эйнштейна к понятию абсолютной одновременности событий по сравнению с механикой Ньютона?
5. Как зависит энергия покоящейся частицы от ее массы и скорости?
6. В чем состоят особенности перехода от классической механики к релятивистской?
7. Является ли масса абсолютной величиной?

8. Что является основным принципом теории относительности?

9. Какие физические истины, принимаемые механикой Ньютона, отвергает теория относительности Эйнштейна?

10. Каково значение теории относительности Эйнштейна для развития физики?

## VII. Render in English:

Существуют пространственно-временные системы, которые движутся с некоторыми постоянными значениями скоростей одна относительно другой (или находятся в состоянии покоя). Специальная теория относительности была неприемлема как наиболее общее описание материи, так как инерциальная система относится только к приближениям тех наблюдений, которые в действительности вызваны неинерциальными системами отсчета. Причина заключается в том, что инерциальная система относится только к описанию, в котором нет внутренних сил и поэтому нет передачи энергии и момента между взаимодействующей материей. С другой стороны, любые измерения (включают ли они соединение микроматерии, макроматерии или то и другое) обязательно вызывают передачу энергии и момента. Эйнштейн сделал вывод, что для того чтобы полностью использовать эту теорию, принцип относительности должен обязательно подразумевать, что законы природы инвариантны по форме относительно преобразований пространственно-временных систем отсчета, находящихся в произвольных относительных движениях.

Расширение теории до неинерциальных систем отсчета привело к общей теории относительности, для которой специальная теория относительности является особым предельным случаем. Можно сказать, что в рассмотрении элементарности взаимодействий, которая следует из основных начальных понятий теории относительности, действительный предел специальной теории относительности не может быть в принципе достигнут, хотя подойти к нему можно как угодно близко.

## VIII. Answer the following questions:

1. What fundamental property of the time coordinate did Einstein recognize?

2. What is the main reason for incorporating the time coordinate with the spatial coordinates?

3. What were the main consequences of this incorporation?

4. What is the universal constant?

5. Why was the universal speed "c" fixed for all applications?

6. What is the intrinsic energy of a body equal to?

7. How does the character of time vary when we pass from classical to relativistic mechanics?



8. Has the space-time coordinate system any objective significance as a separate physical entity?

9. Why should the geometry of space be variable?

10. By what means did the theory of relativity introduce a revolutionary concept into physics?

## IX. Review the article «Space, Time and Elementary Interactions in Relativity».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. Relativistic theory and classical mechanics.
2. Simultaneity of events and principle of casualty.
3. The role of the theory of relativity in modern science.

## LESSON FIVE

### Active Vocabulary

**concept, *n*.**

1. Concept is an idea or general notion.
2. When applied to nuclei, the snapshot concept is theoretical.
*Derivative*: conception.
3. Conception is the act of forming ideas in the mind.
4. An actor must have a clear conception of the part he is going to play.
5. I have no conception of what he means.
*Synonyms*: idea; notion.

**occasion, *n*.**

1. Occasion is the moment or time when something takes place.
2. I have met Mr. Smith on several occasions (i. e. several times).
3. This is not an occasion (i. e. a suitable time) for laughter.
4. You should profit by the occasion (i. e. seize the opportunity).
*Derivatives*: occasional; occasionally.
5. For these students the novelty of the viewpoint adopted does seem, at least occasionally, to throw familiar concept into a new relief.
*Synonym*: opportunity.

**vicinity, *n*.**

1. Vicinity is nearness (to); closeness of relationship, as the vicinity of Mars to the Earth; in close vicinity to.
2. Vicinity is also the neighbourhood; the surrounding districts.
3. There are at least three libraries in the vicinity.



4. In these terms the hard deformed nuclei have deformations in the vicinity of 0.3.
*Synonyms*: neighbourhood; nearness; proximity.

**rest, *n*. and *v*.**

1. Rest is freedom from, or absence of activity, movement, care, anxiety, disturbance, etc.
2. To rest is to be still; stop working, moving, doing things, etc.
3. Rest is necessary after hard work.
4. He rested for an hour before going on with his task.
5. The rest is the remainder, that which is left, the others.
6. Take what you want and throw the rest away.
*At rest*=still, free from movement or agitation.
*Derivatives:* restful, restless.

**define, *v*.**

1. To define is to explain the meaning of; to describe exactly and carefully; to show clearly the shape or outline or limits of a thing.
2. A dictionary defines words.
3. The powers of a judge are defined by law.
4. When the boundary between two countries is not clearly defined, there is often trouble.
*Derivatives*: definition, definite, definitely.
Definite, *adj*. — clear and exact, not doubtful or uncertain.
5. I want a definite answer, "yes" or "no"; I don't want you to answer "perhaps" or "I'm not sure".
*Synonyms*: to explain; to describe.
*Antonyms*: definite — indefinite; definitely — indefinitely.

**refine, *v*.**

1. To refine is to make free from impurities; to purify, as to refine gold (sugar, oil, etc.); to become free from impurities, less rough, improved in manners, etc.
2. He is trying hard to refine his English.
3. The earlier science had only refined upon the ordinary notions of ordinary people.
*Derivative*: refinement.
*Synonyms*: to purify; to improve.

**familiar, *adj*.**

1. Familiar is acquainted with; knowing about (something) well; common; often seen or heard; no longer novel or new.
2. I am not familiar with this term.

3. The notions of the size and shape of a solid object at rest are familiar enough.

*Derivative*: familiarize.

*Synonyms*: usual; common; ordinary.

*Antonym*: unknown.

**simultaneous, *adj*.**

1. Simultaneous is happening or done at the same time.

2. Just by twisting a dial, visitors to the U. N. General Assambly can hear simultaneous interpretations of what the speaker is saying in any of the five official languages.

*Derivatives:* simultaneously, simultaneousness.

*Synonyms*: contemporary; synchronous.

**soft, *adj*.**

1. Soft is changing the shape easily when pressed; not resisting pressure; the opposit of hard, for example, soft ground.

2. Rain water is soft, that is why it is good for washing.

*Derivatives:* softish, softly, softness, soften.

*Synonyms:* gentle; mild.

*Antonyms:* hard; sharp.

**rough, *adj*.**

1. The degree of deformation of a nucleus can be defined by a rough formula.

*In the rough* — not polished or refined; not finished.

2. His plans are in the rough.

*Derivatives:* roughen, roughly.

*Synonyms:* uneven; irregular; incomplete; rude; approximate.

*Antonyms:* refined; purified.

Exercises

**1. Give the English for:**

а) идея, понятие; случай; близость, соседство; отдых, остальное; определять; очищать, повышать качество, усовершенствовать; знакомый; одновременный; мягкий; грубый, приблизительный;

b) общее представление; использовать возможность; по соседству; в состоянии покоя; определенный ответ; знакомое понятие; синхронный перевод; мягкое ядро; приближенная формула.



**2. Give the Russian for:**

the size and shape of solid objects at rest; familiar enough; customary notion of shape; to reveal a true shape; simultaneously; to arrange in a particularly symmetrical configuration; occasional snapshots; to fall neatly into two categories; rough formula; in the vicinity of.

**3. Give derivatives of the following words:**

concept; occasion; to refine; to define; familiar; soft; rough.

**4. Give synonyms of the following words:**

chance; nearness; idea; to improve; to explain; ordinary; mild; synchronous; unrefined.

**5. Read the following words:**

| | |
|---|---|
| atom [ˈætəm] | theory [ˈθiəri] |
| atomic [əˈtɔmik] | theoretical [θiəˈretikəl] |
| nucleus [ˈnju:kliəs] | occasion [əˈkeiʒən] |
| nuclei [ˈnju:kliai] | occasional [əˈkeiʒənəl] |
| rough [rʌf] | casual [ˈkæʒjual] |
| roughly [ˈrʌfli] | vicinity [viˈsiniti] |
| concept [ˈkɔnsept] | familiar [fəˈmiliə] |
| conception [kənˈsepʃən] | familiarity [fəˌmiliˈæriti] |
| physics [ˈfiziks] | simultaneous [ˌsiməlˈteiniəs] |
| physicist [ˈfizisist] | simultaneously [ˌsiməlˈteiniəsly] |

## THE SIZE AND SHAPE OF ATOMIC NUCLEI

*Some nuclei are spherical, some are ellipsoidal and some fluctuate in between. Measurements of radius and precise shape provide tools with which theoretical physicists can refine models of the nucleus.*

by Michel Baranger and Raymond A. Sorensen

*What Are Size and Shape?*

The notions of the size and shape of a solid object at rest are familiar enough, but the nucleus consists of particles in rapid and complicated motion. Does it make sense, then, to refer to its size and shape? A good analogy is provided by an airplane propeller. When it is rotating, it appears as a blurred circle, and a casual observer might take the circle as its intrinsic shape. A careful observer with a fast enough camera, however, can make a photograph that reveals the propeller's true shape. This «snapshot» agrees with our customary notion of shape; the «time exposure» the first observer depended on reveals only an average shape, which may be quite different. Now suppose we take a second snapshot of the propeller, or of another propeller on an identical airplane. The result is the same shape as before, identical as to length of blades, angle between them and so on; the only possible difference is the orientation of the propeller in its plane of rotation. The shape of the propeller is permanent, and so we can say that the propeller is «hard». It would be different if we took snapshots of two identical octopuses, for instance. The two shapes would almost certainly be different; the octopus is «soft».

The shapes and sizes of nuclei must be defined in terms of snapshots. Moreover, we can distinguish between «hard» nuclei, whose shape is permanent, and «soft» nuclei, whose shape is changeable. In addition it is possible to make various time exposures of nuclei. These do not reveal a true shape but only a time average, like the blurred view of a propeller.

How are we going to perform the snapshot experiment in practice? When applied to nuclei, the snapshot concept is theoretical; although there is nothing in the laws of physics that says a snapshot experiment is impossible, it is far beyond present techniques. One would have to illuminate the nucleus with a beam of radiation of very short wavelength, sufficiently intense to interact simultaneously with every nucleon, and then focus the scattered radiation. None of this will be feasible for a long time. The experiments that can actually be done, and that we shall describe, are indirect. Yet with the help of the hypothetical snapshot definition they lead unambiguously to a detailed knowledge of nuclear sizes and shapes.

When the snapshot definition is applied to the shapes of atoms rather than nuclei, they are found to be essentially spherical. It is hard to imagine that nuclei could be anything else, but the truth is that few nuclei are spherical. For most nuclei the snapshots, if they could be made, would reveal a more or less ellipsoidal picture, often a bit pear-shaped in addition, with the ratio of longest to shortest diameter lying between 1 and 1.4. The only really spherical nuclei, those whose snapshots would yield consistently spherical pictures, are those whose Z and N are near special «magic numbers» such that the nucleons are able to arrange themselves in a particularly symmetrical configuration. For the majority of nuclei only an occasional snapshot would be spherical, and the interesting questions are: How deformed, and how hard or how soft, is each nucleus? The nonspherical nuclei seem to fall rather neatly into two categories. First there are «hard deformed» nuclei. These have an essentially permanent cigar-like shape: they are prolate spheroids, with one long axis and two equal short axes. Then there are «soft» nuclei,



whose shape is highly changeable. Snapshots of many identical soft nuclei would include mostly a variety of asymmetric ellipsoids (in which each of the three axes is of a different length) and a sprinkling of spherical and prolate shapes and oblate spheroids (disks with one short axis and two equal long axes).

The degree of deformation of a nucleus can be defined by a rough formula: To obtain the deformation subtract the smallest diameter from the largest and divide the difference by the average diameter. In these terms the hard deformed nuclei have deformations in the vicinity of .3. The deformations of the soft nuclei fluctuate and are smaller, with typical values around .1.

*(to be continued)*

## Exercises

**I. Translate into Russian paying attention to the functions of «it»:**

1. This practical and conceptual framework is not always, perhaps not even usually, fully recognized. And even when it is, to delineate it precisely is not a simple matter.
2. It does seem possible that one can, through a history-of-physics laboratory, make a modest contribution to the better understanding of both physics itself and its significance as a part of human endeavor.
3. It would certainly not be a simple didactic assertion about the value of $e/m$ for the electron.
4. The nucleus directly manifests itself in one natural terrestrial phenomenon, radioactivity, and it is of supreme importance as the source of stellar energy.
5. Does it make sense to refer to the size and shape of the nucleus?
6. In addition it is possible to make various time exposures of nuclei.
7. When applied to nuclei, the snapshot concept is theoretical; although there is nothing in the laws of physics that say a snapshot experiment is impossible, it is far beyond present technique.
8. It is hard to imagine that nuclei could be anything else, but the truth is that few nuclei are spherical.
9. The ground state, or state of lowest energy, is usually the best known because it is the only one that can be stable, but there is much information to be obtained by raising the energy to an excited level.

10. The distribution that is revealed, it should be pointed out, is essentially that of the protons.

### II. Translate into English using the active vocabulary of the lesson:

1. Точные измерения помогли теоретикам усовершенствовать модель ядра.
2. Мы хорошо знакомы с такими понятиями, как форма и размер неподвижного твердого объекта.
3. «Мягкие» ядра — это ядра, форма которых может легко изменяться.
4. Форма и размер атомов должны быть определены в новых терминах.
5. Размер атома — это понятие теоретическое.
6. Необходимо осветить ядро с помощью потока излучения очень короткой длины волны достаточной интенсивности, чтобы обеспечить одновременное взаимодействие с каждым нуклоном.
7. Только на моментальном фотоснимке ядро может иметь сферическую форму.
8. Степень деформации ядра может быть определена с помощью приближенной формулы.
9. В этих терминах ядра, которые с трудом изменяют свою форму, имеют степень деформации, приблизительно равную 0,3.

### III. Translate at sight:

The soft nuclei can rotate too, but they also oscillate through different shapes. A simple kind of oscillation is one in which a nucleus is prolate, becomes spherical, goes on to the oblate shape and back through spherical to prolate once again. More complicated oscillations are also possible. These time-dependent shapes can be inferred from measurements of the spectrum of excited-state energies, which deviate from the simple relation established for the hard deformed nuclei. Measurements of the electromagnetic radiation emitted or absorbed when the oscillation and rotation slow down or speed up are also helpful. Finally, the time-averaged shapes of different excited states are different from what they would be for hard deformed nuclei, and their measurement has just begun.

### IV. Give the situations from the text in which the following words are used:

vicinity; occasion; concept; rest; to refine; to define; familiar; soft; rough; simultaneous.



### V. Correct the false statements:

1. The notions of the size and shape of a solid object at rest are quite unknown up to now.
2. When applied to nuclei, the snapshot concept is practical; and we can easily carry out a snapshot experiment.
3. The experiments that can actually be done, and that we shall describe, are direct.
4. The nonspherical nuclei seem to fall rather neatly into five categories.
5. The «hard deformed» nuclei have a highly changeable form.
6. There are also «soft» nuclei, whose shape is essentially permanent.
7. The degree of deformation of a nucleus can be defined by an exact formula.

### VI. Translate the following Russian questions into English and answer them:

1. Можно ли практически сделать моментальный снимок ядра?
2. Возможно ли поставить прямой эксперимент с моментальным снимком ядра?
3. Правда ли, что только очень немногие ядра имеют сферическую форму?
4. На какие категории делятся несферические ядра?
5. Какие ядра называются «мягкими»?
6. Как может быть определена степень деформации ядра?
7. Является ли формула для определения деформации ядра достаточно точной?
8. Какова степень деформации «жестких» ядер?
9. Какова степень деформации «мягких» ядер?

### VII. Render in English:

*«Я вижу атом!»*

Тех, кто бывал в лаборатории Резерфорда, всегда поражала простота ее оборудования. Никаких сложных приборов! Иные аппараты казались даже примитивными. Но с их помощью знаменитый ученый и его сотрудники отвоевывали у природы больше тайн, чем иные институты, насыщенные сложной и дорогостоящей техникой.

С помощью нехитрого сооружения Резерфорд доказал существование атомного ядра. Это произошло во время опытов, целью которых было определить, как рассеиваются альфа-частицы на металлах. Прибор отмечал поведение таких частиц, проходящих через тончайшую золотую (gold) пластинку.

Выяснилось, что частицы ведут себя по-разному. Одни проходят через пластинку не меняя направление. Другие слегка отклоняются в сторону. А третьи почему-то отлетают обратно к источнику, словно наталкиваются на неожиданный встречный удар.

Резерфорд был поражен результатами эксперимента и говорил впоследствии о нем как о самом невероятном событии в его жизни: «Это было почти столь же невероятно, как если бы вы выстрелили пятнадцатидюймовым снарядом в кусок тонкой бумаги, а снаряд вернулся бы и нанес вам удар».

Но этот «снаряд» в клочья разнес прежние представления о строении атома. Альфа-частица могла отлететь строго назад, только столкнувшись с мощным положительным зарядом, да еще если тот был бы сконцентрирован в малом объеме. А по старым представлениям атом — это расплывчатая сфера больших размеров, на поверхности которой положительный заряд словно размазан тонким слоем.

Резерфорд сделал из этого опыта вывод: у атома есть ядро, в котором сгустилась почти вся масса атома, и именно в ядре сосредоточен весь положительный заряд. Диаметр ядра оказался в 100 000 раз меньше, чем диаметр атома. Атом, который раньше принимали за нечто непроницаемое, по сути дела оказался прозрачным!

Так родилась *резерфордовская модель атома.*

### VIII. Answer the following questions:

1. Why is it difficult to speak about the size and shape of nuclei?
2. What is the average shape of nuclei?
3. What do the terms «hard» and «soft» mean?
4. What is a snapshot?
5. What can you say about the shapes of the atoms?
6. What is the form of the «hard-deformed» nuclei?
7. What is the form of the «soft» nuclei?
8. How may the degree of deformation be defined?
9. What does a nucleus consist of?
10. How are we going to perform the snapshot experiment in practice?

### IX. Speak on the following topics:

1. The characteristics of nuclei.
2. The snapshot and the shape of atom.
3. Spherical and nonspherical nuclei.
4. The energy levels of nuclei.

# LESSON SIX

## Active Vocabulary

### root, *n.*

The root of a number is a quantity which, when multiplied by itself a certain number of times, equals the number, as square root, cube root, fifth root (i. e. a number to be multiplied by itself twice, three times, five times, respectively; 4 is the square root of 16, the cube root of 64, the fourth root of 256).

### deliver, *v.*

1. To deliver is to take and give to the owner; to carry from one person to another person; also to make a speech.
2. A postman is a man who delivers letters and telegrams.
3. Did you deliver my message to your father?
4. Professor Smith will deliver a course of lectures on quantum mechanics.

*Derivative:* delivery.

5. His speech was interesting but his delivery was poor.
6. Your letter came by the second delivery.

### excite, *v.*

1. To excite is to cause strong feeling; to rouse; to set in motion.
2. Everybody was excited by the news of the victory.
3. It's nothing to get excited about.
4. The patient is very ill and must not be excited.

*Synonym:* to provoke.
*Derivative:* excitation.

### expose, *v.*

1. To expose is to leave uncovered or unprotected; (photography) to allow light to reach a film or plate.
2. He exposed a shift of interest from natural philosophy to politics.

*Derivative:* exposure.

3. This is elastic scattering and it yields a time exposure.

*Synonyms:* to show; to exhibit; to display.
*Antonyms:* to hide; to conceal.

### involve, *v.*

1. To involve is to mix up with or in; to surround and interfere with; to complicate.
2. There is a number of difficulties in which this question is involved.
3. He got involved in the trouble.

*Synonym:* to include.

### resemble, *v.*

1. To resemble is to be like; to look like; to be similar to.
2. These brothers resemble each other.
3. The first method most closely resembles ordinary vision, in which we shine light on an object and see how it casts a shadow or diffuses or reflects the light.

*Derivative:* resemblance.

To show (to bear) some (no) resemblance to smth. or smb.

4. The record on the photographic plate (the hologram) shows no resemblance to the recorded subject.

*Synonyms:* to be like; to look like; to be similar.
*Antonym:* to differ.

### scatter, *v.*

1. To scatter is to throw in all directions.
2. Approaching cars scattered the players to both sides of the street.

*Synonym:* to disperse.
*Antonyms:* to collect; to gather.

### shift, *v.*

1. To shift is to move from one place to another; to change position.
2. The wind shifted to the east.



3. Study of shifting of optical spectral lines has yielded many measurements of one kind of average value for the radius.

### shift, *n.*

1. Shift is a change in frequency resulting in a change in position of a spectral line or band (e. g. Doppler shift, Red shift).
2. Doppler shift is a change in frequency of an electromagnetic radiation caused by the motions of the atoms, molecules, or nuclei in the line of sight.

*Synonym:* displacement.

### yield, *v.*

1. One of the main meanings of the verb «to yield» is to produce, to bring forth as a result.
2. In the case of a hard deformed nucleus, all snapshots made in the ground state and the low-lying excited states yield the same intrinsic cigar shape.
3. The heroes of Brest refused to yield the fortress to the enemy.

*Synonyms:* to produce; to bring forth; to give up.

### subsequent, *adj.*

1. Subsequent is following; later.
2. The writer describes the events subsequent to the war.

*Derivative:* subsequently.

3. When an atom is excited by an input of energy and subsequently «relaxes» back to its ground state, its electrons change their orbits.

*Synonyms:* following; later.

## Exercises

### 1. Give the English for:

a) корень; доставлять; возбуждать; делать выдержку (фото); включать (в себя); быть похожим; рассеивать; смещать; производить; последующий; впоследствии;

b) корень квадратный; возбуждать ядро; иметь сходство с чем-либо; рассеиваться под различными углами; упругое рассеяние; расщепление и смещение оптических спектральных линий; производить электроны.

### 2. Give the Russian for:

high-energy particles; long-wavelength probe; to resemble ordinary vision; to deliver electrons; time exposure; distribution of magnetism in the nucleus; subsequently; shifting of optical spectral lines; root-mean-square charge radius; inelastic scattering; distribution of excitation energy; subsequent gamma radiation.

### 3. Give derivatives of the following words:

to deliver; to expose; to resemble; subsequent.

### 4. Give synonyms of the following words:

displacement; to be similar; to disperse; to produce; to show; to provoke; to include.

### 5. Give antonyms of the following words:

to differ; to gather; to hide; to discard; unknown; hard; indefinite; refined; extrinsic.

### 6. Read the followind words:

to excite [ik'sait]
excitation [,eksi'teiʃən]
to expose [iks'pouz]
exposure [iks'pouʒə]
exposition [,ekspə'ziʃən]
to yield [ji:ld]
elastic [i'læstik]
percent [pə'sent]
to resemble [ri'zembl]
resemblance [ri'zembləns]

subsequent ['sʌbsikwənt]
subsequently ['sʌbsikwəntli]
spectrum ['spektrəm]
spectrometer [spək'trɔmitə]
accuracy ['ækjurəsi]
accurate ['ækjurit]
minor ['mainə]
radius ['reidiəs]
moreover [mɔ:'rouvə]
nevertheless [,nevəðə'les]

## THE SIZE AND SHAPE OF ATOMIC NUCLEI

by Michel Baranger and Raymond A. Sorensen

(continued)

*Experimental Methods*

Three general classes of experimental techniques are now being applied to this kind of work. First, one can observe the nucleus with a short-wavelength probe: accelerated electrons or other high-energy particles that are deflected by the nucleus. Second, one can observe it with a long-wavelength probe such as the atom's own electrons. Third, one can excite the nucleus and observe the radiation it emits.



The first method most closely resembles ordinary vision, in which we shine light on an object and see how it casts a shadow or diffuses or reflects the light. An object can be seen, however, only if it is larger than the wavelength of the light; to «see» a nucleus requires very short wavelengths indeed. Short wavelength means high energy, and electromagnetic radiations of such high energy — gamma rays — are difficult to work with. Electron rays, which can be deflected and focused with magnets, make better probes, but they too must be highly energetic: whereas an atom can in effect be seen by an electron microscope with an energy in tens of thousands of electron volts, seeing a nucleus requires electrons of many millions of electron volts (MeV). That calls for a powerful accelerator such as the two-mile linear accelerator at Stanford University, which delivers electrons of 20,000 MeV.

To study a nucleus one directs a beam of high-energy electrons at a target composed of atoms containing the nuclei under investigation. The electrons of the beam are little affected by the electrons in the atoms but they are scattered, or deflected, by the nuclei. A spectrometer records the number of electrons of a certain energy that are scattered through various angles. In most such experiments one records only those electrons that have been simply scattered by the nucleus without exciting it; this is elastic scattering and, as we have explained, it yields a time exposure of the nucleus. From this one can determine the nuclear size to an accuracy about I percent, the variation of the charge density with radius and even the distribution of magnetism in the nucleus.

The second method, like the first, involves the interaction of an electron with the nucleus, but in this case it is one of the nucleus's own atomic electrons. When an atom is excited by an input of energy (from heat or light, for example) and subsequently «relaxes» back to its ground state, its electrons change their orbits and the atom emits a spectrum of radiation at characteristic wavelengths. The size and shape of the nucleus play a very minor but detectable role in the electronic structure of an atom and therefore in its spectrum, and since atomic spectra can be measured with high precision these «hyperfine» effects can be observed. Since the nucleus itself remains unexcited, this method, like the first, yields a time exposure of the nucleus. Moreover, since the atomic spectral method does not involve a short-wave-length probe, its results are averaged in space as well as in time and it does not give a detailed distribution of charge and magnetism. Study of hyperfine splitting and shifting of optical spectral lines nevertheless has yielded many measurements of one kind of average value for the radius, the root-mean-square charge radius, as well as of electric and magnetic moments that carry information about the shape of the nucleus.

Some recent experiments of this type depend on X-ray spectra rather than optical spectra. Whereas optical spectra are generated by the outer electrons, X rays are emitted when one of the inner electrons changes its orbit; being closer to the nucleus, such an electron is influenced more by the nucleus and less by the other electrons. In the past few years such X-ray experiments have also been done with mu-mesonic atoms, in which a mu meson, or muon, is introduced into the atom to replace on the innermost electrons. A muon is 207 times heavier than an electron (but still only a ninth as heavy as a nucleon), and so its innermost orbit lies much closer to the nucleus than any electron's orbit. The nucleus-muon interaction that is reflected in X-ray spectra of muon atoms is therefore quite sensitive to nuclear size, and the radius can be determined to about 1 percent.

The third method, unlike the other two, changes the energy of the nucleus and is capable of giving instantaneous information. One such technique, known as Coulomb excitation, is based on the inelastic scattering of a positively charged projectile such as an alpha particle. The target nucleus is excited into a higher-energy state of internal motion and then emits electromagnetic radiation as it returns to its ground state. The distribution of excitation energy, as well as the spectrum and intensity of the subsequent gamma radiation, give information on the nuclear shape. Since in this case a nucleus is really being observed in motion, more detailed information is obtained about the shape and its changes over time than from the first two (time exposure) methods. The information is space-averaged, however, since the alpha particles, having too low an energy to penetrate the nucleus, behave as a long-wavelength probe.

In summary, it is the high-energy elastic scattering that gives details of the spatial shape of a time average; low-energy inelastic scattering reveals the time behavior of a space average. A fourth method would be high-energy inelastic scattering, in which one measures the number of scattered electrons that excite nuclei to each energy level. It is this method that can give both detailed space and detailed time information, but the experiments are difficult and their application to the study of nuclei has just begun.

*Scientific American*
*August 1969.*

## Exercises

### I. Translate into Russian paying attention to the Emphatic Constructions:

1. This problem did involve a number of difficulties.
2. It is this problem that involved a number of difficulties.
3. For these students the novelty of the viewpoint adopted does



seem, at least, occasionally, to throw familiar concepts into a new relief.

4. It is this contrasting viewpoint that often provides the stimulus for a more critical understanding.
5. This contrasting viewpoint does often provide the stimulus for a more critical understanding.
6. It is this method that yields a time exposure of the nucleus.
7. It is the time exposure of the nucleus that this method yields.
8. This method does yield a time exposure of the nucleus.
9. It is the interpretation of his experiments that led Ampere to believe he had analyzed electromagnetics on sound Newtonian lines.
10. Interpretation of his experiment did lead Ampere to believe he had analyzed electromagnetics on sound Newtonian lines.

### II. Translate into English using the active vocabulary of the lesson:

1. Результаты этого метода являются усредненными как в пространстве, так и во времени.
2. Электроны атомов слабо влияют на электроны пучка, но их рассеивают или отклоняют ядра.
3. В большинстве таких экспериментов регистрируют только те электроны, которые были просто рассеяны ядром, не возбудив его.
4. Атомный спектр может быть измерен с высокой точностью.
5. Первый метод более всего похож на зрительное восприятие, когда мы освещаем объект и смотрим, как он отбрасывает тень, рассеивает или отражает этот свет.
6. Так как само ядро остается невозбужденным, этот метод дает время экспозиции ядра.
7. Второй метод включает в себя взаимодействие электрона с ядром.
8. Третий метод, в отличие от двух других, изменяет энергию ядра и способен давать мгновенную информацию.
9. Атомный спектральный метод не включает коротковолновое зондирование.
10. Изучение смещения оптических спектральных линий дало много однотипных измерений среднего значения радиуса.

### III. Catch the meaning of the text and retell it:

Like an atom, a nucleus can exist in a large number of quantum states. Each state corresponds to a different mode of motion of the constituent nucleons, and the various states differ in such properties as energy, angular momentum, parity and size and shape. In talking about size and shape one must therefore specify the state of the

VI. Translate to English

1. Какие элек лучшими зон-
дами?

2. С помощью ь атом?

3. Что регистр



4. Какие электроны регистрируются в таких экспериментах?

5. Когда электроны атома изменяют свои орбиты?

6. А что происходит в это время с атомом?

7. Какую роль играют размер и форма ядра в электронной структуре атома?

8. Можно ли измерить атомный спектр с высокой точностью?

9. Почему атомный спектральный метод не дает детального распределения заряда?

10. Для развития ядерной физики за последние годы характерно быстрое возрастание объема экспериментального материала и улучшение качества получаемой информации о свойствах ядер, не так ли?

## VII. Render in English:

*«Я вижу атом!»*

Так родилась резерфордовская модель атома. Она представляла его строение подобным Солнечной системе: в центре ядро — Солнце, вокруг по орбитам движутся электроны — планеты. Ядро, по представлениям Резерфорда, состоит из протонов — носителей элементарного положительного заряда — и электронов. Протонов в ядре столько, сколько электронов содержится в ядре атома и на его орбитах. Например, в ядре атома гелия содержится 4 протона и 2 электрона. Заряд ядра гелия равен поэтому +2, и нейтрализуется он двумя электронами на электронной оболочке атома.

Но и эта модель не давала ответа на вопрос, в чем же причина радиоактивности.

Резерфорд мог бы сказать: «Я вижу атом!». Но чутьем гениального ученого он понимал, что атом нужно не только видеть, но и разглядеть во всех деталях. И особенно его ядро. Но у ученых не было средств, которые позволили бы им проникнуть в глубь ядра. Оно представлялось совершенно несокрушимым бастионом, и даже самые мощные осадные орудия не могли разрушить его крепкие стены.

## VIII. Answer the following questions:

1. How many general classes of experimental techniques are now being applied to this kind of work? What are they?

2. Why are electromagnetic radiations of high energy — gamma rays — difficult to work with?

3. What are we to do to study a nucleus?

4. What is elastic scattering?

5. What do recent experiments of this type depend on?

6. When are X rays emitted?

7. What is a muon?

8. Does the third method change the energy of the nucleus? What is the use of doing so?

9. Have you ever heard about Coulomb excitation? What is it?
10. What method can give both detailed space and detailed time information? Why are the experiments still difficult?

**IX. Review the article «The Size and Shape of Atomic Nuclei».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. The liquid-drop model.
2. The shell model.
3. The explanation of deformation by the use of the shell model.
4. The collective model.
5. What is the mechanism of the X ray?

# LESSON SEVEN

## Active Vocabulary

### coil, *n.*

1. Coil is a spiral used for electromagnetic effect or electrical resistance.
2. If there is a relative motion between the playback head of a taperecorder and the tape, a current will be induced to flow in the coil.

### core, *n.*

1. The core is the central or most important part of a thing.
2. The core of an electromagnet is usually made of soft iron.
3. The core of this apple is very bad.

### gap, *n.*

1. A separation in space or a break in continuity is called gap.
2. He tried to stop the gap in his knowledge of astronomy.
3. There is a great gap in the views of Soviet and American ideologists.

*Synonyms:* blank; disparity.

### rate, *n.*

1. Rate is a fixed quantity; a fixed ratio between two things; a quantity, amount, or degree of something measured per unit of something else.
2. The train was going at the rate of 90 kilometres an hour.
3. The average rate of cars in Moscow is 60 km/h.

*At any rate*=in any case.

*Synonyms*: estimation; speed; velocity.

### rise, n.

1. Rise is an elevation of one point above another.
2. The rise of the tide is about 30 ft at this time of the year.
3. To give rise to something means to origin, to start.
4. Sputnics gave rise to a broad research of the atmosphere.

### range *v.*

1. To range means to set in a proper order; to place among others in a position or situation.

2. The bandwidth of this wireless ranges from 9 meters to 1,800 meters.

3. Magnetic recording ranges from the «instant replay» of televised sports events to the memory of computer systems.

4. It is out of my range=it is not my business.

*Synonym:* to line.

### retain, *v.*

1. To retain means to keep on possesion or use; to continue to have.

2. Everybody knows that lead retains heat.

3. The magnetic particles in the tape retain their magnetization after they pass the core.

*Derivative:* retainable.

*Synonym*: to keep.

### require, *v.*

требов.

1. To require means to call for as suitable or appropriate; to demand as necessary or essential.

2. Some tape-recording systems require rapid starting and stopping.

3. Recording of high frequences requires an increase in the relative head-to-tape speed.

4. If the maximum output signal is determined by the efficiency of the recording process, the system does not require linearity.

*Derivative:* requirement.

*Synonyms:* to demand; to lack.

### switch, *v.*

1. To switch means to make a shift or exchange.

2. The magnetization of the particle switches from one direction to the opposite direction.

3. As the field increases, more and more particles are switched.

### vary, *v.*

1. To vary means to make a partial change in something; to make different in some attribute or characteristic; to present under new aspect; to become different.

2. In the process of recording the current in the recording head varies constantly.

3. The microscopic point on the tape senses magnetic fields that vary with time.

4. Tastes vary.

*Derivatives:* variable, variation, variety, various.

*Synonym:* to change.

## Exercises

### 1. Give the English for:

a) катушка; сердечник; щель; зазор; скорость; вызывать что-либо, давать повод к чему-либо; колебаться в пределах; изменять (ся); сохранять; требовать;

b) заполнять пробел; в любом случае; это не по моей части; мнения по этому вопросу расходятся; изменять направление.

### 2. Give the Russian for:

the current applied varies constantly; the core is readily magnetized; north and south poles are separated by a small gap; induced current in the coil; to be sensitive to rates of flux change; to give rise to such devices; to range widely; these properties are retained; high degree of linearity is required; magnetization of particles switches.

### 3. Give derivatives of the following words:

to retain; to require; to vary.

### 4. Give synonyms of the following words:

blank; estimation; to line; to keep; to demand; to change.

**5. Read the following words:**

analogue ['ænəlɔg]
retain [ri'tein]
require [ri'kwaiə]
coercivity [ko(u)ə:'siviti]
to vary ['vεəri]
variable ['vεəriəbl]
variety [və'raiəti]
to process [prə'ses]
process ['prouses]
surface ['sə:fis]

effect [i'fekt]
carrier ['kæriə]
microphone ['maikrəfoun]
to saturate ['sætʃəreit]
saturation [,sætʃə'reiʃən]
communication [kə'mju:ni'keiʃən]
to magnetize ['mægnitaiz]
integral ['intigr(ə)l]
linearity [,lini'æriti]
binder ['baində]

## MAGNETIC RECORDING

*The storage of information in magnetic particle is an integral part of communication and data processing. The demands of different kinds of information have given rise to variations on the basic theme.*

by Victor E. Ragosine

Magnetic recording plays a central role in modern communication and data processing, ranging from the «instant replay» of televised sports events to the memory of computer systems. Its basic principle is straightforward: sound, for example, is transformed into an electric current by a device such as a microphone. The current varies in intensity with variations in the loudness of the sound. The current passes through a coil surrounding an iron core, including proportionately varying degrees of magnetism in the core. A magnetizable surface such as a tape that is moved past the core is correspondingly magnetized in varying degrees. Since the magnetic particles in the tape retain their magnetization after they pass the core, the result is a recording. Playback, which re-creates the sound, is the same process in reverse: the magnetization in the tape induces varying electric currents in the coil, and the currents are transformed into a reproduction of the sound.

### *The recording process*

Let us begin by considering a recording process. The tape consists of a thin plastic base coated with an even thinner layer of magnetic oxide particles in a polymeric binder. The behaviour of each particle under the influence of an external magnetic field is bipolar, meaning that there is no change in the magnetization of the particle until the strength of the field has reached a certain



threshold level whereupon the magnetization of the particle switches from one direction to the opposite direction.

Imagine now a microscopic point on the tape as it approaches the recording head. The point senses an increasing magnetic field as it draws near the gap in the recording head. Nothing happens, however, until the field is strong enough to switch the particles of lowest coercivity. As the field increases, more and more particles are switched. If the field is sufficiently strong, every particle will be switched and the point on the tape will be magnetically saturated. As the point moves past the gap the magnetic field decreases and eventually has no further effect on it.

In the recording and reasonably faithful reproduction of sound, and particularly of analogue data, a high degree of linearity is required, that is, the output of the magnetically recorded surface has to be (as nearly as possible) directly proportional to the input.

Linearity is required in the recording of signals such as music because the information being recorded is contained not only in the frequency of the signal but also in the changes in its amplitude. Linearity is not a requirement in other kinds of modulation and coding. A case in point would be the recording of a signal that was frequency-modulated on a carrier signal; the carrier signal might have a frequency of a million cycles per second and the modulation might cause it to deviate by 200,000 cycles, that is, to a high of 1.2 million and a low of 800,000. The information is contained in the deviation of the frequency from the carrier signal and the rate of change of the deviation. One need only to be able to detect the number of times the signal crosses the zero axis (the carrier signal) in a given period of time, and that requirement does not call for linearity.

*Scientific American*
*November 1969.*

Exercises

**I. Translate into Russian paying attention to the functions of «one»:**

1. One needs only to be able to detect the number of times the signal crosses the zero axes in a given period of time.
2. If one wanted quality in the recording of signals of short wavelength and high frequency, or if one sought to record on one machine and play back on another, thereby requiring a recording that was compatible between two machines, the control of tape speed was inadequate.

3. One is transverse recording which entails recording across the width of a tape rather than along its length.

4. Disk systems, particularly the ones that employ a number of playback heads, offer a further improvement in access time.

5. Without alternating-current bias the responses are not linear and one hears distortion on playback.

6. One can describe how matter interacts with matter in terms of its location in the fixed space-time.

7. To be able to convert the time coordinate of one observer to a combination of time and space of another, one must express time and length in the same units — in frames of reference.

## II. Translate into English using the active vocabulary of the lesson:

1. Сердечник намагничивается, когда ток проходит через витки проволоки.

2. В процессе записи ток в магнитной головке магнитофона постоянно меняется, отражая изменения в интенсивности или частоте получаемого сигнала.

3. Как только прекращается движение ленты относительно воспроизводящей головки магнитофона, в катушке исчезает индукционный ток.

4. Записывающая и воспроизводящая головки магнитофона требуют очень точной обработки.

5. Сердечник имеет форму кольца или прямоугольника; северный и южный полюсы отделены друг от друга узкой щелью, играющей главную роль в процессе записи.

6. Очень немногие металлы сохраняют свои качества при сверхвысоких температурах.

7. Толщина магнитной поверхности ленты должна быть очень маленькой; обычно она колеблется в пределах от стамиллионной до четырехсотмиллионной доли дюйма.

8. Воспроизводящая головка магнитофона очень чувствительна к изменению скорости движения ленты.

9. В некоторых видах магнитофонов слишком близкое расположение звуковых дорожек вызывает снижение качества воспроизведения записи.

10. Частицы изменяют направление движения на противоположное под воздействием внешнего магнитного поля, когда последнее достигает определенного уровня.

## III. Catch the meaning of the text and retell it:

### *Helical Recording*

Although transverse recording offers the advantages of high frequency and reasonable tape consumption, it also imposes the disadvantage of having to control both the longitudinal speed of the tape and the rotational speed of the recording head. In addition, the complexity of the head assembly increases cost. Helical recording provides a compromise between the longitudinal and the transverse method. In the helical format the tape is wrapped around a drum that contains the recording head and the playback head. This format has given rise to machines that cost substantially less than machines for transverse recording but do not perform quite as well. Helical recorders have found increasing use in television applications where picture recording can be at a lower resolution than is acceptable in commercial television.

Magnetic recording need not be only on tape; it can also be done on chips, on relatively short strips and on disks. With chips and strips the recording is usually longitudinal. After the chips or strips are retrived from storage they are put on a rapidly rotating drum, that provides the necessary motion between the head and the recording surface. With disks the head-to-surface motion is provided by rotating the disk, and information is recorded in circles.

## IV. Give the situations from the text in which the following words are used:

playback; reproduction; binder; bipolar; to sense; to be switched; input; linearity; modulation.

## V. Correct the false statements:

1. Magnetic recording does not play any role either in modern communication or in data processing.

2. Current intensity variations do not influence the loudness of the sound.

3. While playback the core magnetizes the surface of the tape.

4. The magnetization of the particle changes constantly independent of an external magnetic field.

5. A high degree of linearity is required neither in recording nor in reproduction.

6. The output of the magnetically recorded surface does not have to be directly proportional to the input.

7. The information being recorded is contained in the frequency of the signal only.

8. Linearity is required in all kinds of modulation and coding.

9. The deviation of the frequency from the carrier signal and the rate of change of the deviation are considered to be of no importance as far as the information is concerned.

10. For a signal to be recorded, it is not necessary to be frequency-modulated on a carrier signal.

## VI. Translate the following Russian questions into English and answer them:

1. Что отличает запись на магнитную ленту от других форм хранения информации?
2. Какие основные требования предъявляются к записывающей и воспроизводящей головкам магнитофона?
3. Что такое магнитная коэрцитивность частицы?
4. Как определяется магнитная коэрцитивность частицы?
5. В каком случае в обмотке катушки не будет индуцированного тока?
6. В чем состоит механизм воспроизведения записи звука?
7. Чем может быть вызвана некачественная запись звука?
8. Каковы основные причины плохого воспроизведения записи?
9. Из чего состоит ферромагнитная лента?
10. Что вы знаете о магнитно-оптических системах?

## VII. Render in English:

Недавно две советские межпланетные научные станции стали спутниками Марса. Спутники оснащены разнообразной научной аппаратурой, среди которой важное место занимают телевизионные устройства. Телевизионные изображения небесных тел содержат разнообразные сведения о структуре и топографических особенностях их поверхности и ее эволюции, о форме планет, об атмосферных явлениях и сезонных изменениях климата. Такая «универсальность» изображений делает их одним из важнейших видов научной информации, а устройства, с помощью которых получают эти изображения, являются весьма эффективным инструментом космических исследований.

Телевизионные устройства, связывающие Землю с «Марсом-2» и «Марсом-3», основаны на принципе фототелевизионной передачи изображения. В этих устройствах изучаемое небесное тело сначала снимается на фотопленку, затем фотопленку автоматически проявляют *, после чего полученное изображение телевизионным способом передается на Землю.

Несмотря на сложность фототелевизионных систем, современные инженерно-технические достижения позволяют сделать эти системы весьма компактными и легкими, что немаловажно для космического аппарата. Важной особенностью фототелевизионных устройств является высокая четкость и точность передачи изображения. Все это послужило основанием для применения таких устройств на многих космических аппаратах — «Луна-3» и «Зонд-3», изучавших обратную сторону Луны, «Лунар Орбитер» и «Луна-12» — американском и советском спутниках Луны, проводивших детальное исследование ее поверхности. На каждом из советских спутников Марса установлена сдвоенная фототелевизионная система, состоящая из приборов, имеющих различные объективы. Таким образом, оба прибора в работе как бы дополняют друг друга.

* проявлять пленку — to develop a film.



## VIII. Answer the following questions:

1. What is the basic principle of magnetic recording?
2. What does the process of recording consist of?
3. Can you describe the composition of the magnetic tape?
4. How can the behaviour of a particle under the influence of an external magnetic field be explained?
5. While the field is increasing the number of switched particles increases correspondingly, doesn't it?
6. How does the linearity influence the reproduction of sound and analogue data?
7. Where is the recorded information contained?
8. What do the processes of recording and playback have in common?
9. What do you know about helical recording?
10. What can you say about magnet-optical and disk systems?

## IX. Review the article «Magnetic Recording».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. Laws of physics that are the basis of magnetic recording.
2. Principles of magnetic recording.
3. Materials for sound recording.
4. Principles of laser energy recording.
5. Spheres of magnetic recording applications.

## LESSON EIGHT

### Active Vocabulary

**image, *n.***

1. Image is a reflection seen in a mirror or through the lens of a camera; a close likeness.
2. He is the very image of his father.
3. The hologram process retains three-dimensional image separation.

*Derivatives:* to imagine, imaginery, imaginable, imagination.

4. Can you imagine life without gas, electricity and radio?
5. I cannot imagine who that man is.

**device, *n.***

1. Device is a mechanism which serves a special purpose or performs a special function, as a device for measuring heat release.
2. The photographic record of the light-wave pattern formed by interference between plane and spherical waves is almost identical to an optical device known as a zone plate.
3. This recognized authority looked upon holograms as diffraction devices.
4. To devise is to think out; to plan; to invent.
5. He devised another plan to carry out this experiment.

**source, *n.***

1. Source is a starting-point; a place of origin.
2. Books are a source of knowledge.
3. These waves create the illusion of a point source of light.
4. She is a reliable source of information, she always knows everything.



**virtue, *n.***

1. Virtue is an ability to produce a definite result; power; it is also goodness; a disposition to do what is right; moral excellence. Remember: *by virtue of*=by means of.
*in virtue of*=on the ground of.
2. Patriotism is a virtue.
3. This climate has the virtues of never being too hot or too cold.

*Derivatives:* virtual, virtually.

4. This hologram will provide an observer with a virtual image comprising two light sources.

**cause, *n.***

1. Cause is that which produces an effect; a thing, person or event that makes a thing happen; a subject in which many people are interested and for which they are willing and ready to make efforts.
2. Never stay away from school without good cause.
3. If you are working in the cause of world peace, you are working in a good cause.

*Synonym:* reason.

**cause, *v.***

1. The verb «to cause» means to be the cause of; make (a thing) happen; bring (a thing) about.
2. What caused his death?

**issue, *v.***

1. To issue is to come, go, flow or pour out; also to give or send out; publish; distribute.
2. The sound of two voices issued from the dining room.
3. In forming holograms two sets of waves are involved, the reference wave and the rather complicated set of waves issue from the scene.

**issue, *n.***

E. g. the most recent issues of a newspaper; to discuss political issues.

**refer, *v.***

1. To refer is to point to as the source or origin of; to place in relation to; to look at for information.

2. He referred his success to the good teaching he had had.
3. The speaker referred to his notes.
4. Don't refer to the matter again.
*Derivative:* reference.
5. You should make references to a dictionary.
6. The book is full of references to (i. e. often mentions) places I know well.
*Synonyms:* to appeal; to apply to.

**interfere, v.**

1. Don't interfere (i. e. Don't interrupt; don't disturb me)!
2. The plane reference waves interfere with the spherical waves issuing from the pinhole.
*Derivative:* interference.
E. g. interference colours; interference figure; interference pattern; interference spectrum.

**opaque, *adj.***

1. Opaque is not allowing light to pass through; that cannot be seen through; dark as opaque glass.
2. A hologram can record a scene which includes a small, very bright reflecting point behind an opaque screen.
*Antonym:* transparent.

**valid, *adj.***

1. Valid is carried out with the correct legal formalities; based on good evidence; that can be accepted; sound; reasonable.
2. The above theory was tested and proved to be valid.
3. Mathematical symbols are valid whether there is anything corresponding to them in nature or not.
4. All of these descriptions of holograms are quite valid.
*Derivatives:* validity, validly.
*Synonyms:* effective; strong; powerful; convincing; sufficient.
*Antonyms:* ineffective; insufficient.

Exercises

**1. Give the English for:**

a) изображение; устройство; источник; сила, действие; причина; выходить, получаться в результате; иметь отношение, ссылаться; вмешиваться; непрозрачный; обоснованный, валидный;



b) трехмерное изображение; оптическое устройство; точечный источник; посредством чего-либо; доброе дело; последний номер газеты; опорная волна; интерференционная картина; матовое стекло.

**2. Give the Russian for:**

a three-dimensional image; an optical device; a point source of light; by virtue of; a virtual image; a good cause; reference wave; interference pattern; opaque screen.

**3. Give derivatives of the following words:**

image; to interfere; to refer; virtue; valid.

**4. Give synonyms of the following words:**

reason; invention; to attribute; effective.

**5. Read the following words:**

device [di'vais]
to devise [di'vaiz]
source [sɔ:s]
virtue ['və:tju:]
virtual ['və:tjuəl]
to cause [kɔ: z]
issue ['isju:]
opaque [ou'peik]
valid ['vælid]
validity [və'liditi]
image ['imidʒ]
to imagine [i'mædʒin]
imaginery [i'mædʒinəri]
imagination [i,mædʒi'neiʃən]
to interfere [,intə'fiə]
interference [,intə'fiərəns]
scene [si:n]
although [ɔ:l'ðou]
holography [hə'lɔgrəfi]
hologram ['hɔləgrəm]

## FUNDAMENTALS OF HOLOGRAPHY

*An authority describes the action as a simple diffraction process, and traces its development from Gabor's elegant synthesis of the basic relationships to modern attempts at applying the technique to 3-D television.*

by Winston E. Kock

In discussing holograms, various authors stress various features. Some describe a hologram as a modulation process, with the reference illumination constituting the carrier wave and light waves reflected from the scene constituting the modulating signal. Others refer to the process as a coding process for storing information on a photographic plate. Still others describe it as a process in which, in addition to recording the amplitude of the light wave, as in the photographic process, the phase is also recorded, by means of the reference wave.

Although all of these descriptions of holograms are quite valid, they do not offer very simple explanations, and therefore they do not aid particularly in the understanding of the hologram process. However, when the interference-pattern aspects of holograms are examined, the reasons for the holographic action are clearly seen. Holography then becomes a rather simple diffraction process, fully understandable without concern for phase, modulation, coding, or other concepts often mentioned.

In forming holograms two sets of waves are involved, the reference wave (usually a simple plane wave) and the rather complicated set of waves issuing from the scene. The hologram is the photographic record of the interference pattern generated by these two sets of waves. Figure 1 shows how a simple hologram, that of a point source of light, might be made. At the left, a beam of laser light falls on the screen and also passes around it, and the plane reference waves interfere with the spherical waves issuing from the pinhole. The photographic record of the light-wave pattern formed by interference between plane and spherical waves is almost identical to an optical device known as a zone plate, a set of concentric annular rings which cause wave energy to be diffracted. The open spaces of a zone plate permit passage of that energy which will add constructively at a desired focal point, and the opaque rings prevent passage of energy which would interfere destructively at the point.

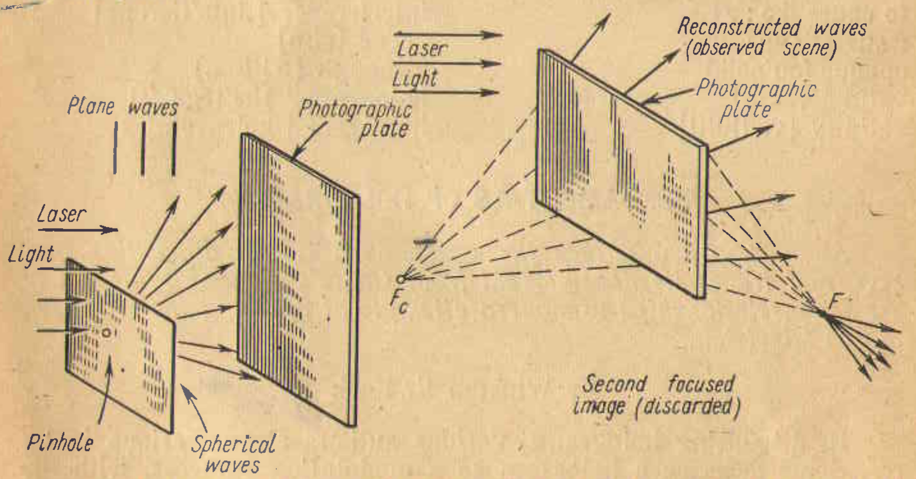


Fig. 1. Circular interference fringes, corresponding to a zone plate, are created by interference pattern formed by plane waves arriving from left and by spherical waves emerging from the pinhole. If a portion of this pattern is recorded on a photographic plate, the resulting hologram, when illuminated, causes waves to be generated, «reconstructing» the image as if it came from the original location of the pinhole.



In Fig. 1, only the upper segments of the circular interference zones which exist in the plane of the photographic plate are recorded. This recording of a reference wave and a second set of waves is the hologram. When the plate is developed and illuminated with laser light, as shown at the right, the diffraction process causes converging waves to be produced, creating a real image of the original scene at the focal point *F*. We shall see shortly that diffraction at the zone plate also generates diverging waves, and these waves create, for a viewer, the illusion of a point source of light located at the conjugate focal point *Fc*. This diverging light is indistinguishable from that originally issuing from the pinhole, and the viewer imagines he sees this source of light located in space behind the illuminated photographic plate.

Had there been two point sources of light in the original scene, two superimposed zone plates would have been recorded on the photographic plate (the hologram), and this hologram, upon illumination, would provide an observer with a virtual image comprising two light sources, both fixed in space, no matter how the observer moved his head from side to side or up and down. Since any scene can be looked upon as being made up of many individual sources of light, and since each of these sources forms, with the reference wave, its own zone plate on a photographic plate, the hologram of an actual scene will, when illuminated, generate a composite image, a combination of virtual images of all of the many original light sources. This is an exact replica of the original scene, and it stands out in space with vivid realism.

*(to be continued)*

## Exercises

**I. Translate into Russian paying attention to the Passive Voice:**

1. Still others describe it as a process in which, in addition to recording the amplitude of the light wave, as in the photographic process, the phase is also recorded, by means of the reference wave.
2. However, when the interference-pattern aspects of holograms are examined, the reasons for the holographic action are clearly seen.
3. Figure 1 shows how a simple hologram, that of a point source of light, might be made.
4. The shapes and sizes of nuclei must be defined in terms of snapshots.
5. The experiments that can actually be done, and that we shall describe, are indirect.

6. Magnetism is referred to in the oldest writings of man.

7. Many materials now commonly used were not even thought of thirty years ago.

8. The positive particle in the nucleus of the atom was given the name of «proton».

9. The charge of an atom is not affected by the number of neutrons present but depends on the balance between electrons and protons.

10. The region surrounding a magnet, in which appreciable magnetic forces exist, is referred to as the magnetic field.

**II. Translate into English using the active vocabulary of the lesson:**

1. Дагерр искал способ запечатлеть изображение на матовом стекле прибора и нашёл его, однако, этот способ уже был предложен ранее.
2. Голограмма записывает интерференционную картину, образованную комбинацией опорной волны и световых волн, исходящих от сцены (множества предметов).
3. Для изготовления голограмм требовались источники, испускающие свет строго определенной частоты, а таких источников в то время еще не существовало.
4. Голография — совсем простой процесс фотографической записи интерференционной картины, образованной двумя наборами световых волн, один из которых называется опорным пучком.
5. Хотя все эти описания голограммы являются вполне обоснованными, они не дают простых объяснений, и поэтому не могут способствовать лучшему пониманию процесса построения голограммы.
6. При обсуждении голографии разные ученые обращали внимание на различные аспекты проблемы.
7. Некоторые ученые описывают процесс построения голограммы как процесс, при котором, кроме регистрации амплитуды световой волны, как и в фотографическом процессе, записывается также с помощью опорной волны фаза.
8. Чтобы получить голограмму, необходимо иметь два набора волн.
9. Световая волна, идущая от лазера, называется опорной волной.

**III. Translate at sight:**

*Parallax and Lens Action*

In viewing a hologram, the observer is usually encouraged to move his head sideways or up and down so that he may grasp its full realism by observing an effect called parallax. In some real scene, more distant objects appear to move with the viewer, whereas closer objects do not. Such effects are very noticeable to a person riding in a train; the nearby telephone poles move past rapidly, but the distant mountains appear to move forward with the traveller. Similarly, the parallax property of holograms constitutes one of their most realistic aspects.

Because hologram viewers invariably do move their heads to experience this parallax effect, hologram designers often include cut-glass objects in the scene to be photographed. In the real situation, glints of light are reflected from the cut glass, and these glints appear and disappear as the viewer moves his head. This effect also occurs for the hologram, and further heightens the realism.

**IV. Give the situations from the text in which the following words are used:**

image, device, source, to cause, to interfere, to issue, to refer, opaque, valid, virtual.

**V. Develop further the following statements:**

1. Some describe a hologram as ...
2. Still others describe it as a process in which, in addition to recording the amplitude of the light wave, as in the photographic process, the phase ...
3. Although all of these descriptions of holograms are quite valid ...
4. The photographic record of the light-wave pattern formed by interference between plane and spherical waves is almost identical to ...
5. This hologram, upon illumination, would provide an observer with ...
6. In forming holograms two sets of waves are involved, the reference wave (usually a simple plane wave) and the rather complicated set of waves ...
7. At the left, a beam of laser light falls on the screen and also passes around it, and the plane reference waves ...

**VI. Translate the following Russian questions into English and answer them:**

1. Являются ли все описания голограммы обоснованными?
2. Дают ли эти описания простые объяснения голограммы?
3. В каком случае голография может быть рассмотрена как обычный процесс дифракции?
4. Что происходит, когда пластинка проявляется и освещается светом лазера?

5. Какие наборы волн используются для получения голограммы?

6. Почему в голографии используются точечные источники света?

7. Является ли голография принципиально новым методом получения объемных изображений предметов?

8. На каком явлении основан этот новый метод получения объемных изображений предметов?

9. Нашла ли голография практическое применение в экспериментальной физике и технике?

10. Присутствуют ли на голограмме элементы, хоть сколько-нибудь напоминающие оригинал?

## VII. Render in English:

*Голограммы и фотографии*

Мы укажем на две основные особенности, которые отличают голограмму от фотографии. Фотографию обычно делают как бы в два этапа: сначала получают негатив, на котором светлые участки сфотографированного предмета выглядят темными, а темные — светлыми, затем с негатива печатают позитив (обращенный негатив), на котором уже получается прямое изображение предмета. В голографии как негатив, так и позитив дают совершенно одинаковые трехмерные изображения предмета. Это свойство вытекает из аналогии между голограммами и зонными пластинками. Мы уже отмечали, что если в зонных пластинках и решетках темные пятна сделать светлыми, а светлые — темными, то изображение, восстановленное с помощью такой копии, не станет негативом, а останется позитивным и неотличимым от изображения, полученного с исходной зонной пластинки. Это и есть одно из основных отличий голографии от фотографии.

Второе отличие голограммы от фотографии заключается в том, что на голограмме в результате записи появляется зонная структура, то есть голограмма в свою очередь становится фотографической зонной пластинкой. Если мы поднесем голограмму к свету, то едва ли увидим какую-либо картину. Скорее всего мы не увидим ничего, что говорило бы нам о записанной на этой пленке какой-либо сцене. На негативе, как почти всем известно, на свету мы всегда видим изображение. Голограмма представляет собой однородную серую пластинку, которая не раскрывает записанных на ней свойств и характеристик сцены до тех пор, пока она не будет освещена светом с надлежащей длиной волны.

## VIII. Answer the following questions:

1. What is a hologram?
2. How do different authors describe a hologram?



3. When does holography become a rather simple diffraction process?

4. What are opaque rings used for?

5. What would have happened if there had been two-point sources of light in the original scene?

6. Why does a hologram generate a composite image, a combination of virtual images of all of the many original light sources?

7. What is a zone plate?

## IX. Speak on the following topics:

1. The principle of making a hologram.
2. The range of possible applications of holography.
3. Photography and holography.
4. Laser and holography.

## LESSON NINE

### Active Vocabulary.

**doubt,** ***n.***

1. Doubt is a state of uncertainty.
*In doubt*=not certain.
*without (a) doubt*=certainly.
2. When in doubt about the meaning of a word, use your dictionary.
3. He will come without doubt.

**doubt,** ***v.***

1. I doubt the truth of the story.
2. I very much doubt whether I shall be able to get there in time.
*Derivatives:* doubtful, doubtfully, doubtless.
*Synonyms:* to hesitate; to be uncertain.
*Antonyms:* to be certain; to be sure.

**view,** ***n.***

1. View is the act of seeing; inspection; the power of seeing; that which is seen; a sight; a prospect; a scene.
2. The object was in full view of the observer.
*On view*=being exhibited
*to have (keep) in view*=to keep in mind.
3. He has a plan in view.
4. View is a mental estimate; an idea; an aspect.
5. He formed a clear view of the situation.

**view,** ***v.***

1. You should view the matter from different view-points.
*Synonyms:* to look at; to examine.



**accept,** ***v.***

1. To accept is to agree to take what is offered or given; to say that something is true, right or satisfactory.
2. Did you accept their invitation to dinner?
*Derivatives:* acceptable, acceptance.
*Synonym:* to receive.
*Antonyms:* to decline; to reject.

**contribute,** ***v.***

1. To contribute is to give (money, help, etc.) to a common cause, as to contribute to the Red Cross; also to give help of an intellectual kind, as to contribute suggestions or ideas (new information on scientific questions, etc.).
2. Good health contributed to his success.
3. These explorers contributed much to our knowledge of the Arctic.
*Derivatives:* contribution, contributory.
*Synonym:* to help.

**miss,** ***v.***

1. To miss is to fail to hit, get, hear, see, notice or understand; it is also to leave out; to omit.
2. You have missed the target.
3. I have missed (i. e. I did not hear) the first part of the speech.
4. He missed (i. e. was too late for) the 9.30 train.
5. There is a page missing from this book.

**remain,** ***v.***

1. To remain is to be left after a part has gone or been taken away; to stay in the same place or condition; to continue to be.
2. After the fire, very little remained of the house.
*Derivative:* remainder.
3. Twenty people came in and the remainder stayed outside.
4. When 65 is divided by 21, the quotient is 3 and the remainder 2.
*Synonym:* to stay.

**realize,** ***v.***

1. To realize is to see clearly; understand; be fully conscious of; also to make real; change (a hope, plan, etc.) into an actual fact.
2. Do you realize your mistake?
3. He could not realize his plans.
*Derivatives:* realizable, realization.

**substitute, *v*.**

1. To substitute is to put or use instead of someone or something else; to take the place of another person or thing.

2. When a three-dimensional object is substituted for one of the two mirrors, a three-dimensional hologram results.

*Derivative:* substitution.

*Synonym:* to replace.

3. Substitute as a noun is a person taking the place of another or a thing used instead of something else.

**slight, *adj*.**

1. Slight is not strong; weak-looking.

2. Slight is also not serious; not important, as a slight illness.

*Derivative:* slightly.

**transparent, *adj*.**

1. Transparent is easy seen through; unmistakable, as a man of transparent honesty; clear, as a writer with a transparent style.

2. He carried out his experiments with transparent three-dimensional objects.

*Derivatives:* transparence, transparently.

*Antonym:* opaque.

## Exercises

**1. Give the English for:**

a) вид, поле зрения; мнение, точка зрения; сомневаться; признавать; делать вклад; оставаться; понимать; заменять; замена; незначительный; прозрачный;

b) быть в поле зрения; не терять из виду; составить себе четкое представление о положении дел; без сомнения; осуществлять планы.

**2. Give the Russian for:**

on view; view-point; without doubt; undoubtedly; two-dimensional transparencies; to accept this generalization; to contribute extensively to something; remainder; to realize one's plans.



**3. Give derivatives of the following words:**

view; doubt; to accept; to contribute; to remain; to realize; to substitute; slight; transparent.

**4. Give synonyms of the following words:**

to be uncertain; to receive; to give; to stay; to understand; to replace.

**5. Give antonyms of the following words:**

to be sure; to be stable; to reject; opaque; ineffective.

**6. Read the following words:**

| | |
|---|---|
| doubt [daut] | to contribute [kən'tribju(:)t] |
| doubtful ['dautful] | contribution [ˌkɔntri'bju:ʃən] |
| doubtless ['dautlis] | to realize ['riəlaiz] |
| view [vju:] | realizable ['riəlaizəbl] |
| view-point ['vju:point] | realization [ˌriəlai'zeiʃən] |
| viewer ['vju:ə] | realism ['riəliz(ə)m] |
| to accept [ək'sept] | to substitute ['sʌbstitju:t] |
| acceptable [ək'septəbl] | substitution [ˌsʌbsti'tju:ʃən] |
| slight [slait] | transparent [træns'pεərənt] |
| slightly ['slaitli] | transparency [træns'pεərənsi] |

# FUNDAMENTALS OF HOLOGRAPHY

by Winston E. Kock

(continued)

### *Three-Dimensional Realism*

In viewing an actual hologram, the three-dimensional illusion is far more realistic than any photo can show. The viewer quickly realizes that much more information about the scene is furnished by a hologram than by other three-dimensional photo processes, such as by stereo photography or by 3-D photos using ridged film. In the hologram reconstruction, the viewer can inspect the three-dimensional scene not just from one direction, as in stereo photography, but from many directions. Because this property of complete realism has undoubtedly given the development of holography great impetus, the chronology of three dimensions in holograms is of interest.

As early as 1949, Gabor wrote, «The photograph contains the total information required for constructing the object, which can be two-dimensional or three-dimensional.». However, he used for his objects two-dimensional transparencies, and said little about recording and reconstructing three-dimensional objects. When Leith and Upatnieks first used lasers in holography, they likewise employed two-dimensional transparencies for their objects. Thus they pioneered in producing the first laser holograms and the first offset holograms, but their first images were still two-dimensional. More recently, Leith and his group have contributed extensively to three-dimensional holography.

George Stroke, a recognized authority on the ruling of precision optical gratings, commenced quite early in looking upon holograms (as we do here) as diffraction devices. In a May, 1964, set of lecture notes he described how light waves, reflected onto a photographic plate by two adjacent, slightly tilted plane mirrors, generate a photographic grating and how, when a three-dimensional object is substituted for one of the two mirrors, a three-dimensional hologram results.

It was not easy for some to accept this generalization. In the discussion period following a lecture by Stroke on holography in Rome in September, 1964, an eminent Italian scientist remonstrated: «The light beam cannot carry information about a three-dimensional object because this is described by three degrees of freedom, whereas a light beam has only two degrees of freedom.». Although the logic of this objection appears at first quite reasonable, we can assure ourselves that three-dimensional information can be recorded on a two-dimensional surface by means of the hologram (zone plate) process.

The three-dimensional reconstruction process is often difficult to understand in the case of certain holograms. Thus, a hologram can record a scene which includes a small, very bright reflecting point behind an opaque screen. In the actual scene, a viewer positioning himself so as to be below the shadow demarcation line would have his view of this point source blocked by the opaque screen. In the reconstruction, however, says the skeptic, the screen is actually not there; it is a ghostlike, evanescent figment of the imagination, so how can it possibly block the reconstructed light issuing from the point?

Here again, the zone-plate analogy provides an answer. In the recording process, only a portion of the reflecting point's zone plate is recorded on the photographic plate. The remainder of it, having been blocked by the screen, is missing. Accordingly, as far as the luminous point itself is concerned, its hologram «window» ends at the demarcation line, and its (partial) zone plate can only diffract laser light in directions encompassed by the pyramid whose vertex is the bright reflecting point and whose base corners are extension points of light beams beyond the holograms. Thus it is seen that the point light source can be blocked by an apparition!

*Laser Focus*
*February 1969.*

## Exercises

### I. Translate into Russian paying attention to the Passive Voice:

1. The light beam cannot carry information about a three-dimensional object because this is described by the three degrees of freedom, whereas a light beam has only two degrees of freedom.
2. We can assure ourselves that three-dimensional information can be recorded on a two-dimensional surface by means of the hologram (zone plate) process.
3. Three general classes of experimental techniques are now being applied to this kind of work.
4. The degree of deformation of a nucleus can be defined by a rough formula.
5. The electrons of the beam are little affected by the electrons in the atoms but they are scattered, or deflected, by the nuclei.
6. In most such experiments one records only those electrons that have been simply scattered by the nucleus without exciting it.
7. Since atomic spectra can be measured with high precision these «hyperfine» effects can be observed.
8. Whereas optical spectra are generated by the outer electrons, X rays are emitted when one of the inner electrons changes its orbit.
9. In the past few years such X-ray experiments have also been done with mu-mesonic atoms, in which a mu meson, or muon, is introduced into the atom to replace one of the innermost electrons.
10. Since in this case a nucleus is really being observed in motion, more detailed information is obtained about the shape and its changes over time than from the first two (time exposure) methods.
11. The distribution that is revealed, it should be pointed out, is essentially that of the protons.

### II. Translate into English using the active vocabulary of the lesson:

1. Однако в своих опытах Габор использовал в качестве объектов двумерные прозрачные предметы (диапозитивы) и очень мало уделял внимания вопросу о том, как записать на фотопластинку трехмерный предмет и как восстановить его изображение.
2. В 1964 году Дж. Строук описал, как световые волны, отраженные на фотографическую пластинку двумя смежными слегка наклонными плоскими зеркалами, образуют фотографическую решетку и как при замене одного из двух зеркал трехмерным предметом получается голограмма, позволяющая восстанавливать трехмерное изображение этого предмета.
3. Некоторые ученые с трудом соглашались

4. Скептик скажет, что экран не может преграждать путь лучам, исходящим от источника.

5. Наблюдатель очень быстро убеждается в том, что голограмма дает нам гораздо больше сведений о предмете (сцене), чем стереофотография.

6. Нет никаких сомнений, что голография имеет целый ряд преимуществ.

7. В процессе изготовления голограммы только часть лучей от источника попадала на фотографическую пластинку.

8. Точечный источник действительно блокируется даже тогда, когда на самом деле экрана нет.

9. Совсем недавно Лейт и группа его сотрудников сделали новый вклад в развитие трехмерной голографии.

10. Если голограмму «расколоть» на несколько кусков, то каждый из них при просвечивании дает ту же картину, что и целая голограмма, если не считать того, что по мере уменьшения размеров голограммы четкость изображения и ощущения объемности ослабевают.

## III. Translate at sight:

One of the properties of ordinary holograms (and zone plates) which limit their usefulness is their single-frequency nature. Because the design of a zone plate is postulated on one particular wavelength, only waves of that wavelength will be properly focused. Inasmuch as holograms are a form of zone plate they, too, suffer from this problem; only single-frequency light waves can properly reconstruct their recorded images. If light comprising many colors is used in the reconstruction process, the various colors are diffracted in different directions, and the picture becomes badly blurred.

## IV. Give the situations from the text in which the following words are used:

remainder; transparency; to view; to accept; to contribute; to miss; to realize; to substitute; undoubtedly; slightly.

## V. Give questions to which the following statements might be the answer:

1. Gabor used for his objects two-dimensional transparencies.
2. Leith and Upatnieks pioneered in producing the first laser holograms.
3. More recently, Leith and his group have contributed extensively to three-dimensional holography.
4. When a three-dimensional object is substituted for one of the two mirrors, a three-dimensional hologram results.
5. It was not easy for some to accept this generalization.



6. A hologram can record a scene which includes a small, very bright reflecting point behind an opaque screen.
7. The remainder of it, having been blocked by the screen, is missing.

## VI. Translate the following Russian questions into English and answer them:

1. Можете ли вы представить голографию без лазеров?
2. Какие предметы использовал Габор в своих опытах?
3. Правда ли, что с развитием голографии в изображении предметов был достигнут чрезвычайно большой реализм?
4. Какой вклад в развитие голографии сделали Лейт и Упатниекс?
5. Почему многим ученым было нелегко принять результаты трехмерного изображения в голографии?
6. Писал ли Строук о фотографической решетке и о замене одного из зеркал трехмерным объектом для получения трехмерной голограммы?
7. Почему на ту часть пластинки, которая блокирована экраном, не падает свет?
8. Знаете ли вы, что в 1962 году советский ученый Ю. Н. Денисюк сделал первую (и притом объемную) голограмму?
9. Как вы относитесь к идее голографического телевидения?
10. Слышали ли вы о голографическом кино? Как вы думаете, получит ли оно широкое распространение? Почему?

## VII. Render in English:

Открытие голографии и получение первых голограмм было встречено с восторгом. И действительно, большая хорошо сделанная голограмма выглядит, как чудо. При виде ее трудно удержаться от возгласа восхищения. В открытии голографии есть одна замечательная черта. Дело в том, что физические принципы, используемые в этой новой науке, были известны давно, но как-то вошло в привычку считать, что дифракционные (волновые) явления света определяют предел разрешающей способности оптического прибора. И физики долго не задавали себе простого вопроса, который сейчас кажется вполне естественным: «Куда девается информация о предмете (источнике света), дающем дифракционную картину, и как восстановить изображение?». Развитие интерференционных методов приучило к тому, что эта информация никуда не исчезает и, если правильно распорядиться установкой, то количество информации об источнике по сравнению с обычными оптическими приборами может даже увеличиться.

Еще и сейчас нам кажется, что если между предметом и фотоаппаратом поместить матовую пластинку, то изображение исчезнет — ведь через матовую пластинку ничего нельзя увидеть.

В то же время пластинка не нагревается, в ней не происходит никаких диссипативных (необратимых) процессов, так что никаких исчезновений не должно быть. Оказалось, что порок кроется не в матовом экране, а в способе регистрации изображения на фотопластинке. Фотопластинка регистрирует только интенсивность света, и обычный фотоаппарат совсем теряет все сведения о фазе приходящего света. То, что придумали Габор и его последователи, сводилось к одному — как заставить фотопластинку регистрировать фазу волны. Кстати, жесткие требования к качеству фотопластинки были следующей по важности причиной, задержавшей развитие голографии.

Как бы то ни было, все трудности оказались преодоленными, и сейчас голография развивается нарастающими темпами. Расширяется область ее применения, постепенно смягчаются требования к источнику света. Несомненно, что в дальнейшем голография так же широко войдет в наш быт, как сегодня вошли магнитофоны и транзисторы.

### VIII. Answer the following questions:

1. What does the viewer quickly realize in viewing an actual hologram?
2. What can the viewer inspect in the hologram reconstruction?
3. Why is the chronology of three dimensions in holograms of interest?
4. What did Gabor write in 1949 about photography?
5. Who pioneered in producing the first laser holograms?
6. What did George Stroke contribute to the three-dimensional holography?
7. What kind of generalization was it difficult for some scientists to accept?
8. Why is it often difficult to understand the three-dimensional reconstruction process in the case of certain holograms?

### IX. Review the article «Fundamentals of Holography».

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. Three-dimensional holography and three-dimensional photography.
2. The scientists in holography.
3. How can three-dimensional reconstruction process be understood in the case of holography?



# LESSON TEN

## Active Vocabulary

### approach, *n*

1. Approach is a way of beginning something. See the examples.
2. When learning a foreign language, the best approach is the study of the spoken language.
3. A natural first approach is to see if sound can be recorded directly on photographic film.

### parity, *n*

1. Parity is equality in rank, position, quality, etc.
2. Parity is also resemblance; analogy.

*Antonym*: disparity, as shocking disparity between the rich and the poor.

### aim, *n*

1. His aim was so good that he hit the animal with the first shot.
2. What is your aim in life (=what do you want to do or be)?

*Synonym*: purpose.

### aim, *v*.

1. He aimed his gun at the lion, fired and killed it.
2. If a high-frequency sound source vibrating at a frequency of five million cycles per second is placed in a tank of water and aimed toward the surface, the water will bulge up where the sound hits the surface.

**avail, *v.***

1. To avail is to be of use or value; help; give help; take advantage of; make use of.
2. You should avail yourself of the books in the library.
*Derivative*: available.
3. Available is capable of being used or obtained.
4. This book is not available now.

**avoid, *v.***

1. To avoid is to keep away from; to keep at a distance from; to escape from.
2. The need for a telescope can be avoided by placing an acoustical lens between the object and the surface.
3. Try to avoid danger!

**distort, *v.***

1. A curved mirror distorts the features.
2. Her face was distorted by rage.
*Derivative*: distortion.
3. When the first method is used, the longitudinal distortion introduced by the disparity in length between sound waves and light waves will ordinarily shift the reconstructed image so far from the surface that it must be viewed with a telescope.
*Synonym*: to spoil.

**penetrate, *v.***

1. To penetrate is to make an entrance into any substance.
2. Sound waves can penetrate opaque objects.
*Derivative*: penetration.
*Synonyms*: to pierce; to perforate.

**recognize, *v.***

1. To recognize is to know again; realize to be identical with something previously known.
2. They recognized the word when they heard it again.
3. He recognized the danger.
*Derivatives*: recognizable, recognition.
4. A laser beam is then used to reconstruct the acoustical hologram into a recognizable pictorial image.
*Synonym*: to acknowledge.



**numerous, *adj.***

1. The word "numerous" means very many; great in number.
2. The methods available for recording acoustical holograms are numerous because of the many different methods that are available for recording sound.

**due to, *adj.*; *prep.***

1. This loss is due to reflection at the interface.
2. The longitudinal distortion, which is due to the difference between the acoustical and the optical wavelengths, causes the reconstructed image to appear much farther from the surface than the actual object is.

## Exercises

### 1. Give the English for:

a) подход; несоответствие; цель; избегать; искажать; искажение; проникать; узнавать; имеющийся в распоряжении; многочисленный; обусловленный, благодаря;

b) сильное неравенство; лучший подход; продольное искажение; узнаваемое изображение; проникать сквозь непрозрачные предметы; избегать опасности; многочисленные методы.

### 2. Give the Russian for:

to give rise; to create an initial hologram; a recognizable pictorial image; opaque objects; interference-fringe patterns; long exposure times; high-frequency sound source; to reconstruct an image; the longitudinal distortion; disparity in length; a three-dimensional image; satisfactory results.

### 3. Give derivatives of the following words:

to aim; to distort; to penetrate; to recognize; to avail.

### 4. Give synonyms of the following words:

to spoil; purpose; to acknowledge; to pierce.

**5. Read the following words:**

| | |
|---|---|
| parity [ˈpæriti] | to approach [əˈproutʃ] |
| disparity [disˈpæriti] | approachable [əˈproutʃəbl] |
| to avoid [əˈvoid] | to recognize [ˈrekəgnaiz] |
| to distort [disˈtɔ:t] | recognition [ˌrekəgˈniʃən] |
| distortion [disˈtɔ:ʃən] | recognizable [ˈrekəgnaizəbl] |
| acoustics [əˈku:stiks] | to cohere [kouˈhiə] |
| acoustical [əˈku:stikəl] | coherent [kouˈhiərənt] |
| numerous [ˈnju:mərəs] | coherence [kouˈhiərəns] |
| to penetrate [ˈpenitreit] | incoherent [ˌinkouˈhiərənt] |
| penetration [ˌpeniˈtreiʃən] | incoherence [ˌinkouˈhiərəns] |

## ACOUSTICAL HOLOGRAPHY

*By "illuminating" an object with pure tones of sound instead of with a beam of coherent light one can create acoustical holograms that become three-dimensional pictures when viewed by laser light.*

by Alexander F. Metherell

Optical holography, the technique for making three-dimensional pictures with the aid of laser beams, has given rise to a new form of holography in which sound waves instead of light waves are used to create the initial hologram. A laser beam is then employed to reconstruct, or translate, the acoustical hologram into a recognizable pictorial image. In other words, acoustical holography makes it possible to create an optical wave-field analogue of an acoustical wave field. Since sound waves can penetrate opaque objects ranging from living tissues to metal structures, the new imaging technique has promising applications in many areas of medicine and technology.

The methods available for recording acoustical holograms are numerous because of the many different methods that are available for recording sound. In optical holography a photographic plate is normally used to record the hologram. To record an acoustical hologram it is necessary to have an acoustical equivalent of the photographic plate. A natural first approach is to see if sound can be recorded directly on photographic film. It can be. A piece of photographic film that has been exposed to light can be placed in a weak fixing solution. If, while the film is in the fixing bath, it is exposed to high-intensity sound, the regions of high sound intensity speed up the fixing process. Subsequent development of the differentially fixed photographic film yields an image corresponding to the sound levels at its surface. This method has been used to record acoustical hologram interference-fringe patterns. The method has serious



limitations, however, because the recording sound must be very intense indeed (about one watt per square centimeter), and even then exposures typically run to 30 minutes.

Another method involves placing a starch plate in an iodine solution. Exposure to sound causes the iodine to stain the starch, thereby recording the sound pattern. Here again high intensity levels and long exposure times are required. If a high-frequency sound source, for example a piezoelectric transducer vibrating at a frequency of five million cycles per second, is placed in a tank of water and aimed toward the surface, the water will bulge up where the sound hits the surface. If two such high-frequency sources are submerged and pointed toward the surface, the acoustical beams will interfere and the resulting interference pattern will reveal itself as a stationary ripple pattern. If an object is now placed in one of the beams, the ripple pattern on the surface will be the hologram of the object.

Such an image can be reconstructed by two methods. The first is a "real time" method that merely involves illuminating the surface with a laser. The ripple pattern acts much as an optical phase hologram; the true image of the object appears below the surface and the conjugate image appears as a real image above the surface. The longitudinal distortion, which is due to the difference between the acoustical and the optical wavelengths, causes the reconstructed images to appear much farther from the surface than the actual object is. The second method is to photograph the ripple pattern, thereby obtaining a hologram that can be reconstructed in the usual manner.

When the first method is used, the longitudinal distortion introduced by the disparity in length between sound waves and light waves will ordinarily shift the reconstructed image so far from the surface that it must be viewed with a telescope. The need for a telescope can be avoided, however, by placing an acoustical lens between the object and the surface in such a way that the three-dimensional image formed by the lens is projected onto the surface. The reference wave remains as before but the hologram is now a focused hologram, so that on reconstruction the reconstructed image appears in the surface. In early experiments acoustical lenses created serious aberrations in the holographic image, but recent work with liquid-filled acoustical lenses has led to quite satisfactory results.

What are the advantages of using sound instead of light? The interaction of sound with solids and liquids is different from the interaction of electromagnetic radiation. Sound can travel a considerable distance through dense, homogeneous matter and lose little energy, and yet it will lose a significant amount of energy when it passes through an interface. This loss is due to reflection at the interface. In contrast, electromagnetic radiation such as X rays will lose a significant amount of energy passing through matter and yet lose a negligible amount at an interface. Therefore sound can be singularly effective in medical diagnosis, in nondestructive testing and in seeing underwater and underground because it is mostly the discontinuities of internal organs, tumors, flaws, submerged objects or subterranean strata, rather than the bulk matter, that is of interest to the observer.

*Scientific American*
*October 1969.*

## Exercises

### I. Translate into Russian paying attention to the Subjunctive Mood:

1. If the velocity of light were to vary with the relative velocity of the star, certain irregularities in the motion of the stars should be observed.

2. Since much of the demonstration apparatus is not commercially available, it is essential that a good metal and woodworking shop be provided. Technical help should be available to assist in the construction and care of apparatus.

3. It would be different if we took snapshots of two identical octopuses, for instance.

4. For most nuclei the snapshots, if they could be made, would reveal a more or less ellipsoidal picture.

5. If the reaction should proceed smoothly the end product might increase.

6. Unless these two particles scatter coherently in "hard" interactions, the small deuteron binding energy should not be expected to keep them together.

7. If a single drop of water were magnified to the size of the earth, each molecule contained in it would be no larger than a football.

8. Since there is no theory for the high transition temperature of a superconductor, it is impossible to say how much this value would be raised above 18 degrees K.

9. One would have to illuminate the nucleus with a beam of radiation of very short wave length, sufficiently intense to interact simultaneously with every nucleon, and then focus the scattered radiation.

10. The discoverers conclude by analogy with their recent finding that vanadium-aluminium "should we ever manage to crystallize it in the (same) structure, would be a very high superconductor".



11. Had there been two point sources of light in the original scene, two superimposed zone plates would have been recorded on the photographic plate (the hologram), and this hologram, upon illumination, would provide an observer with a virtual image comprising two light sources, both fixed in space, no matter how the observer moved his head from side to side or up and down.

### II. Translate into English using the active vocabulary of the lesson:

1. Так как звуковые волны могут проникать сквозь непрозрачные предметы, начиная от живых тканей и кончая металлическими конструкциями, новый изобразительный метод находит широкое применение во многих областях медицины и техники.

2. Оптическая голография, техника для получения объемных изображений с помощью пучков лазера, положила начало голографии, в которой вместо световых волн используются звуковые.

3. Другими словами, акустическая голография делает возможным создание аналога оптического волнового поля в акустическом волновом поле.

4. Методы для записи акустических голограмм многочисленны, потому что существует много различных методов для записи звука.

5. В ранних экспериментах акустические линзы создавали серьезные аберрации в голографическом изображении, но последние работы с акустическими линзами, заполненными жидкостью, привели к удовлетворительным результатам.

6. Кусочек фотографической пленки, который оставался не защищенным от света, помещался в слабый фиксирующий раствор.

7. Были разработаны новые методы для записи акустических голограмм интерферирующих образцов.

8. Такое изображение может быть восстановлено двумя методами.

9. При исследованиях с применением крахмала в растворе йода требуются высокая интенсивность звука и длительные выдержки.

10. Пучок лазера используется для восстановления, или перевода, акустической голограммы в узнаваемый объект.

### III. Translate at sight:

In early experiments with acoustical holography the methods used were straightforward acoustical analogues of optical methods. It gradually became apparent, however, that entirely new techniques could be introduced that have no equivalent in optical holography. For example, when electronic detection is used, the output from the detector (microphone) is an electrical signal of the same frequency and phase as the acoustical signal. Therefore, instead of mixing the acoustical object wave with an acoustical reference wave and sensing the sum of the two, the reference wave can be simulated electronically by detecting the acoustical object wave alone and adding the electrical output from the detector to an electrical reference signal. This signal is taken directly from the electronic signal generator used to power the illuminating sound source. The electronic summation then corresponds to the interference between the object wave and the reference wave. Electronic simulation of the reference wave is now almost invariably used.

### IV. Give the situations from the text in which the following words are used:

approach; disparity; distortion; to penetrate; to aim; to avoid; to distort; available; numerous; due to.

### V. Correct the false statements:

1. In early experiments liquid-filled acoustical lenses created serious aberrations in the holographic image.
2. There are not many methods available for recording acoustical holograms.
3. Sound waves cannot penetrate opaque objects.
4. The interaction of sound with solids and liquids is quite the same as the interaction of electromagnetic radiation.
5. When the first method is used the need for a telescope can be avoided.
6. The true image of the object appears above the surface and the conjugate image appears as a real image below the surface.
7. The new imaging technique can never be used in medicine.
8. Sound loses a significant amount of energy when travelling a considerable distance through dense, homogeneous matter and yet it loses little energy when it passes through the interface.

### VI. Translate the following Russian questions into English and answer them:

1. Какие волны используются в акустической голографии для создания исходной голограммы?
2. Восстанавливаем ли мы изображение с помощью пучка лазера или оно может быть получено от простой лампы?
3. Проходят ли звуковые волны через непроницаемые предметы?
4. В каких областях находит применение новая изобразительная техника?
5. Нужно ли изобретать новые методы для записи акустических голограмм или они появились задолго до изобретения голографии?



6. Что используется для записи голограмм в оптической голографии?
7. Может ли звук быть прямо записан на фотографическую пленку?
8. Какое изображение мы получаем в акустической голографии, плоское или объемное?
9. Одинаково ли хорошо звук проходит через металл и живую ткань?
10. Каковы преимущества использования звука вместо света?

### VII. Render in English:

*Акустические голограммы*

Очень близки к микроволновым голограммам когерентных радаров акустические голограммы, образованные путем записи интерференционной картины звуковых волн. Эта картина, так же как и картина микроволн, преобразуется в интерференционную картину световых волн, которую после соответствующего уменьшения можно рассматривать в лазерном свете.

Р. Мюллер использовал в качестве ультразвуковой голограммной поверхности поверхность, разделяющую жидкость и воздух, причем предмет, который «освещался» чрезвычайно короткими когерентными ультразвуковыми волнами, находился в жидкости. Опорный когерентный пучок также направляется на границу, разделяющую жидкость и воздух. Ультразвуковые волны порождали на поверхности жидкости участки повышенного и пониженного давлений, образуя тем самым стационарную интерференционную картину в форме чрезвычайно мелкой ряби на поверхности жидкости. При освещении лазерным светом такая волнистая поверхность давала изображение погруженного в жидкость предмета. Часто для преобразования акустической интерференционной картины в интерференционную картину световых волн используется неоновая лампочка.

### VIII. Answer the following questions:

1. When and what for is a laser beam employed?
2. Where can the new technique be used?
3. Why does the new imaging technique have promising applications in many areas of medicine and technology?
4. What are the serious limitations of the first method described?
5. What does another method described in the text involve?
6. Why is it necessary to use a telescope? Can the need for a telescope be avoided? In which way can it be done?

4*

7. Is the interaction of sound with solids and liquids different from the interaction of electromagnetic radiation? What's the difference?

8. Do you know anything about the Soviet physicists working in this field? Have you ever heard about Denisyuk's technique?

**IX. Review the article «Acoustical Holography».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. Methods of recording acoustic waves and their usage in acoustical holography.
2. Methods of reconstructing images in acoustical holography.
3. The advantages of using sound instead of light in holography.

# LESSON ELEVEN

## Active Vocabulary

### stress, *n.*

1. Stress is pressure; strain, as times of stress (i. e. times of trouble, difficulty, danger, etc.); importance; emphasis, as to lay (a) stress on something (i. e. to give special importance to it).

2. Stress (in mechanics) is (a) force exerted on a solid body which tends to alter its shape.

*Synonym*: accent.

### stress, *v.*

1. To stress is to emphasize; to lay stress on.

2. It must be stressed that all the considerations are consistent with the special theory of relativity.

### anticipate, *v.*

1. To anticipate is to look forward to a thing before it comes; to see what must be done or needs doing and do it in advance.

2. I anticipate great pleasure from my visit to London.

*Derivative*: anticipation.

3. In anticipation of the possible discovery of faster-than-light particles, Gerald Feinberg named them tachyons, from the Greek word *tachys*.

### believe, *v.*

1. To believe is to feel sure that something is real and true or that a person is telling the truth.

2. People used to believe that the world was flat.

*Derivative*: belief.

3. He has a strong belief in higher education (=he feels that it's a good thing).
*Synonym*: to think.
*Antonym*: to disbelieve.

**conclude, *v*.**

1. After reading his translation, the teacher concluded (i. e. thought) that his knowledge of English was very good.
2. As he didn't get there at six, I concluded that he had been delayed.
*Derivatives*: conclusion, conclusive.
3. After examining his work, I have come to the conclusion that he is a capable student.
*Synonym*: to decide.

**distinguish, *v*.**

1. A person with good eyesight can distinguish distant objects.
2. The twins were so much alike that it was impossible to distinguish one from the other.
*Derivatives*: distinguishable, distinguished.
3. Distinguished is famous; well-known; e. g. a distinguished writer.
*Synonym*: to discriminate.
*Antonym*: to generalize.

**exist, *v*.**

1. To exist is to be; to have actual being; to be real.
2. We cannot exist without air, food and warmth.
3. Does life exist on the planets (i. e. is there any form of life)?
*Derivative*: existence.

**observe, *v*.**

1. To observe is to take notice of; to see and notice; to watch closely and carefully; to study, as to observe the behaviour of birds.
2. I observed him go (going) out.
*Derivatives*: observation, observer.
3. For ordinary particles the energy is a number whose value will change from observer to observer but that will always be positive.



**occur, *v*.**

1. To occur is to happen; to take place; to exist.
2. Don't let this occur again.
3. Several misprints occur on the first page.
*Derivative*: occurrence.

**satisfy, *v*.**

1. To satisfy is to fulfil (desires, hopes, needs, etc.); to make contented; to please.
2. Nothing satisfies him — he is always complaining.
*Derivatives*: satisfaction, satisfactory, satisfactorily.

**swift, *adj*.**

1. Swift is moving fast; capable of moving fast; quick; prompt.
2. In anticipation of the possible discovery of faster-than-light particles, the scientists named them tachyons, from the Greek word *tachys*, meaning swift.
*Derivative*: swiftly.
*Synonym*: rapid.
*Antonym*: slow.

## Exercises

### 1. Give the English for:

a) давление, нажим; подвергать напряжению или давлению; ожидать, предвидеть, опережать; верить, думать, полагать; заключать, делать вывод; отличать, различать; существовать; наблюдать, наблюдатель; случаться, происходить; удовлетворять; быстрый;

b) придавать особое (или большое) значение; в ожидании чего-либо, в предвидении чего-либо; прийти к заключению; выдающийся физик; удовлетворительные результаты.

### 2. Give the Russian for:

it must be stressed; in anticipation of something; to come to the conclusion; a distinguished physicist; to distinguish tachyons from ordinary particles; to have no possibility of existence; with respect to one observer; to satisfy the requirement; expenditure of infinite energy; an imaginary number.

### 3. Give derivatives of the following words:

to anticipate; to believe; to conclude; to distinguish; to exist; to observe; to occur; to satisfy; swift.

### 4. Give synonyms of the following words:

strain; accent; to think; to decide; to discriminate; to watch; to notice; to happen; to exist; to please; fast; quick; rapid.

### 5. Read the following words:

| | |
|---|---|
| tachyon ['tækjɔn] | satisfaction [ˌsætis'fækʃən] |
| effort ['efət] | satisfactory [ˌsætis'fæktəri] |
| basis ['beisis] | to conclude [kən'klu:d] |
| increase (*v.*) [in'kri:s] | conclusion [kən'klu:ʒən] |
| increase (*n.*) ['inkri:s] | conclusive [kən'klu:siv] |
| finite ['fainait] | to distinguish [dis'tiŋgwiʃ] |
| infinite ['infinit] | to accelerate [æk'seləreit] |
| occur [ə'kə:] | accelerator [ək'seləreitə] |
| occurence [ə'kʌrəns] | furthermore ['fə:ðə'mɔ:] |
| to satisfy ['sætisfai] | expenditure [iks'penditʃə] |

## PARTICLES THAT GO FASTER THAN LIGHT

*Efforts to detect such particles, named tachyons, have yielded only negative results. Contrary to common belief, however, their existence would not be inconsistent with the theory of relativity.*

by Gerald Feinberg

Since the formulation of the special theory of relativity by Einstein in 1905 and its subsequent verification by innumerable experiments, physicists have generally believed that the speed of light in a vacuum is the maximum speed at which energy or information can travel through space. Indeed, Einstein's first article on relativity contains the statement that "velocities greater than that of light... have no possibility of existence".

The basis of Einstein's conclusion was his discovery that the equation of relativity implied that the mass of an object increases as its speed increases, becoming infinite at the speed of light (which is usually denoted *c*). Since the mass of a body measures its resistance to a change of speed, when the mass becomes infinite the body cannot be made to go any faster. Stated somewhat differently, the relation between energy and speed implied by relativity is such that as the speed of a body approaches *c* its energy becomes infinite. Since this energy must be supplied by whatever is accelerating the body, an infinite source of energy would be needed to speed up a body to the speed of light from any lower speed. No



such infinite energy source is available, and so it is impossible to make a body go from less than *c* to *c*.

Furthermore, if a body could somehow be made to go from a speed less than *c* to one greater than *c*, the same relativity equations imply that its energy and momentum would become imaginary numbers, that is, numbers containing a square root of a negative number. This situation does not seem to have any physical meaning. Objects with imaginary energy clearly cannot exchange energy with objects having real energy and hence cannot affect them. Accordingly such objects could not be detected by real instruments, and can be said not to exist. Within the context in which Einstein worked, where the properties of objects varied continuously and where the creation of new objects was not considered, it therefore seemed a logical conclusion that no form of energy, and hence no matter, could travel faster than light.

With the development of subatomic physics, however, the context has changed considerably. We now know that the subatomic particles can easily be created or destroyed, and that in their mutual interactions their energies and other properties change discontinuously, rather than in the smooth way envisioned in classical physics. Therefore one can imagine the creation of particles already traveling faster than light, and so avoid the need for accelerating them through the "light barrier" with the attendant expenditure of infinite energy.

In addition, one can consistently require that such particles *always* travel at speeds greater than *c*, which obviously cannot be the case for known particles. If one assumes these conditions, there is no problem in satisfying the requirement that the particles carry real energy and momentum. This can be done mathematically by allowing a certain constant that appears in the relation between energy and speed to be an imaginary number, rather than a real number as it is for ordinary particles. This constant is usually known as the rest mass, because for ordinary objects, which can be slowed to rest, it gives the value of the object's mass when at rest.

| | | |
|---|---|---|
| *a* $E=\frac{mc^2}{\sqrt{1-(v^2/c^2)}}$ | *b* $E_0=m_0c^2$ | *c* $E=\frac{\mu c^2}{\sqrt{v^2/c^2-1}}$ |
| *d* $P=\frac{mv}{\sqrt{1-(v^2/c^2)}}$ | *e* $E^2-p^2c^2=m^2c^4$ | *f* $\frac{v}{c}=\frac{pc}{E}$ |

For hypothetical faster-than-light particles, which can never be brought to rest, this constant is not directly measurable, and there is no need for it to be real. The square of the rest mass, however, can be expressed in terms of the measurable energy and momentum of an object and hence can be directly measured. For ordinary objects the rest mass squared is found to be a positive real number. For faster-than-light particles it would be a negative number; indeed, this fact is the basis of one attempt to detect such particles. It should be mentioned that there is a third class of particles, including photons (light quanta) and neutrinos, for which the rest mass is zero and which always travel at $c$.

The possibility therefore seems to exist that there is a new kind of natural object: one that always travels faster than light. The latter statement is invariant, in the sense that if a body travels faster than light with respect to one observer, it will do so with respect to any other observer himself traveling in relation to the first at less than the speed of light. These are the only observers of which we have any knowledge. It must be stressed that all the considerations given here and below are consistent with the special theory of relativity, and assume the validity of its equations for describing particles, even if the particles travel faster than light.

In anticipation of the possible discovery of faster-than-light particles, I named them tachyons, from the Greek word *tachys*, meaning swift. In order to show how physicists have gone about searching for tachyons, I shall describe some of the properties that would distinguish them from ordinary particles.

*(to be continued)*

## Exercises

### I. Translate into Russian paying attention to different meanings of the verbs «should» and «would»:

1. It follows that if electrically charged tachyons exist, it should be possible to produce them from photons.
2. It should be emphasized that for a tachyon at infinite speed it is the total energy that is zero and not just the kinetic energy.
3. A careful study of the structures would require the use of a phase-contrast microscope.
4. The only unknown factor, apart from their existence, is the rate at which tachyons would be produced.
5. If a tachyon were moving at infinite speed as seen by one observer, its speed as measured by another observer in motion with respect to the first would not be infinite but rather some finite value between $c$ and infinity.



6. Since a liquid-crystal device does not emit light, it should require relatively little power.
7. It should be mentioned that there is a third class of particles, including photons (light quanta) and neutrinos, for which the rest mass is zero and which always travel at $c$.
8. A difficulty in carrying out such a search is that tachyons should lose energy rapidly and become hard to detect.

### II. Translate into English using the active vocabulary of the lesson:

1. Следует подчеркнуть, что все выводы, сделанные нами, должны находиться в соответствии с теорией относительности.
2. Предчувствуя возможное открытие частиц, движущихся быстрее скорости света, учёный назвал их тахионами, от греческого слова *tachys*, что значит «быстрый».
3. Я верю в существование тахионов, а вы?
4. Основным следствием из теории Эйнштейна было открытие зависимости массы тела от его скорости.
5. В этой статье описаны свойства тахионов, отличающие их от обычных частиц.
6. Существование тахионов не противоречит теории относительности.
7. Наблюдения за взаимодействием известных элементарных частиц между собой — один из путей к открытию тахионов.
8. Все были удовлетворены результатами проведенного им эксперимента.
9. Может оказаться, что тахионы вообще не существуют, ведь последнее слово всегда остается за экспериментом.

### III. Catch the meaning of the text and retell it:

The situation with tachyons is similar; to settle the issue of their existence one turns to the experimentalist. This is not to say, however, that he must hope to stumble on them somewhere in the universe. One feature of all particle theories based on relativity is that they imply that if particles of some type exist at all, it must be possible to create them from other particles, provided that enough energy is available. For tachyons this condition of having enough energy is particularly easy to satisfy, because last tachyons have very low energy. It is therefore easy to set up experimental conditions under which tachyons could be produced from other particles if tachyons indeed exist. The only unknown factor, apart from their existence, is the rate at which they would be produced. Among known particles the production rate varies by many orders of magnitude. Pions, for instance, are produced quite readily, whereas neutrinos are very difficult to produce. Therefore whereas an experiment with a positive result could establish the existence of tachyons result could at best establish an upper limit for the rate at which tachyons are produced from the particles involved. Only the demonstration that this rate, in all reactions studied, is much less than the rate of production of any other particles would lead to the conclusion that tachyons probably do not exist at all.

### IV. Give the situations from the text in which the following words are used:

to stress; to anticipate; to believe; to conclude; to distinguish; to exist; to observe; to occur; to satisfy; swift.

### V. Correct the false statements:

1. Efforts to detect particles that go faster than light, named tachyons, have already yielded positive results.
2. The basis of Einstein's conclusion was his discovery that the equations of relativity implied that the mass of an object doesn't depend on its speed.
3. Since the mass of a body measures its resistance to a change of speed, when the mass becomes infinite the body can be made to go much faster.
4. Objects with imaginary energy can exchange energy with objects having real energy and hence can affect them.
5. For ordinary objects the rest mass squared is found to be an imaginary number.
6. The rest mass of the faster-than-light particles can be measured directly.
7. Contrary to common belief, the existence of faster-than-light particles would be inconsistent with the theory of relativity.
8. In anticipation of the possible discovery of faster-than-light particles, scientists named them tachyons, from the Greek word *tachys*, meaning slow.

### VI. Translate the following Russian questions into English and answer them:

1. Что можно особо подчеркнуть, говоря о тенденциях в развитии физики элементарных частиц в настоящее время?
2. Было ли слово «предчувствовать» новым для вас в этом тексте?
3. Можно ли верить предположениям, не опирающимся на принципы теории относительности Эйнштейна?
4. Каково основное заключение теории относительности?
5. Какие свойства отличают тахионы от обычных частиц?
6. Пришли ли ученые к соглашению по поводу существования тахионов?



7. Что произойдет с нейтрино, если его мысленно остановить?
8. Является ли наблюдение тахионов в природе единственным доказательством их существования?
9. Какой должна быть масса покоя тахиона, чтобы удовлетворить уравнениям теории относительности?
10. Что означает греческое слово *tachys*?

### VII. Render in English:

Нейтрино — элементарная частица с зарядом, равным нулю, спином $1/2$ и весьма малой (вероятно, нулевой) массой покоя. Соответствующая нейтрино античастица называется антинейтрино. Понятие нейтрино относится, по-видимому, к двум различным элементарным частицам: к так называемым электронному и к мюонному нейтрино.

В систематике элементарных частиц нейтрино занимает особое место, так как оно является единственной частицей, не участвующей ни в сильных, ни в электромагнитных взаимодействиях. Единственный вид взаимодействия (за исключением гравитационного), в котором может принимать участие нейтрино, это так называемое слабое взаимодействие. Указанное обстоятельство обусловливает, с одной стороны, ряд уникальных свойств нейтрино, а с другой — чрезвычайно затрудняет прямое наблюдение нейтрино. Поэтому большинство сведений относительно природы нейтрино получено из косвенных экспериментов. Непосредственное детектирование нейтрино стало возможным только в последнее десятилетие в связи с постройкой реакторов и мощных ускорителей, дающих интенсивные потоки нейтрино.

### VIII. Answer the following questions:

1. What have physicists thought about the speed of light in a vacuum?
2. What kind of statement does Einstein's first article on relativity contain?
3. What discovery was the basis of Einstein's conslusion that "velocities greater than light... have no possibility of existence"?
4. What is the rest mass?
5. What are imaginary numbers?
6. When can the body not be made to go any faster? Why so?
7. Why is it impossible to make a body go from less than $c$ to $c$?
8. Why can one imagine the creation of particles already traveling faster than light?

**IX. Speak on the following topics:**

1. Einstein's theory of relativity.
2. The problem of accelerating matter to the speeds comparable to *c*.
3. The mass and the rest mass.
4. Other hypothetical particles.
5. Contemporary scientists' views on the applicability boundaries of Einstein's theory.

# LESSON TWELVE

## Active Vocabulary

### feature, *n.*

1. Feature is a part or an element of a thing, especially one that is easily noticed, as the geographical features of a district (e. g. lakes, rivers, mountains).

2. A detailed theory of the interaction of tachyons with matter, which has not yet been worked out, would have to take these features into account.

### agree *v.*

1. I told him about my plan and he at once agreed to it (=said he thought it was good and that he would use it).

2. The principle does not require, however, that different observers agree on the interpretation of any individual process.

3. The experimental results agree with the theory.

*Derivatives*: agreeable, agreement.

4. The description given above is in agreement with the principle of relativity.

*Synonyms:* to consent; to suit.

*Antonyms*: to disagree; to contradict.

### emit, *v.*

1. To emit is to give or to send out.

2. The tachyon is emitted by atom B at the earlier time and absorbed by atom A at the later time.

*Derivative*: emission.

3. It can be seen that this interchange of emission and absorption also removes the problem of negative-energy tachyons, since the reversal between observers of the sign of the energy occurs if and only if the reversal in time-ordering occurs.

*Antonym*: to absorb.

**gain, *v.***

1. One gains experience as one grows older.
2. He gained strength (i. e. became stronger) after an illness.
*Synonyms*: to obtain; to get.
*Antonym*: to lose.

**insist, *v.***

1. To insist is to refer to something repeatedly, for a long time, or with emphasis.
2. I insist on your being there.
*Derivatives*: insistent, insistence.
*Synonym*: to persist.

**interpret, *v.***

1. To interpret is to explain or to show the meaning of, as to interpret a difficult passage in a book.
2. We interpreted his silence as a refusal.
*Derivatives*: interpreter, interpretation.
3. The passage may be given several interpretations.

**mutual, *adj.***

1. Everybody knows that they are mutual friends.
2. We know now that the subatomic particles can easily be created or destroyed, and that in their mutual interactions their energies and other properties change discontinuously.
*Derivative*: mutually.
*Synonym*: reciprocal.

**peculiar, *adj.***

1. Peculiar is belonging to no other; individual, as a style peculiar to the 18th century.
2. This is a matter of peculiar interest.
*Derivatives*: peculiarity, peculiarly.
*Synonyms:* appropriate; particular.
*Antonyms*: general; common.

**stable, *adj.***

1. Stable is fixed; steady; firm; not likely to change.
2. Electron and proton are stable particles.
*Derivatives*: stability, stabilize.



3. Stability is the state or quality of being stable; firmness, as stability of character.
*Antonym*: unstable.

**substantial, *adj.***

1. Substantial is strong; stout; firm, as a substantial building.
2. We are in substantial agreement (i. e. in agreement on the most important points).
*Derivative*: substantially.
*Synonym*: solid.
*Antonym*: unsubstantial.

## Exercises

### 1. Give the English for:

a) особенность, характерная черта, признак, свойство; соглашаться; излучать, выделять; получать, приобретать; настаивать; объяснять, интерпретировать; взаимный; особый; стойкий, постоянный; существенный;

b) принять во внимание эти особенности; прийти к соглашению; приобретать опыт; получать энергию; настаивать на чем-либо; объяснять это явление; взаимное влияние; дело, представляющее особый интерес; стабильные частицы; существенный вклад.

### 2. Give the Russian for:

to take these features into account; to be in agreement; a tachyon emitted by atom A; to gain experience; to gain energy; mutual interactions; peculiar interest; stable particles; a substantial contribution.

### 3. Give derivatives of the following words:

to argee; to emit; to insist; to interpret; mutual; peculiar; stable; substantial.

### 4. Give synonyms of the following words:

to consent; to obtain; to get; to persist; to explain; reciprocal; appropriate; particular; firm; solid.

**5. Read the following words:**

to argee [ə'gri:]
agreeable [ə'griəbl]
agreement [ə'gri:mənt]
to insist [in'sist]
insistent [in'sistənt]
insistence [in'sistəns]
feature ['fi:tə]
elsewhere ['els'wεə]
stable [steibl]
stability [stə'biliti]
instability [,instə'biliti]
mutual ['mju:tʃuəl]
mutually ['mju:tʃuəli]
peculiar [pi'kju:liə]
peculiarly [pi'kju:liəli]
peculiarity [pi,kju:li'æriti]
substantial [səb'stænʃəl]
substantially [səb'stænʃəli]
to interpret [in'tə:prit]
interpretation [in,tə:pri'teiʃən]

## PARTICLES THAT GO FASTER THAN LIGHT

by Gerald Feinberg

(continued)

I shall describe some of the properties that would distinguish tachyons from ordinary particles.

One such property follows directly from the relation between energy and speed given in the equations of relativity. We have seen that for ordinary particles, as their speed increases, their energy also increases. For tachyons, in contrast, an increase in speed results in a decrease in energy. Hence a tachyon that was losing energy by interacting with matter or by radiating light would speed up, whereas a tachyon that was gaining energy from some outside source would slow down, and its speed would approach $c$ from above rather than below. Thus $c$ acts as a limiting speed for tachyons also, but the limit is a lower limit, rather than the upper limit that it is for ordinary objects.

A second property of tachyons that substantially distinguishes them from ordinary particles comes about from the way measurements of energy and time change with the relative motion of observers. For ordinary particles the energy is a number whose value will change from observer to observer but that will always be positive. A tachyon whose energy is positive for one observer, however, might appear to be negative to other observers in motion with respect to the first.

The change in the sign of the energy of a tachyon from observer to observer is connected to another peculiar property of tachyons. If an ordinary particle is seen by one observer to be emitted (say by an atom $A$) at one time and absorbed elsewhere (by atom $B$) at a later time, then any other observer in relative motion will see this process in the same way — as emission by atom $A$ followed at a later time by absorption by atom $B$ — although the time interval will vary from observer to observer. Tachyons, however, because they would travel faster than light, would move between points in "space time" whose time-ordering can vary from observer to observer. Therefore if one observer saw a tachyon emitted by atom $A$ at one time $t_1$ and absorbed by atom $B$ at a later time $t_2$; another observer could find that the time $t_1'$ that he measures corresponding to $t_1$ is later than the time $t_2'$ that he measures corresponding to $t_2$. If this occurs, the latter observer would naturally want to interpret what happens in the following way: The tachyon is emitted by atom $B$ at the earlier time $t_2'$ and absorbed by atom $A$ at the later time $t_1'$.

It can be seen that this interchange of emission and absorption also removes the problem of negative-energy tachyons, since the reversal between observers of the sign of the energy occurs if and only if the reversal in time-ordering occurs. Since the emission of a negative-energy particle and the absorption of a positive-energy particle traveling in the opposite direction produce the same effect on the energy of a system, it is always possible for any observer to insist that all tachyons have positive energy, and that emission and absorption take place in the familiar time-ordering, thus removing the instability problems that negative-energy tachyons would present.

The description given above is in agreement with the principle of relativity requiring that any process that can be seen by one observer must also be a possible process for any other observer. The principle does not require, however, that different observers agree on the interpretation of any individual process. Hence there is no contradiction of the principle of relativity involved in the fact that one observer views as absorption what another views as emission, since both absorption and emission can be witnessed by either observer under suitable conditions. The novelty of tachyons is that emission and absorption must be converted into each other by a change in the observer's velocity, and this implies a closer connection between the two processes than exists for ordinary particles.

It also implies that the number of tachyons in some region of space must vary from observer to observer. Suppose one observer views the process of emission of a tachyon by an atom, with the subsequent escape of the tachyon to infinity. A second observer may view the same process as the tachyon's coming in from outer space and being absorbed by the atom. Hence the two observers will disagree on the number of tachyons present in the past and in the future. Again this situation differs from that for ordinary particles, where the number of particles present at any time is independent of the observer. A detailed theory of the interaction of tachyons with matter, which has not yet been worked out, would have to take these features into account.

Having convinced ourselves that the existence of faster-than-light particles does not imply any contradiction of relativity, we must nevertheless leave the determination of whether such objects really happen in nature to the experimental physicist.

*(to be continued)*

## Exercises

**I. Pick out from the texts of lessons 11 and 12 all the sentences in which the verbs «should» and «would» are used. Translate them into Russian.**

**II. Translate into English using the active vocabulary of the lesson:**

1. Разрабатывая детальную теорию взаимодействия тахионов с веществом, мы должны принять во внимание их характерные особенности.
2. Принцип относительности Эйнштейна не требует, чтобы наблюдатели соглашались в интерпретации какого бы то ни было процесса.
3. Нет ошибки в применении принципа относительности к случаю, когда один из наблюдателей фиксирует излучение там, где другой фиксирует поглощение.
4. Частица с массой покоя, отличной от нуля, не может достигнуть скорости света.
5. Нельзя настаивать на верности теории, не подтвержденной экспериментально.
6. Объекты, имеющие мнимую энергию, естественно, не могут взаимообмениваться энергией с объектами, имеющими действительную энергию.
7. Тахионы обладают весьма своеобразными свойствами по сравнению с обычными частицами.
8. Существенным свойством, отличающим тахионы от обычных частиц, является их ускорение при потере энергии.
9. Интересно узнать, является ли тахион стабильной частицей.

**III. Translate at sight:**

Having convinced ourselves that the existence of faster-than-light particles does not imply any contradiction of relativity, we must nevertheless leave the determination of whether such objects



really happen in nature to the experimental physicist. In the present state of theoretical physics there are few circumstances in which theories flatly predict that certain objects must exist. Instead these theories generally enable us to describe various hypothetical objects, and we must determine by experiment which objects exist in reality. For example, present theories allow for the description of particles with an electric charge equal to half the electron's charge and a mass six times the electron's mass, but we are fairly confident from experiments that no such objects are to be found in nature. We do not, however, know why this is so, and we may not know until we have more fundamental theories than we have now.

**IV. Give the situations from the text in which the following words are used:**

feature; to agree; to emit; to gain; to insist; to interpret; mutual; peculiar; stable; instability; substantial.

**V. Correct the false statements:**

1. We have seen that for tachyons, as their speed increases, their energy also increases.
2. For ordinary particles the energy is a number whose value will change from observer to observer but that will always be positive.
3. The principle of relativity requires that different observers agree on the interpretation of any individual process.
4. The two observers will always agree on the number of tachyons present in the past and in the future.
5. The situation for tachyons is always similar to that for ordinary particles, where the number of particles present at any time is independent of the observer.
6. The existence of tachyons does contradict the theory of relativity.
7. The novelty of tachyons is that emission and absorption must never be converted into each other by a change in the observer's velocity.

**VI. Translate the following Russian questions into English and answer them:**

1. Нужно ли учитывать характерные особенности тахионов при построении теории их взаимодействия с веществом?
2. Может ли тело, имеющее массу покоя равную нулю, достигнуть скорости света?
3. Почему тахион, получая энергию, существенно замедляется?

4. Является ли комплексная масса покоя особым свойством тахиона?

5. Согласуются ли явления испускания и поглощения тахионов с принципом относительности?

6. Можно ли настаивать на верности теории, не подтверждаемой экспериментом?

7. Могут ли различные наблюдатели по-разному интерпретировать один и тот же процесс?

8. Могут ли тахионы взаимообмениваться энергией с обычными частицами?

9. Какие эксперименты доказывают постоянство скорости света?

## VII. Render in English:

Принцип постоянства скорости света находится в прямом противоречии с принципами классической механики. Он устанавливает верхний предел возможных скоростей, тогда как в классической механике возможно сколь угодно большие скорости. Поэтому постулат о постоянстве скорости света приводит к изменению правила сложения скоростей классической механики. Так, сложение скорости света со скоростью источника дает во всех случаях опять-таки скорость света. Классическая формула сложения скоростей одинакового направления очень проста: результирующая скорость равна алгебраической сумме составляющих скоростей. Релятивистская формула, найденная Эйнштейном, более сложна и обладает тем свойством, что при малых скоростях, далеких от скорости света, она практически эквивалентна классической формуле, отклоняясь от нее тем больше, чем больше складывающиеся скорости.

## VIII. Answer the following questions:

1. What properties would distinguish tachyons from ordinary particles?

2. What would happen to a tachyon that was losing energy by interacting with matter or by radiating light? And what about a tachyon that was gaining energy from some outside source?

3. What is the change in the sign of the energy of a tachyon from observer to observer connected to?

4. What is the energy for ordinary particles?

5. Why must we postulate that the proper masses, proper lengths and proper lifetime of tachyons are imaginary parameters?

6. Does the mass of a body measure its resistance to a change of speed?

7. Can objects with imaginary energy exchange energy with objects having real energy?

8. What kind of features would a detailed theory of the interaction of tachyons with matter have to take into account?



## IX. Speak on the following topics:

1. The relation between energy and speed for tachyons.
2. The relative motion of observers and tachyons.
3. The properties of tachyons.
4. Characteristic features of any elementary particle.

**whereas,** ***conj.***

1. Whereas is since; considering that; but in contrast; while; on the other hand.

2. The physicist found that whereas the unit of negative electric charge was embodied in the electron, the unit of positive charge was carried by the proton, a particle 1,840 times heavier than the electron.

## Exercises

### 1. Give the English for:

a) план; бежать, давать утечку, улетучиваться; ударять; последовательный, согласующийся; противоположный, обратный; удобный; точный; вверх; поскольку, в то время как;

b) план работы на год; остроумный план; наоборот; для удобства; точные измерения; приобретать энергию.

### 2. Give the Russian for:

a scheme of work for the year; to escape into the region between the plates; to hit a lead shield; to prevent them from reaching the detector directly; to be inconsistent with the theory of relativity; contrary to the common belief; a convenient way to do something; more precisely.

### 3. Give derivatives of the following words:

consistent; convenient; precise.

### 4. Give synonyms of the following words:

a plan; to evade; to strike; opposite; suitable; exact.

### 5. Give antonyms of the following words:

disparity; to contradict; to generalize; to lose; to miss; common; inconsistent; inconvenient; rough; unsubstantial.



### 6. Read the following words:

| | |
|---|---|
| scheme [ski:m] | through [θru:] |
| to escape [is'keip] | consistent [kən'sistənt] |
| contrary ['kɔntrəri] | consistence [kən'sistəns] |
| precise [pri'saiz] | convenient [kən'vi:njənt] |
| precisely [pri'saisli] | convenience [kən'vi:njəns] |
| precision [pri'siʒən] | compulsory [kəm'pʌlsəri] |
| upward ['ʌpwəd] | ingenious [in'dʒi:njəs] |
| whereas [wεər'æz] | equilibrium [ˌikwi'libriəm] |
| positron ['pɔzitrən] | radioactive ['reidiou'æktiv] |
| photon ['foutən] | photomultiplier [ˌfoutə'mʌltiplaiə] |

## PARTICLES THAT GO FASTER THAN LIGHT

by Gerald Feinberg

(continued)

"Anything that is not forbidden is compulsory", says Murray Gell-Mann's half-facetious totalitarian principle. What then about faster-than-light particles called "tachyons"? Olexa-Myron Bilaniuk and E. C. George Sudarshan argued that valid solutions of Albert Einstein's relativity equations describe such particles. Thus if Einstein's equations are accurate descriptions of the physical universe and if solutions not forbidden are compulsory, tachyons must exist.

The first experiment, which was done two years ago at Princeton University by Torsten Alväger and Michael N. Kreisler, was a search for electrically charged tachyons. It has been known for 35 years that electrically charged particles can be produced in pairs by the passage of high-energy gamma rays (photons) through matter. Many of the known types of charged elementary particles have been made in this way. It follows that if electrically charged tachyons exist, it should be possible to produce them from photons. The fact that tachyons can occur with zero total energy means that a pair of them can be produced by a photon of any energy, whereas a pair of ordinary particles can only be produced by a photon with an energy greater than twice the individual particle's rest energy.

Assuming that charged tachyons are produced, how can they be detected and distinguished from other charged particles that may be produced in the same way, such as an electron-positron pair? A convenient way to do this is to make use of the fact that charged tachyons would continuously radiate photons even when passing through empty space. This phenomenon, known as Cerenkov radiation after the Russian physicist who first observed it from electrons in 1937, occurs whenever a charged object moves through a substance at a speed higher than the speed of light in the substance.

Thus an electron moving through glass at a speed greater than about .7 *c* will emit Cerenkov radiation, since the speed of light in glass is about .7 times its value in free space. Since the speed of a tachyon is greater than that of light in free space, one would expect the tachyon to emit Cerenkov radiation even in a vacuum, and a calculation confirms the expectation: The light would be emitted at a characteristic angle depending only on the speed of the tachyon. Calculation also shows that a tachyon with the same charge as an electron would lose energy so quickly through Cerenkov radiation that even if it is produced with a very high energy, its energy will drop below one electron volt before it has traveled one millimeter. When this happens, the Cerenkov radiation will no longer include visible light, whose photons have energies of more than two electron volts. Instead the radiation will consist of infrared and longer wavelengths, which are a good deal harder to detect. In order to avoid this problem the Princeton experimenters used the ingenious scheme of allowing any tachyons produced to move through a region empty of matter but containing an electric field. The electric field would transfer energy to charged particles, but it would not cause ordinary particles to radiate detectable amounts of light. A tachyon passing through the region, on the other hand, would reach an equilibrium between gaining energy from the field and losing energy through radiation, and would therefore continue to radiate photons of about the equilibrium energy. By fixing the value of the field, the experimenters were able to make this equilibrium energy correspond to photons of visible light, thus making the radiation easy to detect.

In their experiment Alväger and Kreisler used gamma rays from a radioactive cesium source. These high-energy photons hit a lead shield that prevented them from reaching the detector directly. Beyond the shield was a high-vacuum region containing two parallel plates with an electric field between them. Pairs of charged tachyons could be produced by the photons in passing through the lead, and some of these would escape (since they speed up while losing energy) into the region between the plates. A photomultiplier tube was used to detect any photons radiated by the tachyons passing through the region.

No positive indication of Cerenkov radiation, and hence no evidence for tachyon production, was found in this experiment. More precisely, the rate of production of tachyon pairs was found to be less than one ten-thousandth of the known rate for producing electron-positron pairs by photons of slightly higher energy. The mass-energy relation satisfied by tachyons makes it highly unlikely that this rate can depend very sensitively on either the photon energy or the tachyon mass. Therefore it seems that tachyons with a charge approximately equal to the electron's charge simply do not exist. Tachyons with a charge differing from the electron's charge by more than a factor of two in the upward direction would probably not have been seen in the experiment. Of course, uncharged tachyons, which would not emit Cerenkov radiation, would not have been detected either.

*Scientific American*
*February 1970.*



E x e r c i s e s

**I. Pick out sentences from the text in which the verbs «should» and «would» are used. Translate them into Russian.**

**II. Translate into Russian paying attention to different meanings of the verbs «should» and «would»:**

1. If this occurs, the latter observer would naturally want to interpret what happens in the following way...
2. Tachyons, however, because they would travel faster than light, would move between points in "space time" whose time-ordering can vary from observer to observer.
3. For true tachyon-production events this should only reduce the number by the ratio of remaining events to total events, whereas it should eliminate all spurious negative-mass-squared events due to capture in flight.
4. Since a liquid-crystal device does not emit light, it should require relatively little power.
5. According to one of these arguments, if charged tachyons exist, the photon would not be a stable object but instead would decay within some time period into a pair of charged tachyons.
6. Only the demonstration that this rate, in all reactions studied, is much less than the rate of production of any other particles would lead to the conclusion that tachyons probably do not exist at all.
7. In order to show how physicists have gone about searching for tachyons, the scientist will describe some of the properties that would distinguish them from ordinary particles.
8. If negative-energy tachyons were emitted by the unexcited atoms of ordinary matter, this would cause the emitting atoms to be unstable, and hence the existence of such tachyons would contradict the known stability of ordinary matter.

## III. Translate into English using the active vocabulary of the lesson:

1. В противоположность обычному мнению, существование тахионов не противоречило бы теории относительности.
2. Первая попытка обнаружить заряженные тахионы была предпринята два года назад в Принстонском университете.
3. В этой статье обсуждаются результаты поиска заряженных тахионов, в то время как проблема поиска незаряженных тахионов будет обсуждаться отдельно.
4. Удобный способ отличить тахионы от других заряженных частиц состоит в использовании эффекта Черенкова в вакууме.
5. Характерный угол, под которым излучал бы тахион, зависит только от скорости частицы.
6. Чтобы преодолеть трудности, связанные с потерями энергии тахионами, экспериментаторы предложили остроумный метод.
7. Если бы тахион получал точно такую же энергию, как и терял, он бы непрерывно излучал.
8. Фотоны высокой энергии соударялись с экраном, который предохранял их от прямого попадания на детектор.
9. Для обнаружения излучения тахионов был использован фотоумножитель.

## IV. Translate at sight:

In using the missing-mass method the search for neutral tachyons, we note that if a single neutral tachyon is produced, the missing mass squared is a negative number. Furthermore, if two or more neutral tachyons are produced, the missing mass squared can be either positive or negative depending on the configuration. If the missing mass squared is observed to be negative for any events, then necessarily at least one tachyon must have been produced among the neutral particles. In other words, a collection of ordinary particles cannot have a negative mass squared. Hence in order to investigate neutral-tachyon production by means of specific incident particles, one makes a plot of the missing mass squared for all events and looks for any events with a negative missing mass squared. The production of single tachyons would give a peak in the missing-mass-squared distribution at some negative value, whereas the production of two neutral tachyons would give a broad distribution of the total missing mass squared, over both positive and negative values, without any sharp peaks.

## V. Give the situations from the text in which the following words are used:

scheme; to escape; to hit; consistent; contrary; convenient; precise; upward; whereas.



## VI. Translate the following Russian questions into English and answer them:

1. Какими свойствами обладают гипотетические частицы, названные тахионами?
2. Какое явление удобно использовать для обнаружения тахионов?
3. Противоречит ли существование тахионов теории относительности?
4. Можете ли вы дать более точную оценку скорости рождения пар тахионов по отношению к скорости рождения электрон-позитронных пар?
5. Почему тахионы могут быть получены из фотонов любой энергии, в то время как обычные частицы — нет?
6. Какую методику предложили учёные в Принстоне, чтобы заставить тахионы излучать в спектре видимого света?
7. Почему тахионы, если бы они были получены в Принстонском эксперименте, могли бы проникнуть в область электрического поля между пластинками?
8. Зачем в данном эксперименте использовался предохранительный свинцовый экран?
9. Что произойдет, если фотон с энергией, большей чем двойная масса покоя электрона, ударится о свинцовый экран?
10. Могут ли существовать тахионы с зарядом, равным заряду электрона?

## VII. Render in English:

*Счетчики Черенкова*

Каждое новое открытие в ядерной физике тотчас же становится поводом для обсуждения: а нельзя ли приспособить его к измерительной технике? Так произошло и с открытием советского физика П. А. Черенкова. Он обнаружил, что частицы, которые проходят через вещество быстрее, чем через это же вещество проходит свет, излучают электромагнитные колебания. Сила такого свечения зависит от скорости частицы, ее заряда и вещества, через которое она пролетает. На основе этого физического явления Черенков сконструировал счетчик, превосходно измеряющий скорость частиц. А это как раз и было в то время самым трудным — правильно определить скорость частицы.

Счетчики Черенкова применяются теперь для изучения ядерных процессов, которые происходят при больших энергиях частиц. Так, с их помощью была обнаружена новая, весьма интересная элементарная частица — антипротон.

**5. Read the following words:**

rigid [ˈridʒid]
jewel [ˈdʒu:əl]
truth [tru:θ]
celestial [siˈlestjəl]
diverse [daiˈvə:s]
to exhaust [igˈzɔ:st]
fuel [fjuəl]
radius [ˈreidjəs]
enormous [iˈnɔ:məs]
incandescent [ˌinkænˈdesnt]
to incandesce [ˌinkænˈdes]
incandescence [ˌinkænˈdesns]
terrestrial [tiˈrestriəl]
ultradense [ˈʌltrəˈdens]
superfluidity [sju:pəflu:ˈiditi]
superconductivity [ˈsju:pəˌkɔndəkˈtiviti]
radii [ˈreidiai]
to exceed [ikˈsi:d]
to contribute [kənˈtribju:t]
degeneracy [diˈdʒenərəsi]

## SOLID STARS

*Much of the matter in white-dwarf stars and pulsars (neutron stars) is under such enormous pressure that it must be considerably more rigid than normal steel.*

by Malvin A. Ruderman

Children have long been charmed by the notion that a star is a twinkling jewel embedded in the black night sky. Their parents may smile indulgently, having been taught that stars are really spheres of incandescent gas. During the past decade, however, it has become apparent that in some cases the child's picture is closer to the truth: the cores of certain dense stars and the outer layer of still denser ones are now believed to be solid matter. Some stars probably consist mainly of carbon in exotic form. A parent would be a spoilsport indeed if he refused to regard such an object as a twinkling celestial diamond.

In the very densest stars one can expect phenomena and forms of matter that cannot be studied directly in terrestrial laboratories. Curiously this is not because of our inability to reproduce stellar temperatures of many millions of degrees but rather because the behaviour of ultradense matter resembles that expected in some forms of ordinary matter near and even below the lowest temperatures that have ever been achieved on the earth. A description of matter when it is ultradense depends on combining theory and experiments in diverse fields; the cryogenic phenomena of superfluidity and superconductivity, phase transition between solids and liquids, proton- and neutron-scattering data obtained with large cyclotrons, the still imperfect marriage of relativity and quantum mechanics expressed in relativistic quantum field theory and even the interaction of "strange" particles produced in accelerators of the highest energy.

The central region of a dying star contains the densest matter known in the universe. After the star has exhausted the nuclear fuel



that enabled it to shine for billions of years it will, according to present theory, suffer one of three fates.

It may contract forever, approaching but never reaching a radius of a few kilometers and a density exceeding $10^{16}$ grams per cubic centimeter. It is then one of the "black holes" predicted by the general theory of relativity: objects so compact that even light cannot escape their gravitational pull. The black hole is the destiny of all stars whose terminal mass considerably exceeds the mass of the sun. No black hole has ever been observed, but then it is not clear by which of its properties an astronomer might observe it.

Stars lighter than about 1.2 solar masses can die as white dwarfs: stars only about the size of the earth but whose central density can reach $10^8$ grams per cubic centimeter (a pea weighing more than a truck). In white dwarfs the enormous contracting pull of gravity is balanced by the pressure created by rapidly moving electrons. Even in objects cooled to absolute zero a residual electron motion persists. This motion is a consequence of the exclusion principle, enunciated by Wolfgang Pauli in 1925, which "forbids" electrons from getting close to one another (as they must when matter is compressed) unless they move rapidly. The greater the compression, the faster the motion and the greater the resulting pressure. This quantum-mechanical kinetic energy electrons possess when they are near similar neighbors is termed degeneracy energy. Exactly the same kind of motion contributes the pressure that makes ordinary solids and liquids difficult to compress. Without it all familiar forms of condensed matter would collapse.

A third possible fate can befall stars whose mass lies between one-tenth and something less than twice the mass of the sun. They can become neutron stars: stellar corpses in which the pull of gravity is balanced by the same combination of forces that keeps ordinary atomic nuclei from collapsing in spite of the pull of nuclear attractive forces. This combination consists of the degeneracy energy of nucleons (similar to the degeneracy energy of electrons) and short-range nuclear repulsive forces. For such forces to be effective, matter must be compressed until it approaches the density of matter within an atomic nucleus: at least $10^{14}$ grams per cubic centimeter (all the people in the world compressed into a single raindrop). Neutron stars, which were first predicted theoretically nearly 40 years ago, are expected to have a radius of only about 10 kilometers. Within the past few years radio and optical astronomers have discovered apparently rapidly rotating neutron stars. They are the pulsars, neutron stars rotating and beaming radiation to us at rates between 30 times per second and once every few seconds. Perhaps as many as 100 million of the 100 billion stars in our galaxy have burned themselves out and collapsed into neutron stars.

(to be continued)

## Exercises

### I. Translate into Russian paying attention to the modal verbs «can» and «may»:

1. Such a fluid can again supply the pressure needed to counterbalance the pull of gravity.
2. The melting temperature of the lattice can exceed $10^{10}$ degrees.
3. No matter how hot the star may be when it is formed.
4. Such mass can be moved more easily than it can be compressed.
5. The central core of a neutron star is a unique place in which one can expect to encounter phenomena absolutely outside our experience.
6. At the very center of the sphere there may be a core of unknown composition and properties.
7. Near the center of a neutron star where densities may approach $10^{15}$ grams per cubic centimeter neutrons and electrons possess enormous energy.
8. One can calculate that the magnetic field at the surface of a neutron star may be a trillion times larger than the magnetic field of the earth.
9. He can translate articles concerning technical problems.
10. I should like to read this book. — You may take it.

### II. Translate into English using the active vocabulary of the lesson:

1. В то время никто не мог даже подозревать, какие последствия повлечет за собой это открытие.
2. Вырожденная энергия этих частиц настолько велика, что скорость их составляет примерно 99,99% скорости света.
3. Внешняя часть нейтронной звезды представляет собой структуру, жесткость которой объясняется геометрическим расположением ядер.
4. Можно надеяться, что дальнейшее изучение нейтронных звезд даст ученым возможность рассмотреть явления, с которыми еще никто не сталкивался.
5. При температурах, которые могут быть в нейтронных звездах, расположение ядер представляет собой жесткую решетку.
6. Сравнительно недавно считали, что звезды состоят из раскаленных газов.
7. Конечная масса некоторых звезд значительно превышает массу Солнца.
8. Очень немногие знают, что основная цель его исследований — разнообразные виды человеческой деятельности.



9. Каждое новое открытие должно рассматриваться с точки зрения прогресса человечества.
10. Остаточная радиация в эпицентре взрыва ядерной бомбы слишком велика, чтобы ею можно было пренебрегать.

### III. Catch the meaning of the text and retell it:

When matter in a contracting star is compressed to densities beyond $10^8$ grams per cubic centimeter, the velocity of the electrons approaches the velocity of light. The electron energy becomes so great that normal nuclei are no longer stable in the electron sea. When these energetic electrons collide with the protons bound in the nucleus, some of the protons are converted into neutrons. (When an electron and a proton combine to form a neutron, a low-energy neutrino escapes). The more highly matter is compressed the more this reaction proceeds; the number of free electrons is steadily reduced as the number of neutrons is the nuclei increases.

As electrons are removed from the electron sea, the electron pressure that had balanced the crushing inward pull of gravity in the white-dwarf star is no longer sufficient to enable a stable star to form with such matter as its core. When the density exceeds $3 \cdot 10^{11}$ grams per cubic centimeter, the nuclei have become so rich in neutrons that some of the neutrons begin to evaporate into the electron sea. Such matter consists of a uniform electron sea in which nuclei rich in neutrons are embedded. At still higher densities the evaporated internuclear neutrons become the main constituent of matter, in which electrons and a few nuclei are still embedded. At a density near $3 \cdot 10^{14}$ grams per cubic centimeter the nuclei rather suddenly disappear. The few protons that still remain no longer cluster into nuclei but spread themselves uniformaly through the matter as the electrons and much abundant neutrons do.

### IV. Give the situations from the text in which the following words are used:

ultradense; dying; black hole; to be termed; to refuse; to persist; considerably; combination; sphere; terrestrial.

### V. Ask questions to which the following statements might be the answer:

1. They are now believed to be solid matter.
2. The behaviour of ultradense matter resembles that expected in some forms of ordinary matter near and below the lowest temperatures that have been achieved on the earth.
3. According to the present theory, the star suffers one of three fates.
4. No black hole has ever been observed.

5. The residual electron motion is a consequence of the exclusion principle.

6. The greater the compression, the faster the motion and the greater the resulting pressure.

7. Mass of such stars lies between one-tenth and something less than twice the mass of the sun.

8. This combination consists of the degeneracy energy of nucleons and short-range nuclear repulsive forces.

9. Neutron stars are expected to have a radius of only about 10 kilometers.

## VI. Translate the following Russian quest ons into English and answer them:

1. На чем основана теория «твердых» звезд?
2. Почему некоторые формы материи не могут быть изучены в лабораториях?
3. Какие явления нужно знать для описания сверхтвердой материи?
4. Какова судьба звезд, чья конечная масса превышает массу Солнца?
5. Чем объясняется остаточное движение электронов и от чего оно зависит?
6. Что же такое вырожденная энергия?
7. Как объяснить происхождение нейтронных звезд?
8. Сочетание каких сил находится во взаимодействии с силой гравитации?
9. От чего зависит эффективность этих сил?
10. Что такое пульсары? Как они были открыты?

## VII. Render in English:

Президиум Академии наук СССР присудил золотые медали имени М. В. Ломоносова за 1971 год академику В. А. Амбарцумяну за выдающиеся достижения в области астрономии и астрофизики и шведскому физику профессору Ханнесу Альвену за выдающиеся достижения в области физики плазмы и астрофизики. Академик В. А. Амбарцумян — выдающийся советский астроном и астрофизик. Им создана количественная теория свечения газовых туманностей, предложен метод расчета масс, выбрасываемых новыми звездами. Разрабатывая основы статистической механики звездных систем, он показал, что звездные скопления постепенно распадаются вследствие ухода из них отдельных звезд, и на этой основе оценил возрасты звездных скоплений. В 40-е годы В. А. Амбарцумян открыл и исследовал динамически неустойчивые, находящиеся в стадии распада звездные системы нового типа, названные звездными ассоциациями.

В. А. Амбарцумяну принадлежат важные исследования по теории рассеяния света в мутных средах, а также работы по изучению межзвездного поглощения света. Им также была создана теория барионных звезд, обладающих плотностью, превышающей плотность ядерного вещества, открыта и изучена космогоническая активность ядер галактик.

## VIII. Answer the following questions:

1. What are the core and the outer layer of dense stars believed to be?
2. Why can't we study certain phenomena and forms of matter in terrestrial laboratories?
3. How can we describe ultradense matter?
4. What is the "black hole"?
5. What is the pull of gravity in white dwarfs balanced by?
6. What is the residual electron motion?
7. What is the degeneracy energy?
8. What can you say about the origin of neutron stars?
9. What forces are included in the combination that balances the pull of gravity in stellar corpses?
10. What do you know about pulsars?

## IX. Speak on the following topics:

1. The sun, its features and composition.
2. Stars, their dimensions and temperatures (as compared with the sun).
3. Properties of superconductivity and superfluidity.
4. Neutron stars.
5. Pulsars.

## LESSON FIFTEEN

### Active Vocabulary

**lattice,** ***n.***

1. Lattice is a regular geometrical arrangement of points or objects over an area or in space.
2. Space lattice in a nuclear reactor consists of splitting material.
3. Many of the white dwarfs have a core in which the nuclei are frozen in crystalline lattice.

**affect,** ***v.***

1. To affect means to produce an effect upon; to produce a material influence upon or alteration in something.
2. His report affected the public by the examples that had been used.
3. The climate of the Caucasus and the Crimea is affected by the Black Sea.

*Synonyms*: to influence; to impress.

**cancel,** ***v.***

1. To cancel is to neutralize each other's strength or effect.
2. They suddenly cancelled the invitation to participate in the conference.
3. Most of the large positive charge of a neighboring nucleus is cancelled by the negative charge of the electrons.

*Derivative*: cancellation.

**cluster,** ***v.***

1. To cluster is to collect or group together (said of similar things).



2. The children cluster round the New-Year tree.

*Synonyms*: to collect; to group; to gather.

**compel,** ***v.***

1. To compel is to force, to oblige somebody to do something.
2. The rain compelled us to stop playing football.
3. He was compelled by illness to stay at home.

*Synonyms*: to force; to make.

**dissolve,** ***v.***

1. To dissolve is to cause to disperse or disappear; to separate into component parts.
2. The Parliament will not be dissolved in time because of the events in Ireland.
3. These substances can be dissolved by heating only.
4. The atomic lattices of ordinary solid matter dissolve when the thermal energy of the atoms reaches a critical value.

*Derivatives*: dissolvable, dissolvent.

**exceed,** ***v.***

1. To exceed is to extend outside of something; to be greater than or superior to something.
2. In some towns the speed-limit can exceed 60 km per hour.
3. The people which exceed instruction must be punished.
4. 30 exceeds 12 by 18.

*Derivative*: exceedingly.

**repulse,** ***v.***

1. To repulse is to drive back; to resist successfully by force.

*Derivatives*: repulsion, repulsive, repulsively.

2. Repulsion (in physics) is the tendency of certain bodies to repel each other (the opposite of attraction).
3. Repulsion can be observed between two positively charged (or negatively charged) particles.
4. In superdense matter the Coulomb repulsion among nuclei makes the nuclei arrange in a regular crystalline lattice.

*Synonym*: to repel.

**share,** ***v.***

1. To share is to divide and distribute; to use with others.
2. He always shares his money with somebody else.
3. As a rule, two teachers share one group at the lessons of English.
4. I want to share all books among the students.

**ultimate,** ***adj.***

1. Ultimate is most remote in space and time; last in a progression; basic, fundamental.
2. The ultimate structure of compressed iron is very simple.
3. The whole theory was based on the ultimate facts of nature.
*Derivative*: ultimately.
4. As iron is compressed its structure ultimately becomes simpler.

## Exercises

### 1. Give the English for:

a) решетка; действовать на что-либо; сводить на нет; собираться группами; заставлять, вынуждать; таять; превосходить; отталкивать; делить; окончательный;

b) приковывать внимание; максимальная мощность; в конечном счете.

### 2. Give the Russian for:

rigid lattice; repulsion; to be affected; to cancel; to cluster around nuclei; to compel; crystalls dissolve; to exceed $10^{10}$ degrees; to share the book with smb; ultimate results.

### 3. Give derivatives of the following words:

cancel; dissolve; exceed; repulse; ultimate.

### 4. Give synonyms of the following words:

to influence; to collect; to force; to repel; to impress; to group; to make.

### 5. Read the following words:

| | |
|---|---|
| nuclei ['nju:kliai] | to isolate ['aisəleit] |
| nucleus ['nju:kliəs] | isolation [,aisə'leiʃən] |
| valence ['veiləns] | ultrahigh ['ʌltrə'hai] |
| cubic ['kju:bik] | uniformity [,ju:ni'fɔ:miti] |
| either ['aiðə] | uniformly ['ju:nifɔ:mli] |
| neighboring ['neibəriŋ] | observation [,ɔbzə(:)'veiʃən] |
| homogeneous [,hɔmə'dʒi:njəs] | comparable ['kɔmpərəbl] |
| crystalline ['kristəlain] | uniform ['ju:nifɔ:m] |
| to dissolve [di'zɔlv] | nevertheless [,nevəðə'les] |
| dissolvent [di'zɔlvənt] | inconclusive [,inkən'klu:siv] |



## SOLID STARS II

by Malvin A. Ruderman
(continued)

There seems to be no possibility whatever of reproducing the densities of white dwarfs and neutron stars in the laboratory; the present limit of laboratory densities is comparable to the density at the center of the moon. There are, however, compelling reasons for believing that matter at ultrahigh densities is much simpler than ordinary matter, so that many of its properties are predictable from theory alone. An ordinary piece of iron is quite complicated. Nearly all the electrons closely surround individual iron nuclei to which they are attached in orbits much like those in free isolated iron atoms. A very few shared valence electrons are responsible for most of the metal's chemical and metallurgical properties.

As iron is compressed, this structure ultimately becomes much simpler. When its density reaches $10^5$ grams per cubic centimeter, all the electrons in neighboring atoms are pressed so close together that their degeneracy energy exceeds the Coulomb, or electrical, force that binds the negatively charged electrons to the positively charged nuclei. Instead of clustering around their parent nuclei, the electrons distribute themselves more or less uniformly throughout the internuclear space. So great is the energy of these degenerate electrons that they are only slightly affected by the Coulomb forces of the nuclei: their orbits are virtually straight lines. The entire swarm of electrons behaves like a homogeneous negatively charged sea that is unresponsive to the motions and positions of the positively charged nuclei embedded in it.

The forces that nuclei "feel" are then mainly the strong Coulomb repulsion of neighboring nuclei. In normal terrestrial matter this repulsion is effectively much weaker, in part because the nuclei are spaced at greater distances but chiefly because most of the large positive charge of a neighboring nucleus is cancelled by the negative charge of the electrons in orbit around it.

In superdense matter the Coulomb repulsion among nuclei tends to force the nuclei to arrange themselves in a regular crystalline lattice, just as atoms in ordinary matter do when the temperature is low enough. The atomic lattices of ordinary solid matter dissolve (melt) when the thermal kinetic energy of the atoms reaches a critical value sufficient to move them around easily; the value defines the melting point of a particular solid. For ordinary matter the melting point does not exceed a few thousand degrees.

weak [wi:k] слабый.

## IV. Give the situations from the text in which the following words are used:

amount; to compare; to diminish; to encounter; to extend; to predict; to simplify; obvious; unique; apart from.

## V. Give questions to which the following statements might be the answer:

1. This problem was finally resolved by the use of wave mechanics for the electrons.
2. Electron waves are only weakly scattered by the ions in some liquid metals.
3. At high temperatures the deviation from perfection are the root cause of resistance in otherwise perfectly crystalline metals.
4. The mean free paths used in kinetic theory should vary only by a small amount between classical insulating liquids and liquid metals.
5. In mercury and sodium the change is about the same.
6. At low temperatures the ionic vibrations diminish and other imperfections begin to dominate the resistivity.

## VI. Translate the following Russian questions into English and answer them:

1. Можно ли ожидать в ближайшее время большого количества новых данных о жидких металлах?
2. Почему работы Джона Зимана воодушевили многих ученых на развитие и расширение его основных идей?
3. Каким образом Джон Зиман упростил теорию металлов?
4. Предсказывает ли теория механических волн рассеяние электронов на совершенной кристаллической решетке?
5. В чем состоит явное различие между обычным и жидким металлами?
6. Можем ли мы сравнить длину среднего свободного пробега электронов в обычном металле с длиной среднего свободного пробега в жидком металле?
7. Каким образом можно свести к минимуму рассеяние электронов в твердом теле?

## VII. Render in English:

*Металлическая экситонная (электронно-дырочная) жидкость в полупроводниках*

Если в полупроводнике имеются электроны и дырки (скажем, созданные в результате освещения), то при достаточно низкой температуре они должны соединиться в экситоны — водородоподобные «атомы», родственные позитронию.



Критерий высокой плотности и металлизации, грубо говоря, сводится к тому, что размер электронной оболочки сравнивается с межъядерным расстоянием. В случае экситонов в полупроводнике это значит, что их совокупность является плотной при концентрации около $10^{18}$ см$^{-3}$. Таким образом, для экситонов высокая плотность, достигаемая для водорода при давлениях в миллионы атмосфер, отвечает вполне обычной концентрации электронов и дырок в полупроводниках. Уже одна такая возможность имитировать в полупроводниках область сверхвысоких давлений делает обсуждаемый вопрос достаточно важным. Это заключение укрепляется, если задуматься над возможным поведением плотной системы экситонов в полупроводнике. Такая система должна становиться жидкой и образовывать капли. Скорее всего эти капли представляют собой электронно-дырочный металл, то есть подобны жидкому металлу, хотя и не исключена возможность их «молекулярного» строения — в этом случае они аналогичны жидкому водороду, состоящему из молекул. В электронно-дырочной (экситонной) жидкости может в принципе наблюдаться сверхпроводимость и сверхтекучесть. Экспериментальное исследование этой проблемы уже начато.

## VIII. Answer the following questions:

1. Why are liquid metals so interesting?
2. What kind of problem was encountered by physicists in the 1920's in their attempt to explain the resistivities of solid metals?
3. In which way are electrons scattered in a liquid metal?
4. What is the article «Liquid Metals» about?
5. Was it interesting to read? Why?
6. Can you supply any additional information about liquid metals?

## IX. Review the article «Liquid Metals».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. The properties of liquid metals as liquids.
2. The properties of liquid metals as solid metals.
3. Which properties make some of the liquid metals useful to the thermal engineer?

## LESSON NINETEEN

### Active Vocabulary

**array, *n.***

1. Array is a regular and imposing grouping; order.
2. Ions can pass through such an array without creating large disturbances.

*Synonym*: order.

**array, *v.***

1. To array is to place in order.
2. The molecules of certain soaps and other smectic materials array themselves in layers.

**vapo(u)r, *n.***

1. Vapour is the gaseous form to which certain substances may be reduced by heat, as water vapour; to disappear as vapour.
2. In some undetermined way the color can also be changed by chemical vapours.

*Derivatives*: to evaporate, to vaporize.

**align, *v.***

1. To align is to put, come or bring together, especially in a straight line; be in a straight line (e. g. of soldiers).
2. In ordinary liquids the electric forces are not strong enough to keep the molecules aligned because of the molecules' natural tendency to move randomly and independently.
3. As a result perhaps only one in 1,000 molecules would be aligned by an electric field.

*Derivative*: alignment.



**alter, *v.***

1. To alter is to make or become different; to change.
2. Changes in temperature or pressure alter the pitch and period so that new colors are produced.

*Derivatives*: alternate, alternative, alteration.
*Synonym*: to change.

**arrange, *v.***

1. To arrange is to put in order.
2. The molecules of this substance are normally arranged so that all of them in any one region are pointing in the same direction.

*Derivative*: arrangement.

3. This arrangement has been compared to wooden matches in a box.

*Antonym*: to disarrange.

**constrain, *v.***

1. To constrain is to use force, pressure or strong persuasion to make a person do something; (in the passive) to be compelled by some inner force.
2. With respect to their long axes these molecules can move from side to side and up and down, but their many other possible motions are constrained by the forces between them.

*Derivative*: constraint.
*Synonym*: to compel.

**derive, *v.***

1. To derive is to get or obtain.
2. The term nematic, which is derived from the Greek word for thread, refers to the fact that when one examines a nematic substance with a microscope, one sees tiny threadlike structures representing the boundaries between regions of different molecular orientation.

*Derivatives*: derivative, derivation.
*Synonym*: to obtain.

**displace, *v.***

1. To displace is to put out of position or place; to put something or someone else in the place of; to take the place of.
2. Because of the size and shape of the cholesteric molecules, those in neighboring layers displace one another so that their axes are shifted.

*Derivative*: displacement.
*Antonym*: to place.

**enhance,** *v.*

1. To enhance is to add to the value, size or beauty of.
2. An electric field enhances the natural tendency of liquid crystals to assume orderly patterns.

**maintain,** *v.*

1. To maintain is to keep up; to continue; to support; to provide for.
2. These molecules maintain a parallel or nearly parallel arrangement, although each molecule can rotate around an axis pointing in its direction of alignment.

*Derivative*: maintenance.
*Synonyms*: to hold; to sustain.

## Exercises

### 1. Give the English for:

a) порядок; множество; пар; выстраивать в линию, выравнивать; выравнивание; изменять; устраивать; приводить в порядок; принуждать, вынуждать; выводить; смещать; переставлять; замещать; увеличивать, усиливать; устанавливать; поддерживать;
b) химические пары́; распределение температур; двигаться беспорядочно; направление выравнивания; момент смещения электрического диполя.

### 2. Give the Russian for:

nematic liquid crystals; smectic molecules; to constrain; direction of alignment; to some extent; to bear resemblance to; electric-dipole moment; rodlike organic molecules; to give rise to; asymmetrical distribution.

### 3. Give derivatives of the following words:

vapour; to align; to alter; to arrange; to constrain; to derive; to displace; to maintain.

### 4. Give synonyms of the following words:

order; to change; to compel; to obtain, to sustain.



### 5. Give antonyms of the following words:

to disarrange; to complicate; to exhibit; to increase; to inhibit; to place; strict; together.

### 6. Read the following words:

| | |
|---|---|
| array [ə'rei] | to arrange [ə'reindʒ] |
| vapour ['veipə] | arrangement [ə'reindʒmənt] |
| to evaporate [i'væpəreit] | to constrain [kən'strein] |
| to align [ə'lain] | constraint [kən'streint] |
| alignment [ə'lainmənt] | to derive [di'raiv] |
| to alter ['ɔ:ltə] | derivative [di'rivətiv] |
| alteration [ˌɔltə'reiʃən] | to displace [dis'pleis] |
| alternate (*adj.*) [ɔ:l'tə:nit] | displacement [dis'pleismənt] |
| to alternate ['ɔ:ltə:neit] | to maintain [men'tein] |
| to enhance [in'ha:ns], [in'hæns] | maintenance ['meintinəns] |

## LIQUID-CRYSTAL DISPLAY DEVICES

*Liquid crystals (fluids that have certain crystalline properties) respond to an electric field by becoming cloudy or changing color. Effects of this kind can be used for the presentation of images.*

by George H. Heilmeier

There are three types of liquid crystal, termed nematic, smectic and cholesteric. Nematic liquid crystals consist of rodlike organic molecules. With respect to their long axes these molecules can move from side to side and up and down, but their many other possible motions are constrained by the forces between them. They maintain a parallel or nearly parallel arrangement, although each molecule can rotate around an axis pointing in its direction of alignment. This arrangement has been compared to wooden matches in a box; the matches can move to some extent, but they tend to remain parallel within the box. The term nematic, which is derived from the Greek word for thread, refers to the fact that when one examines a nematic substance with a microscope, one sees tiny threadlike structures representing the boundaries between regions of different molecular orientation. Until recently nematic behavior was observed over a rather narrow temperature range near 110 degrees Celsius (230 degrees Fahrenheit). Below that range the substances are fatty solids; above it they are liquids. Substances that behave as nematic liquid crystals over an 80-degree range that includes room temperature have been developed.

Smectic liquid crystals are named for the Greek word for soap, which is the most familiar member of this class. The molecules of certain soaps and other smectic materials array themselves in layers.

Any two layers can slide over each other because the molecules cannot move up and down but only forward and backward or side to side. Like nematic molecules, smectic molecules can rotate freely around their direction of alignment.

Cholesteric liquid crystals bear some resemblance to both smectic and nematic ones. Cholesteric molecules are smectic in that they are arranged in layers. Within each layer, however, the molecular pattern is nematic. Because of the size and shape of the cholesteric molecules, those in neighboring layers displace one another so that their long axes are shifted. This displacement forms the entire structure into a helical pattern.

The pitch and period of the helical structure (the angle of each turn and the distance between turns) give rise to interesting interference colors when light falls on cholesteric substances. Changes in temperature or pressure alter the pitch and period so that new colors are produced. In some undetermined way the color can also be changed by chemical vapors. Cholesteric substances can therefore serve as the active elements in devices that map the distribution of temperatures and in devices that detect vapors.

An electric field affects a liquid-crystal material in two conflicting ways. First, it enhances the natural tendency of liquid crystals to assume orderly patterns. An example is provided by the nematic liquid crystal p-ethozybenzylidene-p'aminobenzonitrile (PEBAB). The molecules of this substance are normally arranged so that all of them in any one region are pointing in the same direction, although the prevailing orientation is different from region to region. When the molecules of a thin film of this material are sandwiched between two plates of glass and are subjected to an electric field, they will behave as if they were little magnets in a magnetic field; they all align themselves so that their electric-dipole moments lie in the field direction.

A molecule has an electric-dipole moment simply because it is an electric dipole, that is, it can be described as an object having two electric charges separated by a distance. In the case of a molecule one end tends to be positively charged and the other negatively charged because of the asymmetrical distribution of the electrons that bind the atoms in the molecule. In ordinary liquids the electric forces are not strong enough to keep the molecules aligned because of the molecules' natural tendency to move randomly and independently. As a result perhaps only one in 1,000 molecules would be aligned by an electric field.

As an electric field is imposing order on a liquid crystal it can also set in motion a chain of events that disrupts the molecular pattern forming under its influence. Nematic solutions contain ionic impurities (positively or negatively charged molecular fragments that are not from the nematic compound) and other ions that are probably produced by dissociation of the nematic compound itself. The electric field pulls the ions toward one or the other of its poles. In a nematic substance such as PEBAB the dipole moment of a molecule lies along



its structural axis, and in an electric field the axes of the molecules of the substance line up parallel to one another. Ions can pass through such an array without creating large disturbances.

*Scientific American*
*April 1970.*

Exercises

**I. Translate into Russian paying attention to modal verbs used with perfect infinitives:**

1. The material should have been made thansparent quickly by applying an alternating current of more than 50 volts and a frequency of 4,000 cycles per second.
2. In the transparent state the two kinds of liquid-crystal molecule might have lined up with their axes pointing in the same direction.
3. Such materials could have been used to produce color effects.
4. Care must have been taken to use nonionic dyes, that is, dyes that do not respond to the electric field; otherwise the dye molecules would have moved through the system and introduce unwanted light-scattering effects.
5. The storage-mode materials — the combinations of nematic and cholesteric liquid crystals — ought to have found application in devices that display information that changes infrequently, for example highway signs, arrival-and-departure boards in airports etc.
6. The dynamic-scattering mode in nematic liquid crystals could have been made to produce images by impulses from such circuitry.
7. Tests patterns of such images must have been broadcast and received.
8. Of course, uncharged tachyons, which would not emit Cerenkov radiation, would not have been detected either.
9. Tachyons with a charge differing from the electron's charge by more than a factor of two in the upward direction or 0.1 in the downward direction would probably not have been seen in the experiment.
10. At bottom a voltage might have been established across the electrodes and the electric field creates turbulence in the liquid crystal.

## II. Translate into English using the active vocabulary of the lesson:

1. Название «нематический» произошло от греческого слова, обозначающего «нить».

2. Под микроскопом видны мельчайшие нитевидные структуры, представляющие собой границы между участками вещества с различной ориентацией молекул.

3. Вещества нематического типа допускают лишь такое движение молекул, при котором сохраняется направление их естественных осей.

4. Наиболее длинная ось молекулы жидкого кристалла указывает направление группировки атомов в ней.

5. В графите атомы углерода располагаются в слоях, слабо взаимодействующих между собой.

6. Ассиметричное распределение электронов в молекуле должно вести к возникновению у нее электрического дипольного момента.

7. Характер интерференционной картины зависит от параметров кристалла — угла наклона и периода решетки.

8. До недавнего времени поведение нематических веществ изучалось только в узком интервале температур.

9. В отсутствие внешнего поля атомы имеют тенденцию двигаться беспорядочно и независимо.

10. Наличие преобладающих ориентаций молекул жидкого кристалла ведет к анизотропии.

## III. Translate at sight:

Liquid-crystal substances have been a scientific curiosity* since the 1890's, when their peculiar properties first began to be recognized. A substance of this type flows, pours and assumes the shape of its container as if it were a liquid. At the same time its molecules, unlike the molecules of a liquid, tend to form loosely ordered arrays rather like the regular lattice of a crystal. In recent years liquid crystals have stimulated the imagination of engineers. These substances are currently being used to create a new family of devices for the display of symbols such as numbers and letters. They may also make it possible to devise a window that can be made cloudy or transparent at the flick of a switch, and a television set no thicker than a picture frame**.

* curiosity — a strong desire to get knowledge and new information.

** frame — a border of wood or other material, рама.

## IV. Give the situations from the text in which the following words are used:

array; vapour; to align; alignment; to alter; to arrange; arrangement; to constrain; to derive; to displace; to enhance; to maintan.



## V. Develop further the following statements:

1. These molecules can move from side to side and up and down, but their many other possible motions are...

2. They maintain a parallel or nearly parallel...

3. Each molecule can rotate around an axis pointing in its direction of...

4. In some undetermined way the color can also be changed by...

5. Like nematic molecules, smectic molecules can rotate freely around...

6. Because of the size and shape of the cholesteric molecules, those in neighboring layers...

## VI. Translate the following Russian questions into English and answer them:

1. Есть ли порядок в расположении молекул жидких кристаллов?

2. В каких материалах молекулы располагаются слоями?

3. Можно ли изменить цвет жидких кристаллов с помощью химических паров?

4. Как можно изменить цвет жидких кристаллов?

5. В каких веществах молекулы расположены слоями?

6. Что увеличивает электрическое поле в жидких кристаллах?

7. Когда атомы имеют тенденцию двигаться беспорядочно и независимо?

## VII. Render in English:

Приборы для получения изображения на жидких кристаллах изготовляются очень просто. Тонкая пленка жидкого кристалла помещается между двумя стеклянными пластинками, каждая из которых покрыта с одной стороны проводящим материалом. По крайней мере одно из покрытий должно быть прозрачным, для чего во многих приборах в качестве покрытия используется окись олова. Если прибор предназначен для контроля за передачей света, то из такого материала должны быть оба покрытия. Если прибор предназначен для показа изображения в отраженном свете, последний электрод может быть хорошо отражающей пленкой алюминия. В любом приборе электроды могут быть сконструированы так, что различные сегменты или элементы прибора могут давать число, букву или другой вид изображения. Благодаря тому, что слой жидкость-кристалл имеет толщину порядка тысячных дюйма и удерживается между пластинками капиллярными силами, обычная проблема, связанная с текучестью жидкостей, не возникает.

### VIII. Answer the following questions:

1. How many types of liquid crystal do you know? What are they?
2. What kind of molecules do nematic liquid crystals consist of?
3. What fact does the term nematic refer to?
4. How do the molecules of certain soaps and other smectic materials array themselves?
5. What do cholesteric liquid crystals bear some resemblance to?
6. How do changes in temperature or pressure alter the pitch and period?
7. Can the color also be changed by chemical vapors? Why so?
8. In what ways does an electric field affect a liquid-crystal material?
9. Why are the electric forces in ordinary liquids not strong enough to keep the molecules aligned?
10. What are the applications of liquid crystals?

### IX. Review the article «Liquid-Crystal Display Devices».

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. What are crystals?
2. The structure of nematic substances.
3. Cholesteric liquid crystals and their properties.
4. The behavior of liquid-crystal material in an electric field.

# LESSON TWENTY

## Active Vocabulary

### viscosity, *n.*

1. The property of a fluid that resists internal flow by counteracting forces is called viscosity.
2. By viscosity of a solid the capability of yielding continually under stress is meant.

*Derivative*: viscous.

### cease, *v.*

1. To cease means to come to an end; to die out.
2. At high densities neutron fluid ceases to be compressible.
3. The rain ceased, the sun appeared.

*Synonym*: to stop.

### collapse, *v.*

1. To collapse means to break down completely; to disintegrate.
2. The chair collapsed when a big man sat in it.
3. If you work too hard, your health may collapse.

*Synonym*: to disintegrate.

### collide, *v.*

1. To collide means to come together with solid impact; to be opposed.
2. If the aims of two countries collide, there may be war.
3. Smaller gas clouds may have formed first and later collided and agglomerated into galaxies.
4. In winter motor-cars collide more often than in summer.

*Derivative*: collision.

**couple, *v*.**

1. To couple means to bring in such close proximity as to permit mutual influence.
2. These people are coupled by the same work and interest.
3. We couple the name of Leningrad with the idea of the first socialist revolution in the world.

*Synonym*: to join.
*Antonym*: to decouple.

**disturb, *v*.**

1. To disturb is to destroy the tranquillity or composure of something.
2. Don't disturb him, he is very busy now.
3. The war disturbed all the peaceful plans of the Soviet people.

*Derivative*: disturbance.

4. Political disturbances have been common in Europe during recent years.

**evolve, *v*.**

1. To evolve is to work out, to produce by natural evolutionary process.
2. The atomic number of the nuclei in the core depends on how the star evolved.

*Derivative*: evolution.
*Synonyms*: to derive; to develop.

**prefer, *v*.**

1. To prefer is to choose or like above another; to bring forward for consideration.
2. I prefer to work in the morning.
3. They prefer to spend their holidays together with their friends.

*Derivatives*: preferable, preference.

**survive, *v*.**

1. To survive means to remain in existence.
2. The four-element theory of Empidocles survived in one form or another for about 2,000 years.

**backward(s), *adj*.**

1. Backward means toward the past.
2. Can you say the alphabet backwards? (=Z,Y,X,W,V, etc.)
3. It is not easy to walk backward.





## 1. Give the English for:

a) вязкость; разрушаться; переставать; прекращать; сталкиваться; соединять; нарушать (покой, состояние); развиваться; предпочитать; продолжать существовать; обратно, назад, в обратном порядке;

b) определение вязкости; перестает быть плазмой; столкновение электронов; процесс соединения частиц; возмущения на солнце; намечать план; называть в обратном порядке.

## 2. Give the Russian for:

viscosity; gravitational collapse; it ceases to be a plasma; gas clouds collide; to couple; to disturb the development; to evolve; preferred scales; to survive in various forms; backward.

## 3. Give derivatives of the following words:

viscous; to collide; to disturb; to evolve; to prefer.

## 4. Give synonyms of the following words:

to stop; to disintegrate; to join; to derive; to develop.

## 5. Read the following words:

epoch [ˈi:pɔk]
viscosity [visˈkɔsiti]
viscous [ˈviskəs]
to emerge [iˈmə:dʒ]
orbit [ˈɔ:bit]
to decouple [diˈkʌpl]
to survive [səˈvaiv]
to inhibit [inˈhibit]
collapse [kəˈlæps]
to disturb [disˈtə:b]
disturbance [disˈtə:bəns]
inhomogeneity [in,hɔmoudʒeˈni:iti]
oscillation [,ɔsiˈleiʃən]
turbulence [ˈtə:bjuləns]
perturbation [,pə:tə:ˈbeiʃən]
observation [,ɔbzə:ˈveiʃən]
irregularity [i,regjuˈlæriti]
fluctuation [,flʌktjuˈeiʃən]
to agglomerate [əˈglɔməreit]
agglomeration [ə,glɔməˈreiʃən]

## THE ORIGIN OF GALAXIES

*The size, shape and other properties of the observed galaxies are traced to slight density enhancements in the expanding primordial fireball. Enhancements of certain mass were favored over others.*

by Martin J. Rees and Joseph Silk

Let us return now to the epoch of the primordial fireball and ask: How were inhomogeneities in the fireball affected by the presence of the intense radiation field? Radiation would inhibit the process of gravitational collapse. Under radiation pressure nonuniformities in the fireball would take the form of oscillations, pressure waves or turbulence. These disturbances, in turn, will be dissipated by viscosity and the development of shock waves. Some wavelengths will be attenuated more severely than others, so that inhomogeneities of favored size will be preserved whereas those less favored will tend to be destroyed. The aim of recent work has been to determine what scales of perturbation are most likely to survive the various processes until the scattering of photons comes to an end. Any perturbation whose survival and growth is specially favored should eventually dominate, almost irrespective of how nonuniformities were initially distributed in the primordial fireball. An encouraging result that has already emerged from these studies is that $10^{12}$ solar masses, roughly the half of a large galaxy, is one such preferred scale.

After the electrons in the initial plasma have been bound into atoms radiation no longer affects the distribution of mass. At this point the surviving perturbations are free to amplify gravitationally. (It should be noted, however, that on small scales — less than $10^6$ solar masses — the kinetic energy atoms exerts a pressure of its own that inhibits gravitational collapses.) The first generation of bound systems will therefore condense from whatever scale of fluctuations had the largest amplitude at the time of decoupling, that is, when the fireball ceased to be a plasma of electrons and other particles.

At what stage did protogalaxies stop expanding and separate out from the rest of the universe? We might guess that this happened when the mean density was comparable to the present density in the outlying parts of galaxies. In 1962 Olin J. Eggen, Donald Lynden-Bell and Allan A. Sandage of the Hale Observatories investigated the likely early history of our own galaxy by studying very old stars in the galactic halo. These stars probably formed while the galaxy was collapsing to its present disklike shape (and before the birth of the stars in the Milky Way), and their orbits indicate that our galaxy attained a maximum radius of about 100,000 light years. One can tentatively estimate that galaxies such as our own formed when the universe was 1,000 times denser than it is now, about half a billion years after the expansion began.

Extrapolating backward in time, we find that the protogalaxies would have taken the form of nonuniformities roughly 1 percent denser than the average density of the universe at the decoupling epoch. It is an attractive possibility that those are the dominant surviving irregularities, all smaller scales having been smoothed out during the fireball phase. There are, however, some types of fluctuation that are not eradiated in the fireball, so that smaller gas clouds may have formed first and collided and agglomerated into galaxies. Robert H. Dicke and P. J. E. Peebles of Princeton have suggested that globular clusters — compact groups of about $10^5$ or $10^6$ stars that orbit around galaxies — may represent that small fraction of clouds which managed to avoid collisions, fragmented into stars and survived.



Clusters of galaxies would have evolved from initial irregularities of smaller amplitude but larger scale than those destined to form single galaxies.

The only contribution of cosmologists to date toward explaining galaxy formation has been to calculate what scales of perturbation are most likely to survive or amplify in the fireball, thereby reducing the need to build these preferred scales into the initial conditions. This removes one element of arbitrariness in the initial conditions prescribed for the universe. There still remains, however, the task of explaining both the origin of the nonuniformity of the universe on all scales except the very largest, and the apparent uniformity encountered on the largest scale.

*Scientific American*
*June 1970.*

E x e r c i s e s

**I. Translate into Russian paying attention to modal verbs used with perfect infinitives:**

1. This implies that galaxies must have formed when conditions in the universe were much different from those now prevailing.
2. It seems clear that the material destined to condense into galaxy cannot always have been in discrete lumps but may have existed merely as slight enhancements above the mean density.
3. Because of the atomic nature of matter the early universe could never have been completely smooth.
4. No structures such as galaxies or stars could have existed in anything like their present form.
5. As a result the microwave background photons would not all have been red-shifted by exactly the same amount.
6. In some directions they might have been scattered off material with a random velocity toward us whereas in other directions the best-scattering surface may have been receding from us.
7. The energy released by the collapse of the protogalaxy would probably have been radiated away by hot gas before most of the stars formed.
8. These scientists should have developed several prototypes.

**II. Translate into English using the active vocabulary of the lesson:**

1. Шаровые скопления представляют собой компактные группы из $10^5$—$10^6$ звезд.

2. Галактические скопления могли развиваться из неоднородностей большого масштаба.

3. Возникновение неоднородностей во Вселенной все еще остается необъясненным.

4. Позднее небольшие газовые облака сталкивались и объединялись в Галактике.

5. Излучение может замедлить гравитационный коллапс.

6. В этом процессе уцелели лишь возмущения плотности определенных масштабов.

7. Только вернувшись назад во времени можно было бы оценить величину неоднородностей плотности материи.

### III. Translate at sight:

Only in the past two or three years has it been realized that the background radiation acts as a gigantic homogenizer on certain preferred scales. To understand just now how this works we must look more closely at Gamow's model of the universe. In the early stages, when the universe consisted of a primordial fireball, no structure such as galaxies or stars could have existed in anything like their present form. All space would have been filled with radiation (photons) and hot gas, consisting of the nuclei or hydrogen and helium and the accompanying electrons. The photons would be repeatedly scattered from the electrons. For at least first 100,000 years of its history (beginning roughly 10 seconds after its emergence from the initial singularity) the universe can be pictured as a composite gas in which some of the «atoms» are particles and the rest are photons. For the universe as a whole there are now at least 10 million times more photons than particles. From thermodynamic considerations one can conclude that photons must also have greatly outnumbered particles in the fireball. For a gas in equilibrium each species of particle contributes to the total pressure in proportion to its number. This still holds (very nearly) for photons, so that the radiation would make an overwhelmingly dominant contribution to the pressure. (During the first 10 seconds, when the temperature exceeds a few billion degrees, the situation is less simple because pairs of photons can interact to form an electron and a positron.)

### IV. Give the situations from the text in which the following words are used:

to inhibit; to be attenuated; aim; encouraging result; bound systems; plasma; to extrapolate; to be eradiated; globular clusters; to be fragmented into.



### V. Correct the false statements:

1. The process of gravitational collapse does not depend on radiation.
2. Under radiation pressure nonuniformities would keep the same form.
3. All wavelengths are attenuated severely.
4. Radiation begins to affect the distribution of mass just after the electrons in the initial plasma have been bound.
5. Protogalaxies begin to expend when the mean density was comparable to the present density in the outlying parts of galaxies.
6. The oldest stars in our galaxy halo formed after the galaxy had collapsed to its present disklike shape.
7. All types of fluctuation are eradiated in the fireball.

### VI. Translate the following Russian questions into English and answer them:

1. Какой фактор в состоянии задержать развитие гравитационного коллапса?
2. Какие формы принимают неоднородности в первоатоме?
3. Что ведет к исчезновению неоднородностей в первоатоме?
4. Возмущения каких масштабов уцелеют во всевозможных сглаживающих процессах?
5. Каков порядок «привилегированного» масштаба в солнечных массах?
6. С какого момента оставшиеся возмущения начинают свободно усиливаться гравитацией?
7. Из неоднородностей какого характера развиваются скопления галактик?
8. Какой физический процесс в первоатоме называется «разделкой»?
9. Что произошло с небольшими облаками газа?

### VII. Render in English:

*Навстречу «плазменным взрывам»*

Полярные сияния по современным представлениям — это гигантские «плазменные взрывы», происходящие на огромных расстояниях от поверхности Земли. Плазма околоземного пространства разогревается при этом до десятков миллионов градусов. К сожалению, в земных лабораториях не удается пока создать на длительное время спокойную и достаточно горячую плазму. А в околоземном пространстве она существует постоянно и порой разогревается до температур, необходимых, чтобы получить управляемую термоядерную реакцию. Поэтому экспериментальное изучение процессов в магнитосфере Земли представляет интерес не только для геофизиков. Быть может, оно окажет помощь, пусть даже небольшую, земным термоядерным исследованиям.

Изучение эффектов, связанных с полярными сияниями, имеет много других практических приложений. Известно, что в полярных районах происходят очень странные явления, которые до сих пор еще очень плохо изучены. Есть, например, неподтвержденные указания, что во время полярных сияний ионный состав верхней атмосферы и его концентрация претерпевают значительные изменения. В магнитосфере и ионосфере возникают электрические поля и токи. Даже в океанах и почве наблюдаются электромагнитные и инфразвуковые волны. Эти явления охватывают огромные пространства — примерно с широт Ленинграда и Якутска, то есть практически всю северную часть земного шара. С нашими знаниями о них тесно связаны прогноз радиосвязи, расчет времени существования спутников, обеспечение радиационной безопасности космонавтов.

### VIII. Answer the following questions:

1. Why does radiation inhibit the process of gravitational collapse?
2. What processes take place in the fireball with pressure non-uniformities under radiation?
3. What is the mechanism of gravitational collapse?
4. Why is this problem so important in astrophysics?
5. Why can we suppose that small gas clouds were formed first?
6. What do you know about globular clusters?
7. How do they consider the evolution of clusters?
8. What happens to the kinetic energy of atoms of small scale stars?
9. At what stage did the protogalaxies stop expanding?
10. What is the connection between the problems of astrophysics and those of nuclear physics?

### IX. Review the article «The Origin of Galaxies».

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. Influence of radiation field on the distribution of mass in the primordial fireball.
2. The epoch of bound system generation.
3. Investigations of early history of our own galaxy.
4. Theory of Ambartsumyan; everything you know about it.

# LESSON TWENTY-ONE

## Active Vocabulary

### conjugation, *n.*

1. Conjugation is either the act of joining together, uniting or combining or the state of being joined together.
2. We can also ask if nature is symmetrical with respect to the operation called charge conjugation (*C*), which means reversing the sign of all electrically charged particles.

### bear, *v.*

1. To bear is to carry; to support.
2. The ice is too thin to bear your weight (=it will break if you go on it).

*To bear in mind*=to remember.

3. At the same time we must always bear in mind that nature apparently does not feel obliged to conform to the limitations of the physicist's imagination.

*Synonym*: to support.

### flow, *v.*

1. To flow is to move or spread along or over, as water does.
2. Rigorous tests have been made of nature's indifference to which way time flows.

### flow, *n.*

1. Flow is something that flows; a stream or outburst, as a good flow of oil from a well; a constant flow of water from a spring; a flow of angry words.

*Synonym*: a stream.

**inquire, *v.***

1. To inquire is to ask to be told; try to get information by asking, as to inquire a person's name; to inquire what a person wants (where to stay; how to do something).

2. When we inquire into the symmetry of nature under the operation termed parity ($P$), we are asking if there is any difference between our world and a mirror image of it.

*Derivatives*: inquest, inquiry.
*Synonym*: to ask.
*Antonym*: to answer.

**oblige, *v.***

1. To oblige is to force or require to act in a certain way.

2. The law in the USSR obliges parents to send their children to school.

3. We must always bear in mind that nature apparently does not feel obliged to conform to the limitations of the physicist's imagination.

**violate, *v.***

1. To violate is to break (a law, a treaty, an oath, etc.); to act contrary to (one's conscience, etc.).

2. If the invariance of parity and charge conjugation were not violated, we could never hope to be able to distinguish left from right in an absolute sense.

*Derivatives*: violation, violence, violent, violently.
*Synonyms*: to break; to infringe.

**aware, *predic. adj.***

1. Aware is knowing; conscious.

2. Are you aware (=do you know) that you are sitting on my hat?

3. He is aware of (=he realizes) his danger.

*Antonym*: unaware.
*Derivative*: awareness.

**contemporary, *adj.***

1. Contemporary is made at, existing at or belonging to the same time.

2. Contemporary is also a person belonging to the same time.

3. These three fundamental symmetries are denoted in contemporary physics by the letters $P$, $C$ and $T$.



**rare, *adj.***

1. Rare is thin; not dense; loosely packed together; uncommon; unusual.

2. These scientists observed a rare mode of decay of neutral $K$ mesons that, it appears, can only be interpreted as a violation of $CP$ symmetry.

*Derivative*: rarely.
*Synonyms*: uncommon; unusual; infrequent.
*Antonyms*: common; usual; frequent.

**afterward(s), *adv.***

1. Afterwards is later.

2. These scientists suggested several experiments that might detect the violation. When these were performed soon afterward, the tests proved that parity was indeed violated.

*Synonym*: later.
*Antonym*: at once.

## Exercises

### 1. Give the English for:

a) сопряжение; выдерживать, поддерживать; течь, поток; интересоваться; спрашивать; обязывать, принуждать, заставлять; нарушать; сознавать, знать; современный, современник; редкий; впоследствии, потом, позже;

b) зарядовое сопряжение; помнить, иметь в виду; чувствовать себя обязанным; сознавать важность симметрии; нарушение соответствия; современная физика; редкий вид распада; эксперименты, выполненные впоследствии.

### 2. Give the Russian for:

contemporary physics; mirror image; charge conjugation; to bear in mind; a certain rare mode of decay; validity of the theorem; the ultimate proof.

### 3. Give derivatives of the following words:

to inquire; to violate; aware; rare.

### 4. Give synonyms of the following words:

a stream; to support; to ask; to break; to know; uncommon.

**5. Read the following words:**

| | |
|---|---|
| to inquire [in'kwaiə] | contemporary [kən'tempərəri] |
| inquiry [in'kwaiəri] | equivalent [i'kwivələnt] |
| to violate ['vaiəleit] | rigorous ['rigərəs] |
| violation [,vaiə'leiʃən] | reverse [ri'və:s] |
| violance ['vaiələns] | reversal [ri'və:səl] |
| violent ['vaiələnt] | to observe [əb'zə:v] |
| aware [ə'wɛə] | observation [,ɔbzə(:)'veiʃən] |
| unaware ['ʌnə'wɛə] | coordinate (*n., adj.*) [kou'ɔ:dinit] |
| awareness [ə'wɛənis] | to coordinate [kou'ɔ:dineit] |
| afterwards ['a:ftəwədz] | conjugation [,kɔndʒu'geiʃən] |

## EXPERIMENTS IN TIME REVERSAL

*With the presumed symmetry of charge and parity disproved, rigorous tests have been made of nature's indifference to which way time flows. No proof to the contrary has yet appeared but the hunt for it goes on.*

by Oliver E. Overseth

The assumed indifference of elementary physical laws to the direction of time is an example of the basic symmetry property of nature. In fact, it is one of three fundamental symmetries that are of considerable importance to an understanding of the basic forces of nature. The three are denoted in contemporary physics by the letters *P*, *C* and *T*. When we inquire into the symmetry of nature under the operation termed parity (*P*), we are asking if there is any difference between our world and a mirror image of it. This is equivalent to asking if nature distinguishes left from right, since in a mirror image left and right, become inverted. We can also ask if nature is symmetrical with respect to the operation called charge conjugation (*C*), which means reversing the sign of all electrically charged particles. This is asking whether or not we would ever know if suddenly in the middle of the night the signs of all charges were reversed. In other words, does nature distinguish the world from the antiworld? The third symmetry is the one this article is concerned with: Are the laws of nature indifferent to the direction of time (*T*)?

Our awareness of the importance of these symmetries is due in large part to the physicists T. D. Lee and C. N. Yang. A dozen years ago they pointed out that a paradox resulting from observation of the decay of an elementary particle, the *K* meson, would be resolved if parity were violated in the interaction responsible for the decay. They suggested several experiments that might detect the violation. When these were performed soon afterward, the tests proved that parity was indeed violated. The implication of these observations is that nature distinguishes left from right. It was subsequently realized, however, that a parity violation was always accompanied by a violation of charge conjugation, and that the combined symmetry (*CP*) appeared to be respected by nature. The conservation of *CP* in physical processes means that left in the world becomes right in the antiworld; hence nature does not distinguish left from right in an absolute sense since there is no way to distinguish the world from the antiworld. Nature appeared to be quite symmetrical after all.

This situation changed dramatically five years ago with a discovery by James H. Christenson, James W. Cronin, Val L. Fitch and René Turlay of Princeton University. They observed a certain rare mode of decay of neutral *K* mesons that, it appears, can only be interpreted as a violation of *CP* symmetry. This finding, subsequently confirmed by other groups, implies that nature does distinguish left from right and world from antiworld in an absolute sense.

A further implication is that nature is not indifferent to the direction of the flow of time. This implication enters the picture by way of a fundamental theorem of physics. Known as the *CPT* theorem, it was enunciated 15 years ago. It requires that the laws of physics remain unchanged under the combined operation of all three of these symmetry principles; that is to say, all the equations of physics must still be valid when we go through them and reverse the sign of all spatial coordinates, change the sign of all charges and reverse the sign of time. Once we assume that *CPT* symmetry is conserved, then the Princeton observation of *CP* violation implies that a *T* violation must occur as well. That is why the Princeton observation triggered the search for direct evidence of a breakdown of time-reversal invariance.

The implication that time reversal is violated because a *CP* violation has been observed is entirely dependent, of course, on the validity of the *CPT* theorem. Proof of the theorem is based on very general principles, and at the present stage of theoretical development in physics it would be difficult to conceive of a basic physical theory that did not satisfy the *CPT* theorem. «If *CPT* invariance were to fail», writes a distinguished theorist, «then I would say all hell will break loose». At the same time we must always bear in mind that nature apparently does not feel obliged to conform to the limitations of the physicist's imagination. The ultimate proof of the *CPT* theorem's validity must be left to experiment.

A symmetry principle or conservation law is a statement of some knowledge forever denied to us by experiment. If the invariance of parity and charge conjugation were not violated, we could never hope to be able to distinguish left from right in an absolute sense. Thus the discovery of violations of assumed symmetries opens a way for us to make experimental determinations that were previously thought to be impossible. In this sense we should welcome discoveries of symmetry breakdowns, and physics currently appears to be in era of such discoveries.

*Scientific American*
*October 1969.*

## Exercises

### I. Translate into Russian paying attention to the Nominative with the Infinitive:

1. It was subsequently realized, however, that a parity violation was always accompanied by a violation of charge conjugation, and that the combined symmetry (*CP*) appeared to be respected by nature.
2. Nature appeared to be quite symmetrical after all.
3. Thus the discovery of violations of assumed symmetries opens a way for us to make experimental determinations that were previously thought to be impossible.
4. The nonspherical nuclei seem to fall rather neatly into two categories.
5. The electrons seem to be required to pick their way through a dense collection of ions whose own electric fields scatter and deflect them.
6. In some real scene, most distant objects appear to move with the viewer, whereas closer objects do not.
7. When the snapshot definition is applied to the shapes of atoms rather than nuclei, they are found to be essentially spherical.
8. Postulate 5 is assumed to be true or false.
9. Ptolemy's error was pointed out in the fifth century by Proclus, who gave his own «proof», based on an argument that turned out to be just as circular as Ptolemy's.
10. This situation does not seem to have any physical meaning.

### II. Translate into English using the active vocabulary of the lesson:

1. Таким образом, открытие нарушения предполагаемой симметрии дает нам возможность сделать экспериментальное определение того, что, как думали ранее, определить невозможно.
2. Эти три симметрии обозначаются в современной физике буквами *C*, *P* и *T*.
3. Они наблюдали редкий вид распада нейтральных *K*-мезонов, который, как оказалось, может быть интерпретирован только как нарушение *CP* симметрии.
4. Когда эти эксперименты были проведены, они подтвердили, что соответствие было действительно нарушено.
5. Вот почему принстонское наблюдение стимулировало поиски прямого доказательства нарушения инвариантности при перемене знака времени.
6. Окончательное доказательство обоснованности *CPT*-теоремы должно быть осуществлено экспериментально.
7. Открытие позитрона было триумфом и квантовой механики и теории относительности. Значительно позднее выяснилось, что вывод о существовании позитрона является всего лишь частным случаем общего предсказания так называемой *CPT*-теоремы.
8. В названии теоремы, буквы *C*, *P* и *T* (взятые вместе) подчеркивают, что все три преобразования — замена частицы на античастицу, зеркальное отражение, обращение времени — должны происходить одновременно.
9. Понятие «античастицы» возникло на рубеже двадцатых и тридцатых годов нашего столетия.
10. Английский физик Поль Дирак попытался вывести такое уравнение движения электрона, которое, с одной стороны, базировалось бы на принципах квантовой механики — еще молодой в ту пору науки о движении элементарных частиц, а с другой стороны, согласовывалось бы с выводами теории относительности — уже признанного в те годы уточнения законов пространства и времени.

### III. Catch the meaning of the text and retell it:

This symmetry of the basic laws of nature with respect to the direction of the flow of time has long been a principle of physics. Eddington himself touched on time at considerable length (in his Gifford Lectures of 1927). After discussing the physical and philosophical foundations of the then new theories of relativity, gravitation and quantum mechanics, he concluded: «The laws of nature are indifferent as to a direction of time. There is no more distinction between past and future than between right and left».

Today we have come to realize that the laws of nature are not indifferent to right and left, and we now suspect that they also make a distinction between past and future. As a result of recent findings in elementary-particle physics the principle of the symmetry of the flow of time has been seriously challenged. An intense search is now under way to see if violations of the principle can be detected experimentally. Workers in the fields of atomic, nuclear and high-energy physics have undertaken a multipronged * attack on the problem. No violation has yet been confirmed, but there is good reason to believe an assymetry exists. It may be very small and difficult to detect, or perhaps we have not yet looked in the right places.

* multipronged — here violent.

### IV. Give the situations from the text in which the following words are used:

conjugation; to bear; to flow; to inquire; to oblige; to violate; to be aware; contemporary; rare; afterward.

### V. Give questions to which the following statements might be the answer:

1. Nature appeared to be quite symmetrical after all.
2. They observed a certain rare mode of decay of neutral *K* mesons.

3. Nature distinguishes left from right and world from antiworld in an absolute sense.
4. Proof of the theorem is based on very general principles.
5. It would be difficult to conceive of a basic physical theory that did not satisfy the *CPT* theorem.
6. The ultimate proof of the *CPT* theorem's validity must be left.
7. Physics currently appears to be in an era of big discoveries.

## VI. Translate the following Russian questions into English and answer them:

1. Является ли природа симметричной по отношению к операции, называемой зарядовым сопряжением?
2. Существует ли какая-либо разница между нашим миром и его зеркальным изображением?
3. Правда ли, что природа отличает левое от правого и мир от антимира в абсолютном смысле?
4. Природа совершенно симметрична, не так ли?
5. Что наблюдали ученые из Принстонского университета?
6. Когда была сформулирована *CPT*-теорема?
7. Почему мы должны приветствовать открытия крушения симметрий?
8. Следует ли думать, что для каждого движения частицы должно найтись симметричное относительно какого-либо из трех — *C*, *P* или *T* — преобразований, взятого отдельно от остальных?
9. Могут ли существовать атомы антиматерии, симметричные «обычным» атомам в том смысле, что на месте протонов и нейтронов в их ядрах расположены антипротоны и антинейтроны, а электронные оболочки заселены позитронами?
10. Могут ли существовать тела из антивещества?

## VII. Render in English:

*Нарушение CP-инвариантности*

В 1956 году было открыто несохранение пространственной четности (*P*) при слабых взаимодействиях. Однако обнаруженные вплоть до 1964 года распады удовлетворяли принципу комбинированной четности, согласно которому все взаимодействия инвариантны относительно *CP*-сопряжения, то есть одновременной пространственной инверсии и зарядового сопряжения *C* (замены частицы на античастицу).

В 1964 году было сделано открытие, значение которого, видимо, исключительно велико, хотя еще далеко не полностью понято. Речь идет об обнаружении распада $K_2^0 \to \pi^+ + \pi^-$. ($K_2^0$ — долгоживущий нейтральный *K*-мезон), который может идти только при нарушении комбинированной четности. Итак, в природе наблюдается нарушение *CP*-инвариантности. Такой результат приводит, возможно, к фундаментальным выводам о неэквивалентности правого и левого, о неэквивалентности прямого и обратного направлений времени, о неэквивалентности частиц и античастиц. С другой стороны, по-видимому, не исключена возможность связать *CP*-несохранение с действием какого-то нового сверхслабого взаимодействия.

Какова причина или каково более глубокое физическое содержание *CP*-неинвариантности? Какова роль этого несохранения в микрофизике, макрофизике и астрофизике?

Несмотря на очень большие усилия, за шесть прошедших лет ответов на эти вопросы еще не получено. Несомненно, проблема *CP*-несохранения — одна из самых интригующих, а по всей вероятности, и самых важных в современной физике.

## VIII. Answer the following questions:

1. What is an example of the basic symmetry property of nature?
2. What are the three fundamental symmetries denoted by in contemporary physics?
3. What are we asking, when we inquire into the symmetry of nature under the operation termed parity (*P*)?
4. What is the third symmetry?
5. What did the physicists Lee and Yang point out a dozen years ago?
6. What did they suggest? What did the tests prove?
7. What does the conservation of *CP* in physical processes mean?
8. What did the scientists of Princeton University observe?
9. Can you say some words about the *CPT* theorem?
10. Why should we welcome discoveries of symmetry breakdown?

## IX. Review the article «Experiments in Time Reversal».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. Symmetries in physics and their role in description of elementary particles.
2. Historical review of the views on the inversions in nature.
3. *CPT* theorem and its sequels.
4. Four kinds of prime forces and their role.
5. Symmetries and mathematical beauty of physical laws.

# LESSON TWENTY-TWO

## Active Vocabulary

### sink, *n.*

1. Sink is a basin (of stone, porcelain, lead, etc.) with a drain. It is placed under a water tap in a kitchen and is used for washing dishes in, etc.

2. Since the early 19th century physicists and engineers have regarded the flow of heat in materials as a diffusion-like process that is proportional to the temperature difference per unit length of material between the heat source and the heat sink.

### apply, *v.*

1. To apply is to make use of; to put close to; to cause to touch.

2. A pulse of heat is applied to one end of the box, creating extra phonons at that end.

*Derivative*: application.

3. The doctor said that application of ice to the forehead might make me feel better.

*Synonym*: to use.

### except, *v.*

1. To except is to leave or keep out; omit; set apart (from a general list, statement, etc.).

2. When I say that most students are lazy, of course I except you (i. e. I do not include you in my condemnation).

*Derivatives*: exception, exceptional.

3. The only other known exception to the rule of heat flow by diffusion was observed some years earlier in «superfluid» liquid helium, where the wavelike thermal behavior was described as «second sound».

*Antonym*: to include.



### except, *prep.*

1. Except is not including; apart from; but.

2. We come to the University every day except Sunday.

### appropriate, *adj.*

1. Appropriate is fit or suitable.

2. It is well known that classical physics is not adequate to describe phenomena on the atomic or the molecular level, so that it is appropriate to seek a quantum-mechanical description of these «thermal waves».

*Derivative*: appropriately.

*Synonym*: suitable.

### flat, *adj.*

1. Flat is smooth, even and level.

2. People used to think that the world was flat; now we know that it is round.

3. The top of a table is flat.

*Derivative*: to flatten (out).

4. One second later some of the added thermal energy of the rod will have flowed away from the heated end toward the end in the ice water, and the temperature profile will begin to flatten out.

*Synonym*: level.

### gradual, *adj.*

1. Gradual is taking place by degrees, little by little or step by step; rising or falling in a way that is not steep.

2. There was a gradual change for the better in the patient's condition.

*Derivative*: gradually.

3. This process is rapid at first because the temperature gradient is large, but it gradually slows down as the temperature gradient becomes smaller.

*Synonym*: slow.

*Antonyms*: rapid; quick; fast.

### minute, *adj.*

1. Minute is very small, as minute particles of dust; also careful and precise, as minute description.

2. Impurities scatter phonons so strongly that their presence even in minute amounts leads to thermal diffusion.

*Synonyms*: small; little; tiny.

*Antonyms*: large; big; great.

**rapid,** *adj.*

1. Rapid is quick; swift, as a rapid river; a rapid thinker; done or performed quickly (of action).
2. This process is rapid at first because the temperature gradient is large.

*Derivative*: rapidly.
*Synonyms*: quick; fast; swift.
*Antonym*: slow.

**elsewhere,** *adv.*

1. Elsewhere is somewhere else; in, at or to some other place.
2. At the moment the end is heated that part of the rod shows a considerable increase in temperature; elsewhere the temperature is still at zero degrees C.

## Exercises

### 1. Give the English for:

a) раковина (для стока воды); прилагать, применять, употреблять, прикладывать; исключать; подходящий; ровный, плоский; мелкий, мельчайший; подробный, детальный; быстрый; где-нибудь в другом месте; постепенно;

b) поглотитель тепла; приложенный импульс тепла; исключение из правила; выравнивать(ся); незначительное количество; быстротекущий процесс.

### 2. Give the Russian for:

wavelike thermal behavior; to tell the difference; heat sink; in a completely different manner; under the right conditions; hypothetical experiment; uniform temperature; the top end of the rod; a fraction of a second; considerable increase in temperature; to flatten out; to slow down; eventually; to obtain information; at a fixed point on the rod; time of arrival; particle representation of thermal waves; a matter of common experience; minute amounts.

### 3. Give derivatives of the following words:

to apply; to except; appropriate; flat; rapid; gradual.

### 4. Give synonyms of the following words:

to use; suitable; level; swift; slowly; tiny.



### 5. Give antonyms of the following words:

to answer; to be unaware; to free; to include; to regress; to uncouple; common; large; slow; at once; rapid.

### 6. Read the following words:

| | |
|---|---|
| apply [ə'plai] | appropriate [ə'proupriit] |
| application [ˌæpli'keiʃən] | to appropriate [ə'prouprieit] |
| except [ik'sept] | appropriately [ə'proupriitli] |
| minute [mai'nju:t] | inappropriate [ˌinə'proupriit] |
| elsewhere ['els'wɛə] | proportional [prə'pɔ:ʃənəl] |
| gradual ['grædjuəl] | proportionality [prəˌpɔ:ʃə'næliti] |
| analogous [ə'næləgəs] | phenomenon [fi'nɔminən] |
| engineer [ˌendʒi'niə] | phenomena [fi'nɔminə] |
| superfluid ['sju:pəflu(:)id] | hypothesis [hai'pɔθisis] |
| material [mə'tiəriəl] | hypothetical [ˌhaipou'θetikəl] |

## «SECOND SOUND» IN SOLID HELIUM

*Until recently thermal waves analogous to «first sound», or ordinary acoustic waves, were thought to exist only in liquid helium. They have now been detected in solid helium and may occur in other substances.*

by Bertman and David J. Sandiford

Since the early 19th century physicists and engineers have regarded the flow of heat in materials as a diffusion-like process that is proportional to the temperature difference per unit length of material between the heat source and the heat sink; the constant of proportionality for a given material is called its thermal conductivity. Recent experiments have shown, however, that heat can sometimes flow in a completely different manner. Investigators at Duke University have reported that under certain conditions heat can flow in solid helium as a wave. The only other known exception to the rule of heat flow by diffusion was observed some years earlier in «superfluid» liquid helium, where the wavelike thermal behavior was described as «second sound». It now seems likely that the phenomenon of second sound is much more general than had been supposed, and that under the right conditions second sound should be detectable in many materials other than liquid and solid helium.

How can one tell the difference between heat flowing as a wave and heat flowing by diffusion? It is helpful to consider the following hypothetical experiment. A long rod with one end in a bucket of ice water is at a uniform temperature of zero degrees Celsius. A source of heat (such as a butane lamp) is brought near the top end of the rod and the flame is allowed to heat that end for a fraction of a second. What happens to the temperature of the rod?

At the moment the end is heated that part of the rod shows a considerable increase in temperature; elsewhere the temperature is still at zero degrees C. One second later some of the added thermal energy of the rod will have flowed away from the heated end toward the end in the ice water, and the temperature profile will begin to flatten out. At subsequent one-second intervals the temperature profile will continue to flatten as some of the heat flows from the hot end of the rod to the cold end. This process is rapid at first because the temperature gradient is large, but it gradually slows down as the temperature gradient becomes smaller. Eventually all the added heat leaves the sample material and the rod returns to a uniform temperature of zero degrees C.

If one places a thermometer at some position on the rod, what temperatures will be recorded after the heat is applied to the end? Obviously one can obtain this information from the temperature profiles already described. The size and shape of the temperature pulse depend on where the thermometer is placed; close to the heated end the pulse will be high in temperature and not as extended in time as it would be if the thermometer were farther away where the temperature rise is lower. These results are characteristic of heat flow by diffusion.

Now, suppose temperature could move through a material as a wave. Then the corresponding temperature profiles would look completely different. The temperature increase would move with a constant speed through the material, and all the heat would immediately be taken from the hot end of the rod. The heat would be contained within a small region of space that changed its position in a very simple way. The temperature recorded at a fixed point on the rod would rapidly rise and fall again. Moreover, the temperature pulse would not vary in height or width with changes in the position of the thermometer. Only the time of arrival of the heat pulse would change. Until recent years the only known example of a temperature pulse moving in this way was observed in superfluid liquid helium at a temperature near absolute zero.

It is well known that classical physics is not adequate to describe phenomena on the atomic or the molecular level, so that it is appropriate to seek a quantum-mechanical description of these «thermal waves». One of the important results of quantum theory is that wave phenomena also have particle properties and can be described as particles. The particle representations of thermal waves are called phonons, in analogy to the photons of light. Hence a solid can be described as a box containing a gas of phonons.

Let us now consider the flow of heat in the light of our model of a solid as a box containing a gas of phonons. A pulse of heat is applied to one end of the box, creating extra phonons at that end. As the phonons interact with their neighbours they are subjected to many interactions that deflect their direction of flow. The gas of phonons then transports thermal energy by diffusion.



Why, then, is it a matter of common experience that thermal diffusion is nearly always observed? The answer is that it is very difficult to obtain most substances in pure enough form so that the condition of resistive mean free path being much greater than the normal mean free path is satisfied. Impurities scatter phonons so strongly that their presence even in minute amounts leads to thermal diffusion. The key to the observation of second sound in solid helium is that this substance can be obtained in extremely pure form. All chemical impurities are frozen out at the temperature of liquid helium, so that a solid made from this liquid is very pure.

Second sound is at least as fundamental as diffusion. Its general absence is due only to the accident that most solids are basically dirty and the fact that most experiments are not performed at a sufficiently low temperature.

*Scientific American*
*May 1970.*

## Exercises

**I. Translate into Russian paying attention to the Nominative with the Infinitive:**

1. Until recently thermal waves analogous to «first sound», or ordinary acoustic waves, were thought to exist only in liquid helium.
2. Accordingly, such objects could not be detected by real instruments, and can be said not to exist.
3. That can be done mathematically by allowing a certain constant that appears in the relation between energy and speed to be an imaginary number, rather than a real number as is for ordinary particles.
4. A tachyon whose energy is positive for one observer, however, might appear to be negative to other observers in motion with respect to the first.
5. Hard deformed nuclei are found to have larger radii than soft ones with about the same A.
6. The kinetic energy of each state is found to be related to its angular momentum in exactly the same way as for a rotating top; this is the main observation leading to the conclusion that such a nucleus is hard.
7. The fact that the volume per nucleon seems to be the same for all nuclei points the way to the simplest nuclear approximation, the liquid-drop model.

8. The hologram appears to be a uniform gray sheet, and it reveals none of the characteristics or features of the scene recorded (as in a photographic negative) until it is properly illuminated.

9. Exactly how does a substance such as mercury (which happens to be molten at room temperature) behave as a liquid, and how does it behave as a metal?

10. The electrons seem to be required to pick their way through a dense collection of ions whose own electric fields scatter and deflect them.

### II. Translate into English using the active vocabulary of the lesson:

1. Сначала этот процесс происходит очень быстро, так как градиент температуры высок, но затем он постепенно замедляется, так как градиент температуры уменьшается.

2. Источник тепла приближают к верхнему концу стержня, и пламя нагревает его в течение доли секунды.

3. Эти результаты характерны для распространения тепла путем диффузии.

4. Единственное исключение из правила, согласно которому тепло распространяется посредством диффузии, наблюдалось в «сверхтекучем» жидком гелии.

5. Секунду спустя часть добавочной энергии стержня уйдет от нагретого конца стержня по направлению к другому концу, и температурный профиль будет выравниваться.

6. Следует искать квантомеханическое описание этих «температурных волн».

7. Большинство веществ очень трудно получить в достаточно чистом виде.

8. Для наблюдения «второго звука» в твердом гелии необходимо получить это вещество в чрезвычайно чистом виде.

9. Все химические неоднородности вымораживаются при температуре жидкого гелия настолько, что твердое тело, полученное из этой жидкости, является очень чистым.

10. Неоднородности рассеивают фононы настолько сильно, что их присутствие даже в очень маленьких количествах приводит к температурной диффузии.

### III. Translate at sight:

As in all other physical phenomena, energy must be conserved in all three-phonon processes: the total energy of the resulting phonons must equal the total energy of the incident phonons. In addition the wave front of the emerging thermal wave will be given by adding together the displacements of the incoming waves. As a result the direction of the resulting phonons is not arbitrary but is subject to this interference condition. Directions of physical quantities are specified by using vectors to describe them, and the phonon wavelengths and direction can be related to a vector quantity called quasi-momentum, a quantity whose magnitude is inversely proportional to the wavelength. Quasi-momentum is conserved in a normal three-phonon process in much the same way that real momentum is conserved in collisions of gas molecules.

### IV. Give the situations from the text in which the following words are used:

sink; to apply; exception; appropriate; to flatten out; minute; rapid; elsewhere; gradually.

### V. Correct the false statements:

1. Investigators at Duke University have reported that under no conditions heat can flow in solid helium as a wave.

2. A source of heat is brought near the top end of the rod and the flame is allowed to heat that end for thirty minutes.

3. At the moment the end is heated that part of the rod shows a considerable decrease in temperature.

4. Eventually all the added heat leaves the sample material and the rod returns to a uniform temperature of 100°C.

5. Classical physics is quite adequate to describe phenomena on the atomic or the molecular level.

6. The particle representation of thermal waves are called positrons, in analogy to the photons of light.

7. Impurities scatter phonons but slightly, so their presence even in great amounts is negligible.

8. General absence of second sound is due only to the fact that most solids are extreamly pure and that most experiments are not performed at a sufficiently high temperature.

### VI. Translate the following Russian questions into English and answer them:

1. Недавно эксперименты показали, что тепло иногда может течь совершенно другим путем, не так ли?

2. Может ли при определенных условиях тепло течь в твердом гелии как волна?

3. С каких пор физики рассматривали поток тепла в материалах как процесс диффузии?

4. В чем различие между протеканием тепла как волны и протеканием тепла путем диффузии?

5. Есть ли основания думать, что явление «второго звука» является более общим, чем предполагалось?

6. Может ли «второй звук» наблюдаться в твердом гелии? При каких условиях?

7. «Второй звук» может наблюдаться не только в жидком и твердом гелии, но и в других веществах, не так ли?

8. Почему надо искать квантомеханическое описание «температурных волн»?

9. Как называются частицы, соответствующие «температурным волнам»? Почему?

10. Почему в обычных экспериментах почти всегда наблюдается температурная диффузия?

## VII. Render in English:

*Механизм теплопроводности*

Теплопроводность — это мера легкости, с которой тепловая энергия распространяется посредством диффузии. Например, теплопроводность воздуха может быть измерена при помощи простого эксперимента. Рассмотрим две пластинки, разделенные воздушным промежутком; верхняя — при 330°К, нижняя — при 300°К. Молекулы, сталкивающиеся с верхней пластинкой, после столкновения имеют среднюю кинетическую энергию, пропорциональную температуре пластинки. То же самое справедливо для молекул, сталкивающихся с нижней пластинкой. Другими словами, молекулы вверху имеют бо́льшую кинетическую энергию (на 10%), чем молекулы внизу. В среднем поток молекул вверх точно равен потоку вниз (так как число молекул фиксировано); это эквивалентно тому утверждению, что полный момент молекул, движущихся вверх, равен моменту молекул, движущихся вниз.

Хотя число молекул, сталкивающихся с верхней пластинкой, равно числу молекул, покидающих ее, те молекулы, которые движутся вниз, приобретают бо́льшую кинетическую энергию, чем те, которые движутся вверх. Следовательно, имеется средний поток хаотической кинетической энергии, направленной вниз. Теория этого явления была разработана с развитием кинетической теории газов, была установлена связь теплопроводности со средней длиной свободного пробега, средней скоростью молекул и удельной теплоемкостью газа. Теплопроводность газа, таким образом, является хорошо изученным явлением.

## VIII. Answer the following questions:

1. What is called the thermal conductivity of a given material?
2. How can heat flow in a material?
3. What have recent experiments shown?
4. What kind of description of thermal waves is it appropriate to seek? Why?



5. What is the difference between the temperature profiles recorded in the two different experiments?
6. Why is the thermal diffusion but not the thermal wave nearly always observed?
7. Why are the low temperatures desired?

## IX. Review the article «Second Sound» in Solid Helium».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. History of the problem of heat flowing.
2. Heat flowing by diffusion.
3. Heat flowing by the wave process.
4. Phonons.
5. Methods of observing the second sound.

# LESSON TWENTY-THREE

## Active Vocabulary

### boundary, *n.*

1. Boundary is a line that marks the end or limit; a dividing line.

2. These free electrons, or conduction electrons, can cross grain boundaries and can even pass from one metal to another.

*Synonym*: border.

### drift, *n.*

1. Drift is a motion of being carried along by wind or water.

2. Drift is also something that is carried or driven along by wind, water, etc.

3. According to this view, an electric current maintained in a metal wire by an applied voltage can be described as a slow drift of the electron gas in the direction of the electric field.

4. Big drifts of snow made progress difficult.

### appear, *v.*

1. To appear is to come into sight; to arrive; to seem.

2. When we reached the top of the hill, the town appeared below us.

3. He promised to be here at four o'clock but didn't appear until six.

4. It appears to me (=I think) that you are all mistaken.

*Derivative*: appearance.

*Synonyms*: to arrive; to seem.

*Antonym*: to disappear.

5. Disappearance is passing out of sight or existence.



### perceive, *v.*

1. To perceive is to receive into the mind; understand; to become aware through one of the senses, especially that of sight.

2. This effect is easy to perceive in the case of light waves.

*Derivative*: perception.

*Synonym*: to distinguish.

### respond, *v.*

1. To respond is to answer; to make reply; to react to; to be influenced by and act accordingly, as to respond to treatment.

*Derivatives*: response, responsible, responsibility.

2. You did it on your own responsibility (i. e. without being ordered to do it).

3. The car-driver is responsible for the passengers' safety.

*Synonyms*: to answer; to reply.

### treat, *v.*

1. To treat is to act or behave towards; to consider; to regard; to deal with; to discuss.

2. Don't treat him as a child (as if he were a child).

3. You should better treat it as a joke.

4. This magazine treats of the progress of scientific research.

*Derivative*: treatment.

5. For a more satisfactory view of the situation one must resort to the quantum-mechanical treatment, in which plane electron waves are assumed to travel in the direction of the moving electrons.

### abrupt, *adj.*

1. Abrupt is quick; sudden; not expected; steep.

2. The road is full of abrupt turns and is dangerous for motorcars.

3. The abrupt disappearance of resistance to an electric current in certain metals at temperatures near absolute zero was discovered by this scientist.

*Derivative*: abruptly.

*Synonyms*: quick; sudden.

### novel, *adj.*

1. Novel is new; strange; unusual, as a novel idea.

2. Tiny «quantized vortexes» appear in certain superconducting metals under the influence of a magnetic field. This macroscopic quantum effect can now be studied directly by a novel photographic technique.

*Derivative*: novelty.

3. Novelty is newness; strangeness; the quality of being novel; a new or unusual thing; something strange or unfamiliar.

*Synonyms*: new; strange.

*Antonyms*: old; familiar.

### perfect, *adj.*

1. Perfect is without fault; excellent; complete; whole; exact; accurate, as a perfect circle.

*Derivatives*: perfectly, perfection.

2. Perfection is the act of perfecting; the state of being perfected, as busy with the perfection of detail.

3. Imperfection is the state of being imperfect or incomplete.

4. In a normal metal dynamic and static imperfections in the crystal lattice are responsible for the scattering of de Broglie waves and hence for the electrical resistance.

### owing, *part. adj.*

1. Owing is still to be paid; due.
2. He paid all that was owing.

### owing to, *prep.*

1. Owing to is caused by; resulting from; due to; on account of.
2. Owing to the rain, we could not come.
3. Owing to the high velocity of the electrons the wavelength of the de Broglie waves is normally rather short.

## Exercises

### 1. Give the English for:

a) граница; медленное течение; появляться; казаться; исчезновение; понимать, осознавать; отвечать; обращаться, обходиться, относиться; обрабатывать, подвергать действию; неожиданный, резкий, быстрый; новый, странный, необычный; по причине, вследствие, благодаря; совершенный, идеальный, безупречный; недостаток, дефект;

b) быстрое исчезновение; быть ответственным (за что-либо); совершенный кристалл; динамические и статические дефекты; пересечь границу; благодаря высокой скорости электрона.



### 2. Give the Russian for:

an abrupt disappearance; a perfect crystal; to cross grain boundaries; a slow drift of electrons; quantum-mechanical treatment; owing to the high velocity of the electron; a novel idea.

### 3. Give derivatives of the following words:

to appear; to perceive; to respond; to treat; abrupt; novel; perfect.

### 4. Give synonyms of the following words:

border; to seem; to distinguish; to reply; sudden.

### 5. Read the following words:

| | |
|---|---|
| boundary ['baundəri] | response [ris'pɔns] |
| to perceive [pə'si:v] | responsible [ris'pɔnsəbl] |
| perception [pə'sepʃən] | responsibility [ris,pɔnsə'biliti] |
| abrupt [ə'brʌpt] | consequent ['kɔnsikwənt] |
| quantum ['kwɔntəm] | consequence ['kɔnsikwəns] |
| to quantize ['kwɔntaiz] | consequently ['kɔnsikwəntli] |
| interior [in'tiəriə] | perfect (*n., adj.*) ['pə:fikt] |
| individual [,indi'vidjuəl] | to perfect [pə'fekt] |
| component [kəm'pounənt] | perfection [pə'fekʃən] |
| to respond [ris'pɔnd] | imperfection [,impə'fekʃən] |

## THE MAGNETIC STRUCTURE OF SUPERCONDUCTORS

*Tiny «quantized vortexes» appear in certain superconducting metals under the influence of a magnetic field. This macroscopic quantum effect can now be studied directly by a novel photographic technique.*

by Uwe Essmann and Hermann Träuble

The superconducting state of matter is characterized by two fundamental properties. One, the abrupt disappearance of resistance to an electric current in certain metals at temperatures near absolute zero, was discovered by the Dutch physicist Heike Kamerlingh Onnes in 1911. The other, the tendency of a superconductor to expel a magnetic field from its interior, was discovered by the German investigators W. Meissner and R. Ochsenfeld in 1933. The problem of interpreting what actually goes on inside a superconductor at the submicroscopic level took many years to solve and ultimately required a better understanding of the behavior of electrons in a normal, or nonsuperconducting, metal.

Every piece of metal is composed of small grains, each of which is a perfect crystal consisting of a three-dimensional periodic arrangement of metal atoms. The characteristic electrical properties of metals arise from the fact that one or more electrons per atom no longer circulate around the individual atoms but instead move freely through the entire crystal at a rather high velocity. These free electrons, or conduction electrons, can cross grain boundaries and can even pass from one metal to another. In many respects they can be regarded as a negatively charged «electron gas» that fills the open latticework of the crystal and exactly balances the positive charge of the ionized lattice atoms. According to this view, an electric current maintained in a metal wire by an applied voltage can be described as a slow drift of the electron gas in the direction of the electric field.

The treatment of moving electrons as discrete charged particles does not, however, fully describe the electronic state of a metal. For a more satisfactory view of the situation one must resort to the quantum-mechanical treatment, in which plane electron waves, also known as de Broglie waves, are assumed to travel in the direction of the moving electrons. The wavelength of such a wave is inversely proportional to the velocity of the moving electrons, and its amplitude is directly proportional to the density of the electrons.

The free-electron gas in a metal can thus be viewed as a superposition of many plane de Broglie waves. When the waves are reflected at the walls of the crystal, they propagate in all possible directions and the net current is zero. Owing to the high velocity of the electrons the wavelength of the de Broglie waves is normally rather short; in fact, it is comparable to the distance between the atoms in the crystal lattice. When a voltage is applied to the metal crystal, an additional wave component in the direction of the electric field is superposed on the de Broglie waves, and a macroscopic current starts to flow.

How would such de Broglie waves interact with the ions of the crystal lattice? An ideal crystal can be thought of as consisting of a sequence of parallel planes, each with a two-dimensional periodic arrangement of ions. It can be shown that the de Broglie waves can travel between such crystal planes without a loss in intensity. Consequently one would not expect a perfect crystal to have any electrical resistance.

A real metal crystal, on the other hand, always exhibits an electrical resistance in the normal conducting state. This indicates that the de Broglie waves of the conduction electrons are scattered. In general a wave is scattered at obstacles whose dimensions are greater than or comparable to the wavelength. (This effect is easy to perceive in the case of light waves. The headlight beams of an automobile, for instance, are not scattered on a clear night because the air molecules are small compared with the wavelength of light. On a foggy night, however, the situation changes: since the fog droplets can have a diameter greater than or comparable to the wavelength of the light,



the headlight beams are scattered and may interfere with the driver's vision.)

In a normal metal dynamic and static imperfections in the crystal lattice are responsible for the scattering of de Broglie waves and hence for the electrical resistance. At room temperature by far the largest component of the resistance is the result of thermal effects, which cause the ions to oscillate around their ideal lattice positions. Only at very low temperatures is electrical resistance mainly the result of static defects such as impurity atoms and vacant lattice sites.

*(to be continued)*

## Exercises

### I. Translate into Russian paying attention to the Complex Object:

1. Consequently one would not expect a perfect crystal to have any electrical resistance.

2. At room temperature by far the largest component of the resistance is the result of thermal effects, which cause the ions to oscillate around their ideal lattice positions.

3. Because we expected the flux lines to be separated by distances on the order of a hundred-thousandth of a centimeter, extremely small particles were obviously needed to resolve single flux lines.

4. One would expect that to happen if somewhere in the superconducting winding the upper critical field is surpassed.

5. This fact limits the accuracy of the gauge because the bedrock on which the instrument is mounted is nearly always fractured, a condition that allows local effects to mask the regional or global strain state of the earth.

6. In solids molecules have fixed lattice sites but their thermal motion causes them to vibrate around these equilibrium positions.

7. According to this argument we would expect the deformation to be roughly equal to the number of nucleons in unfilled shells divided by the total number of nucleons.

8. This scientist could show the penetration depth to be essentially the same regardless of the strength of the magnetic field.

9. We know A. V. Shubnikov to have made the first systematic measurements of the properties of Type II superconductors.

10. Many scientists made various attempts to describe how the superconducting channels might be arranged, but none succeeded.

## II. Translate into English using the active vocabulary of the lesson:

1. Для металлов характерно резкое уменьшение электрического сопротивления при температурах, близких к абсолютному нулю.
2. Благодаря применению небольших добавок к рабочему газу камеры можно добиться сильного увеличения скорости дрейфа в очищающем поле.
3. Искровая камера запускается высоковольтным импульсом с очень крутым фронтом.
4. Увеличение разрешающей способности искровой камеры можно легко понять из следующих соображений.
5. Различие в электронной структуре металлов и проводящих жидкостей (электролитов) вызывает появление электрического поля на границе между ними.
6. Чтобы понять новый подход к этому явлению, необходимо прежде всего осветить результаты целого ряда экспериментов.
7. Динамические и статические несовершенства в кристаллической решетке влияют на электрическое сопротивление.
8. Долгие годы сверхпроводимость оставалась не только необъясненным явлением (пожалуй, самым загадочным в области макрофизики), но и не находила почти никакого практического применения.
9. Последнее объясняется тем, что сверхпроводимость вплоть до настоящего времени наблюдается только при низких температурах.
10. Исследования в области высокотемпературной сверхпроводимости только начинаются. Совсем не исключена возможность добиться успеха сравнительно скромными (хотя и современными) средствами.

## III. Translate at sight:

For many years the intrusion of a magnetic field into a Type II superconductor could not be understood. An explanation in terms of an increase of the penetration depth of the magnetic field was not possible, because it could be shown that the penetration depth is essentially the same regardless of the strength of the magnetic field. As a working hypothesis Kurt Mendelssohn proposed in 1934 that in high magnetic field most of a Type II superconductor is penetrated by the magnetic field and only some thin channels are left superconducting. This «mixed» state of normal and superconducting regions was called the Shubnikov phase in honor of the Soviet physicist Aleksei V. Shubnikov, who made the first systematic measurements of the properties of Type II superconductors. Various attempts were made to describe how the superconducting channels might be arranged, but none could be strictly proved by theoretical arguments or by experiments.



## IV. Give the situations from the text in which the following words are used:

boundary; drift; disappearance; to perceive; to be responsible for; treatment; abrupt; consequently; owing to; imperfection.

## V. Develop further the following statements:

1. Every piece of metal is composed of small grains, each of which is ...
2. These free electrons, or conduction electrons, can cross ...
3. According to this view, an electric current maintained in a metal wire by an applied voltage can be described as ...
4. In general a wave is scattered at obstacles whose dimensions are greater than or comparable to the wavelength. This effect is easy to ...
5. In a normal metal dynamic and static imperfections in the crystal lattice are ...
6. For a more satisfactory view of the electronic state of a metal one must resort to ...

## VI. Translate the following Russian questions into English and answer them:

1. Что открыл Камерлинг Оннес в 1911 году?
2. Каков путь свободного электрона при прохождении его из одного металла в другой?
3. Как можно представить электрический ток?
4. Как мы можем препятствовать ослаблению тока в проводе, прикладывая к нему постоянное напряжение?
5. Что мы должны изменить в наших теоретических изысканиях, если мы видим, что рассмотрение движущихся электронов как дискретных заряженных частиц не дает полного представления об электронном состоянии металла?
6. От чего в основном зависит электрическое сопротивление при очень низких температурах?

## VII. Render in English:

При температурах ниже определенной (свойственной данному металлу) критической температуры некоторые металлы и сплавы переходят в так называемое сверхпроводящее состояние. При переходе в сверхпроводящее состояние расположение атомов в кристаллической решетке металла, его механические свойства и оптические свойства в области видимого света и более коротковолновых излучений остаются практически неизмененными. Другие же свойства, особенно электрические и магнитные, значительно изменяются.

Главное свойство сверхпроводников — полное отсутствие электрического сопротивления постоянному току. Если исследуемый образец включен в цепь, в которой внешним источником создается электрический ток, то при понижении температуры образца ниже критической температуры падение напряжения на нем скачком обращается в нуль.

### VIII. Answer the following questions:

1. What is the superconducting state of matter characterized by?
2. What is every piece of metal composed of?
3. Does the treatment of moving electrons as discrete charged particles fully describe the electronic state of a metal?
4. What happens when the waves are reflected at the walls of the crystal?
5. How would such de Broglie waves interact with the ions of the crystal lattice?
6. What indicates that the de Broglie waves of the conduction electrons are scattered?
7. What is responsible for the scattering of de Broglie waves and for the electrical resistance?

### IX. Speak on the following topics:

1. Two fundamental properties of the superconducting state of matter.
2. The nature of characteristic electrical properties of metal.
3. The reason why the electron gas is viewed as a superposition of the de Broglie waves.
4. The interaction between the «electron gas» and the lattice of the crystal.

# LESSON TWENTY-FOUR

## Active Vocabulary

### favo(u)r, *n.*

1. Favour is a friendly regard; good-will; approval; support; a willingness to help, protect and be kind to, as to win a person's favour; to look on a plan (a person) with favour (i. e. to approve); under favour (i. e. cover or protection) of something or somebody.

2. May I ask a favour of you (i. e. ask you to help me)?

*Derivatives*: favourable, favourably.

3. Favourable is in favour of; suitable; helpful; showing approval; giving support.

4. The BCS theory, as it is now called, reveals that below the superconducting transition temperature it is energetically favourable for the conduction electrons to accept a new state by combining to form what are called Cooper pairs.

*Synonyms*: approval; support.

### order, *n.*

1. Order is an arrangement; way of placing; the way one thing follows another; the condition in which everything is carefully arranged or in a normal, healthy and efficient state, as names arranged in alphabetical (i. e. A. B. C.) order.

2. He left his affairs in perfect order (i. e. his papers, accounts of money, etc. were carefully arranged).

*Synonym*: arrangement.

*Antonym*: disorder.

### order, *v.*

1. To order is to arrange; to direct.

2. Below the superconducting transition temperature it is energetically favourable for the condition electrons to accept a new, more ordered state by combining to form what are called Cooper pairs.

**accommodate, *v.***

1. To accommodate is to supply with what is needed; to make fit or suitable.

2. When you go to a strange country, you have to accomodate yourself to new ways of living (=change your ways to suit the new ways).

*Derivative*: accommodation.

3. Accommodation is a helpful or convenient thing.

4. The free energy of the metal can be decreased if electrons with opposite velocities are paired by accommodation to a common lattice vibration.

*Synonym*: to fit.

**assemble, *v.***

1. To assemble is to gather together; to collect; to fit or put together, as to assemble a motor-car.

2. The pupils assembled (were assembled) in the school hall.

*Derivative*: assembly.

3. The de Broglie wavelength of the Cooper-pair assembly would be large compared with the dimensions of the lattice imperfections.

*Synonyms*: to collect; to fit.

**connect, *v.***

1. To connect is to join or fasten together; unite.

2. The two towns are connected by a railway.

3. A rough model of the resulting bound state consists of two negatively charged balls connected by a spring and oscillating with respect to each other.

*Derivative*: connection.

*Synonyms*: to join; to unite.

*Antonym*: to disconnect.

**correlate, *v.***

1. To correlate is to have a relation to each other; to bring (one thing) into relation with another.

2. Below the superconducting transition temperature, however, the lattice vibrations correlated with the moving electrons become dominant.

*Derivatives*: correlation, correlative.

3. Correlation is showing the relation between things; the relation itself.



**overwhelm, *v.***

1. To overwhelm is to cover completely; to flow over or pour down on.

2. In a metal this interaction of electrons is overwhelmed by the background «noise» of the remaining electrons and ions and hence is negligible.

**vanish, *v.***

1. To vanish is to disappear, gradually or suddenly; to go out of sight; to pass out of existence.

2. Under this condition scattering processes are rare and the electrical resistance of a superconductor vanishes.

*Synonym*: to disappear.

*Antonym*: to appear.

**dense, *adj.***

1. Dense is packed closely together; thick, as a dense fog, a dense forest.

*Derivatives*: densely, density.

2. Density (in physics) is the proportion of weight to volume.

3. Lead has a much greater density than wood.

4. In order to appreciate the difference between the resistance of the normal state and the resistance of the superconducting state at a given current density one must examine the corresponding de Broglie waves.

**extreme, *adj.***

1. Extreme is (of space) at or near the end or edge; furthest off, as the extreme end of a line; the extreme edge or border of a field.

2. Extreme is also (of persons, their opinions and tempers) very advanced; not moderate; going to great lengths.

*Derivative*: extremely.

3. Under this condition scattering processes are extremely rare and the electrical resistance of a superconductor vanishes.

*Synonym*: uttermost.

## Exercises

### 1. Give the English for:

а) расположение, одобрение; польза, интерес, помощь; благоприятный, подходящий, удобный; порядок, последовательность; приспосабливать, снабжать, согласовывать; собирать(ся), монтировать; соединять; устанавливать соотношение; подавлять, сокрушать; исчезать; плотный; крайний, чрезвычайный;

b) благоприятные условия; более упорядоченное состояние; при данной плотности; чрезвычайно редкий.

**2. Give the Russian for:**

energetically favourable for; a more ordered state; to be overwhelmed by the background «noise»; uncorrelated thermal vibrations of the lattice; two negatively charged balls connected by a spring; in order to appreciate the difference; at a given current density; extremely rare.

**3. Give derivatives of the following words:**

favour; to accommodate; to assemble; to connect; to correlate; dense; extreme.

**4. Give synonyms of the following words:**

approval; arrangement; to fit; to collect; to join; to disappear; uttermost.

**5. Read the following words:**

favour [ˈfeivə]
favourable [ˈfeivərəbl]
to assemble [əˈsembl]
to overwhelm [ˌouvəˈwelm]
extreme [iksˈtri:m]
extremely [iksˈtri:mli]
transition [trænˈsiʒən]
mechanism [ˈmekənizm]
mechanics [miˈkæniks]
mechanical [miˈkænikəl]
momentum [mouˈmentəm]
to accomodate [əˈkɔmədeit]
accomodation [əˌkɔməˈdeiʃn]
to correlate [ˈkɔrileit]
correlative [kɔˈrelətiv]
inconsequential [inˌkɔnsiˈkwenʃəl]
to oscillate [ˈɔsileit]
oscillation [ˌɔsiˈleiʃən]
microscopic [ˌmaikrəsˈkɔpik]
macroscopic [ˌmækrousˈkɔpik]

## THE MAGNETIC STRUCTURE OF SUPERCONDUCTORS

by Uwe Essmann and Hermann Träuble

(continued)

The behavior of electrons in the superconducting state could not be interpreted satisfactorily until 1957, when the first submicroscopic theory of superconductivity was put forward by John Bardeen and other scientists of the University of Illinois. The BCS theory, as it is now called, reveals that below the superconducting transition temperature it is energetically favourable for the conduction electrons to



accept a new, more ordered state by combining to form what are called Cooper pairs.

The formation of these electron pairs in a superconductor can best be understood by considering the ways in which the conduction electrons can interact in a metal. First of all there is the well-known Coulomb force, or repulsive force, between any two particles with the same electric charge. In a metal this interaction of electrons is overwhelmed by the background «noise» of the remaining electrons and ions and hence is negligible. The net interaction of electrons in a metal is attractive and arises from lattice vibrations that accompany the moving electrons. As the electrons pass near the positive lattice ions, vibrations of the ion lattice are induced as a result of the mutual electrical attraction of these oppositely charged particles. The vibrations are weak, and their influence at high temperatures is inconsequential compared with the influence of the uncorrelated thermal vibrations of the lattice. Below the superconducting transition temperature, however, the lattice vibrations correlated with the moving electrons become dominant. A quantum-mechanical calculation shows that the free energy of the metal can be decreased if electrons with opposite velocities are paired by accommodation to a common lattice vibration. A rough model of the resulting bound state consists of two negatively charged balls connected by a spring and oscillating with respect to each other. The balls move with opposite velocities while the spring (representing the lattice) serves as a medium for the exchange of mechanical momentum.

In actuality electrons are continuously exchanged between Cooper pairs. This detail is unimportant, however, because entry into the superconducting state requires only that *enough* electrons be condensed in the paired state. The concentration of the Cooper pairs depends on the temperature, with all the conduction electrons paired at absolute zero.

A Cooper pair can in a sense be regarded as a new particle, with twice the charge and mass of an electron, that can exist only in a metal. The effective diameter of a Cooper pair is called its coherence length and is of the order of a hundred-thousandth of a centimeter. The mechanism by which Cooper pairs are formed implies that all such pairs in a given superconductor are in the same state of motion. Either their centers of mass are at rest or, if the superconductor carries a current, they move with one and the same velocity in the direction of the current.

In order to appreciate the difference between the resistance of the normal state and the resistance of the superconducting state at a given current density one must examine the corresponding de Broglie waves. It has been shown above that in the normal conducting state an electric current can be described as a superposition of many plane de Broglie waves. Since the lengths of these waves are short, the waves are scattered at lattice imperfections. In the superconducting state the situation is completely different. Here the current is maintained by a large number of Cooper pairs, all moving with the same velocity and in the same direction. Hence the Cooper pairs are represented collectively by one de Broglie wave. Since the density of the moving Cooper pairs is quite high, only a small velocity is necessary for a given current. As a result the wavelength of the de Broglie wave is large. Even at extremely high current densities the de Broglie wavelength of the Cooper-pair assembly would be large compared with the dimensions of the lattice imperfections. Under this condition scattering processes are extremely rare and the electrical resistance of a superconductor vanishes. The formation of macroscopic de Broglie waves is the basic reason for the peculiar features of the superconducting state.

*Scientific American*
*March 1971.*

## Exercises

### I. Translate into Russian paying attention to «for»-phrases:

1. The BCS theory, as it is now called, reveals that below the superconducting transition temperature it is energetically favourable for the conduction electrons to accept a new, more ordered state by combining to form what are called Cooper pairs.

2. For such forces to be effective, matter must be compressed until it approaches the density of matter within an atomic nucleus.

3. In order for the readout system to follow displacements of more than a few fringes it is provided with a limiting switch that interrupts the fringe-following mechanism after it has traveled a distance of a fringe or so.

4. This calls for an ingenious system to compensate for thermal expansion and contraction, which amounts to several inches at the air gaps between the pipes and the interferometer mirrors.

5. Since the emission of a negative-energy particle and the absorption of a positive-energy particle traveling in the opposite direction produce the same effect on the energy of a system, it is always possible for any observer to insist that all tachyons have positive energy, and that emission and absorption take place in the familiar time-ordering, thus removing the instability problems that negative-energy tachyons would present.

6. For the hypothetical faster-than-light particles, which can never be brought to rest, this constant is not directly measurable, and there is no need for it to be real.

7. The main difficulty is the large energy required for intrinsic conduction to occur.

8. The general idea is to heat a plasma, or ionized gas, of deuterium or tritium to more than 100 million degrees centigrade and hold the plasma together by means of magnetic field long enough for some of the ions to fuse, releasing energy in the form of radiation.



### II. Translate into English using the active vocabulary of the lesson:

1. Новая теория показывает, что температура ниже температуры сверхпроводимости оказывается энергетически более предпочтительной для электронов проводимости.

2. При комнатной температуре электрон-электронное взаимодействие в металле пренебрежимо мало по сравнению с тепловым движением электронов.

3. Даже при очень больших плотностях тока длина волны де Бройля куперовского ансамбля была бы большой по сравнению с размерами неоднородностей кристаллической решетки.

4. Свободная энергия металла может быть уменьшена, если электроны приспосабливаются к колебаниям решетки.

5. Величина эффективного диаметра куперовской пары имеет порядок стотысячной доли сантиметра.

6. Так как плотность движущихся куперовских пар достаточно велика, то для данного тока необходима только малая скорость.

7. Скорость хаотического движения электронов в кристалле устанавливается в соответствии с тепловыми колебаниями ионов.

8. При этих условиях процессы рассеяния особенно редки, и электрическое сопротивление сверхпроводника исчезает.

9. Приближенная модель результирующего связанного состояния состоит из двух отрицательно заряженных шариков, связанных пружиной и осциллирующих по отношению друг к другу.

10. Принципиальным и неясным моментом является возможность создания высокотемпературных сверхпроводников, то есть металлов, остающихся сверхпроводящими при температурах порядка 100°K, а еще лучше — и при комнатной температуре.

### III. Catch the meaning of the text and retell it:

In the 1960's the Soviet theorists V. L. Ginzburg and L. D. Landau were in the process of inventing a set of mathematical equations suitable for describing the transition to the superconducting state. They assumed the existence in a superconductor of a macroscopic quantum state corresponding to a single de Broglie wave. It was not until seven years later, however, that the Ginzburg-Landau equations were solved for Type II superconductors. This calculation, carried out by the Soviet physicist A. A. Abrikosov, led to the prediction that the mixed state of a Type II superconductor in a magnetic field consists of a system of tiny vortexes of circulating supercurrent associated with the individual magnetic-flux lines.

In Abrikisov's model the flux lines are aligned parallel to the applied field, with each line leading exactly one quantum of magnetic flux through the superconductor. The magnetic field in a single vortex is spread over a region with a diameter of about two magnetic-penetration depths, with its maximum at the axis. The concentration of the superconducting Cooper pairs declines within the coherence length toward the axis of the flux line. At the axis the metal is in principle a normal conductor. The mutual interaction of two flux lines is repulsive in a typical Type II superconductor. The flux lines are held together by the external applied field and arrange themselves in a triangular lattice. Their density increases with increasing magnetic field and can be calculated by dividing the measured induction by the fluxoid quantum. The flux lines are further assumed to be «nucleated» at the surface of the specimen as the magnetic field surpasses the lower critical field, and to move from the surface into the interior of the specimen. At the upper critical field the normal conducting cores of the flux lines overlap and the whole interior of the specimen becomes a normal conductor.

### IV. Give the situations from the text in which the following words are used:

assembly; accommodation; to connect; to correlate; to overwhelm; to vanish; dense; extremely; favourable; ordered.

### V. Develop further the following statements:

1. The BCS theory reveals that below the superconducting transition temperature it is energetically ...
2. In a metal this interaction of electrons is ...
3. The vibrations are weak, and their influence at high temperatures is inconsequential compared with the influence of the ...
4. A quantum-mechanical calculation shows that the free energy of the metal can be decreased if electrons with opposite velocities are paired by ...
5. A rough model of the resulting bound state consists of two negatively charged balls ...
6. Under this condition scattering processes are extremely rare and the electrical resistance of a superconductor ...

### VI. Translate the following Russian questions into English and answer them:

1. Почему силы электрического отталкивания между электронами в металле играют незначительную роль?
2. Каким образом происходит уменьшение внутренней энергии металла по квантовомеханическим представлениям?



3. Как осуществляется связь между двумя электронами в паре Купера?
4. Какие условия являются наиболее подходящими для образования пáры Купера?
5. При каких плотностях тока длина волны де Бройля куперовской пары была бы большой по сравнению с размерами дефектов кристалла?
6. Как отражается исчезновение процессов рассеяния на сопротивлении сверхпроводника?
7. Удивились ли бы вы, если бы в очередном номере физического журнала прочли о создании высокотемпературного сверхпроводника? Почему?
8. Но в случае создания высокотемпературного сверхпроводника возникла бы сенсация и о новостях мы узнали бы из газет или радиопередач, не так ли?
9. Вероятно ли, что высокотемпературные сверхпроводники создать очень трудно или вообще невозможнó?
10. Является ли вопрос о создании высокотемпературных сверхпроводников до сих пор открытым?
11. Попытки ответить на этот вопрос представляются исключительно привлекательными, правда?

### VII. Render in English:

Согласно современным представлениям, основной причиной сверхпроводимости является образование связанных пар электронов (так называемый эффект Купера), благодаря чему электронная жидкость приобретает свойство сверхтекучести. Пáры образуются вследствие действия особых сил притяжения между электронами. Обычно это силы, связанные с колебаниями решетки. Кристаллическая решетка даже при температуре, равной нулю, находится в колебательном движении (так называемые нулевые колебания). Благодаря электростатическому взаимодействию зарядов электрона и ионов решетки в окрестности каждого электрона режим колебаний решетки изменяется, что вызывает дополнительные силы, действующие на другой электрон. С точки зрения квантовой теории эти силы появляются вследствие того, что электроны могут обмениваться фононами — квантами колебаний решетки. Эти силы всегда соответствуют притяжению и могут превышать непосредственное кулоновское отталкивание электронов.

Большая сложность взаимодействия частиц в реальных металлах пока не дает возможности заранее предсказать, в каких металлах можно ожидать преобладания притяжения электронов над отталкиванием, то есть появления сверхпроводимости.

Пáры, образующиеся под воздействием фононного притяжения, обладают спином, равным нулю, то есть они состоят из электронов с противоположными спинами, и орбитальный момент такой пары равен нулю.

**VIII. Answer the following questions:**

1. When was the behavior of electrons in the superconducting state satisfactorily interpreted?
2. What is the BCS theory?
3. How can the formation of these electron pairs in a superconductor be understood?
4. When can the free energy of the metal be decreased?
5. What does a rough model of the resulting bound state consist of?
6. What does the mechanism by which Cooper pairs are formed imply?
7. What are the Cooper pairs represented collectively by?

**IX. Review the article «The Magnetic Structure of Superconductors».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. The ways of interaction of the conduction electrons in a metal.
2. Cooper pairs and superconductivity.
3. Some properties of a Cooper pair.
4. The connection between a Cooper pair and de Broglie waves.
5. Peculiarities of the scattering the de Broglie waves on the imperfections in superconducting state.

# LESSON TWENTY-FIVE

## Active Vocabulary

### evidence, *n.*

1. Evidence is clearness, something that does not require any additional explanation.
2. There was not enough evidence to prove him guilty.

*In evidence*=attracting attention.

4. She is the sort of woman who likes to be very much in evidence.

*Derivatives*: evident, evidently.

### stream, *n.*

1. An unbroken flow of liquid, or gas, or any particles of matter is called stream; sometimes by stream a ray or beam of light is meant.
2. In the street there's a constant stream of cars, taxis and buses.
3. The jet stream itself is the main evidence for negative viscosity in atmosphere.

*Derivative*: streamline.

4. Streamline is the path of a fluid particle relative to a solid body past which the fluid is moving in smooth flow without turbulence.

*Synonym*: flow.

### confirm, *v.*

1. To confirm means to make strong, or valid, or sure.
2. A theory is valid only if it can be confirmed experimentally.
3. These observations confirmed the validity of the theory of Ambartsumyan.

*Derivative*: confirmation.

4. Confirmation of this rotational pattern has come from Doppler measurement of line-of-light velocities.
*Synonym*: to verify.

**plot,** ***v.***

1. To plot means to locate a point by means of coordinates.
2. These curves were plotted to represent the equation in graphic form.
3. The evidence is supplied by carefully plotting the movements of the sunspots.
*Synonym*: to plan.

**prevail,** ***v.***

1. To prevail means to be or become effective; to be predominant.
2. Simple lines prevail in modern buildings.
3. Prevailing feature of his report is evidence of explanation.
*Derivatives*: prevalence; prevalent.

**restrain,** ***v.***

1. To restrain means to limit, restrict, or keep under control; to moderate or limit the force, effect, or development.
2. The number of the explanations was restrained by the lack of time.
3. Rainy weather restrained us from going to the sea.
*Derivative*: restraint.

**superimpose,** ***v.***

1. To superimpose means to place over or above something.
2. These two curves are evidently superimposing each other.
3. Airmasses from the North superimpose warm flows in this region.

**sustain,** ***v.***

1. To sustain means to give support to; to support the weight of; to support as true or legal; to confirm.
2. Food sustains life.
3. Can this shelf sustain (the weight of) all these books?
4. The ship sustained the shock.
*Derivatives*: sustainable, sustenance.

**average,** ***adj.***

1. Average means being about midway between extremes; medial in value.



2. The average temperature in June in Moscow is 20°C.
3. Even average number of unemployment in the U. S. A. is very high.
*Synonym*: mean.

**thorough,** ***adj.***

1. Thorough means carried through to completion; complete in all respects; marked by full detail.
2. A thorough investigation of the case brought positive results.
3. You'll find what has been damaged in the mechanism only after thorough inspection.
*Derivatives*: thoroughly, thoroughness.
4. The natural fluid systems have been studied thoroughly.
*Synonyms*: attentive; complete.

## Exercises

### 1. Give the English for:

a) очевидность; поток; подтверждать; наносить; преобладать; ограничивать; накладывать; поддерживать; средний; тщательно;
b) это совершенно очевидно; заметный, бросающийся в глаза; непрерывный поток частиц; это требует подтверждения; поддерживаться чем-либо.

### 2. Give the Russian for:

evidence for a low velocity; streamline; confirmation of this rotational pattern; to plot; prevailing features; to restrain motion; to superimpose; to be sustained by; average flow; thorough studies.

### 3. Give derivatives of the following words:

evidence; stream; to confirm; to prevail; to restrain; to sustain; thorough.

### 4. Give synonyms of the following words:

flow; to verify; to plan; mean; attentive.

### 5. Give antonyms of the following words:

to appear; careless; to disconnect; disorder; inconsequent; to reject; vague; to disappear.

**6. Read the following words:**

viscosity [vis'kɔsiti]
turbulence ['tə:bjuləns]
profile ['proufi:l]
altitude ['æltitju:d]
latitude ['lætitju:d]
equator [i'kweitə]
equatorial [,ekwə'tɔ:riəl]
character ['kæriktə]
characteristic [,kæriktə,ristik]
circumference [sə'kʌmfərəns]
to dissociate [di'souʃieit]
dissociation [di,sousi'eiʃən]
confirmation [,kɔnfə'meiʃən]
effort ['efət]
gradient ['greidjənt]
to sustain [səs'tein]
to confirm [kən'fə:m]
meteorology [,mi:tjə'rɔlədʒi]
to exhibit [ig'zibit]
exhibition [,eksi'biʃən]
thoroughly ['θʌrəli]
westerlies ['westəliz]

## NEGATIVE VISCOSITY

*In most fluid systems differences in velocity are obliterated by positive viscosity. In some rotating systems, however, nonuniform flows can be maintained by negative viscous effects due to eddies.*

by Victor P. Starr and Normann E. Gaut

The natural fluid system that has been most thoroughly studied and that has most clearly exhibited negative-viscosity effects is the earth's atmosphere. The most characteristic feature of atmospheric motions is the presence of an irregular turbulent flow in middle latitudes (in both hemispheres) consisting of eddies in a spectrum of sizes superimposed on an average flow from west to east. These eddies account for the familiar and constantly changing patterns seen in the daily weather map.

If the wind flow at a height of nine or ten kilometers is averaged along circles of latitude, it can be seen that the prevailing westerlies build up to a maximum where the jet streams are found, that is, between 30 and 45 degrees latitude in both hemispheres. Prevailing easterlies of lower maximum velocity are centered on or near the Equator. There is also evidence for a low-velocity flow from east to west near the poles.

The jet stream itself, which often reaches a velocity of 150 miles per hour at altitudes between 35,000 and 40,000 feet, is the most obvious evidence for negative viscosity in the atmosphere. If there were no mechanisms for chanelling momentum into this swift-flowing river of air, it would be quickly slowed down by the frictional effects of positive viscosity feeding momentum vertically into ground and ocean surfaces.

The jet stream and the prevailing westerlies are evidently produced and sustained by the horizontal patterns of turbulence that meteorologists call cyclones and anticyclones.



A much larger fluid system that exhibits negative viscous effects is the photosphere, or visible surface, of the sun. The evidence is supplied by carefully plotting the movement of sunspots, which were first observed in the 17th century by Galileo. It was subsequently noted that sunspots near the equator travelled more rapidly across the face of the sun than sunspots farther to the north or south did. This led to recognition that the photosphere does not rotate at a uniform rate but rotates faster at the equator — a phenomenon not known at the equatorial acceleration. A velocity profile of the sun's mean rate of rotation shows a pronounced bulge at the equator and a reverse bulge in each hemisphere. Confirmation of this rotational pattern has come from Doppler measurements of line-of-sight velocities at the edge of the solar disk.

The differences in the physical characteristics of the sun's atmosphere and of the earth's atmosphere are clearly enormous. The circumference of the sun is about 100 times that of the earth. The photosphere is some 400 kilometers thick and ranges in temperature from 4,500 degrees Kelvin at the top, where it joins the overlying chromosphere, to perhaps 8,000 degrees K. at the bottom. Because of the high temperature much of the gas in the photosphere is dissociated into free electrons and free nuclei of atoms, chiefly nuclei of hydrogen. This electrically charged plasma interacts strongly with the sun's magnetic field and produces kinds of turbulence that can be observed only indirectly and that are difficult to treat theoretically. The main evidence for eddies in the mean circulation of the photosphere comes from careful observation of sunspot motions. Worldwide observations of sunspots extending back more than 75 years were collected and analyzed under the guidance of Fred Ward at the Air Force Cambridge Research Laboratories. A particular effort was made to correlate the north-south and east-west movement of spots to see if any systematic transport of momentum could be discovered. The analysis showed that enough momentum was indeed being carried toward the equator to produce the higher rotation rate of the sun's equatorial region.

There is theoretical work suggesting that patterns in the large-scale magnetic features of the sun should correlate with fluid motions on the same scale. These studies, together with experiments on numerical models, indicate that fluid flow in the solar atmosphere should exhibit, at least statistically, streamline patterns that are mirror images of the patterns present in the earth's atmosphere. Because the sun's patterns show tilts that are the reverse of those in the earth's atmosphere, momentum on the sun is carried toward the equator rather than away from it, thus providing another example of negative eddy viscosity.

The ultimate source of the energy that sustains the transfer of momentum to the equator is the sun's nuclear furnace. We do not know if there is a temperature difference between the sun's poles and the equator. If there is, it could drive the solar circulation much as the earth's atmosphere is driven by the pole-to-equator temperature gradient. Other mechanisms are conceivable, however, for feeding energy into the eddies. It also seems probable that the sun's magnetic field plays an important role in restraining large-scale motions.

*Scientific American*
*July 1970.*

## Exercises

### I. Translate into Russian paying attention to the Gerund:

1. As the photograph accompanying this article will testify, we have succeeded in achieving that goal.
2. The problem of interpreting what actually goes on inside a superconductor at the submicroscopic level took many years to solve and ultimately required a better understanding of the behavour of electron in a normal, or nonsuperconducting metal.
3. By stirring a cup of coffee one can produce a miniature of whirlpool.
4. Hydrodynamicists have had great difficulty in trying to derive equations of turbulent viscosity.
5. The idea of evolving quite now the plan for the next three years is worth considering.
6. When they entered the room the students were busy discussing current events.
7. Soviet scientists succeeded in constructing an absolutely unique TV system which the famous «Lunokhod» was equipped with.
8. I am proud of being a citizen of the Soviet Union.
9. We are fond of skiing in winter time.

### II. Translate into English using the active vocabulary of the lesson:

1. Можно сказать, что земная атмосфера, имеющая наиболее ярко выраженную отрицательную вязкость, тщательно изучена.
2. Преобладание восточных ветров возле экватора также является подтверждением скорости потоков, идущих с востока на запад.
3. Доказательство того, что солнечная фотосфера является огромной системой с отрицательной вязкостью, можно получить, тщательно нанеся на карту движение солнечных пятен.
4. Западные ветры обычно вызываются и поддерживаются циклонами и антициклонами.



5. Главной особенностью атмосферного движения является существование беспорядочных турбулентных потоков в средних широтах, представляющих собой вихри, наложенные на средний поток, направленный с запада на восток.
6. Движение солнечных пятен подтверждает тот факт, что фотосфера вращается быстрее, чем экватор.
7. Кажется вполне вероятным, что солнечное магнитное поле ограничивает движение в фотосфере.
8. Самым очевидным доказательством отрицательной вязкости в атмосфере является наличие реактивного потока, который на высоте от 35 до 40 тысяч футов достигает скорости 150 миль в час.
9. Основным источником энергии, который поддерживает перенос количества движения к экватору, является внутренняя ядерная энергия.
10. Главное доказательство наличия вихрей в основном круговороте фотосферы получается при тщательном наблюдении движения солнечных пятен.

### III. Translate at sight:

By vigorously stirring a cup of coffee one can produce a miniature whirlpool, the center of which is rotating more rapidly than the edges. As soon as the stirring stops, the velocity in the center of the cup slows down and the velocity near the periphery tends to increase. None of this is surprising. When faster-moving particles collide with slower-moving ones, part of the momentum of the faster is transferred to the slower. When the particles of different velocities are constituents of a fluid system, we say that the fluid resists shear. We have come to expect that if shear is induced in a fluid — whether by a teaspoon or by the exhaust from a rocket — the shear will inexorably decrease with the passage of time. We do not expect momentum to be transferred from a slower-moving part of a fluid to a faster-moving part, an event that would seem as unlikely as water running uphill. And yet under certain circumstances, which are not at all rare, the amount of shear in a fluid can increase rather than decrease. In contradistinction to molecular viscosity, which is always positive, this behavior of fluids is termed negative viscosity.

The first suggestion that negative viscosity might develop temporarily in a fluid was made in 1895 by Osborne Reynolds, the British physicist who contributed so extensively to the theory of fluids in motion.

### IV. Give the situations from the text in which the following words are used:

clearly; spectrum; circles of latitude; both; along; Equator; low-velocity; obvious; horizontal; to be supplied by; movement; rotational pattern; mean circulation; statistically.

## V. Give questions to which the following statements might be the answer:

1. The most characteristic feature of atmospheric motions is the presence of an irregular turbulent flow in middle latitudes consisting of eddies in a spectrum of sizes.

2. Prevailing easterlies of lower maximum velocity are centered on or near the Equator.

3. The jet stream and the prevailing westerlies are evidently produced and sustained by the horizontal patterns of turbulence.

4. The evidence is supplied by carefully plotting the movement of sunspots.

5. A velocity profile of the sun's mean rate of rotation shows a pronounced bulge at the equator and a reverse bulge in each hemisphere.

6. The circumference of the sun is about 100 times that of the earth.

7. Much of the gas in photosphere is dissociated into free electrons and free nuclei of atoms, chiefly atoms of hydrogen.

8. Momentum on the sun is carried toward the equator rather than away from it, thus providing another example of negative viscosity.

## VI. Translate the following Russian questions into English and answer them:

1. Что является наиболее характерной особенностью атмосферного движения?

2. Какие доказательства отрицательной вязкости атмосферы вы знаете?

3. Что является обоснованием отрицательной вязкости фотосферы Солнца?

4. Какую роль играет взаимодействие магнитного поля Солнца с солнечной плазмой в фотосферных явлениях?

5. Что такое циклоны и антициклоны?

6. Из чего вытекает основное доказательство существования вихрей в средней циркуляции фотосферы?

7. Что является основным источником энергии, которая поддерживает перенос количества движения к экватору?

8. Почему особенно важно было найти связь между северо-южными и восточно-западными движениями пятен?

9. Какая нейтральная жидкая система наиболее тщательно изучена и почему?

10. Какова основная характерная особенность атмосферных движений?



## VII. Render in English:

Гидродинамики испытывали большие затруднения, пытаясь вывести уравнения для турбулентной вязкости, которые приближались бы по своей простоте к хорошо обоснованным уравнениям молекулярной вязкости. Одно приближение состояло в том, чтобы приписать вихревым потокам массы «смешанную длину», грубо соответствующую среднему свободному пробегу молекулы. Проблема, конечно, состоит в том, что вихревые потоки массы не имеют точных границ. Вторая трудность состоит в том, что «смешанная длина» не может соответствовать среднему свободному пробегу потому, что пробег вихря не является свободным.

Вихревые потоки массы взаимодействуют с другими массами постоянно, так что нельзя отойти от механизма сплошных сред, как это можно сделать для молекул.

Наиболее явно аналогия между молекулярной вязкостью и турбулентной вязкостью нарушается при наблюдении настоящих систем потока. Молекулярная вязкость всегда положительна, что означает, что любая кинетическая энергия, приложенная к системе потока, как целое, в результате проявляется в кинетической энергии самих молекул. Турбулентная вязкость, однако, может быть как положительной, так и отрицательной.

## VIII. Answer the following questions:

1. What is the most characteristic feature of atmospheric motions?
2. What does the middle latitude turbulent flow consist of?
3. Where and in what cases are the jet streams found?
4. What are the jet streams and the prevailing westerlies produced by?
5. What do the meteorologists call cyclones and anticyclones?
6. What larger system exhibits negative viscous effects?
7. When were sunspots first observed?
8. What made scientists think that the photosphere does not rotate at a uniform rate?
9. What are streamline patterns?
10. What works of Soviet scientists concerning this particular field do you know?

## IX. Review the article «Negative Viscosity».

## X. Write an annotation on the article.

## XI. Speak on the following topics:

1. Molecular viscosity.
2. Turbulent, eddy, or virtual viscosity.
3. The earth as a neutral system exhibiting negative viscosity.
4. The sun's photosphere as a fluid system that exhibits negative viscosity effects.

# LESSON TWENTY-SIX

## Active Vocabulary

### crust, *n.*

1. Crust is the outer portion of a thing.
2. High mountains are covered with crust of ice even in summer.
3. In most stars the crust ends a few kilometers below the surface.

### earthquake, *n.*

1. Earthquake is a shaking or trembling of the earth that is volcanic or tectonic in origin.
2. Japan is a land of earthquakes.

### fringe, *n.*

1. Fringe is one of various light or dark bands produced by the interference or difraction of light.
2. At the detector the interference is visible as a pattern of parallel dark and light «fringes» with the light fringes representing the constructive interference of light waves and the dark fringes destructive interference.

*Derivative*: fringy.

### gauge, *n.*

1. Gauge is an instrument with a graduated scale for measuring or indicating quantity.
2. The Benioff gauge consists of a long quartz cylinder.
3. Sensitivity and accuracy are very important characteristics for any gauge.



### strain, *n.*

1. Strain is an excessive physical or mental tension; excessive or difficult labor; deformation of a material body under the action of applied forces.
2. Sleepless nights are a strain on the nerves.
3. Engineers always calculate strains of a bridge.
4. Earth's strains can be detected by a seismograph.

### attach, *v.*

1. To attach means to bring into an association; to bind; to connect.
2. You can't take any of these chairs as they are attached to one another.
3. He has always had skill of attaching people to him.
4. These people are attached to the expedition.

*Synonym*: to fasten.

### invent, *v.*

1. To invent means to create or produce for the first time.
2. Non-Euclidean geometry was invented in the 19th century.
3. A. S. Popov invented radio in 1906.

*Derivatives*: invention, inventor.

4. The invention of ultrasensitive gauges makes it possible to determine if the gravitational waves predicted by the general theory of relativity actually exist.

*Synonyms*: to create; to discover.

### mount, *v*

1. To mount means to set on something that elevates; to go up; to attach or assemble for use.
2. The monument to Peter the First is mounted on a big rock.
3. The two mirrors are mounted on heavy blocks.
4. This device is so small and simple that can be mounted on an ordinary table.

*Synonym*: to ascend.

### persist, *v.*

1. To persist means to remain unchanged or fixed in a specified character, condition or position.
2. Still other kinds of strain persist for days or years, and some strains are very weak.

*Derivatives*: persistance, persistent.
*Synonym*: to continue.

**sensitive,** ***adj.***

1. Sensitive means capable of indicating minute differences; readily affected or changed by various agents.
2. A thermometer is sensitive to heat.
3. The Benioff gauge is so sensitive that it can detect a change in strain amplitude in the earth's crust as weak as one part in $10^9$.

*Derivative:* sensitivity.

## Exercises

### 1. Give the English for:

a) кора; землетрясение; край; напряжение; деформация; прикреплять; присоединять, придавать; изобретать; устанавливать, поднимать (ся); продолжать существовать; чувствительный;

b) земная кора; одна из форм этого напряжения — землетрясение; состояние напряжения; счетчик Гейгера-Мюллера; придавать значение; продолжать существовать несмотря ни на что.

### 2. Give the Russian for:

earth's crust; earthquake; light fringes; gauge; weak strain; to attach importance to smth; to attach to oneself; to invent; to mount; to persist for some time; sensitive; ultrasensitive.

### 3. Give derivatives of the following words:

fringe; to invent; to persist; sensitive.

### 4. Give synonyms of the following words:

to fasten; to create; to continue; to discover; to ascend.

### 5. Read the following words:

laser ['leisə]
gauge [geidʒ]
colleague ['kɔli:g]
cylinder ['silində]
seismology [saiz'mɔlədʒi]
seismograph ['saizməgra:f]
seismography [saiz'mɔ:grəfi]
oblique [ə'bli:k]
analogous [ə'næləgəs]
microseism ['maikrə,saizm]
interferometer [,intəfiə'rɔmitə]
to monitor ['mɔnitə]
monitoring [,mɔni'tɔriŋ]
continuous [kən'tinjəs]



continuity [,kɔnti'nju:iti]
quartz [kwɔ:ts]
circuit ['sə:kit]
barometer [bə'rɔmitə]
barometric [,bærə'metrik]
geophysical [,dʒiə'fizikəl]

## MEASURING EARTH STRAINS BY LASER

*Large interferometers operating with laser beams make it possible to detect tiny distortions of the earth's crust with unprecendented sensitivity. One of these laser strain meters is 1,020 meters long.*

by Victor Vali

The solid earth is in a continuous state of strain. The most obvious and powerful form of this strain is an earthquake, which consists of shocks representing abrupt changes in the strain state of the earth's crust and mantle. These shocks are composed of pressure waves and shear waves, and they are followed by other strains: Rayleigh waves (analogous to waves in water) and Love waves (long waves undulating at right angles to the direction of propagation). Still other kinds of strain persist for days and years, and some strains are so weak and slow as to be undetectable by seismographs. These include microseisms with strain amplitudes of only a few parts in $10^{10}$ and with wave periods of a few seconds, and tides in the solid earth with amplitudes of a few parts in $10^8$ and wave periods of 12 hours. The recording and analysis of these strain states reveal much about the earth's internal activity and structure.

Until recently the most accurate instrument for monitoring strains was the Benioff gauge, developed 30 years ago by the late Hugo Benioff of the California Institute of Technology. The Benioff gauge is so sensitive that it can detect a change in strain amplitude in the earth's crust as weak as one part in $10^9$. In the past few years, however, there has been much interest in strain gauges that are even more sensitive. This interest has been stimulated partly by the possibility that if a greater range of seismic frequences could be analyzed, information might be obtained that would permit the prediction of earthquakes. With ultrasensitive gauges it might also be possible to determine if the gravitational waves predicted by the general theory of relativity actually exist.

The invention of the laser has enabled workers at a number of institutions, including my colleagues and myself at the Boeing Scientific Research Laboratories and the University of Washington, to develop such instruments. Called geophysical laser strain meters, these instruments are basically large interferometers: devices for measuring changes in length by the constructive and destructive interference of light waves. In principle they should be able to measure strain amplitudes with an accuracy of a few parts in $10^{15}$. Some of these instruments already operate with an accuracy as high as one part in $10^{12}$ for brief periods.

This is clearly an advance on earlier earth-strain gauges as those of the Benioff type. The Benioff gauge consists of a long cylinder of fused quartz mounted so that the earth can move back and forth under it. One end of the cylinder is fixed on a bedrock and the other has a readout system that continually measures the distance between it and a post planted in bedrock. Such a readout device may consist of a circuit connecting a plate on the end of the quartz cylinder to a plate attached to the post. The two plates serve as a condenser in an electric oscillator, and as a horizontal strain increases or decreases the distance between them, the resonance frequency is recorded.

Such an instrument is vulnerable to variations in temperature, barometric pressure and humidity, all of which can change the length of the cylinder. It is also difficult to make a fused-quartz cylinder that is longer than 20 or 30 meters. This fact limits the accuracy of the gauge because the bedrock on which the instrument is mounted is nearly always fractured, a condition that allows the local effects to mask the regional or global strain state of the earth. If these strain conditions are to be averaged out so that more general strain states can be recorded, the gauge must be able to make measurements over greater distances.

About five years ago it was decided that these limitations might be overcome by adapting a laser interferometer to serve as a strain gauge. The advantages of such a gauge can be seen in a 1,020-meter instrument that R. C. Bostrom and I have developed, which is located in an abandoned railroad tunnel some 500 meters underground at Stevens Pass, Wash. This gauge is basically an extended interferometer of the Fabry-Perot type. In it a beam of red light from a helium-neon laser traverses the entire length of a 1,020-meter aluminium tube. Before the beam enters the tube it passes first through a partly reflecting mirror mounted at an oblique angle to it and then a second partly reflecting mirror at right angles to it. Half of the light passes through the oblique mirror, and a substantial amount of it is reflected back from the second mirror, strikes the other side of the oblique mirror and is directed into a detector mounted at right angles to the main beam. The rest of the light travels the length of the tube, strikes a third mirror at the other end and is reflected back to the second mirror. Some of it passes through the second mirror and is directed, along with the light originally reflected from the other side of that mirror, into the detector.

The two mirrors at the ends of the tube form a resonant cavity in which the light waves travelling down the tube can interfere with the light waves travelling back. At the detector the interference is visible as a pattern of parallel light and dark «fringes» with the light fringes representing the constructive interference of light waves and the dark fringes destructive interference. The two mirrors are mounted on granite blocks fixed in bedrock, and when an earth strain slightly changes the distance between them, the position of the fringes shifts.

*(to be continued)*



## Exercises

### I. Translate into Russian paying attention to the Gerund:

1. Such a beam can be projected over almost any terrestrial distance and reflected back to its place of origin without drastic reducing in intensity or coherence.
2. Our delegation arrived in the Hague for the purpose of discussing this urgent problem.
3. The fact that the instrument is located deep underground insulates it from the random thermal strains set up by changing of the surface temperature.
4. Such an accuracy permits measuring earth strain up to a few parts in $10^{15}$ over 1,020 meters.
5. His skill of carrying on most complicated experiments was known to everybody.
6. This work is still far from being finished.
7. You must continue solving this task.
8. He mentioned having showed these slides at the conference.
9. Excuse my interrupting you.
10. Keep taking the measurements.

### II. Translate into English using the active vocabulary of the lesson:

1. Внутри Земли всегда существуют напряжения, которые проявляются в разных формах.
2. Главной причиной землетрясений является деформация.
3. Землетрясение состоит из ряда толчков, представляющих собой резкое изменение состояния напряжений земной коры и мантии.
4. Этот прибор обладает достаточной чувствительностью, чтобы зарегистрировать малые толчки.
5. В свое время изобретение этого прибора открыло большие возможности для исследователей.
6. Лазерный прибор устанавливают на особый фундамент, чтобы избежать влияния вибрации.
7. Когда расстояние между зеркалами изменяется, смещается расположение интерференционных полос.
8. Если к плоской поверхности какого-нибудь металла приложить другой металл, то между ними возникнет разность потенциалов.
9. Измерительные приборы подобного типа могут выдерживать различные нагрузки.
10. Эти сверхчувствительные приборы были получены с завода совсем недавно.

## III. Catch the meaning of the text and retell it:

The Stevens Pass instrument and some other laser gauges detect changes in the strain state of the earth by registering the movement of fringes. To follow the movement of a fringe the Stevens Pass strain meter has a mechanism that locks on to it the way a space probe's navigation sensor locks on to a star. This mechanism consists of a galvanometer fitted with a mirror. The mirror reflects light from the fringe into photomultiplier tubes that in turn control the current flowing through the galvanometer. When the tubes detect a decrease in the light level, indicating that the fringe is no longer centered on the mirror, the current flowing through the galvanometer is increased and turns the mirror so that it centers the fringe again. A piezoelectric crystal or the driving mechanism from a high-fidelity loudspeaker can also be used as a tracking device.

The galvanometer can trace the movement of a fringe to within 1 percent of the distance between fringes. Since the distance between two consecutive fringes represents half the wavelength of the light used in the interferometer, the distance between fringes in the laser strain meter is equivalent to about 30 angstroms — roughly 15 times the diameter of an atom. The noise level in a laser is so low that measurements down to $10^5$ part of a fringe separation are practical. Such an accuracy would permit measurements of earth strain up to a few parts in $10^{15}$ over 1,020 meters. Normally the 1,020-meter instrument detects microseims with an amplitude of one part in $10^{10}$, and for short periods of time its sensitivity is equivalent to one part in $10^{12}$.

## IV. Give the situations from the text in which the following words are used:

to be composed of; to be undetectable; to reveal; strain gauges; fused quartz; actually; circuit; fractured; main beam; constructive; slightly.

## V. Develop further the following statements:

1. Still other kinds of strains ...
2. This interest has been stimulated partly by ...
3. Called geophysical laser strain meters ...
4. The Benioff gauge consists of ...
5. It is also difficult to make a fused-quartz cylinder ...
6. This fact limits the accuracy of the gauge because ...
7. Half of the light passes through the oblique mirror ...
8. The rest of the light travels the length of the tube ...
9. The two mirrors at the end ...
10. At the detector the interference is visible ... .



## VI. Translate the following Russian questions into English and answer them:

1. Какие явления подтверждают существование деформаций в земной коре?
2. Все ли деформации можно обнаружить сейсмографами?
3. Какова чувствительность прибора Бениоффа?
4. В каких целях могут быть использованы сверхчувствительные измерительные приборы?
5. Что такое лазерный выпрямитель напряжения?
6. Как устроен этот прибор?
7. Что может влиять на точность показаний измерителя напряжения?
8. Что вы можете сказать об устройстве прибора, установленного в Стивенс Пас?
9. Какую роль в этом приборе играет угол установки зеркал?
10. Какие другие приборы подобного типа вы знаете?

## VII. Render in English:

Основным преимуществом лазерного измерительного прибора является его длина. Тогда как длина прибора Бениоффа составляла 20 метров, длина лазерного измерительного прибора практически не имеет ограничений, и, следовательно, его чувствительность может быть очень высокой. Лазерный луч расходится очень незначительно даже в полосе отражения. Световые волны в пучке также могут сохранять когерентность на значительных расстояниях, т. е. волны остаются в фазе. Такой луч может быть послан почти на любое расстояние и отражен назад в исходную точку без значительного уменьшения интенсивности или когерентности. Таким образом, можно легко получить интерференционную картину даже для больших расстояний.

Аналогично прибору Бениоффа на лазерный измеритель воздействуют атмосферные условия. Изменения в давлении, температуре, составе воздуха создают помехи, которые могут изменить лазерный пучок; вот почему трубка нового прибора разрежена. Фактически весь путь света прибора заключен внутри трубки. Только один миллиметр воздуха отделяет главные зеркала от концов трубки, которые заканчиваются оптическими плоскостями, поставленными для уменьшения отражения. Тот факт, что прибор находится глубоко под землей, объясняется необходимостью изолировать его от влияний внешней среды.

## VIII. Answer the following questions:

1. What is an earthquake?
2. What other kinds of strain do you know?
3. How can we reveal the earth's internal activity and structure?

4. For what purposes should a greater range of seismic frequences be analysed?

5. How can the gravitational waves (if they actually exist) be determined?

6. What is geophysical laser strain meter?

7. What are the disadvantages of this device?

8. How does the laser strain meter work?

9. What role do the set of mirrors and resonant cavity of this device play?

10. What is the contribution of the Soviet scientists to seismology?

**IX. Speak on the following topics:**

1. Strain state of the earth.
2. The Benioff gauge.
3. Laser interferometer as strain gauge.
4. Advantages and disadvantages of the laser strain meter.

# LESSON TWENTY-SEVEN

## Active Vocabulary

### fracture, *n.*

1. Fracture is the act or process of breaking or state of being broken; the breaking of something that is hard.

2. The Caucasus is rich of fractures that are the result of ancient earthquakes and other forms of the earth strain.

3. The material of the earth's mantle must shake at a certain rate before earthquake-producing fracture takes place.

*Derivatives*: fraction, fractional.

### value, *n.*

1. Value is worth; that quality which makes a thing desirable or useful; meaning; significance; effect.

2. This book will be of great (little, some, no) value to you in your studies.

3. The word is used with all its poetic value.

*Derivative*: valuable.

4. Valuable is of great value, worth or use.

5. He is fond of collecting valuable books.

6. Continuous recording of strain in areas of high earthquake probability might be very valuable.

### value, *v.*

1. To value is to estimate the worth or price of; also to regard highly; to consider to be of great worth.

2. From his parents he learned to value education.

*Synonyms*: to appreciate; to estimate.

### constitute, *v.*

1. To constitute is to establish; to found; to give lawful form to something; to form.

2. In the past people did not know that invisible smallest particles constitute any matterial piece.

3. All these questions constitute one important problem of what is going on in our Galaxy.

*Derivatives*: constituent, constitution.

*Synonyms*: to form; to compose.

**contract,** *v.*

1. To contract means to concentrate, to become less in size.

2. These waves produce expansions and contractions; therefore a planetary body would oscillate slightly in shape.

3. The theory represented a radically different point of view, and it had the merit of explaining such processes as expansion and contraction.

*Synonyms*: to condense; to compress.

**convince,** *v.*

1. To convince is to overcome by argument; to bring by argument to belief.

2. I can't convince my friend of his mistake though it is obvious.

3. That is a very convincing reason.

*Derivative*: convincingly.

**explore,** *v.*

1. To explore is to examine minutely; to make or conduct a systematic search.

2. Soviet scientists have been exploring Siberia and the Far East since 1923.

3. Columbus discovered America but did not explore the new continent.

*Derivative*: exploration.

*Synonym*: to examine.

**relate,** *v.*

1. To relate is to show or establish logical or causal connection between something.

2. The noise spectra on the moon and on the earth are not related.

*Derivatives*: relationship, relative, relativity.

3. A related and relatively unexpensive engineering application of the laser strain meter would be a continuous monitoring.

*Synonym*: to join.



**strike,** *v.*

1. To strike is to deliver a blow; to collide.
2. It is impossible to strike a woman.
3. Strike while the iron is hot.

*Synonym*: to hit.

**probable,** *adj.*

1. Probable is likely to happen or prove true; likely, as a probable result.

2. It is possible but not probable that he will have passed all his exams by the end of May.

*Derivatives*: probability, probably.

3. Probability is the state or quality of being probable; chance.

4. A century ago people could not predict the probability of the earthquakes.

*Synonym*: possible.

**weak,** *adj.*

1. Weak is lacking in strength; not able to sustain much weight, pressure, or strain; not able to resist external force.

2. The temperature change was too weak to be detectable.

3. She is very weak after her illness.

4. In the lower part of the wave band disturbances are always weak.

*Derivatives*: weaken, weakly.

## Exercises

### 1. Give the English for:

a) трещина, разрыв; ценность; ценный; ценить; составлять; сжиматься; убеждать; исследовать; относиться, иметь отношение; ударять; возможный; слабый;

b) быть убежденным в чем-либо; составлять одно целое; ценное предложение; куй железо, пока горячо; незначительные помехи.

### 2. Give the Russian for:

to be fractured; to be of some value; to be valuable; to value; to constitute a problem; process of contraction; to be convinced of something; relative significance of the event; strike the iron while it is hot; to be weak.

**3. Give derivatives of the following words:**

fracture; value; to constitute; to convince; to explore; to relate; probable; weak.

**4. Give synonyms of the following words:**

fracture; value; to constitute; to convince; to explore; to relate; probable; weak.

**5. Read the following words:**

| | |
|---|---|
| diameter [dai'æmitə] | earthquake ['ə:θkweik] |
| quiet ['kwaiət] | adequate ['ædikwit] |
| antenna [æn'tenə] | valuable ['væljuəbl] |
| horizon [hə'raizn] | appropriate [ə'proupriit] |
| to occur [ə'kə:] | to contract [kən'trækt] |
| causal ['kɔ:zəl] | contraction [kən'trækʃən] |
| to cause [kɔ:z] | to approximate [ə'prɔksimeit] |
| period ['piəriəd] | approximation [ə,prɔksi'meiʃən] |
| basis ['beisis] | approximate, *adj.* [ə'prɔksimit] |
| meteor ['mi:tjə] | to reveal [ri'vi:l] |
| area ['εəriə] | interstellar [,intə'stelə] |

## MEASURING EARTH STRAINS BY LASER

by Victor Vali
(continued)

Laser strain meters along with Benioff gauges and other instruments, may play a role in revealing the causes of earthquakes such as the one that struck Alaska in 1964. The scientific and engineering data available today are not adequate to prevent casualties. Where large earthquakes will occur can be predicted, but it is impossible to estimate their magnitude accurately or to tell when they will take place. It is known, however, that the material of the earth's mantle, where earthquakes occur, is not brittle but must creep at a certain rate before an earthquake-producing fracture or slippage takes place. Continuous recording of strain in areas of high earthquake probability might therefore be very valuable.

A related and relatively inexpensive engineering application of the laser strain meter would be a continuous monitoring of the strain state of man-made structures such as dams and large buildings. Some of the things one would want to know are the effects of earthquakes on these structures, the change of strain as caused by the changes in the ground, and the changes in the structure itself. Mine collapses might conceivably be predicted by placing strain meters in appropriate locations where the creep rate could be measured.



A laser strain meter might also be set up that would use the entire earth or the moon as a receiving antenna for detecting gravitational radiation. According to the general theory of relativity, a rotating or collapsing mass such as a double star should emit gravitational waves. The forces of these waves that would interact with a detector are transverse to the direction of propagation, as electromagnetic radiation is. These waves produce expansions and contractions; therefore a planetary body «feeling» them would oscillate slightly in shape. Such changes in shape give rise to weak strains that could be detected by an ultrasensitive strain gauge.

In 1961 Robert L. Forward of the Hughes Research Laboratories and his colleagues reported their attempt to detect interstellar gravitational radiation with the earth as the receiving antenna. The data obtained with a Benioff gauge at the Lake Isabella site in California during a seismically quiet period. In spite of these favorable conditions the power spectrum of the gauge did not show any peaks at the normal vibrational modes of the earth. Such peaks would be expected if the form of the planet were oscillating. Forward was therefore only able to set an approximate upper limit for the effects of gravitational radiation. The increased length and sensitivity of geophysical laser strain meters make it desirable to continue the search for gravitational radiation by the use of such instruments.

Gravitational radiation might also be recognized by its peculiar polarization characteristics. When light is linearly polarized, that is, when its waves undulate in a single plane, a filter that can detect the polarization will encounter the same polarization state with each rotation of 180°. Einstein's equations predict that gravitational radiation would be polarized in such a way that a detector would encounter the same state with each rotation of 90 degrees. Therefore if the earth were the receiving antenna, it could be expected to detect the same polarization state once every six hours. To put it another way, if the gravitational radiation came from a fixed direction in space, the amplitude of the radiation and accordingly the strain it would create would be modulated in six-hour periods.

A simultaneous observation of this radiation from the earth and the moon would constitute convincing proof of its existence; since there would be no relation between the noise spectra on the moon and on the earth, a common strain (slightly shifted in phase) could not be dismissed as the result of some unidentified internal cause.

Because the moon has no atmosphere the lunar measurements would not require any long evacuated pipes. One of the best places to put a laser strain meter would be across the crater Copernicus. It is about 100 kilometers in diameter and its rims are high enough to be above the horizon. Furthermore, it is one of the areas that may be explored in future lunar landings.

The moon appears to be a particularly good gravitational antenna. The tides in the solid moon have a period of 27 days, in contrast with the terrestrial period of 12 hours. On the basis of the general similarity in constitution between the moon and the earth it has been estimated that the lunar tides have an amplitude of two meters or more. There is increasing evidence, however, that this value may be far too high.

The discovery of mass concentrations («mascons») under some lunar maria indicates, according to Zdenek Kopal of the University of Manchester, that the rigidity of the moon is at least 1,000 times higher than has been thought. This means that the amplitude of the lunar tides is less than a centimeter. On this basis the change in the diameter of the crater Copernicus during one lunar-tide cycle is less than .5 millimeter, corresponding to about 2,000 fringes in the interferometer. Kopal has estimated that a detectable moonquake caused by the impact of a meteorite will take place on the average less than once in a century. In any case relatively small meteors are effective in generating seismic waves on the moon because their energy is spent in the regolith, the moon's granular surface layer. Preliminary results from the «Apollo II» seismograph confirm that the moon is an extremely quiet body.

The period of the lowest normal mode of lunar oscillation is about 15 minutes. This is some 3,000 times shorter than the period of the lunar tides, so that there should be no difficulty in discriminating between such oscillations and lunar tides even when the amplitude ratio is $10^5$ or more. The observation of lunar oscillations would be of interest in itself, whether the cause is the impact of meteorites, moonquakes or gravitational radiation. The exact frequency of the oscillations and the way they die out would reveal much about the internal constitution of the moon.

*Scientific American*
*December 1969.*

## Exercises

### I. Translate into Russian paying attention to the Gerund:

1. There was still little hope of our being in time.
2. Is there any possibility of his receiving us today?
3. There should be no difficulty in discriminating between such oscillations and lunar tides even when the amplitude ratio is $10^5$.
4. The capture efficiency for positrons can also be enhanced by surrounding a portion of the accelerator tube with a coaxial solenoid.
5. They know about Novosibirsk scientists' having obtained the same figures.



6. In the event of the expedition being sent to the Caucasus the range of work will be increased.
7. They insisted on this suggestion being confirmed as soon as possible.
8. The electrostatic precipitators on smoke stacks are good for trapping particles with radii larger than about a micron.
9. Calculating a pulsar's magnetic-field strength at its surface depends on the theoretical model.
10. The laser having been invented enabled the scientists to broaden their investigations.

### II. Translate into English using the active vocabulary of the lesson:

1. Измерение напряжений земной поверхности с помощью лазеров может сыграть важную роль в «разоблачении» землетрясений, часто происходящих в разных районах Земли.
2. После землетрясений в земной коре появляются большие и малые трещины.
3. Там, где вероятность землетрясений особенно велика, непрерывная запись напряжений была бы особенно ценной.
4. Относительно недорогое применение лазеров для измерения напряжений делает их полезными в промышленном отношении.
5. Общая теория относительности предсказывает существование гравитационных волн.
6. Даже очень слабые напряжения могут быть обнаружены современными приборами, обладающими большой чувствительностью.
7. Убедительное доказательство существования гравитационных волн еще не найдено.
8. Исследования лунной поверхности могут стать составной частью многих открытий.
9. Расширение и сжатие, но очень малое, могут быть созданы гравитационными волнами.

### III. Catch the meaning of the text and retell it:

Several other laser interferometers representing innovations in this field are now recording earth strains or are being put into operation. One of them is the forerunner of the Stevens Pass instrument: the first geophysical strain meter, which Krogstad, R. W. Moss and others proposed and built some years ago. In order to test the accuracy of this instrument, it was originally installed parallel to the California Institute of Technology's Benioff gauge at the Big Dalton Canyon site. The instrument has since been modified and moved to an abandoned mine on the Kern River fault in California, a location that minimizes thermal strains. Now operated by Joleroy Gauger and D. V. Slade of the Douglas Advanced Research Laboratory it monitors the shear motion across the fault. It consists of one Fabry-Perot cavity that is 10 meters long and another that is 25 meters long.

The observed amplitude of earth tides detected by this instrument is about 10 times larger than normal, indicating a magnification of strain across a fault. Another interesting phenomenon observed at this site is the fine structure of the fault motion. A typical recording shows a cluster of back-and-forth motions that usually continue for a few minutes. The earth normally returns to its original strain after the event ends. Sometimes, however, a new strain state is established. These events could be caused by small strains some distance from the recording site. When such a strain is relieved, the original strain state at the instrument is reestablished.

### IV. Give the situations from the text in which the following words are used:

cause; slippage; area; inexpensive; expansion; to give rise; favorable; to be expected; proof; noise spectra; furthermore.

### V. Correct the false statements:

1. Neither laser strain meter nor Benioff gauges play any role in revealing earthquakes.
2. It is possible both to estimate the magnitude of earthquakes accurately and tell when they will take place.
3. We are not interested in the change of strain as caused by the changes in the ground.
4. A planetary body does not «feel» gravitational waves.
5. Gravitational radiaton can't be recognized by its polarization characteristics.
6. If the gravitational radiation came from a fixed direction in space, the amplitude of the radiation would not be modulated.
7. The lunar measurements would require long evacuated pipes.
8. The amplitude of the lunar tides is much more than 1 cm.

### VI. Translate the following Russian questions into English and answer them:

1. Какие землетрясения, нанесшие наиболее сильные удары по земной коре, вы знаете?
2. Все ли трещины в земной коре являются следствием землетрясений?
3. В чем ценность предсказания землетрясений, если их пока нельзя предотвратить?
4. В каких районах СССР вероятность землетрясений наиболее велика?
5. Будут ли двойные звезды испускать гравитационные волны согласно общей теории относительности?



6. Могут ли гравитационные волны вызвать расширение или сжатие поверхности планеты?
7. Что нужно сделать для того, чтобы прибор смог определять очень слабые напряжения?
8. Что может стать составной частью убедительного доказательства существования гравитационных волн?

### VII. Render in English:

Нестабильность длины лазерного излучения создает серьезные затруднения в работе. Изменение длины волны может вызвать неточность результатов, потому что получающиеся изменения ширины интерференционной полосы или ударной частоты не отличаются от изменений, вызванных напряжением. С помощью специально построенных лазеров, помещенных в термо- и акустически изолированную оболочку, смещение длины волны может быть уменьшено до $10^{-10}$ в час. Это, однако, недостаточно для сверхчувствительных измерений натяжения, например, таких, какие должны быть сделаны для обнаружения гравитационного излучения.

Для стабилизации частоты используются две различные системы. Одна из них монтируется на 30-сантиметровом стержне плавленного кварца и помещается в термостат. Этот стержень образует резонатор интерферометра Фабри-Перо, и часть света, излученного лазером, отклоняется в этот резонатор. Если длина волны лазерного излучения изменяется, выходной сигнал системы также изменяется и с помощью обратной связи подается назад на лазер так, что первоначальная длина волны может быть восстановлена. Качество системы определяется постоянной длиной стержня, на котором сделан стабилизирующий резонатор.

### VIII. Answer the following questions:

1. What do you know about the material of the earth's mantle?
2. Why is continuous strain recording in areas of high earthquake probability so valuable?
3. What can be the earthquake effect on man-made structures?
4. Are there any possibilities to predict mine collapses?
5. What is gravitational radiation?
6. Why should a rotating or oscillating mass emit gravitational waves?
7. What do gravitational waves produce?
8. What does Einstein's equation predict?
9. Why is the crater Copernicus one of the best places for a laser strain meter installation?
10. Why is the moon considered to be an extremely quiet body?

**IX. Review the article «Measuring Earth Strains by Laser».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. Application of laser strain meters and Benioff gauges in human life and engineering.
2. What do you know about the gravitational waves?
3. Future lunar measurements by means of laser strain meters.
4. The moon and what we know about it.
5. «The earthquakes of the century».

## LESSON TWENTY-EIGHT

### Active Vocabulary

**design, *n*.**

1. Design is a drawing, sketch, plan or outline from which a thing may be made; something planned in the mind; a purpose or intention.

2. I was unable to carry out my design (i. e. to do what I had planned).

*Synonyms:* scheme; plan.

**link, *n*.**

1. Link is a person or thing that connects or unites other persons or things or that fills an empty space.

2. To link is to join; connect, as to link things together.

3. The fundamental constants are the quantitative links in the web of theory that binds physics together.

**arise, *v*.**

1. To arise is to appear; to come into notice; to begin; to result (from).

2. If you come to a foreign country without knowing its language, a number of problems arise.

**concern, *v*.**

1. To concern is to have to do with; have connection with or relation to; be of importance to; affect the interest of.

2. That does not concern you (i. e. it is not your business; you have or should have no interest in it).

3. Experiments designed to redetermine the numerical values of these quantities to ever greater levels of accuracy can yield information concerning the overall correctness of the basic theories of physics.

**deal, *v.***

1. To deal is to have relations with; to do business with.
2. That man is easy (hard, difficult, impossible, etc.) to deal with (i. e. it is easy to do things with him, to make plans, etc.).
3. Most experiments deal with a complex system in which a variety of interrelated and often poorly understood phenomena are involved.

**lack, *v.***

1. To lack is to be without, as to lack (=be unable to find) words with which to express one's thanks.
*Synonym:* to want.

**lack, *n.***

1. Lack is want, shortage or need.
2. The plants died for lack of water.

**remove, *v.***

1. To remove is to move; to shift or take from one place to another; to depart; to go from one place to another.
2. The student was removed from one group to another one.
*Derivative:* removal.
3. Measurements of these constants to ever greater levels of accuracy are important, therefore, not just because they add another decimal point but because the added decimal point may lead to the discovery of a previously unknown inconsistency, or the removal of a known inconsistency, in our physical description of nature.

**pertinent, *adj.***

1. Pertinent is to the point; referring directly (to the matter in hand), as a pertinent remark (reply, etc.).
2. The pertinent theory usually provides only an approximation based on a simplified conceptual model of the system.
*Derivatives*: pertinently, pertinence, pertinency.

**relevant, *adj.***

1. Relevant is relating to the matter in hand; to the purpose, as relevant details.



2. The value of $e$ is then calculated on the basis of many such measurements on different drops (combined with a knowledge of other relevant quantities such as the local value of the acceleration due to gravity, distance between the plates, the voltage difference between the plates, the pressure and viscosity of the air and the density of the oil).
*Derivatives*: relevance, relevancy.

**vast, *adj.***

1. Vast is great; huge; extensive.
2. If one looks at the entire structure of physics, one sees a vast array of apparently divergent fields: solid-state physics, atomic physics, nuclear physics, elementary-particle physics and so on.
*Synonyms:* great; huge; extensive.
*Antonyms*: small; minute; tiny.

## Exercises

### 1. Give the English for:

a) замысел, план; намерение, цель; проект, чертеж; связь, соединение, связующее звено; возникать, появляться; дело, отношение, касательство; иметь дело, относиться; недостаток, недостаточность; перемещать; уместный, подходящий, имеющий отношение к делу; огромный, обширный;

b) информация, касающаяся общей правильности основных физических теорий; иметь дело со сложными системами; недостаток точности; устранение известного противоречия; подходящая теория.

### 2. Give the Russian for:

experiments designed to redetermine the numerical values of these quantities; information concerning the overall correctness of the basic theories of physics; lack of precision; to deal with a complex system; pertinent theory; vast array of apparently divergent fields; removal of a known inconsistency; relevant quantities.

### 3. Give derivatives of the following words:

concern; to deal; to remove; pertinent; relevant.

### 4. Give synonyms of the following words:

to intend; to join; to want; suitable; huge.

## 5. Give antonyms of the following words:

centre; to descend; to disconnect; to expand; strong; tiny; small.

## 6. Read the following words:

design [di'zain]
designer [di'zainə]
to concern [kən'sə:n]
to remove [ri'mu:v]
removal [ri'mu:vəl]
pertinent ['pə:tinənt]
pertinence ['pə:tinəns]
relevant ['relivənt]
irrelevant [i'relivənt]
vast [va:st]

fundamental [,fʌndə'mentl]
numerical [nju(:)'merikəl]
conceptual [kən'septjuəl]
vacuum ['vækjuəm]
quantity [,kwɔntiti]
quantitative ['kwɔntitətiv]
universe [,ju:ni'və:s]
divergent [dai'və:dʒənt]
horizontal [,hɔri'zɔntl]
vertical ['və:tikəl]

# THE FUNDAMENTAL PHYSICAL CONSTANTS

*Experiments designed to redetermine the numerical values of these quantities to ever greater levels of accuracy can yield information concerning the overall correctness of the basic theories of physics.*

by Barry N. Taylor, Donald N. Langenberg and William H. Parker

Contrary to popular opinion, physics is usually not a very exact science. A physicist is often quite pleased with himself if he measures some property of matter to an accuracy of within a few percent and finds that his measurement agrees with a theoretical prediction, again to within a few percent. In some cases finding agreement to within an order of magnitude (a factor of 10) is a considerable achievement. This comparative lack of precision arises from two main sources. First, most experiments deal with a complex system in which a variety of interrelated and often poorly understood phenomena are involved. Second, the pertinent theory usually provides only an approximation based on a simplified conceptual model of the system.

There are, on the other hand, a few special quantities in physics that can — indeed must — be known to a much greater accuracy. These are the fundamental physical constants. They include such quantities as the velocity of light in a vacuum ($c$), Planck's constant ($h$), the charge of the electron ($e$), the mass of the electron ($m$) and the fine-structure constant ($a$).





### The Importance of Accuracy

Why is it important to know the numerical values of the fundamental constants with great accuracy? First of all, the quantitative predictions of the basic theories of physics depend on the numerical values of the constants that appear in the theories. An accurate knowledge of these values is therefore essential if one hopes to achieve an accurate quantitative description of the physical universe. More important, the careful study of the numerical values of these constants, as determined from experiments in the different fields of physics, can in turn test the overall consistency and correctness of the basic theories of physics themselves. If one looks at the entire structure of physics, one sees a vast array of apparently divergent fields: solid-state physics, atomic physics, nuclear physics, elementary-particle physics and so on. The unifying force that binds all these fields together is theory. And the fundamental constants are the quantitative links in the web of theory that binds physics together. Measurements of these constants to ever greater levels of accuracy are important, therefore, not just because they add another decimal point but because the added decimal point may lead to the discovery of a previously unknown inconsistency, or the removal of a known inconsistency, in our physical description of nature.

### Lessons from the Past

An easily understood example of how the accurate redetermination of a fundamental constant with improved methods can lead to an improved understanding of a particular physical phenomenon can be found by looking back at attempts to measure the fundamental unit of electric charge. Robert A. Millikan conducted his famous oil-drop experiments to determine $e$ from about 1907 to 1917. In this experimental method the motion of small, weakly charged oil drops moving in air between two horizontal and parallel metal plates is followed as a function of time. First the time it takes a particular drop to fall a measured distance under the influence of gravity alone is determined. Next a voltage difference is established between the two plates in such a way that the resulting force on the charged drop causes it to rise (that is, to move against gravity), and the time it takes the drop to rise a measured distance is determined. The value of $e$ is then calculated on the basis of many such measurements on different drops (combined with a knowledge of other relevant quantities such as the local value of the acceleration due to gravity, distance between the plates, the voltage difference between the plates, the pressure and viscosity of the air and the density of the oil). Millican's final value, reported in 1917, was $4.774 \pm .002$ (in a certain set of units with which we shall not concern ourselves here).

That this value was significantly in error became clear in the 1930's with the development of a new method for obtaining $e$. The technique consisted of separately measuring two other physical quantities: the Avogadro number (N) and the faraday (F). The Avogadro number is the number of atoms or molecules contained in a mole, which is defined as a mass in grams equal to the atomic or molecular weight of a substance; the faraday is the amount of charge that must pass through a solution in order to electrolytically deposit a mole of an element contained in the solution. These two quantities are related by the simple equation $F=Ne$. It therefore follows that $e$ equals $F/N$, so that $e$ can readily be obtained if $F$ and $N$ are known. The Avogadro number was determined by carefully measuring the density, atomic weight and crystal-lattice spacing (the distance between the planes of atoms) of a particular substance with X-ray techniques. The faraday was determined by measuring the mass of material electrolytically deposited on an electrode when a known current flowing for a known time was allowed to pass through a solution containing the material.

The value of $e$ deduced in this way was $4.8021 \pm .0009$, significantly different from the Millikan value. The major source of this disturbing discrepancy was later traced to the use by Millikan of an incorrect value for the viscosity of air. Millikan had taken a value that was almost entirely based on a measurement by one of his students, but it was subsequently shown that the student had made a rather subtle mistake. In order to measure the torsion constant of a certain wire used in the viscosity-determination experiment he had used a mass that was entirely different from the mass the wire supported during the experiment, and it was later discovered that the torsion constant of a wire varies both with the mass supported and with the geometry of the mass. When Millikan's data were reevaluated with a correctly determined value for the viscosity of air, the value of $e$ obtained agreed with the indirect value calculated from the Avogadro number and the faraday.

*Scientific American*
*October 1970.*

## Exercises

### I. Translate into Russian paying attention to the functions of the Participle:

1. The pertinent theory usually provides only an approximation based on a simplified conceptual model of the system.
2. More important, the careful study of the numerical values of these constants, as determined from experiments in the different fields of physics, can in turn test the overall consistency and correctness of the basic theories of physics themselves.
3. The unifying force that binds all these fields together is theory.
4. An easily understood example of how the accurate redetermination of a fundamental constant with improved methods can lead to an improved understanding of a particular physical phenomenon can be found by looking back at attempts to measure the fundamental unit of electric charge.
5. When Millikan's data were reevaluated with a correctly determined value for the viscosity of air, the value of $e$ obtained agreed with the indirect value calculated from the Avogadro number and the faraday.
6. The detailed answer here naturally depends on the properties being compared, but an overall impression is that the differences are not great.
7. The hologram appears to be a uniform gray sheet, and it reveals none of the characteristics or features of the scene recorded (as in a photographic negative) until it is properly illuminated.
8. The remainder of the reflecting point's zone plate, having been blocked by the screen, is not recorded on the photographic plate.
9. Having convinced ourselves that the existence of faster-than-light particles does not imply any contradiction of relativity, we must nevertheless leave the determination of whether such objects really happen in nature to the experimental physicist.

### II. Translate into English using the active vocabulary of the lesson:

1. Эксперименты, предназначенные для повторного определения численных значений этих величин с еще более высокой степенью точности, могут дать информацию об общей правильности основных физических теорий.
2. Эта относительно недостаточная точность возникает по двум основным причинам.
3. В большинстве экспериментов используются сложные системы, которые включают в себя множество взаимосвязанных и зачастую малопонятных явлений.
4. Относящаяся к данному вопросу теория дает только приближение, опирающееся на упрощенную для понимания модель системы.
5. Если посмотреть на строение физики в целом, можно увидеть огромное множество кажущихся разными разделов: физика твердого тела, атомная физика и т. д.
6. Переопределение физических констант поможет нам устранить известную непоследовательность в нашем физическом описании природы.

7. Величина заряда электрона вычисляется на основе многих таких экспериментов в сочетании со знанием других относящихся к данному вопросу величин.

### III. Translate at sight:

The charge and mass of the electron are examples of constants that, in addition to characterizing a particular elementary particle, are the fundamental units whose multiples are used to characterize all the other elementary particles that constitute matter. The charge of an alpha particle, say, is twice the fundamental unit of charge, whereas the mass of the neutral pi meson is 264.1 times the fundamental unit of mass of the electron.

The fine-structure constant is an example of a fundamental constant that can be expressed as a combination of other constants. Because such combinations always appear in theoretical equations in exactly the same way, they are really fundamental constants in their own right. The fine-structure constant is the basic constant of quantum electrodynamics, the quantum theory that describes the interaction of elementary particles with electromagnetic fields (the fine-structure constant is a measure of the strength of these interactions). There are, of course, many other examples of fundamental constants of such type, and you know them very well.

### IV. Give the situations from the text in which the following words are used:

link; to design; to arise; to concern; to deal (with); to lack; to remove; pertinent; relevant; vast.

### V. Give questions to which the following statements might be the answer:

1. The pertinent theory usually provides only an approximation based on a simplified conceptual model of the system.
2. The quantitative predictions of the basic theories of physics depend on the numerical values of the constants that appear in the theories.
3. The unifying force that binds all these fields together is theory.
4. The fundamental constants are the quantitative links in the web of theory that binds physics together.
5. The technique consisted of separately measuring two other physical quantities.
6. That this value was significantly in error became clear in the 1930's with the development of a new method for obtaining *e*.



### VI. Translate the following Russian questions into English and answer them:

1. Что может дать физикам постановка и планирование экспериментов, переопределяющих численное значение фундаментальных физических констант?
2. Отражает ли теория связь между различными разделами физики?
3. Из-за каких основных причин возникает недостаточная точность в обработке результатов эксперимента?
4. Что такое фундаментальные физические константы?
5. Почему важно знать численные значения фундаментальных констант с большой точностью?
6. Каким образом уточнение фундаментальной константы усовершенствованными методами может привести к более полному пониманию определенного физического явления?
7. Каким образом было определено число Фарадея?

### VII. Render in English:

Физические константы — постоянные величины, являющиеся характеристиками микрообъектов или входящие в качестве коэффициентов в математические выражения фундаментальных физических законов. Постоянство физических констант установлено и подтверждается современными наиболее совершенными и точными методами измерений. К физическим константам относятся массы, заряды и другие свойства элементарных частиц, постоянная Планка, гравитационная постоянная, скорость света в пустоте и т. д. Численные значения физических констант, как правило, зависят от выбора единиц измерений. В свою очередь, если приравнять единице и лишить размерности некоторые физические константы, то можно построить так называемые *естественные системы единиц*. В число физических констант, наряду с независимыми, включаются и такие, которые могут быть представлены как комбинация нескольких независимых физических констант. Так, например, константы в законе смещения Вина и законе излучения Стефана-Больцмана могут быть выражены через постоянную Планка и постоянную Больцмана.

Точное определение значений физических констант — весьма важная задача, так как этой точностью определяется часто точность физического эксперимента, от чего может зависеть, в свою очередь, решение вопроса о справедливости той или иной теории. В связи с этим в ряде стран ведется систематическая работа по уточнению всех важнейших физических констант.

### VIII. Answer the following questions:

1. Why is physics not a very precise science?
2. What is the initial idea of the fine-structure constant?

3. What methods of determining the velocity of light do you know?

4. What was the mistake in Millikan's experiment?

5. How was the mistake found?

6. Are there a limited number of fundamental constants in nature?

7. Why is it important to know the numerical values of the fundamental constants with great accuracy?

**IX. Review the article «The Fundamental Physical Constants».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. The constant of gravitation interaction. Its sense, importance and determination.

2. The determination of the length constant of a crystal.

# LESSON TWENTY-NINE

## Active Vocabulary

### instant, *n.*

1. Instant is an exact or precise moment of time; a very short space of time.

2. Come here this instant (=at once).

3. I shall be back in an instant.

4. Some physicists point out that the quantities involved in equations of motion, namely dynamical variables referring to one instant of time, are not connected very closely with experimental results.

*Derivative:* instantly.

*Synonym:* moment.

### set, *n.*

1. Set is a number of things of the same kind, considered as a group.

2. One must introduce a set of quantities $A$, of any mathematical nature, to describe the physical state at a certain time.

### collect, *v.*

1. To collect is to bring or gather together; to come together.

2. The probability amplitudes, collected together, form the S-matrix.

*Derivatives:* collection, collector.

*Synonym:* to assemble.

### discard, *v.*

1. To discard is to throw a thing away as useless or because it is no longer wanted; to give up (a belief, habit, etc.); to have nothing to do with (a person who used to be a friend).

2. The equations of motion that are so successful for most of physics cannot be simply discarded for one branch of physics.
*Synonym:* to dismiss.

**express,** *v.*

1. To express is to show or to make known a meaning, idea or feeling (by words, looks or actions).
2. He is able to express himself in English (=make himself understood).
3. Some physicists say that a theory should be expressed in terms of quantities directly connected with observation.
*Derivative:* expression.
*Synonym:* to signify.

**hold,** *v.*

1. To hold is to have or exercise power or control over; to control or restrain; to keep from action; to keep the same; to last; to continue.
2. How long will this fine weather hold?
3. The determinism implied by the equations of motion does not hold generally in the atomic world.
4. But there exists a quantum mechanics, based on equations of motion, valid for low energies, with determinism holding between observations and getting disturbed only by observations.
*Synonyms:* to keep; to retain.

**incline,** *v.*

1. To incline is to lean, slope, or cause to lean, slope; to turn, or cause to turn, from the usual or vertical position; to tend; to be disposed.
2. His letter inclines me to think that he does not want to come.
3. Many theoretical physicists are inclined to give up the attempt of applying the equations of motion in a theory.
*Derivative:* inclination.
*Synonym:* to tend.

**incorporate,** *v.*

1. To incorporate is to form into a corporation; to become a corporation; to join or unite (one thing with another); to become joined or united.
2. Your suggestions will be incorporated in the plan.
3. One knows some properties of the S-matrix from general physical principles and one can get a great deal more information about it by incorporating experimental results.
*Derivative:* incorporation.
*Synonyms:* to combine; to join; to unite.



**obey,** *v.*

1. To obey is to do what one is told; to carry out orders; to respond to guidance or control.
2. Soldiers must obey orders.
3. The difficulties of applying equations of motion in a theory that must obey relativity are so serious that many theoretical physicists are inclined to give up the attempt and build theories independent of equations of motion.

**fair,** ***adj.***

1. Fair is clear; clean; fresh.
2. Please make a fair (=new and clean) copy of this translation.
*Derivative:* fairly.
3. Fairly is thouroughly; completely.
4. The theories of most fields, such as solid-state physics, spectroscopy of atoms and molecules, and chemical physics, are based, fairly satisfactorily, on equations of motion.

## Exercises

### 1. Give the English for:

a) мгновенье, момент; набор, комплект; собирать(ся); отбрасывать, отказываться; выражать; иметь силу, оставаться в силе; соблюдаться; быть склонным, расположенным; сочетать, объединять; подчиняться; удовлетворять условиям уравнения; совершенно, весьма;
b) набор величин; детерминизм, существующий между наблюдениями; учитывать релятивистские закономерности; собранные вместе амплитуды вероятностей; вполне удовлетворительный.

### 2. Give the Russian for:

to introduce a set of quantities; determinism holding between observations and getting disturbed only by observations; to obey relativity; to be inclined to give up the attempt; one instant of time; to be expressed in terms of quantities; quantities directly connected with observation; by incorporating experimental result; fairly satisfactorily.

**3. Give derivatives of the following words:**

instant; to collect; to express; to incline; to incorporate; fair.

**4. Give synonyms of the following words:**

moment; to assemble; to dismiss; to signify; to keep; to tend; to combine; clear.

**5. Read the following words:**

to discard [dis'ka:d]
to incline [in'klain]
fair [fɛə]
fairly ['fɛəli]
classical ['klæsikəl]
equation [i'kweiʃən]
initial [i'niʃəl]
serious ['siəriəs]
relative ['relətiv]
relatively ['relətivli]

instant ['instənt]
instantaneous [,instən'teinjəs]
inclination [,inkli'neiʃn]
to incorporate [in'kɔ:pəreit]
incorporation [in,kɔ:pə'reiʃən]
to calculate ['kælkjuleit]
calculation [,kælkju'leiʃən]
probability [,prɔbə'biliti]
amplitude ['æmplitju:d]
electrodynamics [i'lektroudai,næmiks]

## CAN EQUATIONS OF MOTION BE USED IN HIGH-ENERGY PHYSICS?

*The formalism that has been so successful for classical physics might lead to a useful, as well as aesthetically pleasing, theory of particles.*

by P. A. M. Dirac

Let us understand precisely what is meant by equations of motion. One must introduce a set of quantities A, of any mathematical nature, to describe the physical state at a certain time. The equations of motion are then

$$dA/dt = \text{function (A)} \qquad (I)$$

By integrating the equations, one can calculate A at a later time in terms of the initial set A.

The determinism implied by the equations of motion does not hold generally in the atomic world. But there exists a quantum mechanics, based on equations of motion, valid for low energies, with determinism holding between observations and getting disturbed only by observations. The question is whether there exists a similar theory based on equations of motion that is also valid for high-energy physics?



Up to the present, equations of motion have not had any significant success in high-energy physics, apart from the limited domain of electrodynamics. The difficulties of applying equations of motion in a theory that must obey relativity are so serious that many theoretical physicists are inclined to give up the attempt and build theories independent of equations of motion.

### *S-matrix Theory*

Some physicists point out — quite justifiably — that the quantities involved in equations of motion, namely dynamical variables referring to one instant of time, are not connected very closely with experimental results, and they say that a theory should be expressed in terms of quantities directly connected with observation. This is a pretty good argument, and is one that led Werner Heisenberg in 1925 to construct matrix mechanics, which evolved into our present quantum mechanics.

In the case of high-energy physics one is concerned with calculating the probabilities for emission, absorption and scattering of particles. These probabilities are given, if one assumes the same general principles that work so well for low-energy physics, by the squares of the moduli of certain numbers, called probability amplitudes. The probability amplitudes, collected together, form the S-matrix. Thus a knowledge of the S-matrix would provide all the information needed in high-energy physics.

If one had equations of motion, one could integrate them to get the S-matrix. But perhaps the S-matrix exists independent of the existence of the equations of motion. This belief, which has had a great deal of success, defines a school of physics, the «no-equations-of-motion» school. One knows some properties of the S-matrix from general physical principles and one can get a great deal more information about it by incorporating experimental results. The school hopes that ultimately sufficient information will be obtained to determine the S-matrix completely.

In spite of the progress of the S-matrix school, I believe that high-energy physics should be based on equations of motion because they are so necessary for low-energy phenomena. High-energy physics forms only a small fraction of the whole of physics. The theories of most fields, such as solid-state physics, spectroscopy of atoms and molecules, and chemical physics, are based, fairly satisfactorily, on equations of motion. We believe in the unity of physics. The equations of motion that are so successful for most of physics cannot be simply discarded for one branch of physics. Although these equations may need modification, perhaps involving different kinds of variables, one would still expect to retain the basic structure of equation I. The result would be differential equations in the time, which one has to integrate to get results comparable with experiments.

*Physics Today*
*April 1970*

## Exercises

### I. Translate into Russian paying attention to the functions of the Participle:

1. The determinism implied by the equations of motion does not hold generally in the atomic world.
2. But there exists a quantum mechanics, based on equations of motion, valid for low energies, with determinism holding between observations and getting disturbed only by observations.
2. Thus a knowledge of the S-matrix would provide all the information needed in high-energy physics.
4. Having been examined, the students went home.
5. Having asked the teacher about the results of the test, the students left the room.
6. Asked to carry out this experiment, he agreed immediately.
7. Being very busy, he could not help me.
8. Carried out in a hurry, the experiment did not produce good results.
9. When applied to nuclei, the snapshot concept is theoretical; although there is nothing in the laws of physics that says a snapshot experiment is impossible, it is far beyond present techniques.

### II. Translate into English using the active vocabulary of the lesson:

1. До сих пор уравнения движения не играли какой-либо существенной роли в этой области физики, если не считать некоторых ограниченных разделов физики.
2. Многие физики-теоретики предпочитают отказаться от подобных попыток и строят теории, не связанные с уравнениями движения.
3. Некоторые физики считают, что динамические переменные, относящиеся к какому-то моменту времени, не слишком связаны с экспериментальными результатами.



4. Гейзенберг и его ученики надеются получить исчерпывающую информацию, которая позволит полностью определить S-матрицу.
5. Теории в таких областях, как физика твердого тела, атомная и молекулярная спектроскопия, химическая физика, основываются — и достаточно надежно — на уравнениях движения.
6. Уравнения движения, столь плодотворные в большинстве направлений физики, не могут быть просто отвергнуты для одной из ее ветвей.
7. Эти уравнения должны сохранить основную структуру.
8. В результате мы получили бы дифференциальные уравнения по времени, интегрирование которых привело бы к выражениям, допускающим сравнение с экспериментом.

### III. Translate at sight:

Low-energy physics is governed by quantum electrodynamics, which deals with charged particles interacting with the electromagnetic field. One would expect it to apply to all physical processes with energies up to a few hundred MeV, where the possibility of creation of other particles arises. One must therefore begin by establishing the equations of quantum electrodynamics in a satisfactory form. A number of problems arise here.

Maxwell's theory, together with the relativistic theory of the electron, provides definite equations of motion. One may proceed to solve them by a perturbation method, treating the interaction between the electrons and the field as small. The solutions are expressed as power series in the coupling constant, a small number. However, one soon runs into divergent integrals.

### IV. Give the situations from the text in which the following words are used:

instant; set; to collect; to discard; to express; to hold; to incline; to incorporate; to obey; fairly.

### V. Correct the false statements:

1. It is very easy to apply equations of motion in a theory that must obey relativity.
2. Many theoretical physicists are inclined to apply equations of motion in a theory that must obey relativity.
3. Recently equations of motion have had a great success in high-energy physics.
4. The determinism implied by the equations of motion generally holds in the atomic world.
5. Dirac does not believe that high-energy physics should be based on equations of motion.

6. The equations of motion that are so successful for most of physics can be simply discarded for one branch of physics.

### VI. Translate the following Russian questions into English and answer them:

1. Соблюдается ли в атомном мире детерминизм, заключенный в уравнениях движения?
2. Нет ли теории, основанной на уравнениях движения, которые применимы и в физике высоких энергий?
3. Кто построил матричную механику?
4. Каким образом мы могли бы получить S-матрицу?
5. Трудности использования уравнений движения в теории, которая должна учитывать релятивистские закономерности, очень серьезны, не так ли?

### VII. Render in English:

Физика высоких энергий стимулировала развитие ряда новых математических способов расчета и объяснения экспериментальных результатов. Многие из этих методов весьма слабо связаны с методами, используемыми в других разделах физики, многие же сами по себе остаются в ряде отношений несовершенными или просто неудовлетворительными. Они применялись с переменным успехом. Методы, основанные на уравнениях движения, совершенно необходимые для физики низких энергий, оказались трудно приложимыми к физике высоких энергий, и от них в значительной мере пришлось отказаться. Но если мы верим в единство физики, мы должны верить и в то, что некоторые основные идеи одинаково применимы ко всем ее областям. Не следовало бы в таком случае использовать уравнения движения в физике высоких энергий, подобно тому как мы это делаем в физике низких энергий? Это нужно сделать. Математически изящная теория имеет больше шансов оказаться правильной, чем уродливая теория, лишь увязывающая между собой отдельные экспериментальные данные.

### VIII. Answer the following questions:

1. What kind of determinism does not hold generally in the atomic world?
2. What is quantum mechanics based on?
3. What kind of determinism holds in quantum mechanics?
4. Why are there many theoretical physicists who are inclined to give up the attempt of applying equations of motion in a theory?
5. How do they build their theories?
6. What argument led W. Heisenberg to construct matrix mechanics?



7. What is the S-matrix formed of?
8. Why does Dirac believe that high-energy physics should be based on equations of motion?
9. What theories (in what fields of physics) are based, fairly satisfactorily, on equations of motion?
10. How can one get results comparable with experiments?

### IX. Review the article «Can Equations of Motion be Used in High-Energy Physics?»

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. High-energy physics difficulties.
2. S-matrix theory.
3. World description in quantum mechanics.
4. The unity of physics.
5. The theory of elementary particles and high-energy physics.

## LESSON THIRTY

### Active Vocabulary

**influence,** ***n.***

1. Influence is the power or capacity of causing an effect in indirect ways; the act of producing an effect without apparent exertion of force.
2. Books have positive influence upon children's minds.

**neighbo(u)r,** ***n.***

1. Neighbor is one living or located near another.
2. England's nearest neighbor is Ireland.
3. When the big tree fell it brought down several of its smaller neighbors.

*Derivative:* neighborhood.

**belong,** ***v.***

1. To belong means to become attached or bound, to be an attribute, part, or function of a person or a thing.
2. The idea of spaceflights belongs to K. E. Tsiolkovsky.
3. This star belongs to the neighboring galaxy.

**justify,** ***v.***

1. To justify means to prove or show to be right, or reasonable, to show to have had a sufficient legal reason.
2. The Prime Minister justifies the action of the government.

*Derivatives:* justifiable, justification.

3. It is justifiable to talk about the anomalies of water.

*Synonym:* to maintain.



**melt,** ***v.***

1. To melt means to become changed from a solid to a liquid state; to disappear as if dissolving.
2. Ice melts at 0°C.
3. It is easy to melt butter.
4. On the top of high mountains the snow does not melt even in summer.

*Synonym:* to dissolve.

**mention,** ***v.***

1. To mention means to refer to something; to specify by name; to speak of something or somebody.
2. Moscow was first mentioned in ancient books in 1147.
3. It was mentioned in several articles that an increase in temperature also increases the entropy.

**participate,** ***v.***

1. To participate means to take part in something.
2. Soviet scientists participate in great many of conferences concerning different branches of science.

*Derivatives:* participant, participation.

3. By participation we sometimes mean something that two or more things or persons posses together, not only the act of taking part in something.

**mere,** ***adj.***

1. Mere means apart from anything else.
2. In this case we can't answer by mere «yes» or «no».

*Derivative:* merely.

3. We don't know yet whether it represents a new, polymeric form of water or is merely ordinary water.

**pure,** ***adj.***

1. Pure means unmixed with any other matter; containing nothing that does not properly belong.
2. As the international unit of mass a cubic centimeter of pure water was chosen.
3. Pure facts do not require any proof.

*Derivatives:* purify, purification, purity.

**remarkable,** ***adj.***

1. By remarkable anything that is worth being noticed is meant.
2. A remarkable feature of Faraday's theory is its simplicity.

3. I. V. Kurchatov was one of the most remarkable Soviet scientists.

*Derivative:* remarkably.

### Exercises

**1. Give the English for:**

a) влияние; сосед; принадлежать; подтверждать правоту; таять; упоминать; принимать участие; явный; простой; чистый; примечательный;

b) быть авторитетом для кого-либо; под влиянием чего-либо; температура плавления; как уже было упомянуто; чистота вещества; примечательный факт.

**2. Give the Russian for:**

to have influence; neighbor; to belong to smb; to justify the analogy; melting point; to mention; participation; mere facts; pure substance; remarkable event.

**3. Give derivatives of the following words:**

neighbor; to justify; to participate; mere; pure; remarkable.

**4. Give synonyms of the following words:**

to maintain; to dissolve; velocity; to vary.

**5. Read the following words:**

anomalous [ə'nɔmələs]
to justify ['dʒʌstifai]
justification [,dʒʌstifi'keiʃən]
to participate [pa:'tisipeit]
participation [pa:,tisi'peiʃən]
to recognize ['rekəgnaiz]
unrecognizability ['ʌn,rekəg-naizi'biliti]
porous ['pɔ:rəs]
porousness ['pɔ:rəsnis]
coefficient [,koui'fiʃənt]
pure [pjuə]
impurity [im'pjuəriti]
quasi ['kwa:zi]
polymer ['pɔlimə]
polymeric [,pɔli'merik]
molecule ['mɔlikju:l]
molecular [mou'lekjulə]
capillary [kə'piləri]
merely ['miəli]
anomaly [ə'nɔməli]



## SUPERDENSE WATER

*One of the codiscoverers of this remarkable substance takes up the question of whether it represents a new, polymeric form of water or merely ordinary water with impurities.*

by Boris V. Derjaguin

*The Anomalies of Water*

Water is distinguished from all other liquids by the fact that its structure (that is, the mutual arrangement of the nearest molecular neighbors) is very strongly and specifically reflected in its properties. Certain of these structure-dependent properties differ so much from the properties of other liquids that it is justifiable to talk about the anomalies of water. Among them the best known is the anomaly concerning the expansion of water, which (as was mentioned in previous articles) is characterized by a maximum density at 4 degrees C. It is natural to expect as a result of this fact that if a solid substratum is capable of changing the structure of continuous layers of water, then their thermal expansion must also be changed simultaneously.

This expected dependence was first detected in 1961 by N. N. Fedyakin, then working at the Kostroma Polytechnical Institute, in the course of his observations of the expansion of columns of water in ultrafine capillaries. When the increase in the length of a column of water was plotted as a function of the temperature in glass capillaries of various radii, it became apparent that in capillaries with a radius greater than one micron the water expands in the expected way, displaying a maximum density at 4 degrees C.

For very narrow capillaries the expansion proceeds differently, and in ultranarrow capillaries it is changed to the point of unrecognizability. In the ultranarrow capillaries not only does the minimum of the volume disappear but also the coefficient of expansion is made constant over the entire temperature range studied; in short, the anomalous expansion of water completely vanishes!

It is well known that the anomalous expansion of water under normal conditions results from its loose structure. This porousness in turn is determined by the influence of the hydrogen bond, in which the hydrogen atom serves as a bridge connecting two oxygen atoms belonging to two different water molecules, with an energy that is intermediate between the energy of the usual chemical bond (such as the bond, say, between the oxygen and hydrogen atoms in an individual molecule of water) and the energy of molecular attraction between neighboring molecules. Each atom of oxygen appearing in the structure of any given molecule is able to be joined by hydrogen bridges with four other molecules; two of these bridges involve the participation of the hydrogen atoms of the given water molecule, and the other two involve the participation of hydrogen atoms belonging to other water molecules. Thus oxygen exhibits, in addition to its normal double valency, which is expanded on the formation of the molecule itself, an extra «quasi-valence» of two enabling it to be joined with two more water molecules by hydrogen bonds.

The most «pure» and complete form of such a system of hydrogen bridges is formed in a crystal of ordinary ice, or ice I. In ice I each atom is joined by a hydrogen bond to its four nearest neighbors. The crystal as a whole is a skeleton-like structure formed by a network of hydrogen bonds. It is precisely such a structure, in which each molecule has only four nearest neighbors, that determines the porousness of ice, thereby accounting for a number of its properties, in particular its ability to float in water. One can say, taking the quasi-chemical nature of the hydrogen bond into account, that a crystal of ice essentially represents a single polymer molecule in which the oxygen acts as if its valence were four. In this respect an ice crystal resembles a crystal of diamond, which is composed of a network of chemical bonds between carbon atoms with a valence of four.

When ice melts, the perfect regularity of the distribution of the water molecules and of the network of hydrogen bonds is destroyed, but not completely. With a subsequent increase of the temperature from zero degrees C., the thermal motion of the molecules destroys an ever increasing number of the hydrogen bridges, a process favoring the occupation of the empty spaces in the structure of the liquid. Therefore water contracts in spite of the fact that thermal motion simultaneously tends to increase the average distance between the molecules. Only above 4 degrees C. does the latter tendency take the upper hand, whereupon water begins to expand.

*Scientific American*
*November 1970.*

## Exercises

### I. Translate into Russian paying attention to the functions of the Participle:

1. Thales and his successor, building the practical experience of those who had preceded them, consequently benefited from a large legacy of technological knowledge.
2. Comparing the flowing of wine and of olive oil, Lucretius concluded that the oil must be made up of particles that are larger.



3. The first positron beam produced by the accelerators was developed around 1958.
4. While applying a bias current, the magnetic particles in a spot of tape are subjected to many cycles of the current when crossing the gap of the reading head.
5. Having considered both these theories it was easier to decide which was the true description of the world.
6. Having achieved saturation later the idea was precipitated in Euclid as the postulate of parallels.
7. Digging in these layers of the history ideas, we have come on a large enough number of fragments to suppose that they are the remains of a unique Athenian vase.
8. Having been supposed to be true, this theory was taken without being reconsidered.
9. The amount of momentum being carried northward greatly exceeds the amount being carried southward.
10. When asked he could not give a proper answer immediately.

### II. Translate into English using the active vocabulary of the lesson:

1. Заслуга создания неевклидовой геометрии принадлежит ученым 19 века.
2. В течение ряда лет в Институте физической химии АН СССР проводится ряд экспериментов по изучению изменчивости свойств жидкостей при специальных лабораторных условиях под влиянием сил, контактирующих с поверхностями тел, твердых или жидких, и т. д.
3. Средства, затраченные на исследование аномальных свойств жидкостей, оправданы полученными результатами.
4. Представители многих научно-исследовательских институтов и вузов страны неоднократно принимали участие в различных международных симпозиумах.
5. Чем выше концентрация «носителей аномальностей», тем больше их кривая на графике расширений отличается от кривой чистой воды.
6. С повышением температуры количество и размеры капле-видных включений уменьшаются, они как будто растворяются.
7. Все эксперименты, упомянутые выше, проводились в 1965—1966 гг.
8. Примечателен тот факт, что в сверхтонких капиллярах коэффициент расширения жидкости становится постоянным в изучаемом диапазоне температур.
9. При таких условиях атомы начинают более интенсивно обмениваться электронами со своими «соседями».
10. В этой статье нет ничего интересного, кроме простого перечисления фактов.

## III. Catch the meaning of the text and retell it:

Returning to the experiments of Fedyakin, it is clear that we can now explain them by the fact that in very narrow capillaries, owing to the influence of the walls, the formation of the skeleton of hydrogen bridges between the water molecules is impeded, removing the restriction on the number of nearest neighbors and making it possible for the molecules to be arranged more densely. As a consequence, further contraction does not take place with an increase of the temperature, as is the case for the ordinary state of water near zero degrees C., and water in narrow capillaries expands as a normal liquid.

The foregoing account raises an important question: To what extent are the properties of water columns with special properties free from the influence of the products of dissolution, or leaking out, of the walls of the capillaries? This possibility was discounted by the experiments of Karasev, Khromova and the author, which showed that the expansion of water existing in pores between particles of quartz ($SiO_2$) powder changes in the same way. Moreover, after removing the water from the powders its normal expansion was reestablished, which would be impossible if everything were determined by a solution of $SiO_2$ in water. Simultaneously this result demonstrated that in pores near a surface of $SiO_2$ water experiences an unstable, reversible change of its properties that vanishes after it is removed from the surface.

## IV. Give the situations from the text in which the following words are used:

to be distinguished from; to differ; to concern; function; to disappear; to be determined by; bridge; attraction; to involve; complete; perfect; empty.

## V. Develop further the following statements:

1. Water is distinguished from all other liquids by ...
2. It is natural to expect as a result of this fact ...
3. When the increase in the length of a column of water ...
4. In the ultranarrow capillaries not only does the minimum ...
5. This porousness in turn is determined by the influence of the hydrogen bond, ...
6. Thus oxygen exhibits, in addition, to its normal double valency, ...
7. The crystal as a whole is a skeleton-like structure, ...
8. When ice melts, ...
9. With a subsequent increase of the temperature from ...



## VI. Translate the following Russian questions into English and answer them:

1. Чем можно объяснить способность льда плавать в воде?
2. В чем состоит аномальное расширение воды?
3. Чем объясняется аномальное расширение воды?
4. Что такое водородная связь?
5. Чему приблизительно равна энергия водородной связи в $H_2O$?
6. Где наиболее часто наблюдаются такие же водородные связи?
7. Что такое «квази-валентность» кислорода?
8. В чем основное сходство кристаллов льда и алмаза?
9. Какие структурные изменения происходят при плавлении льда?
10. За счет чего происходит разрушение водородных мостиков?

## VII. Render in English:

Среди свойств жидкостей имеются такие, которые зависят не от расположения молекул, а только от их (молекул) вида. Молекулярное преломление относится к этому классу; оно, например, одинаково для льда, воды и водяного пара. Такие свойства иногда называют структурной нечувствительностью. Свойства, являющиеся структурно чувствительными, зависят в большей или меньшей степени от строения жидкости; типичным свойством этого класса является вязкость.

В течение длительного времени не существовало подходящего метода наблюдения такого структурного свойства, как вязкость жидкости, которая изменяется по мере того, как она приближается к твердой стенке или удаляется от нее. Затем, около тридцати лет назад, был развит подобный метод. Он называется методом «выдувания». Пленка жидкости, толщиной в несколько микронов, наносится на нижнюю поверхность щелевидного канала. Поток воздуха, проходящий по щели, создает постоянную тангенциальную силу, вызывающую перемещение слоев пленки параллельно основанию, или нижней поверхности, канала.

Картина этого потока напоминает колоду игральных карт, сдвинутых так, что противоположные концы верхней и нижней карты находятся на наибольшем расстоянии друг от друга. В результате такого наклона, при котором соответствующие слои перемещаются, скользя один по другому, край жидкости превращается в слабо наклоненный клин с определенным профилем.

## VIII. Answer the following questions:

1. What is the anomaly of water expansion?
2. What is the way to destroy the anomaly of water expansion?

3. What can you say about the energy of hydrogen bond?
4. What is the hydrogen bridge?
5. What is quasi-valence of the oxygen molecule?
6. Where can we observe a purer form of hydrogen bridge?
7. What is the resemblance between a crystal of ice and a diamond?
8. How can you explain that a crystal of ice floats in water?
9. What happens when ice melts?
10. How does the destruction of hydrogen bridges occur?

**IX. Review the article «Superdense Water».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. The anomalies of water.
2. Hydrogen bonds and their structure.
3. Impurity hypothesis.
4. Loose structure of water.
5. Experiments of Fedyakin; their results.
6. What is being carried on in this particular field now.

# LESSON THIRTY-ONE

## Active Vocabulary

### access, *n*.

1. Access is a way of getting to a place; also the chance of getting, using or meeting.

2. The only access to the place is across the river.

*Easy (difficult) of access*=easy (difficult) to get to or reach.

3. Students must have access to good books.

*Derivative*: accessible.

4. Accessible is obtainable; easy to be reached.

5. The house is not accessible by the car.

6. Some deserts in Africa are hardly accessible for people.

### drawback, *n*.

1. Drawback is anything that takes away from satisfaction.

2. Other people's drawbacks are always noticed much easier than those of our own.

3. The main drawback of this method consists of its being too complicated.

### endeavo(u)r, *n*.

1. Endeavor is a serious determined effort; work with set purpose.

2. The success of any work is provided by common endeavor of the people doing it.

3. We must make every endeavor not to be late.

*Synonym*: attempt.

### leak, *n*.

1. By leak a crack or hole that usually by mistake admits or lets escape is meant.

2. We could not get vacuum because of the leak in the chamber.
*Derivatives:* leakage, leaky.
3. Leakage of military secrets in the time of war may have serious results.

**scale,** ***n.***

1. Something graduated especially when used as a measure or rule is called scale.
2. By scale a proportion between two sets of dimensions is very often meant.
3. The scales of these pressure-gauges (manometres) have been made in pounds per square inch.
*Synonym:* measure.

**desire,** ***v.***

1. To desire is to hope for something; to express a wish for something.
2. Our rooms are all that one can desire.
3. His behavior leaves much to be desired.
*Derivative:* desirable.
*Synonyms:* to wish; to want.

**immerse,** ***v.***

1. To immerse is to imbed in something; to involve deeply; to absorb.
2. The sun having set, the town immersed in darkness.
3. The simplest method for making measurements at low temperatures is to immerse the specimen under study in a cold liquid.
*Derivative:* immersion.
4. Disappearance of a celestial body behind or into the shadow of another is called immersion.

**improve,** ***v.***

1. To improve is to make greater in amount or degree; to increase the value of something; to make better.
2. The conditions of life of our people have been considerably improving.
3. He came back from his holiday with greatly improved health.
*Derivative:* improvement.

**perform,** ***v.***

1. To perform is to fulfill; to carry out an action; to do in formal manner or according to the prescribed plan.



it be,
tures 2. Every student must perform several independent experiments desiring the term.
is as s. Experiments with superdense matter can't be performed in distr estrial laboratories.
le *Derivative:* performance.

**state,** ***v.***

1. To state means to set by regulation or authority; to express in words.
2. This condition was especially stated by the head of the delegation.
3. The third law of electrodynamics states that it is impossible to reach absolute zero.
4. He'd like to state his case.
*Derivative:* statement.
*Synonym:* to report.

## Exercises

### 1. Give the English for:

a) достигать; доступный, достижимый; недостаток; стремление; утечка (жидкости, информации); шкала; желать; погружать; улучшать; проводить, выполнять; говорить;

b) серьезный недостаток; стремиться к чему-либо; утечка информации; улучшенный вариант; проводить эксперимент; этот закон гласит.

### 2. Give the Russian for:

access; desire; an important drawback; common endeavor; heat leak; wide scale of experiments; to immerse; to improve; to perform; to state a condition; to be accessible for.

### 3. Give derivatives of the following words:

access, leak, to desire, to immerse, to improve, to perform, to state.

### 4. Give synonyms of the following words:

attempt; measure; to wish; to report; to want.

### 5. Give antonyms of the following words:

unfair, to disobey, to freeze, to harden, advantage, to worsen.

### 6. Read the following words:

| | |
|---|---|
| zero ['ziərou] | procedure [prə'si:dʒə] |
| to align [ə'lain] | to immerse [i'mə:s] |
| endeavor [in'devə] | vapor ['veipə] |
| isotropic [,aisə'trɔpik] | to evaporate [i'væpəreit] |
| isotropy [ai'sɔtrəpi] | to vibrate [vai'breit] |
| to dilute [dai'lju:t] | vibration [vai'breiʃən] |
| dilution [dai'luʃən] | to approach [ə'proutʃ] |
| Celsius ['selsiəs] | accessible [æk'sesəbl] |
| Kelvin ['kelvin] | thermodynamics [,θə:moudai-'næmiks] |
| Fahrenheit ['færənhait] | violent ['vaiələnt] |

## NEW METHODS FOR APPROACHING ABSOLUTE ZERO

*Low-temperature physicists have recently devised three different experimental procedures capable of lowering the temperature range accessible for research to within millidegrees of absolute zero.*

by O. V. Lounasmaa

The atoms and molecules that make up all forms of matter are in constant thermal motion; the higher the temperature, the higher their average speed. In solids molecules have fixed lattice sites but their thermal motion causes them to vibrate around these equilibrium positions. In principle there is no upper limit of temperature; as thermal motion becomes increasingly violent a solid body first melts and evaporates. Finally, as the temperature is increased still further, atoms lose some or all of their electrons, thereby forming a plasma, or cloud of charged particles. This situation exists inside stars, where the temperature is many millions of degrees Celsius.

In contrast, there is a definite stop at the other end of the temperature scale. Theoretically when thermal motion ceases, the coldest possible temperature — «absolute zero» — has been reached. This limiting temperature is —273.16 degrees C. (which is equal to —459.69 degrees on the Fahrenheit scale). A fundamental postulate of physics, the third law of thermodynamics, states that it is impossible to reach absolute zero. By suitable experimental procedures one can come closer to this temperature, but ultimate success will remain elusive, no matter how hard one tries.

Low temperature physicists constantly try to extend the temperature range accessible to experimental investigation closer and closer to absolute zero. There are at least two good reasons for this endeavor. First, certain fundamentally important properties of matter, such as superconductivity and superfluidity, occur only at such low temperatures. It is always possible that new, perhaps completely unsuspected and equally interesting properties will be found when



it becomes possible to make measurements at still lower temperatures. The second reason for experiments near absolute zero is the desire to study matter under conditions at which thermal disorder is as small as possible. A typical example is the study of the angular distribution of gamma rays emitted from radioactive nuclei. A nucleus can be regarded as being either a sphere or an ellipsoid that has a definite magnetic axis with a north and a south pole. Normally those elementary nuclear magnets are randomly oriented because of their thermal motion. Even the highest magnetic fields available in the laboratory are not strong enough to align the nuclei unless the thermal motion has been reduced sufficiently by cooling the specimen to .01 degree K. or below. If this can be achieved, one should in principle be able to study the gamma ray emission from the aligned nuclei. Such experiments have actually been done, and it has been found that the intensity of the radiation is no longer isotropic (that is, nondirectional) in space. This result, made possible by advanced low-temperature techniques, was very important for the development of nuclear theory. Sometimes temperatures in the vicinity of .001 degree K. or lower are required to bring order into a nuclear system.

The simplest and most common method for making measurements at low temperatures is to immerse the specimen under study in a cold liquid. Nitrogen, which boils at 77 degrees K., and helium, which boils at 4.2 degrees are the liquids normally used. The temperature of any liquid can be further reduced by pumping on it. The pump removes molecules from the vapor phase. These are replaced by the fastest molecules from the liquid phase, thereby reducing the average thermal motion and hence cooling the liquid. Unfortunalety, in every substance the number of molecules in the vapor per unit volume decreases rather rapidly with the absolute temperature. As a result a temperature is soon reached at which there are so few molecules in the vapor phase that further cooling becomes impossible. For ordinary liquid helium, which has a total of four nucleons (protons plus neutrons) in its nucleus, and hence is referred to as helium 4, this limit is approximately .9 degree K. For the rare helium isotope helium 3, which contains only three nucleons, the limit is .3 degree. For all other substances the limiting temperature is much higher.

A technique called magnetic cooling has for many years been the only practical way for reaching temperatures below .3 degree K. By using a suitable paramagnetic salt it is possible, under favorable conditions, to reduce the temperature to within .003 degree K. of absolute zero. I shall not describe this method in detail now. It suffices to say here that the main drawback of magnetic cooling is that it is a «one shot» rather than a continuous method of refrigeration and that its cooling capacity is relatively small. There are many types of important experiments that cannot be performed in a cryostat that employs magnetic cooling. It is also important to be able to push the temperature range available for experimental investigations still further toward absolute zero.

Recently three new methods have become available for reaching temperatures in the millidegree (.001 degree K.) or submillidegree region. These are known as the helium-3/helium-4 dilution process, the Pomeranchuk method and nuclear cooling. A dilution refrigerator can maintain temperatures in the vicinity of 10 to 20 millidegrees continuously and in the presence of a relatively large heat leak. By the Pomeranchuk method the temperature has been reduced to two millidegrees in a rather simple apparatus. By nuclear cooling .85 millidegree has been reached, and it is clear that a refrigerator of this type, when improved, will make many types of experiments in the submillidegree region possible.

*(to be continued)*

## Exercises

### I. Translate into Russian paying attention to the Elliptical Constructions:

1. When applied to nuclei, the snapshot concept is theoretical; although there is nothing in the laws of physics that says a snapshot experiment is impossible, it is far beyond present technique.

2. It had been observed that some nuclei did not fission once when excited but waited a measurable time.

3. Since any scene can be looked upon as being made of many individual sources of light, and since each of these sources forms, with the reference wave, its own zoneplate on a photographic plate, the hologram of an actual scene will, when illuminated, generate a composite image, a combination of virtual images of all of the many original light sources.

4. By «illuminating» an object with pure tones of sound instead of with a beam of coherent light one can create acoustical holograms that become three-dimensional pictures when viewed by laser light.

5. When in doubt about the meaning of a word, use your dictionary.

6. This constant is usually known as the rest mass, because for ordinary objects, which can be slowed to rest, it gives the value of the objects' mass when at rest.



7. This makes it possible to conjecture that many other liquids, when in the vicinity of foreign substrate, are in a state corresponding to a special boundary phase in which the molecules are distributed in a more highly ordered state.

8. By measuring the heat capacity of the moistened powder with the aid of a sensitive calorimeter and substracting then from it the heat capacity of the powder when dry, one can determine the specific heat capacity of the nitrobenzene film.

9. Although still young, the dilution refrigeration has already proved itself as a research tool in experiments that formerly could not be carried out at very low temperatures.

10. By nuclear cooling .85 millidegree has been reached, and it is clear that a refrigerator of this last type, when improved, will make many types of experiments in the submillidegree region possible.

### II. Translate into English using the active vocabulary of the lesson:

1. Физики пытаются приблизить область температур, доступных для экспериментального исследования, как можно ближе к абсолютному нулю.

2. Причиной проведения экспериментов в области абсолютного нуля является желание изучить материю, когда «термический беспорядок» по возможности мал.

3. Метод осуществления измерений при низких температурах состоит в погружении исследуемого образца в холодную жидкость.

4. Такой холодильник, если он будет улучшен, позволит проводить эксперименты в области температур менее 0,001 K.

5. Градуировка шкалы этого прибора сделана в фунтах на квадратный дюйм.

6. Иногда утечку газа замечают только тогда, когда уже нельзя или очень трудно предотвратить катастрофу.

7. Некоторые эксперименты не могут быть проведены при помощи магнитного охлаждения.

8. Серьезные недостатки в работе этой лаборатории должны быть устранены в ближайшее время.

9. Третий закон термодинамики гласит о невозможности достижения абсолютного нуля.

### III. Catch the meaning of the text and retell it:

Nuclear cooling, or adiabatic demagnetization utilizing the nuclear instead of the electronic magnetic properties of matter, was produced in 1934 by Nicholas Kurti and Franz E. Simon of the University of Oxford and by Cornelius J. Gorter of the University of Leiden. The first practical realization of this method was not achieved until 1955.

Conventional magnetic cooling was briefly mentioned at the beginning of the article given above; the method utilizes the electronic elementary magnets of a suitable paramagnetic salt. The basic principle of both electronic and nuclear magnetic cooling is the same, but there are significant differences in practice. Because the nuclear elementary magnets are about 2,000 times smaller than the electronic magnets, the starting temperature for nuclear cooling must be much lower. Actual figures are about one degree K. for electronic cooling and about .01 degree for nuclear cooling. Considerably higher magnetic fields are also required in the latter case. The necessary starting conditions for nuclear-cooling experiments, are thus difficult to achieve. There is an important compensation, however. The ultimate temperature that can be reached depends on the mutual interactions of the elementary magnets; it is impossible to cool to a temperature lower than that at which spontaneous ordering of the elementary magnets occurs. In the electronic case the limiting temperature is about .003 degree, whereas in the nuclear case it is approximately .0000005 degree!

## IV. Give the situations from the text in which the following words are used:

definite, thermodynamics, range, reason, thermal, specimen, shot, to maintain, possible.

## V. Correct the false statements:

1. The atoms and molecules that make up all the forms of matter are in temporary thermal motion.
2. There isn't either upper, or lower limit of temperature.
3. A fundamental postulate of physics, the third law of thermodynamics, states that it is difficult to reach absolute zero.
4. To study matter under conditions at which thermal disorder is as small as possible can't be interesting for anybody.
5. In every substance the number of molecules in the vapor per unit volume increases rather rapidly with the absolute temperature.
6. It is impossible to reduce the temperature to within .003 degree K. of absolute zero by using a paramagnetic salt.
7. There are very few types of important experiment that can't be performed in a cryostat employing magnetic cooling.
8. By Pomeranchuk method the temperature has been reduced to .85 millidegree in a very complicated apparatus.



## VI. Translate the following Russian questions into English and answer them:

1. Какой из основных законов физики говорит о невозможности достижения абсолютного нуля?
2. Каковы причины проведения экспериментов при температурах, близких к абсолютному нулю?
3. Имеет ли температурная шкала ограничения в обе стороны, или верхней границы шкалы в принципе не существует?
4. Каков наиболее общий принцип понижения температуры?
5. Каковы нижние достижимые температуры для протонов $He^3$ и $He^4$?
6. Что является главным недостатком метода магнитного охлаждения?
7. В какой области температурной шкалы можно будет проводить эксперименты, если улучшить технику ядерного охлаждения?
8. С помощью какого метода можно понизить температуру $He^3$ до 3 градусов К.?

## VII. Render in English:

В 1950 году советский физик И. Я. Померанчук предложил новый метод охлаждения, основанный на необычных свойствах жидкого и твердого гелия-3 при низких температурах. Успешные эксперименты, использующие эффект Померанчука, были выполнены в 1956 году Юрием Онуфриевым в Институте физических проблем в Москве. В этих экспериментах была достигнута температура около $2 \cdot 10^{-3}$ градусов.

Прежде чем объяснить этот новый метод работ, следует обратиться к обсуждению фазовых и энтропийных диаграмм гелия-3.

Диаграмма энтропии гелия-3 очень подходит для изучения эффекта Померанчука. Энтропия — это величина, характеризующая беспорядок физической системы (короче говоря, энтропия — это мера беспорядка). Чем больше порядок, тем меньше энтропия. Например, когда температура увеличивается, тепловое движение становится больше и, следовательно, ее энтропия возрастает. В твердом теле атомы расположены в систематическом порядке, тогда как в жидкостях порядка в расположении атомов не наблюдается. Таким образом, энтропия жидкости обычно выше, чем энтропия соответствующего твердого тела при одной и той же температуре. Энтропийная диаграмма особенно подходит для количественного изучения адиабатических процессов, т. е. процессов, в которых система, находящаяся под наблюдением, термически изолирована от окружающей среды. Известно, что при адиабатических процессах энтропия остается постоянной.

**VIII. Answer the following questions:**

1. What causes the vibration of molecules in solids?
2. Why is there no upper limit for temperature?
3. How can the stop at the lower end of the temperature scale be explained?
4. What are the reasons for trying to extend the temperature range closer to absolute zero?
5. How can a radioactive nucleus be regarded?
6. Under what conditions will it be possible to study the gamma-ray emission from the aligned nuclei?
7. What does the simplest and most common method for making measurements at low temperatures consist of?
8. At what stage of experiment does cooling become impossible?
9. What role does a paramagnetic salt play in magnetic cooling?
10. What are the three new methods of cooling that have recently become available?

**IX. Speak on the following topics:**

1. The Fahrenheit, Celsius and Kelvin temperature scales.
2. Why is it impossible to reach absolute zero?
3. Are the physicists in need of low temperatures and why?
4. Magnetic cooling.
5. The Pomeranchuk effect.

# LESSON THIRTY-TWO

## Active Vocabulary

### chamber, *n.*

1. Chamber is a natural or artificial enclosed space or cavity.
2. British Parliament consists of two Chambers.
3. A revolver with six chambers is called a six-shooter.

### commerce, *n.*

1. Commerce is the exchange or buying and selling on a large scale involving transportation from place to place.
2. To have no commerce with smb = to have nothing to do with smb.

*Derivatives:* commercial, commercially.

3. Apart from experimental system, the highest tape speed in commercially available instrumentation recorders is 120 inches per sec.

### correspond, *v.*

1. To correspond means to be in agreement; to be equivalent or parallel.
2. The building exactly corresponds with the design.
3. The streets in some old towns do not correspond to the needs of modern traffic.
4. The double lines on the map correspond to roads.

*Derivatives:* correspondance, corresponding, correspondingly.
*Synonym:* to agree.

### employ, *v.*

1. To employ means to make use of something or somebody.

2. Several laser strain meters have been employed since 1970.
3. He employs his evenings reading books.
*Derivative:* employment.
*Synonym:* to use.

**fill, *v.***

1. To fill means to put into as much as can be contained; to occupy the whole of something.
2. The glass is filled with water.
3. The channel of the river was filled with sand.
4. To fill one's shoes = to take one's place or position.

**master, *v.***

1. To master means to become skilled in the use of something; to gain a thorough understanding of something.
2. He has been mastering his French for four years, and now he is speaking it quite well.

**separate, *v.***

1. To separate means to disperse in space or time; to become divided or detached; to isolate from a mixture.
2. Below about .8 degree K, a liquid mixture of helium-3/helium-4 isotopes separates into two components.
3. It is absolutely impossible to separate these two gases under normal conditions.
*Derivatives:* separately, separation.
4. Helium-3 is concluded in the dilution refrigerator reducing the temperature even further and causing the phase separation.
*Synonyms:* to part; to divide.

**former, *adj.***

1. Former means coming before in time, relating to the past, occuring in the past.
2. In former times = long ago.
*Derivative*: formerly.
3. The dilution refrigerator has already proved itself in experiments that formerly could not be carried out.
*Antonym:* latter.

**latter, *adj.***

1. Latter means relating to, or being the second of the two things referred to.
2. The number of helium-3 atom is, in the latter case, independent of temperature.



3. They are two different men, the former being unlike the latter.
*Antonym:* former.

**paramount, *adj.***

1. Paramount means superior to all others; supreme; the highest.
2. The relativity theory significance is paramount at present.
*Synonym:* dominant.

## Exercises

### 1. Give the English for:

a) камера, палата; торговля; применять, использовать; заполнять; справляться, овладевать (языком, знаниями); отделяться, разделяться; до этого времени, первый (из двух названных); недавно, последний (из двух названных); первостепенный;

b) не иметь ничего общего с кем-либо; быть заполненным чем-либо; занимать чье-либо место; совершенно самостоятельный вопрос; в прежние времена; главное внимание.

### 2. Give the Russian for:

mixing chamber; commercial purpose; corresponding solid; methods employed; to be filled with smth; to master one's knowledge of; an entirely separate question; it was formerly used; in the latter case; paramount influence.

### 3. Give derivatives of the following words:

commerce; to correspond; to employ; to separate; former.

### 4. Give synonyms of the following words:

to agree; to use; to part; dominant; to divide.

### 5. Read the following words:

latter ['lætə]
isotope ['aisoutoup]
machine [mə'ʃi:n]
chamber ['ʃeimbə]
to master ['ma:stə]
sign [sain]
boundary ['baundəri]
commerce [kə'mə:s]
similar ['similə]
similarly ['similəli]
similarity [,simi'læriti]
circular ['sə:kjulə]
to circulate ['sə:kjuleit]
circulation [,sə:kju'leiʃən]
paramount ['pærəmaunt]
spontaneous [spɔn'teinjəs]
to separate ['sepəreit]
separate, *adj.* ['seprit]
separation [,sepə'reiʃən]
component [kəm'pounənt]

## NEW METHODS FOR APPROACHING ABSOLUTE ZERO

by O. V. Lounasmaa

(continued)

The principle of the dilution refrigerator was originally suggested in 1962 by Heinz London, G. R. Clarke and E. Mendoza of the Atomic Energy Research Establishment at Harwell in England. The first successful machines of this type were built in the U.S.S.R. by B. S. Neganov and M. Liburg in late 1965. Since then many cryostats of this new type have been constructed and successfully employed for a variety of measurements down to 10 millidegrees.

The operation of the dilution refrigerator is based on the peculiar properties exhibited by mixtures of helium 3 and helium 4 at low temperatures. Below about .8 degree K. a liquid mixture of these two isotopes spontaneously separates into two components, one of the phases being rich in helium 3 and the other rich in helium 4. Because of its lower density the helium-3-rich phase floats on top of the helium-4-rich phase. As the temperature is lowered further, the concentrations of helium 3 and helium 4 in the two phases change; below about .05 degree K. the upper, or concentrated, phase is practically pure helium 3 and the lower, or dilute, phase has 6.4 percent of helium 3 dissolved in the helium 4. The 6.4 percent solubility of helium 3 in helium 4 even at absolute zero is of paramount importance for the success of the dilution refrigerator.

There is indeed a remarkable difference at low temperatures between the thermal properties of liquid helium 3 and liquid helium 4. The common isotope, helium 4, is almost completely inert, its specific heat being practically equal to zero below .3 degree K. In contrast, the specific heat of liquid helium 3 is very large at low temperatures. As a result one may think of the helium 4 in the dilute phase as acting only as a supporting medium, or «ether», for the helium-3 atoms. From this point of view an investigating and useful comparison can be made in terms of operating principles between the ordinary evaporation-type refrigerator and the helium-3/helium-4 dilution refrigerator. The concentrated phase in the dilution refrigerator, where helium-3 atoms are close to one another, corresponds to the liquid phase in the evaporation refrigerator; similarly, the dilute phase in the dilution refrigerator, with only 6.4 percent of the helium-3 atoms, corresponds to the vapor phase in the evaporation refrigerator. The positions of «liquid» and «vapor» have thus been interchanged in the two systems. When molecules move upward from the liquid into the vapor phase in the evaporation refrigerator, the temperature is lowered. Similarly, when helium-3 atoms move downward from the concentrated to the dilute phase in the dilution refrigerator, cooling results. That is how a dilution refrigerator operates.

It is now easy to see the importance of the 6.4 percent solubility of helium 3 in helium 4 in the dilute phase. In an ordinary evaporation refrigerator the vapor becomes depleted of molecules rather soon, whereas in a dilution refrigerator the concentration of helium-3 atoms in the «vapor», or dilute, phase remains constant at 6.4 percent as the temperature is lowered. Thus the number of helium-3 atoms that cross the phase boundary per unit of time is, in the latter case, independent of temperature. The reason it is impossible to reach absolute zero by the dilution method is that the amount of cold produced when one helium-3 atom crosses the phase boundary becomes smaller when the absolute temperature is reduced. For instance, the cooling power of a given dilution refrigerator at 10 millidegrees is four times smaller than it is at 20 millidegrees.

In practice the operation of a dilution refrigerator proceeds as follows. After the cryostat has been cooled, first with liquid nitrogen to 77 degrees K. and then with liquid helium to 4.2 degrees, the helium-4 pot is filled. The temperature of the inner part is then reduced to 1.2 degrees by pumping on the helium-4 pot, and condensation of the helium-3/helium-4 mixture begins. Next, helium 3 is circulated in the dilution refrigerator, reducing the temperature even further and causing the phase separation to occur in the mixing chamber. The dilution process then starts operating and the refrigerator reaches its lowest temperature in one to two hours.

Although the dilution refrigerator is still young, it has already proved itself as a research tool in experiments that formerly could not be carried out at very low temperatures. Its main advantages are continuous refrigeration and large cooling power. Once the necessary «know-how» has been mastered it is perhaps easier to build and operate a dilution refrigerator than a cryostat employing magnetic cooling. A clear sign of the success of the dilution principle is that refrigerators of this type are now produced commercially.

*Scientific American*
*December 1969*

### Exercises

**I. Translate into Russian paying attention to the Absolute Participle Construction:**

1. Since electrons eminating from the filament of the residual gas analyzer impinged upon the ion collector of the ionization gauge to the extent of indicating a negative current, the total pressure being measured with the residual gas analyzer.

2. The plane of the surface fixes the plane of the reflected beams and the prism and holder can move around on the surface plate, the reflection always remaining parallel to a given line.

3. The temperature is raised gradually to 1700 degrees C., care being taken that the pressure remains less than $10^{-5}$ Torr.

4. System resolution would seem to fall into two categories, energy and image resolution linked by the common problem of background noise.

5. The matter and antimatter annihilating each other, a system can't exist half matter and half antimatter.

6. The levels of energy being different, the atom can emit electromagnetic waves.

7. The electron possessing large energy, it is free to move in crystal lattice.

8. Positions of neighbor atom being correlated with the positions of considering atom, the theoretical treatment of solid helium is very complicated.

9. The moderate pressure being applied, large change in the lattice happens.

10. The liquid helium being subjected to a pressure of about 25 atmospheres, the solid helium is obtained.

## II. Translate into English using the active vocabulary of the lesson:

1. Измерительные приборы, созданные на советских заводах, с успехом применяются как в Советском Союзе, так и во многих зарубежных странах.

2. При 8° K. жидкая смесь двух изотопов гелия разделяется на две компоненты: одна из фаз богата гелием-3, другая — гелием-4.

3. Вопросы первостепенной важности не могут решаться в такое короткое время.

4. Фаза, содержащая только 6,4% атомов гелия-3, соответствует парообразной фазе в испаряющем холодильнике.

5. Количество атомов гелия-3, которые пересекают фазовую границу за единицу времени, в последнем случае не зависит от температуры.

6. Система охлаждения должна быть заполнена водой до включения двигателя.

7. При дальнейшем снижении температуры в камере происходит разделение смеси на две фазы.

8. Новый тип холодильника позволяет проводить эксперименты, которые до этого времени считались невозможными или во всяком случае трудновыполнимыми.

9. Советские студенты должны постоянно совершенствовать свои знания.



## III. Translate at sight:

Before discussing the principle and the experimental arrangements for nuclear cooling the scientist briefly digresses from the main topic to explain how a superconducting heat switch works. These devices, important in many low-temperature cryostats, are based on two observed facts: First, a metal (such as lead, tin or zinc) that becomes a superconductor of electricity at low temperatures is much poorer conductor of heat in the superconducting state than it is in the normal state. Second, superconductivity can be destroyed by a modest magnetic field, thereby returning the metal to its normal state even though it is at a low temperature. A superconducting heat switch is made by placing a suitable conductor (for example a tin wire) inside a small coil. When a sufficiently high electric current flows in the coil, the magnetic field produced inside it is high enough to destroy superconductivity in the tin wire; heat flows and the switch is thus in its «on» position. By cutting the current off the switch is turned into its superconducting or «off» position.

## IV. Give the situations from the text in which the following words are used:

spontaneously, solubility, evaporation, to cross, to be cooled, to cause, mixing, tool, to operate, to be produced.

## V. Develop further the following statements:

1. The first successful machines of this type ...
2. Below about .8 degree K. a liquid mixture of ...
3. The 6.4 percent solubility ...
4. The concentrated phase in the dilution refrigerator, ...
5. Thus the number of helium-3 atoms that cross ...
6. After the cryostat has been cooled, ...
7. Next, helium 3 is circulated in the dilution refrigerator, ...
8. Although the dilution refrigerator is still young, ...
9. Once the necessary «know-how» ...
10. A clear sign of the success of the dilution refrigerator ...

## VI. Translate the following Russian questions into English and answer them:

1. Ниже какой температуры смесь двух изотопов гелия разделяется на две компоненты?

2. Что имеет первостепенное значение для успешной работы холодильника, о котором говорится в статье?

3. Какой фазе в испаряющем холодильнике соответствует разбавленная фаза в установке, которая была описана в статье, и за-

висит ли от температуры в последнем случае число атомов гелия-3, проходящих через фазовую границу в единицу времени?

4. В чем состоит основное отличие тепловых свойств гелия-3 и гелия-4 при низких температурах?

5. Для каких целей были созданы новые типы холодильников?

6. Могли ли прежде проводиться эксперименты при низких температурах?

7. Каким важным секретом овладели создатели установок нового типа?

8. Какими причинами объясняется широкое производство холодильных установок, при помощи которых можно добиться низких температур?

9. Что является причиной разового разделения в смешивающей камере?

10. Какое вещество используется обычно для заполнения рабочей камеры холодильной установки?

### VII. Render in English:

Особенно существенной для успешного применения эффекта Померанчука является начальная низкая температура. Использование гелия-4 для передачи давления также дает некоторые практические преимущества. Аппарат может быть сделан относительно простым и эффектов частичного нагревания можно будет избежать. Гелий-4 имеет, как это было отмечено выше, незначительную теплоемкость при интересующих нас температурах и, таким образом, все тепловые эффекты, благодаря более теплой жидкости, перемещающейся в камеру с гелием-4, отсутствуют. Есть, конечно, альтернативные методы для сжатия камеры с гелием-3; например, различные виды механических приборов могут быть использованы очень широко. Эти приборы вызовут, очевидно, некоторое нагревание, и поэтому требуются еще более сложные приборы, движущие части которых должны быть снаружи самой холодной части криостата. Сейчас слишком рано предсказывать, какое влияние будет иметь метод Померанчука на низкотемпературные охлаждения. Ясно, что пока еще требуется тщательное изучение его (метода) потенциальных возможностей, но этот метод может стать очень эффективным в интервале $(2 \div 10) \cdot 10^{-3}$.

### VIII. Answer the following questions:

1. What is the main principle of cryostats of the new type?.

2. What is the operation of the dilution refrigerator based on?

3. What is of paramount importance for the success of the dilution refrigerator?

4. What is the difference between the thermal properties of liquid helium 3 and liquid helium 4?



5. How can you describe the concentrated phase in the dilution refrigerator?

6. What is the difference between the vapor phase of an ordinary evaporation refrigerator and that of a dilution refrigerator?

7. How does the operation of a dilution refrigerator proceed?

8. How long does it take the dilution refrigerator to reach its lowest temperature?

9. In what respect has the dilution refrigerator already proved itself?

10. What is the contribution of the Soviet scientists in this particular field?

### IX. Review the article «New Methods for Approaching Absolute Zero».

### X. Write an annotation on the article.

### XI. Speak on the following topics:

1. Principles of the dilution refrigerator.

2. Why is the 6.4 percent solubility of helium 3 in helium 4 of importance for the success of the dilution refrigerator.

3. Nuclear cooling.

4. Superconducting heat switch.

5. The possible lowest temperature we can reach.

# LESSON THIRTY-THREE

## Active Vocabulary

### spot, *n.*

1. Spot is a particular place or region; a mark, stain or blot.
2. The scanning electron microscope employs a flying spot of electrons to scan the object, producing a television-like image.

*Synonym:* place.

### convert, *v.*

1. To convert is to change from one state, use or purpose into another, as to convert water into steam.
2. This information can be converted into «effective» resolution capable of revealing where individual heavy atoms are located.

*Derivative:* convertible.

### depict, *v.*

1. To depict is to make a picture of; to describe carefully in words.
2. The instrument has been pushed close to the theoretical limit of its resolving power, which falls just short of the power needed to depict individual atoms.

*Synonym:* to describe.

### extract, *v.*

1. To extract is to pull or get out (with effort); to get; to obtain.
2. The goal of seeing individual atoms with an electron microscope has been achieved with an instrument that extracts a maximum of information from the electrons after they strike their target.

*Derivative:* extraction.



### govern, *v.*

1. To govern is to control or direct; to decide; to determine; to influence.
2. The resolution of the image is governed by the size of the focused spot of electrons.

*Derivative:* government.
*Synonyms:* to rule; to regulate.

### resolve, *v.*

1. To resolve is to decide; to determine; to make up one's mind; to explain; to remove (doubt or difficulty).
2. He resolved that nothing should hold him back.
3. He resolved (up)on making an early start.

*Derivative:* resolution.

4. Although the resolution of the transmission electron microscope was a dramatic improvement over the resolution of the light microscope, it did not quite reach the values its developers had hoped for.

*Synonyms:* to decide; to determine.

### revive, *v.*

1. To revive is to return to a state of consciousness or to one's former normal state; to come into use again.
2. Flowers revive in water.
3. In 1948 the concept of the scanning instrument was revived.

*Derivative:* revival.
*Synonym:* to renew.

### startle, *v.*

1. To startle is to surprise; to frighten.
2. The resulting image can depict topographic features with a brilliance and clarity that is often startling.

### conventional, *adj.*

1. Conventional is according to accepted rules or traditions; not new or original; not showing imagination.
2. The transmission electron microscope is analogous to a conventional light microscope.

*Derivative:* convention.

3. Convention is a custom, practice or usage that has been established by general consent.

*Synonyms:* common; usual; ordinary.
*Antonyms:* uncommon; unusual.

**magnificent,** ***adj.***

1. Magnificent is very splendid, grand or stately; excellent, as a magnificent house.

2. The transmission instrument has been under development for nearly 40 years, and the magnificent images it produces are familiar to all technical workers.

*Derivative:* magnificence.
*Synonym:* excellent.
*Antonym:* bad.

## Exercises

### 1. Give the English for:

a) пятно; превращать, переделывать; изображать; извлекать; управлять, регулировать; разрешать; возрождать; удивлять; обычный; прекрасный, великолепный;

b) показать отдельные атомы; получать максимум информации; разрешающая способность электронного микроскопа; возродить идею; удивительные результаты; обычный микроскоп; замечательное изображение.

### 2. Give the Russian for:

to extract a maximum of information; conventional light microscope; magnificent images; resolving power; the resolution of the transmission electron microscope; to revive a concept; to depict topographic features.

### 3. Give derivatives of the following words:

to convert; to extract; to govern; to resolve; to revive; convention; magnificence.

### 4. Give synonyms of the following words:

a place; to describe; to rule; to decide; to renew; common; excellent.

### 5. Read the following words:

| | |
|---|---|
| to depict [di'pikt] | to govern ['gʌvən] |
| to extract [iks'trækt] | government ['gʌvnmənt] |
| extraction [iks'trækʃən] | electron [i'lektrən] |



| | |
|---|---|
| microscope ['maikrəskoup] | revival [ri'vaivəl] |
| startle ['sta:tl] | convention [kən'venʃən] |
| to resolve [ri'zɔlv] | conventional [kən'venʃənəl] |
| resolution [,rezə'lu:ʃən] | magnificent [mæg'nifisnt] |
| to convert [kən'və:t] | individual [,indi'vidjuəl] |
| convertible [kən'və:təbl] | target ['ta:git] |
| to revive [ri'vaiv] | biological [,baiə'lɔdʒikəl] |

## A HIGH-RESOLUTION SCANNING ELECTRON MICROSCOPE

*The goal of seeing individual atoms with an electron microscope has been achieved with an instrument that extracts a maximum of information from the electrons after they strike their target.*

by Albert V. Crewe

Two different types of electron microscope are currently in use. The transmission electron microscope is analogous to a conventional light microscope. The scanning electron microscope employs a flying spot of electrons to scan the object, producing a television-like image. The transmission instrument has been under development for nearly 40 years, the magnificent images it produces being familiar to all technical workers. The instrument has been pushed close to the theoretical limit of its resolving power, which falls just short of the power needed to depict individual atoms.

The scanning electron microscope, on the other hand, is under active development, its potentials still being explored. Although its resolving power cannot exceed that of the transmission instrument, it can be used in such a way as to provide more information about the specimen under its scanning beam, and that information can be converted into «effective» resolution capable of revealing where individual heavy atoms are located. With our experimental scanning electron microscope we have been able to identify the location of uranium atoms in specially synthesized compounds. With further development it should be possible to see uranium and other heavy atoms used as «stains» to reveal the microstructure of a wide variety of biological materials.

The resolving power of any microscope has a fundamental limit that is approximately equal to the wavelength of the radiation employed. The wavelength of visible light is about half a micron, which is about 5,000 times the diameter of most atoms and 10 to 20 times the diameter of the smallest viruses and many structures of interest in the living cell. If one could build a useful X-ray microscope, one could improve on the resolving power of a light microscope by a factor of at least 10 and possibly as much as 100, but unfortunately no one has yet found a way to construct genuinely satisfactory lenses and other optical components for wavelengths in the X-ray region.

The confirmation of the wave nature of the electron in 1927 stimulated thinking about a microscope with a resolving power far beyond that conceivable even with X rays. The transmission electron microscope was invented five years later in Germany by M. Knoll and Ernst Ruska. In their instrument a beam of electrons illuminates the specimen to be studied; the electrons that are transmitted through the specimen are focused by magnetic lenses on a fluorescent screen. By placing a photographic plate in the focal plane a permanent record, or electron micrograph, can be produced.

Although the resolution of the transmission electron microscope was a dramatic improvement over the resolution of the light microscope, it did not quite reach the values its developers had hoped for. Electrons with an energy of a few thousand volts have a wavelength comparable to the diameter of an atom: about one angstrom, or a ten-thousandth of a micron. It was soon recognized, however, that the theoretical limit of resolution is considerably larger than the wavelength of the electron, for the reason that electron lenses do not work quite as well as light lenses. This is not a matter of technology but rather is a fundamental limitation established by the character of the electric and magnetic fields that nature allows us to form. Because of this inherent limitation the best resolution that can be obtained with a transmission electron microscope is about 50 times the wavelength of the electron. Therefore an electron the theoretical limit of resolution is considerably larger than the wavelength of .04 angstrom, can under ideal circumstances achieve a resolving power of about two angstroms.

A scanning electron microscope was first proposed in 1938 by Knoll and a year later by Manfred von Ardenne. Their proposals were not immediately pursued, perhaps because of the success of the transmission electron microscope and perhaps also because the necessary technology was not quite available. In 1948 the concept of the scanning instrument was revived by C. W. Oatley, and the first models reached the market some 10 years later.

In the scanning electron microscope a beam of electrons is brought to a fine focus and is scanned across the specimen in a raster pattern similar to the one used in producing a television image. Electrons leaving the specimen (not necessarily the same electrons that strike it) can be collected and used to modulate the beam of a cathode ray picture tube. The resolution of the image is governed by the size of the focused spot of electrons. Depending on the source and character of the electrons selected for display, the image can take several forms. Most scanning electron microscopes are designed primarily to collect and display the secondary electrons emitted from the surface of a solid specimen when it is struck by the primary electrons in the flying spot. The resulting image can depict topographic features with a brilliance and clarity that is often startling.

*(to be continued)*



## Exercises

### I. Translate into Russian paying attention to the Absolute Participle Construction:

1. All told, some 70 elements are classified as metals.
2. In many metals, however, this is quite wrong, the mean free paths estimated from their resistivities being much longer.
3. Once the necessary «know-how» having been mastered it is perhaps easier to build and operate a dilution refrigerator than a cryostat employing magnetic cooling.
4. One must say «on the average» because even at very low temperature the atoms in a solid vibrate around their lattice sites, their excursions becoming progressively larger as the temperature rises.
5. In forming holograms two sets of waves are involved, the reference wave (usually a simple plane wave) and the rather complicated set of waves issuing from the scene.
6. While the film is in the fixing bath, it is exposed to high-intensity sound, the regions of high sound intensity speeding up the fixing process.
7. It is characteristic of the purity of the system that this sublimated deposit is also colourless and transparent, in all earlier work such deposits having shown a green colour due to incorporation of nitrogen, even when more or less colourless crystals were obtained in the growth cavity.
8. The pressure being about $10^{-5}$ Torr pumping is stopped.

### II. Translate into English using the active vocabulary of the lesson:

1. Чтобы различить объект, сканирующий электронный микроскоп использует летящие сгустки электронов.
2. Прекрасные изображения мельчайших структур получают с помощью сканирующего электронного микроскопа высокой разрешающей силы.
3. Изображения, полученные с помощью сканирующего электронного микроскопа, поражают своей яркостью и чистотой.
4. Электронные потоки в микроскопе управляются магнитными полями.
5. Традиционный световой микроскоп по своей конструкции намного проще любого электронного микроскопа.
6. Отработанные электроны удаляются из окрестностей экрана на анод.
7. В 1948 году идея сканирующего микроскопа была возрождена.
8. Картина этой структуры очень хорошо изображается сканирующим электронным микроскопом.

## III. Catch the meaning of the text and retell it:

The solution to the problem of obtaining a very bright electron source is provided by the phenomenon known as field emission. The technique for exploiting field emission consists in applying a negative voltage to a very sharp metal point. The negative field drives electrons away from the point in great numbers. A tungsten point about 1,000 angstroms in diameter will emit a stream of electrons carrying up to one milliampere of current. In our laboratory, however, we work with a total emitted current of only five to 10 microamperes. The resolution attainable with these field-emission sources is much better than the tip diameter of 1,000 angstroms suggests.

The electrons all leave the surface of the tungsten with nearly the same velocity because they vary in energy by no more than about .2 volt. As a result they will follow electric lines of force with great precision; the lines of force in turn can be made almost exactly radial. The electrons therefore appear to originate from a tiny sphere located within the 1,000-angstrom point of the emitter. Calculations indicate that the apparent diameter of the source is only about 30 angstroms. Such an electron source is bright enough for a scanning microscope of the highest conceivable resolution.

## IV. Give the situations from the text in which the following words are used:

spot; to convert; to depict; to extract; to govern; to resolve; to revive; to startle; conventional; magnificent.

## V. Develop further the following statements:

1. The goal of seeing individual atoms with an electron microscope has been achieved with an instrument that ...
2. The transmission electron microscope is analogous to ...
3. The instrument has been pushed close to the theoretical limit of its resolving power, which falls just short of the power needed to...
4. In 1948 the concept of the scanning instrument was ...
5. The resolution of the image is governed by ...
6. The resulting image can depict topographic features with a brilliance and clarity that ...

## VI. Translate the following Russian questions into English and answer them:

1. Какова основная характеристика любого микроскопа?
2. Каково основное отличие в принципе работы сканирующего и обычного электронного микроскопа?
3. Почему идея сканирующего микроскопа была возрождена?
4. Что удивляет нас в сканирующем микроскопе?
5. Для чего используют магнитные поля в электронных микроскопах?
6. Почему удаляют электроны из окрестности экрана?
7. Какие элементы в электронном микроскопе являются традиционными?
8. Почему сканирующий микроскоп не может выявить структуру атома?

## VII. Render in English:

Электронный микроскоп — прибор для получения с очень большим увеличением изображений микрообъектов, в котором в отличие от светового микроскопа вместо световых лучей пользуются пучками быстролетящих в вакууме электронов, ускоренных электрическим напряжением в несколько десятков (а иногда и сотен) тысяч вольт, а вместо стеклянных линз — электронными линзами. Принципиально разрешение электронным микроскопом могло бы превосходить разрешение светового микроскопа в сотни тысяч раз, так как длины волн де Бройля для электронов при вышеупомянутых ускоряющих напряжениях примерно в сотни тысяч раз короче, чем световые волны. Однако в электронных микроскопах разрешение определяется не только явлениями дифракции, но и различными (почти не корригируемыми) аберрациями электронных линз, которые (за исключением приосевого астигматизма) исправляются главным образом диафрагмированием и применением электронных пучков малых апертур. Поэтому разрешение лучшего современного электронного микроскопа просвечивающего типа, достигающее 4,5—5 Å, всего в несколько сот раз превосходит разрешение лучшего светового микроскопа (2000—2500 Å).

## VIII. Answer the following questions:

1. What does the scanning electron microscope employ?
2. What kind of images does the transmission instrument produce?
3. What is a fundamental limit of the resolving power of any microscope equal to?
4. How could the resolving power of a light microscope be improved?
5. When was the transmission electron microscope invented?
6. Why is the theoretical limit of resolution considerably larger than the wavelength of the electron?
7. What is the best resolution that can be obtained with a transmission electron microscope?
8. Why was a scanning electron microscope not a success when it was first proposed?

## IX. Speak on the following topics:

1. From visible light to the electron beam.
2. The transmission electron microscope.
3. The scanning electron microscope.

# LESSON THIRTY-FOUR

## Active Vocabulary

### clue, *n.*

1. Clue is something that helps to solve a problem or a mystery.
2. Energetic electrons can be sorted and used as clues to the composition of the specimen.

*Synonym:* key.

### damage, *n.*

1. Damage is harm or injury that makes something less useful or less valuable.
2. Storms sometimes cause great damage.

*Synonyms:* injury; loss.

### damage, *v.*

1. To damage is to make less useful or valuable; to hurt or spoil.
2. Several valuable pictures were damaged by fire.
3. A serious problem of electron microscopy is that the electron beam can damage the specimen.

*Antonym:* to improve.

### essence, *n.*

1. Essence is that which makes a thing what it is; the true inner nature of a thing.
2. The essence of morality is right intention.

*Derivatives:* essential, essentially.

3. Essential is necessary; required; that must be present.
4. Exercise and fresh air are essential to the preservation of health.



5. One can show, however, that when the scanning microscope uses transmitted electrons to modulate the intensity of the display tube, the two instruments are essentially identical.

### filament, *n.*

1. Filament is a very fine thread (e. g. as in an electric lamp bulb).
2. To improve the resolving power of the scanning microscope to equal the resolving power of the transmission microscope one must therefore find an electron source roughly a million times brighter than the hot tungsten filament that is normally used.

### specimen, *n.*

1. Specimen is a part of something, or one of a group, taken as an example of the whole.
2. If one second is required to produce a satisfactory exposure, each resolvable element in the specimen has been illuminated for that time.

### assign, *v.*

1. To assign is to give (a person) for his use or enjoyment, or as his share of work or duty; to choose a person (for a task or a duty); to name or to fix.
2. Your teacher assigns you work to do at home.
3. Two students were assigned to translate the article.
4. In principle it is possible to collect every electron from the specimen and to assign each electron to a particular group according to the kind of interaction it has experienced.

*Derivative:* assignment.

### blur, *v.*

1. To blur is to make confused in shape or appearance.
2. Tears blurred her eyes (=made it difficult for her to see clearly).
3. For example, the less energetic electrons, which only blur the image in the transmission microscope, can be sorted and used as clues to the composition of the specimen.

### emerge, *v.*

1. To emerge is to come out; to come into view; to become known (as the result of enquiry); to appear.
2. No new ideas emerged during his speech.
3. In the transmission microscope all the electrons that emerge

in a certain conical volume are simply collected and passed through a magnetic lens to form an image on the screen.

*Derivatives:* emergence, emergency.

*Synonyms:* to appear; to occur.

*Antonyms:* to disappear; to vanish.

**restrict, *v.***

1. To restrict is to limit; to keep within a certain size, scope, etc.

2. The relatively low intensity of the available sources restricts commercial scanning microscopes to a resolving power of about 100 angstroms, and even at this resolution 100 or more seconds may be needed to form a complete image.

*Derivatives:* restriction, restrictive.

*Synonym:* to limit.

**worth, *predic. adj.***

1. Worth is having a certain value or price; deserving of; giving a satisfactory return for.

2. The book is well worth reading.

3. We worked hard but it was worth it.

4. We may ask whether such an effort is worth-while if the two kinds of microscope are indeed fundamentally identical.

*Derivatives:* worthy, worthless.

## Exercises

### 1. Give the English for:

a) ключ (к разгадке чего-либо); ущерб; сущность, существо; нить накала; образец; приписывать; сделать неясным, затуманивать, затемнять; возникать, появляться; ограничивать; стóящий;

b) ключ к разгадке структуры образца; повреждать образец; вольфрамовая нить; приписать каждый электрон к какой-то определенной группе; сделать изображение неясным; быть в основном одинаковыми.

### 2. Give the Russian for:

to be essentially identical; each resolvable element in the specimen; roughly a million times brighter; a tungsten filament; to blur the image; to assign each electron to a particular group; clues to the composition of the specimen; to damage the specimen.



### 3. Give derivatives of the following words:

to assign; to emerge; to restrict, essence; worth.

### 4. Give synonyms of the following words:

key; loss; to appear; to limit; necessary.

### 5. Read the following words:

clue [klu:]
damage ['dæmidʒ]
to blur [blə:]
specimen ['spesimən]
to assign [ə'sain]
assignment [ə'sainmənt]
to emerge [i'mə:dʒ]
emergency [i'mə:dʒənsi]
worth [wə:θ]
worthy ['wə:ði]
worthless ['wə:θlis]
filament ['filəmənt]
to restrict [ris'trikt]
restrictive [ris'triktiv]
essential [i'senʃəl]
essentially [i'senʃəli]
to transmit [træns'mit]
transmission [træns'miʃən]
apparent [ə'pærənt]
unfortunately [ʌn'fɔ:tʃnitli]

## A HIGH-RESOLUTION SCANNING ELECTRON MICROSCOPE

by Albert V. Crewe

(continued)

These two types of microscope seem at first to be very different from each other. One can show, however, that when the scanning microscope uses transmitted electrons to modulate the intensity of the display tube, the two instruments are essentially identical. The identity becomes clear if one arranges the geometries of the two instruments so that the point source of the beam in the scanning microscope is regarded as being equivalent to the image of a point on the fluorescent screen of the transmission electron microscope (see the illustration). The action of the scanning coils is then seen to be equivalent to moving the location of the apparent electron source.

One might therefore suppose it would be a simple matter to build a scanning microscope with the same resolving power as a transmission electron microscope. Unfortunately the kind of electron source needed in the scanning microscope is quite different from the source in the transmission microscope, and it introduces special limitations on resolving power. The transmission microscope produces an image of all the illuminated points at the same time. Thus if one second is required to produce a satisfactory exposure, each resolvable element in the specimen has been illuminated for that time. The scanning microscope, on the other hand, illuminates each element for only a small fraction of the total exposure time, for only a millionth of a second if the raster pattern is to contain a million distinguishable elements. In this case the intensity of the electron beam would have to be a million times greater than it is in a transmission microscope in order to achieve the same resolution. The relatively low intensity of the available sources restricts commercial scanning microscopes to a resolving power of about 100 angstroms, and even at this resolution 100 or more seconds may be needed to form a complete image. To improve the resolving power of the scanning microscope to equal the resolving power of the transmission microscope one must therefore find an electron source roughly a million times brighter than the hot tungsten filament that is normally used.

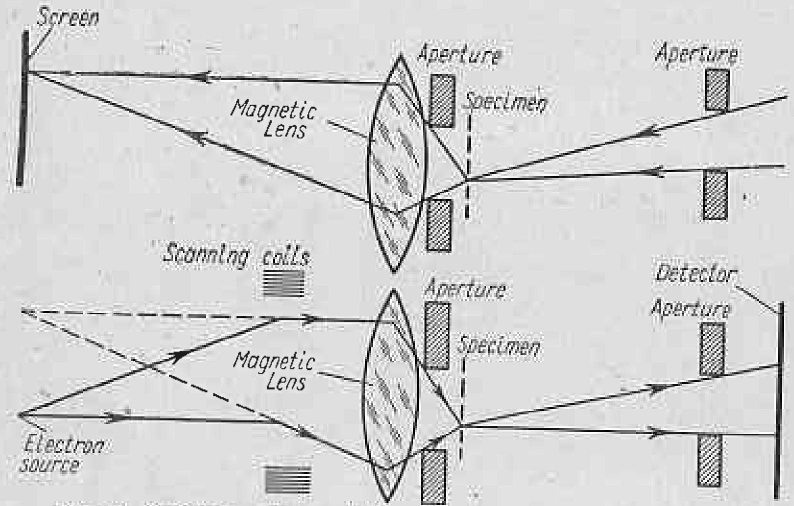


Fig. 3. *Similarity of two kinds of microscope* is clarified by rearranging them in this fashion. In the transmission electron microscope (top) the electrons are shown originating at the right and traveling to the left. In the scanning electron microscope (bottom) the electrons travel in the opposite direction. In terms of electron optics it makes no difference which way the electrons pass through a specimen or through a magnetic field. The rearrangement emphasizes that the role of the scanning coils in the scanning microscope is to shift the apparent source of the electrons. In both instruments the efficiency of the magnetic lens sets the ultimate limit on resolving power. With electrons of 100,000 volts the ultimate resolving power of each instrument is about two angstroms.

At this point the reader might justifiably ask whether such an effort is worth-while if the two kinds of microscope are indeed fundamentally identical. What would be gained by improving the resolution of the scanning microscope to equal the resolution of transmission instruments? To understand the answer to this question it is necessary to consider more closely the way the two instruments



produce their images. In the transmission electron microscope the electron beam is modified in various ways as it passes through thicker and thinner sections of the specimen. The electrons also lose energy in characteristic ways according to the atomic composition of the material. Indeed, such information can be used to identify the material. In the transmission microscope all the electrons that emerge in a certain conical volume are simply collected and passed through a magnetic lens to form an image on the screen. Electrons that have lost energy, however, are bent more strongly than full-energy electrons; hence they come to focus at a slightly different point and blur the image.

In the scanning microscope the electrons are magnetically focused before they ever reach the specimen. The entire region around the specimen is thus available for any kind of electron-detecting device one can conceive. In principle it is possible to collect every electron as it emerges from the specimen and to assign each electron to a particular group according to the kind of interaction it has experienced. Without detracting in any way from the resolution of the microscope the collecting and sorting procedure can significantly increase the amount of quantitative information that can be extracted from the specimen. For example, the less energetic electrons, which only blur the image in the transmission microscope, can be sorted and used as clues to the composition of the specimen.

A serious problem of electron microscopy is that the electron beam can damage the specimen. The microscopist is always aware that his micrograph may be revealing not the specimen itself but only its charred remains. Although much has yet to be learned about the problem, it is clear that in this regard the scanning microscope should be an improvement on the transmission instrument because it makes every electron that leaves the specimen available as a potential source of information. This is the most one can ask of any observing instrument.

*(to be continued)*

## Exercises

**I. Translate into Russian paying attention to the clauses joined asyndetically:**

1. To understand the answer to this question it is necessary to consider more closely the way the two instruments produce their images.

2. In principle it is possible to collect every electron as it emerges from the specimen and to assign each electron to a particular group according to the kind of interaction it has experienced.

3. This is the most one can ask of any observing instrument.

4. The transmission instrument has been under development for nearly 40 years, and the magnificent images it produces are familiar to all technical workers.

5. One of the central problems we are faced with now is to estimate the nature of the forces between two positively charged ions in the presence of a high density of macroscopically uniform conduction electrons.

6. They retain that magnetism, thus serving as permanent magnetic memories (much like the magnetic memory elements of a computer) of the direction of the earth's field in the place and at the time they solidified.

7. In other words, the kinetic energy the atom has because of its localization does not exceed the depth of the potential well.

### II. Translate into English using the active vocabulary of the lesson:

1. Можно показать, что когда сканирующий микроскоп использует передаваемые электроны для модуляции интенсивности, то оба прибора являются существенно идентичными.

2. Каждый разрешаемый элемент в образце должен освещаться в течение определенного времени.

3. Относительно низкая интенсивность имеющихся в наличии источников ограничивает разрешающую силу сканирующих микроскопов примерно до 100 Å.

4. Если бы удалось найти электронный источник приблизительно в миллион раз ярче, чем горячая вольфрамовая нить, то мы смогли бы увеличить разрешающую силу сканирующего микроскопа.

5. Заслуживающей внимания проблемой является увеличение разрешающей силы сканирующего микроскопа.

6. Все электроны, которые возникают в определенном конусообразном объеме, собираются и проходят через магнитную линзу, образуя изображение на экране.

7. В принципе возможно отнести каждый электрон к отдельной группе согласно виду взаимодействия.

8. Электроны меньших энергий, которые только затемняют изображение, могут быть использованы как ключи к разгадке состава образца.

10. Эти два вида электронных микроскопов существенно отличаются по способу их работы.

### III. Catch the meaning of the text and retell it:

Our objective remained, however, to build a scanning microscope of much higher resolution. Since it is not possible to obtain a probe much smaller than 100 angstroms with the simple system I have described, we saw that we would have to demagnify the image of the probe. This can be done with the aid of an electron lens identical in design with the objective lens in high-resolution transmission electron microscopes. Equations were available for calculating the exact size of the electron probe that would be yielded by any given combination of lens and electron gun.

It turns out that if a lens of very short focal-length is used, the defects of the electron gun are demagnified to the point where they are essentially negligible. In that case the size of the scanning probe is determined entirely by the properties of the magnetic lens. The situation then becomes precisely the same as the one that exists in transmission electron microscopes, where the ultimate resolution is also determined solely by the objective lens. One therefore concludes that a scanning microscope equipped with a field-emission source is capable of matching the resolution of a transmission electron microscope when both are operated at the same voltage and employ the same lens. We have been able to verify this with our microscope: the calculated resolution of the instrument is 4.6 angstroms as compared with a measured resolution of five angstroms at the normal operating voltage of 30,000 volts. This equals the resolution of a transmission instrument operated at the same voltage.

### IV. Give the situations from the text in which the following words are used:

clue; damage; filament; specimen; to assign; to blur; to emerge; to restrict; essentially; worth.

### V. Give questions to which the following statements might be the answer:

1. The two instruments are essentially identical.

2. Each resolvable element in the specimen has been illuminated for that time.

3. To understand the situation it is necessary to consider more closely the way the two instruments produce their images.

4. A serious problem of electron microscopy is that the electron beam can damage the specimen.

5. Two types of electron microscope are currently in use.

6. The scanning electron microscope employs a flying spot of electrons to scan the object, producing a television-like image.

7. The resolving power of any microscope has a fundamental limit that is approximately equal to the wavelength of the radiation employed.

8. The confirmation of the wave nature of the electron stimulated thinking about a microscope with a resolving power far beyond that conceivable even with X ray.

## VI. Translate the following Russian questions into English and answer them:

1. Где находится образец по отношению к магнитной линзе в сканирующем микроскопе?
2. Что ограничивает разрешающую способность сканирующих микроскопов?
3. Почему необходим электронный источник в миллион раз ярче, чем вольфрамовая нить?
4. В каком случае два микроскопа являются существенно идентичными?
5. Какие электроны могут быть использованы как ключи к разгадке структуры образца?
6. Какой вред формированию изображения наносят электроны меньших энергий?
7. Какая проблема возникает при рассмотрении попадания электронного пучка на образец?
8. Что происходит с электронами, которые выходят из образца в случае сканирующего микроскопа?
9. Чем определяются границы разрешающей способности электронных микроскопов?
10. Какое основное достоинство сканирующего микроскопа?

## VII. Render in English:

В просвечивающих электронных микроскопах изображение объекта создается прошедшими через него электронами. Таким электронным микроскопом можно исследовать не только тонкие (несколько сот Å) объекты, но и поверхности массивных объектов. Основные части трехлинзового просвечивающего электронного микроскопа: осветительная система, камера объектов, фокусирующая система, блок регистрации конечного изображения (фотокамера с экраном, покрытым люминофором). Узлы электронного микроскопа вакуумно сочленены друг с другом и образуют колонну микроскопа, внутри которой на всем пути прохождения электронов поддерживается давление $10^{-4}$—$10^{-5}$ *мм* ртутного столба. Для создания высокого ускоряющего напряжения и питания электромагнитных линз применяются электрические питающие устройства высокой стабильности. Осветительная система электронного микроскопа состоит из электронной пушки и одной или двух конденсорных линз; она формирует и фокусирует на объекте электронный пучок необходимой интенсивности, апертуры и сечения.

## VIII. Answer the following questions:

1. Do these two types of microscope seem at first to be very different from each other? Why so?
2. When does the identity of these two types of microscope become clear?
3. Is the kind of electron source needed in the scanning microscope quite the same as the source in the transmission microscope?
4. What kind of image does the transmission microscope produce?
5. What must one do to improve the resolving power of the scanning microscope to equal the resolving power of the transmission microscope?
6. Are these two kinds of microscope indeed fundamentally identical?
7. What would be gained by improving the resolution of the scanning microscope to equal the resolution of transmission instruments?

## IX. Speak on the following topics:

1. The way the two instruments produce their images.
2. The resolving power of the electron microscope.

# LESSON THIRTY-FIVE

## Active Vocabulary

**pattern,** ***n.***

1. Pattern is a person or thing serving as a model; a sample.
2. The detector will then produce a signal proportional to the number of electrons elastically scattered by the specimen at each point in the raster pattern.

*Synonym:* example.

**reciprocity,** ***n.***

1. Reciprocity is the practice of giving and taking, of making mutual concessions; mutual action; the granting of privileges in return for similar privileges.
2. With a little mathematical analysis one can prove a principle of reciprocity, which states that the scanning microscope is capable of reproducing all the phenomena that occur in the transmission microscope.

**ring,** ***n.***

1. Ring is a circular line or mark or formation, as the rings of a tree (showing its age); a ring of light round the moon.
2. The children danced in a ring.
3. Let us consider the electrons that pass through the ring-shaped detector.
4. The verb «to ring» means to encircle; to surround.

*Synonym:* circle.

**bend,** ***v.***

1. To bend is to force something out of a straight line into a different shape; to make or become curved or crooked.



2. The tall man bent forward to listen to the little girl.
3. One can separate the two groups of electrons by passing them through a magnetic spectrometer, an instrument that uses a magnetic or electric field to bend the path of a charged particle into a curve.

*Antonym:* to straighten.

**clarify,** ***v.***

1. To clarify is to make or become clear.
2. To clarify this important point let us imagine a beam of electrons striking a specimen in a scanning microscope and ask how the electrons are distributed in space some distance below the specimen.

*Derivatives:* clear, clarity.

**transfer,** ***v.***

1. To transfer is to remove or carry from one place or person to another; to move from one occupation or place to another.
2. He has transferred from Leningrad to Moscow.

*Derivatives:* transferable, transferability.
*Synonym:* to remove.

**broad,** ***adj.***

1. Broad is wide; large; going a long way in all directions.
2. Electrons that have been elastically scattered fan out over an angle several times broader than the angle formed by electrons that have been inelastically scattered.

*Derivative:* to broaden.
*Antonym:* narrow.

**genuine,** ***adj.***

1. Genuine is real; not false, pretended or imitation, as a genuine picture by Repin.
2. When we operated our high-resolution scanning microscope for the first time, we observed phenomena that convinced us, if we had any remaining doubt, that the fundamental identity of the scanning microscope and the transmission microscope is genuine.

*Synonym:* intrinsic.
*Antonyms:* false; unreal.

**incident,** ***adj.***

1. Incident is likely to occur.
2. Incident is also falling or striking on — used especially of light rays on a plane.

3. In inelastic scattering the incident electron transfers some of its energy to an atom in the specimen and therefore emerges with diminished energy.

**sharp, *adj.***

1. Sharp is with a thin, fine, cutting edge; not blunt, as a sharp knife; not round; having a point; abrupt, as a sharp bend in the road; well-defined; clear; distinct; not blurred, as a sharp outline.

2. The electrons of lower energy follow a path of sharper radius than the full-strength electrons do.

*Derivative:* sharply.
*Synonyms:* clear; distinct.
*Antonym:* blunt.

## Exercises

### 1. Give the English for:

a) образец, пример; взаимодействие, взаимный обмен; кольцо, круг; сгибать(ся), гнуть(ся); прояснять; переносить, перемещать; широкий; подлинный, истинный; падающий; случайный; острый;

b) принцип взаимного обмена; прояснить ситуацию; перенести часть энергии; падающие электроны.

### 2. Give the Russian for:

genuine identity; to prove a principle of reciprocity; to clarify this important point; an incident electron; an electron-detector in the shape of a ring; to bend the path of a charged particle into a curve; a path of sharper radius; to have any remaining doubt; to divide the emerging electrons into two groups; to provide a simple way of separating the emerging electrons into two general groups.

### 3. Give derivatives of the following words:

reciprocity; to clarify; to transfer; broad; sharp.

### 4. Give synonyms of the following words:

example; circle; to remove; wide; intrinsic; clear; distinct.

### 5. Give antonyms of the following words:

to blur; to clarify; to doubt; to improve; to straighten; to vanish; bad; blunt; false; narrow; unusual; worthless.



### 6. Read the following words:

| | |
|---|---|
| pattern ['pæt(ə)n] | to reciprocate [ri'siprəkeit] |
| to clarify ['klærifai] | reciprocation [ri,siprə'keiʃən] |
| clear [kliə] | reciprocity [,resi'prɔsiti] |
| clarity ['klæriti] | to transfer [træns'fə:] |
| broad [brɔ:d] | transferable [træns'fə:rəbl] |
| to broaden [brɔ:dn] | elastic [i'læstik] |
| genuine ['dʒenjuin] | elastically [i'læstikəli] |
| genuinely ['dʒenjuinli] | diameter [dai'æmitə] |
| identity [ai'dentiti] | spectrometer [spek'trɔmitə] |
| identical [ai'dentikəl] | fluorescent [fluə'resnt] |

## A HIGH-RESOLUTION SCANNING ELECTRON MICROSCOPE

by Albert V. Crewe

(continued)

When we operated our high-resolution scanning microscope for the first time, we observed phenomena that convinced us, had we any remaining doubt, that the fundamental identity of the scanning microscope and the transmission microscope is genuine. For example, as we were scanning a carbon film perforated with small holes, we observed that the holes were producing interference fringes exactly like the fringes produced in a transmission electron microscope. With a little mathematical analysis one can prove a principle of reciprocity, which states that the scanning microscope is capable of reproducing all the phenomena that occur in the transmission microscope.

The reverse, however, may not be true. To clarify this important point let us imagine a beam of electrons striking a specimen in a scanning microscope and ask how the electrons are distributed in space some distance below the specimen. For simplicity we shall divide the emerging electrons into two groups: those that have been «elastically» scattered by the atoms within the specimen and those that have been «inelastically» scattered. In elastic scattering the electron itself loses no energy but is merely altered in direction. In inelastic scattering the incident electron transfers some of its energy to an atom in the specimen and therefore emerges with diminished energy.

Electrons that have been elastically scattered fan out over an angle several times broader than the angle formed by electrons that have been inelastically scattered. This difference provides a simple way of separating the emerging electrons into two general groups. Placed below the specimen is an electron-detector in the shape of a ring. The inner diameter of the ring is chosen so that it passes the narrow cone of inelastically scattered electrons (together with electrons that are not scattered at all); the outer diameter of the ring is made large enough to include virtually all the electrons scattered elastically. The detector will then produce a signal proportional to the number of electrons elastically scattered by the specimen at each point in the raster pattern. This number is proportional to the four-thirds power of Z (the atomic number of the atoms at that point) and to the number of atoms struck by electrons in the beam.

Now let us consider the electrons that pass through the ring-shaped detector. They consist of a mixture of inelastically scattered electrons, which by definition have lost energy, and unscattered electrons of undiminished energy. The scattered electrons will have lost 20 or 30 volts in passing through almost any thin specimen. One can separate the two groups of electrons by passing them through a magnetic spectrometer, an instrument that uses a magnetic or electric field to bend the path of a charged particle into a curve. The electrons of lower energy follow a path of sharper radius than the full-strength electrons do. Suitably placed detectors can then monitor the two populations of electrons. The number of inelastically scattered electrons is proportional to the one-third power of Z and to the number of atoms in the focused spot. With the three detectors described one can obtain simultaneous readings of the number of electrons that are elastically scattered, inelastically scattered and unscattered.

Where would the electrons collected by the three detectors in our microscope appear in a transmission electron microscope? The electrons that pass through the specimen without scattering produce the primary image in a transmission instrument. The electrons that lose energy by inelastic scattering arrive at the fluorescent screen (or photographic plate) out of focus and therefore degrade the image. It is possible to analyze the energy lost by all the electrons that reach the fluorescent screen and thereby to learn something about the composition of the specimen, but the analysis, is difficult and inefficient. The elastically scattered electrons, which are collected by the ring-shaped detector in the scanning microscope, can also be used for contrast in a transmission instrument by equipping it with a conical illumination system. This is «dark field» microscopy. In a transmission microscope with such a system, however, only a few percent of the elastically scattered electrons is it possible to collect. Our simple ring detector can collect upward of 90 percent of all the elastically scattered electrons.

*Scientific American*
*April 1971.*



Exercises

**I. Translate into Russian paying attention to inverted order of words (Inversion):**

1. When we operated our high-resolution scanning microscope for the first time, we observed phenomena that convinced us, had we any remaining doubt, that the fundamental identity of the scanning microscope and the transmission microscope is genuine.
2. Placed below the specimen is an electron-detector in the shape of a ring.
3. In a transmission microscope with such a system, however, only a few percent of the elastically scattered electrons is it possible to collect.
4. Had there been two point sources of light in the original scene, two superimposed zone plates would have been recorded on the photographic plate (the hologram).
5. A hologram, however, always records the wave pattern existing at its plane, and this original wave pattern possesses the intrinsic ability to form the pyramid image as it would have been formed had the opaque sheet been removed.
6. Considered in the next section are the most important reactions of this type.
7. Had there been no earth's gravitation, the satellites would have moved through airless space in a straight line at a uniform speed. It is the gravitation that makes them move round the earth.
8. Hardly ever is light observed directly from its source.
9. Neither are any definite reasons known why it should not be possible to extrapolate the laboratory results in this field to cosmic physics.
10. All atoms of the same chemical element contain the same number of protons in their nuclei. Associated with these protons, however, is a variable number of neutrons, each having almost exactly the same mass as a proton but no electrostatic charge.

**II. Translate into English using the active vocabulary of the lesson:**

1. При наблюдении определенных физических явлений мы убеждаемся в подлинной идентичности сканирующего и просвечивающего электронных микроскопов.
2. Очень важно обсудить эту часть проблемы.
3. При неупругих столкновениях электрон передает часть своей энергии атому образца.
4. Электроны, падающие на образец, рассеиваются под разными углами.

5. В магнитном спектрометре для искривления траектории заряженной частицы используется электрическое или магнитное поле.

6. Электроны низких энергий более резко отклоняются магнитным полем, чем электроны высоких энергий.

7. Электроны, рассеянные упруго на атомах образца, обнаруживаются детектором.

8. Для регистрации рассеянных электронов наиболее удобны кольцевые детекторы.

## III. Translate at sight:

The advantage of the scanning microscope is that all three types of signal can be extracted simultaneously. The signals that carry the most information are those generated by the two types of scattered electron, with the inelastically scattered ones being more abundant for light elements. An obvious way to treat the two signals is to divide the larger signal by the smaller. The ratio is proportional to Z, the atomic number of the atoms in the spot focused on the specimen. Either signal can then be used to calculate the number of atoms in the spot. If there is more than one species of atom within the focused spot, the situation is more complicated, but in any event the two signals allow one to solve for two unknowns. Perhaps the most important conclusion is that unstained biological objects are readily visible even when they are very small and that quantitative measurements can be made enabling one to calculate their average atomic number and their average molecular weight.

## IV. Give the situations from the text in which the following words are used:

pattern; reciprocity; ring; to bend; to clarify; to transfer; broad; genuine; incident; sharp.

## V. Develop further the following statements:

1. The fundamental identity of the scanning microscope and the transmission microscope is ...

2. With a little mathematical analysis one can prove a principle of ...

3. Electrons that have been elastically scattered fan out over an angle several times ...

4. An electron-detector in the shape of ...

5. The detector will then produce a signal proportional to the number of electrons elastically scattered by ...

5. Now let us consider the electrons that pass through ...

6. The electrons of lower energy follow a path of ...



## VI. Translate the following Russian questions into English and answer them:

1. В чем смысл принципа взаимности?

2. Чем обусловлена кольцевая форма детектора рассеянных электронов?

3. Как распределяется энергия между атомом и сталкивающимся с ним электроном?

4. Как действует магнитное поле на траекторию электрона?

5. Каково действие высокоэнергетических электронов на образец?

6. Как зависит радиус кривизны траектории электрона от его энергии?

7. Можете ли вы сравнить спектральное распределение при упругих и неупругих соударениях?

8. Говорят, что непосредственной проблемой, которая привела Габора к открытию голографии, явилось усовершенствование электронного микроскопа. Правда ли это?

9. Основная трудность, которая мешала Габору получить хорошее изображение, заключалась во взаимных помехах, которые возникали на стадии восстановления изображения из-за одновременного появления мнимого и действительного изображений, не так ли?

## VII. Render in English:

Электронные пучки сканируют поверхность экранов трубок синхронно с электронным зондом, сканирующим поверхность исследуемого образца. Образование изображений на экранах трубок происходит вследствие того, что интенсивность электронных пучков модулируется усиленными сигналами соответствующих излучений. Например, характеристическое рентгеновское излучение выделяется из общего потока специальным рентгеновским кристаллическим спектрометром. По выходе из последнего оно улавливается счетчиком Гейгера и преобразуется в электрический сигнал. После усиления этот сигнал модулирует яркость электронного луча, сканирующего экран электронно-лучевой трубки, предназначенной для воспроизведения изображений в рентгеновских лучах. Изображения, полученные на экранах трубок, несут в себе информацию о самых разнообразных свойствах исследуемой поверхности.

## VIII. Answer the following questions:

1. What did the scientists observe when they operated their high-resolution scanning microscope for the first time?

2. How can a principle of reciprocity be proved? What does it state?

3. Why is it so difficult to build the scanning microscope with the resolving power equal to that of the transmission microscope?
4. Why did the scientists divide the emerging electrons into two groups? What are they?
5. What is the difference between elastic scattering and inelastic scattering?
6. What do the electrons that pass through the ring-shaped detector consist of?
7. Where would the electrons collected by the three detectors in our microscope appear in a transmission electron microscope?

**IX. Review the article «A High-Resolution Scanning Electron Microscope».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. Serious problems of electron microscopy.
2. Three types of detectors.
3. The fundamental identity of the scanning microscope and the transmission microscope.

# LESSON THIRTY-SIX

## Active Vocabulary

### extent, *n.*

1. Extent means space or degree to which a thing is extended.
2. From the top we were able to see the full extent of the park.
3. I was surprised by the extent of his knowledge.
4. The ministry was prepared to supply money for the plan to the extent of 100,000 roubles.
5. I agree with you to a certain extent.

*Synonyms:* size; length; space; amount; degree.

### staff, *n.*

1. Staff is a group of persons working together.
2. The Moscow State University teaching staff consists of qualified specialists.
3. The staff of our laboratory is working according to the programme.

*Synonym:* personnel.

### wealth, *n.*

1. Wealth is large number or quality; all material objects that have some economic value.
2. Siberia with its wealth of minerals is one of the richest regions of the U.S.S.R.
3. The Tretyakov Gallery is the national wealth of the Soviet Union.

### complete, *v.*

1. To complete means to finish; to bring to an end; to make perfect.

2. I need one more volume to complete my set of «Physics Encyclopedia».

*Derivative:* completion.

*Synonym:* to close.

**cope, *v.***

1. To cope means to overcome problems and difficulties.
2. The Soviet people coped with greatest difficulties after World War II.
3. The police were not able to cope with the demonstration.

**establish, *v.***

1. To establish means to bring into existence; to found.
2. Newton established the law of gravity.
3. The Union of the Soviet Socialist Republics was established in 1922.

*Derivative:* establishment.

**execute, *v.***

1. To execute means to put into effect; to make or produce especially by carrying out a design.
2. The Five-Year plan is being executed by the Soviet people.
3. The device was executed according to the designs of Michelangelo.

**guide, *v.***

1. To guide means to regulate and manage; to direct.
2. In the U. S. A. it is the monopoly capital that guides the state.
3. You must be guided by your sense of what is right and what is wrong.

*Synonym:* to lead.

**bold, *adj.***

1. Bold means ready to do things that may be dangerous; overbrave, clear and easy to see.
2. Soviet scientists worked out a bold plan of exploration the northern regions of our country.
3. A bold decision is half of success.



**huge, *adj.***

1. Huge means very large or extensive; of great size or area.
2. The area of the U.S.S.R. is huge as compared to those of many European countries.
3. Ivan Poddubny was a man of huge physical strength.

*Synonym:* enormous.

## Exercises

### 1. Give the English for:

a) размер, количество, величина, степень; (служебный) персонал, штат; богатство; завершать; справляться; создавать, основывать; руководить, руководствоваться, направлять, вести; дерзкий, смелый; огромный;

b) до некоторой степени; профессорско-преподавательский состав; природные богатства; завершать работу; справиться с поставленной задачей; выполнять программу; руководствоваться собственным опытом.

### 2. Give the Russian for:

necessary extent of knowledge; to a certain extent; teaching staff; mineral wealth; to complete one's work; to cope with difficulties; to execute the programme; to be guided by the experience; bold plans.

### 3. Give derivatives of the following words:

to complete; to establish; to decide; to repulse; to conclude.

### 4. Give synonyms of the following words:

size; personnel; to close; to lead; enormous; amount.

### 5. Read the following words:

project [ˈprɔdʒekt]
talent [ˈtælənt]
genius [ˈdʒiːnjəs]
bold [bould]
staff [staːf]
completion [kəmˈpliːʃən]
recruitment [riˈkruːtmənt]
to establish [isˈtæbliʃ]
establishment [isˈtæbliʃmənt]
guiding [ˈgaidiŋ]

| | |
|---|---|
| huge [hju:dʒ] | to design [di'zain] |
| to execute ['eksikju:t] | integral ['intigrəl] |
| vigour ['vigə] | economic [,i:kə'nɔmik] |
| to complete [kəm'pli:t] | economy [i:'kɔnəmi] |

## AKADEMGORODOK: EASTERN CENTRE FOR WESTERN SCIENCE

*The decision to build a «science city» in the heart of Siberia was taken just ten years ago. Now a further experimental scheme, to bring the results of scientific advance to industry more quickly and efficiently, is about to be started.*

by Robin Clarke

Ten years ago, on June 9, 1957, one of the most far reaching decisions in the history of Soviet science and technology was made in Moscow by the Cabinet of Ministers. It was a decision to turn 15 square kilometres of Siberian forest, some 3300 kilometres east of Moscow, into a thriving new city of advanced science. Today the job is virtually complete. Akademgorodok is one of the Soviet Union's most creative scientific centres with a university, 16 research institutes and a population of nearly 40,000 people including 10 Academicians and 36 corresponding members. It has developed several research projects of unique importance and has pushed through a massive recruitment scheme for spotting mathematical and scientific talent at an age early enough for young people to be brought to the centre and, under intensive training, to be transformed into first class scientists long before they are 30 years old.

Writers searching for words to describe what is certainly one of the seven wonders of the scientific age have called it a «forcing house of scientific genius» and «a powerhouse for the scientific élite». Akademgorodok is certainly both of these but it is also something much dearer to the hearts of the Soviet scientists whose inspiration it was: a bold experiment.

A decision has been taken to build a further centre, some four or five kilometres from Akademgorodok, which will be concerned solely with industrial development; the installations that are now being built there have no real equivalent in other parts of the world, for once again the experiment will involve unique solutions. The nearest English term for these installations is «experimental factories». They will be financed by industry and run by scientists and engineers from Akademgorodok. They will incorporate experimental production lines and the final aim is to use them to provide blue-prints for the industrial products of the future, completely worked out production processes and, in addition, the necessary staff to run the first new industrial processes and to train other engineers to operate them. It is a uniquely Soviet experiment which has been planned with thoroughness and executed with vigour. If it proves as successful as the first Siberian experiment, it might also provide an indication of how better to use Europe's scientific and technological progress to industrial advantage.

The Institute of Nuclear Physics was established at Akademgorodok and the first electron storage rings were built. This was only an experimental model but it proved successful. Bunches of electrons travelling in opposite directions, each with an energy of 160 MeV, were made to collide. The available energy of the resulting collision was equivalent to that produced by a 100 GeV particle beam hitting a stationary target. This huge increase in available energy is due solely to the fact that, if particles are made to collide when moving with equal velocity in opposite directions, the centre of mass of the two particle system is at rest. No energy is used up in moving the centre of mass of the system — as it is with a beam of particles hitting a stationary target — and nearly all the energy is available for the production of the secondary particles which it is the object of the experiment to study.

The average age of the Akademgorodok scientists is less than 30. Even without any special selection processes nearby Novosibirsk University is able to boast a 27 year old Professor of Mathematics, Yuri Ershov, who took his Ph. D. at the age of 26. But one of the guiding principles of this town was that it should provide a centre at which outstanding pupils from Siberia, and from the far eastern and central Asian regions of the Soviet Union, could be trained to their maximum ability as fast as possible.

The selection process begins at the age of 14-15. Tests are printed in the major local newspapers once a year and an average of 10,000 completed replies are received. Roughly half of the respondents are then visited by a team of representatives from Akademgorodok who set a second ability test during visits to about 20 major cities. The winners of this round, usually about 600 in number, are then invited to Akademgorodok for a month's intensive instruction in a number of sciences delivered mainly as lectures by senior members of the Institutes. They are then tested again solely on what they have learned in the previous month. About 200 students are then admitted immediately to the School of Physical Mathematics. It is far too early to assess this programme in any detail but all the indications are that it is providing a nucleus of outstanding young scientists who might otherwise never have reached university. At any rate many of those who specialize in mathematics are able to enter university at second year level as a result of the intensive training at Akademgorodok.

It is this emphasis on the ability of youth to cope with complex science at an early age which gives Akademgorodok much of its character. There is a special boarding school also designed for intensive training and the local café called «Under the integral sign».

Membership was open only to those who could perform integration until it was realized that this rule excluded too many girls.

The output of Akademgorodok should be, perhaps for the first time in the history of technology, a flow of new and advanced technical ideas for use by industry from which all technical and economic problems have already been removed. It is an utterly logical step and one which could no doubt be adopted in various forms in other countries of different political persuasions.

*Science*
*August 1967.*

## Exercises

### I. Translate into Russian paying attention to inverted order of words (Inversion):

1. Again it has been the size of Akademgorodok which has enabled this work to proceed so swiftly — in few other places could the combined effort of mathematicians, computer specialists, chemists, thermodynamicists and other scientists be called upon to operate together.
2. So great is the energy of these degenerate electrons that they are only slightly effected by the Coulomb forces of the nuclei.
3. Filling the shell is liquid helium 3 near absolute zero.
4. And thus might the sun and all fixed stars be formed, supposing the matter were of a lucid nature.
5. Of equal significance was the emergence, in Thales' monist theory of matter, of the yearning for simplicity that has been the hallmark of the scientific investigator ever since.
6. Each of the systems generated from these principles must be self-consistent; in neither of them can two contradictory propositions coexist, because they would reciprocally destroy themselves.
7. In the passage just quoted from «Ethica ad Eudemum» appears the singular image of quadrangle the sum of whose angles attains the maximum possible value of eight right angles.
8. Even more baffling is the discovery that some quasars emit as much radiation as 1,000 galaxies, the energy apparently coming from a colossal explosive event in a region less than 1 percent the size of the solar system.
9. Yet although Hartsoecker made a real attempt to relate the shape of the atoms to properties of materials such as melting point or susceptibility to corrosion, could not his theory — and others like it — lead anywhere.



10. The annihilation technique is important because photons have no charge and cannot be energy analyzed by magnetic or electric fields.

### II. Translate into English using the active vocabulary of the lesson:

1. Окружающих всегда удивляла степень осведомленности И. В. Курчатова по самым разнообразным вопросам.
2. В докладе было отмечено, что сотрудники кафедры физики моря и вод суши хорошо подготовили экспедиционную аппаратуру.
3. Государственный Эрмитаж — национальное богатство и гордость советских людей.
4. Диссертация этого аспиранта должна быть завершена к середине апреля.
5. Преподаватели факультета надеются, что их выпускники успешно справятся с любыми трудностями, которые могут возникнуть в процессе работы.
6. В 1972 году весь советский народ отмечал 50-летие Союза Советских Социалистических Республик, который был основан в 1922 году.
7. На территории Сибири располагаются огромные запасы нефти, газа и других полезных ископаемых.
8. При решении подобных вопросов нельзя руководствоваться только собственным мнением.
9. В нашей стране самые смелые мечты претворяются в жизнь.
10. Работа была выполнена в исключительно сложных условиях.

### III. Catch the meaning of the text and retell it:

At this time it was realized that if a regional centre of science was going to be set up it would have to reach a certain critical size. If it were too small a sense of isolation would prevail; if it were too large, communications might be difficult, the stimulating environment might be lost, and the centre might become indistinguishable from any other city. From the beginning, Akademgorodok was planned as a town of a specific size and, now that it is completed, it will not be further enlarged.

Once the decision was made, the work was carried out more quickly than is possible in most places with a more favourable climate. The environment was far from ideal for this region of Siberia has an eight month long winter during which the temperature frequently falls well below —25°C. Steaming hot concrete, with added antifreeze, was used throughout the winter building. As well as the scientific institutes, a shopping centre, a hotel and new roads all had to be built. As if this was not enough, the planners added an artificial sea 120 km long by 40 km wide to act as a combined pleasure centre and source of hydroelectric power. In less than ten years the town was functioning as it had been planned and was already becoming known as an international research centre.

## IV. Give the situations from the text in which the following words are used:

creative, inspiration, blue-prints, thoroughness, storage, at rest, ability, Asian, to be invited to, output, step.

## V. Give questions to which the following statements might be the answer:

1. Akademgorodok is one of the Soviet Union's most creative centres with a university, 16 research institutes and a population of nearly 40,000 people including 10 Academicians and 36 corresponding members.
2. The nearest English term for these installations is «experimental factories».
3. The available energy of the resulting collision was equivalent to that produced by a 100 GeV particle beam hitting a stationary target.
4. About 200 students are then admitted immediately to the School of Physical Mathematics.
5. There is a special boarding school also designed for intensive training and the local café is called «Under the integral sign».
6. The output should be, perhaps for the first time in the history of technology, a flow of new and advanced technical ideas for use by industry from which all technical and economic problems have already been removed.

## VI. Translate the following Russian questions into English and answer them:

1. Как можно охарактеризовать решение о создании Академгородка?
2. Что Р. Кларк называет «экспериментальными фабриками»?
3. Какие эксперименты, проводившиеся в Институте ядерной физики, описаны в статье?
4. Каким образом проводится отбор и подготовка сибирских школьников к поступлению в высшие учебные заведения?
5. Что является, с вашей точки зрения, отличительными чертами Академгородка?



6. Что вы знаете о Физико-математической школе, которая находится в Академгородке?
7. Что вы можете рассказать о Физико-математической школе, организованной при Московском государственном университете?
8. Какие выдающиеся ученые работают в этой школе?
9. Какие мероприятия, помогающие выявить наиболее способных к физике и математике школьников, проводятся вашим университетом (институтом, факультетом)?
10. Какое значение имеет создание научных центров, подобных Академгородку?

## VII. Render in English:

*Новый шаг к разгадке тайн материи*

Группа советских физиков, возглавляемая Ю. Д. Прокошкиным, на крупнейшем в мире Серпуховском ускорителе протонов добилась замечательного достижения — ими получено антивещество.

Антиядро изотопа гелия-3 просуществовало, возможно, всего какую-то миллионную долю секунды, но его наличие, его физические характеристики зафиксированы сложнейшей аппаратурой, разработанной и изготовленной группой профессора Прокошкина.

Это достижение советской ядерной физики подтверждает реальность существования антивещества, задолго до этого предсказанного теоретически. Современная физика установила, что каждой элементарной частице, входящей в состав атома того или иного вещества, должна обязательно соответствовать античастица.

Благодаря ускорителям большой мощности физики уже получили отдельные античастицы: антипротон и антинейтрон. Но только в последнее время стало возможным соединение этих частиц в антиядро. Поэтому столь важно открытие антиядра изотопа гелия-3: оно открывает путь к познанию самых сокровенных тайн материи. Технически это был чрезвычайно сложный эксперимент, и вот он осуществлен. Но будет ли возможно в дальнейшем получить достаточно большое количество антивещества? Пока на этот вопрос ответ отрицателен.

## VIII. Answer the following questions:

1. When was it decided to create a new city of advanced science?
2. What do you know about the scientists working today in Akademgorodok?
3. Why is Akademgorodok called «one of the seven wonders of the scientific age»?
4. Why is it so dear to the hearts of the Soviet scientists?
5. What can you say about the Siberian Institute of Nuclear Physics?
6. What's the average age of the Akademgorodok scientists?

7. What are the guiding principles of Akademgorodok?

8. Why is it so necessary to begin the selection process of outstanding pupils at the age of 14-15?

9. What are the results of the intensive training of such pupils at Akademgorodok?

10. What are the lessons to be learned from Akademgorodok?

**IX. Review the article «Akademgorodok: Eastern Centre for Western Science».**

**X. Write an annotation on the article.**

**XI. Speak on the following topics:**

1. The development of the Soviet science in the course of last five years.
2. The discoveries and achievements made at Akademgorodok.
3. The Siberian Branch of the Academy of Science.
4. Scientific centres of the nearest future.

# SUPPLEMENTARY TEXTS

## Supplementary Text to Lesson 1

We have, with the cooperation of a few interested students and the generous support of the National science Foundation, prepared sufficient material, both written and practical, for a modest and preliminary trial of the instructional laboratory, in which students from Barnard and Columbia Colleges have participated. We cannot conclude from this limited experience that our efforts and expectations have been justified, but we do have some reassurance that we are not entirely mistaken. Some students, at least, do find in this approach and emphasis an interest they do not associate with more orthodox laboratory instruction. Especially for those who have no intention of becoming professional scientists, the emphasis on historical context does seem to evoke a response that the formal science itself does not. For these students the methods of science are usually unfamiliar and alien to their intellectual concerns and aspirations. Close juxtaposition of the historical, conceptual and practical helps to connect elements so often divorced, the human and the scientific. In the history of physics laboratory the student is confronted not only with the formal contents and potentiality of science but also with a glimpse of historical actuality, the thoughts and aims, as well as the achievements, of individual persons working in a particular social and intellectual environment.

There are also students whose appetite for physics (or science) demands nourishment rather than stimulation. For these students the novelty of the viewpoint adopted does seem, at least occasionally, to throw familiar concepts into a new relief. This contrasting viewpoint often provides the stimulus for a more critical and thorough understanding.

*Physics Today, February 1970.*

## Supplementary Text to Lesson 2

The major theoretical advance came in 1758 with the publication of the immensely influential "Theory of Natural Phylosophy" by Roger Joseph Boscovich, a theory of such importance that nearly 150 years later Lord Kelvin could describe himself as a "true Boscovichean".

The theory of Boscovich was diametrically opposed to the theory of Newton, who had postulated an attractive force between atoms at very small distances. Boscovich said the force must be repulsive, basing his argument on what happens when two particles collide and then recoil. Could two such particles eventually meet? If they met, that is, came into physical contact, and if they were hard and impenetrable, it would imply a discontinuous change in velocity at the moment of contact. This was something Boscovich could not accept, and it led him to put forward two startling but simple proposals: that the fundamental particles were nonextended and that they never actually met. (The alternative explanation, that the particles were finite in size and compressible, he rejected as unnecessarily complicated). The central feature of Boscovich's theory dealt with the law of force between atoms.

A notable feature of his theory was its simplicity. It made very few assumptions. Only one kind of particles was needed to explain the infinite diversity of matter. Since there was only one kind of atom, the intricacies of nature were all explained by the form of a single interatomic force curve. The curve was so flexible, that any physical or chemical phenomenon could be accomodated without difficulty. The main weakness in the theory lay in the fact that it was entirely qualitative, but this was unavoidable in Boscovich's days.

*Scientific American,*
*November 1969.*

## Supplementary Text to Lesson 3

### *Annihilation Photons*

We have already discussed two applications for secondary positron beams. They are conventional scattering experiments in which the target is stationary and colliding-beam experiments in which the target is an electron moving in the opposite direction with the same velocity and energy. In a third application, of particular interest at SLAC *, positrons are now being used to produce "tertiary" beams of annihilation photons.

In this third application, the positron beam is momentum analyzed and strikes a target or "radiator" at the end of the accelerator, analogous to the converter in which the positrons were initially produced. Two main processes can then occur. First, the positrons can radiate photons by deceleration in the electric fields of the target nuclei and electrons — the first step in the production of a new cascade shower. Second, unlike the electrons incident on the converter, the positrons hitting the final radiator can annihilate with atomic electrons to produce pairs of photons, each of which has a well defined energy for a given angle with respect to the incident positron direction. Annihilation is enhanced relative to radiation by using a radiator material near the top of the periodic table, for example, liquid hydrogen, lithium or beryllium.

Annihilation photons are quite distinct from radiation photons, which can have any energy up to the incident energy of the radiating positron or electron. Furthermore, annihilation photons are distributed over a broader angular region. At a particular angle the complete spectrum consists of a sharp spike at the annihilation — photon energy characteristic of that angle, superimposed on a diffuse background of radiation photons. The underlying background is identical to the ordinary radiation spectrum produced by electrons for the same experimental conditions.

Annihilation photons provide physicists with a partially monochromatic beam, that is, a beam in which a substantial fraction of the photons have the same energy. The annihilation technique is important because photons have no charge and cannot be energy analyzed by magnetic or electric fields. Partially monochromatic beams can also be produced by scattering laser light off a beam of electrons or positrons, but this possibility is still being developed.

*Physics Today,*
*February 1969.*

* SLAC — Stanford Linear Accelerator Center.

## Supplementary Text to Lesson 4

*The Unified Field Concept*

The basic elements of the language of a fully exploited theory of relativity are continuous field variables. These are *continuously* mapped functions of the space and time coordinates. This feature is a consequence of the assumption that the valid laws of nature are invariant in form under the transformations of the Einstein group (the group of *continuous transformations* among the space-time frames of reference that are in arbitrary motion relative to each other). Einstein showed, for example, that even with the idea of a finite propagation time for the interaction between distant bits of matter, it is not possible to consider this matter in discrete quantities within relativity theory. It would not be possible in this case, for example, to define the conserved quantities of the system, such as energy and momentum. The approach of relativity theory then necessitated an expression in terms of field equations, where the field variables relate to densities. In the final analysis, to compare the predictions of the theory with the experimental facts, it becomes necessary to integrate certain prescribed functions of these field variables over all of the coordinates in which they are mapped. Thus we see that the basic elements of the language in relativity theory are not the space and time coordinates themselves but rather a certain set of functions that are continuously mapped in the space-time coordinate system.

*Physics Today,*
*February 1969.*

## Supplementary Text to Lesson 5

The ability of nuclei to oscillate and change their shape is of the utmost importance for nuclear fission. In a nuclear reactor uranium or plutonium nuclei, which are ordinarily hard deformed nuclei, are set in motion by the absorption of a neutron. This motion is a change in shape: the nucleus becomes more and more deformed into a cigar shape, until finally it necks down near the middle and breaks into two pieces. All of this takes place with the introduction of the very small amount of energy brought in by the neutron, but the two positively charged pieces repel each other strongly and fly apart, producing a large amount of energy. As the two pieces break apart, a few neutrons are freed, which serve to cause other such fission events, sustaining the energy output of the reactor. One of the interesting discoveries of the past several years is that heavy deformed nuclei sometimes have not one but two shapes, one more deformed than the other and both of them nearly stable. It had been



observed that some nuclei did not fission at once when excited but waited a measurable time. A number of experiments now show quite convincingly that such nuclei are first knocked into a more deformed shape that is nearly stable but finally elongate and fission.

*Scientific American,*
*August 1969.*

## Supplementary Text to Lesson 6

The results of time-exposure (elastic) experiments lead to determination of the radius of spherical nuclei and of the spherical image, as it were, of deformed nuclei. The distribution that is revealed, it should be pointed out, is essentially that of the protons. The reason is that the probes (electrons and muons) interact primarily with the charge, and only weakly with the magnetism, of the nucleus — and only the protons are charged. (Neutrons and protons do attract each other through the nuclear force, however, making it likely that their spatial distributions are similar, and some experiments confirm that this is generally true). What is determined is the charge density as a function of distance from the center. Until recently only two parameters of that function could be determined: $c$, the distance at which the charge density has fallen to half of its central value, and $t$, the surface thickness, which is usually defined as the radial distance from the point where the density is .9 of its central value to the point where it has dropped to .1 of the central value.

The results of the electron-scattering and the muon X-ray experiments show that, except for the lightest nuclei, the surface thickness is about the same for all spherical nuclei: approximately 2.5 fermis. (A fermi is $10^{-13}$ centimeter). The radius parameter $c$, on the other hand, increases with increasing nuclear mass. In fact, the nuclear volume per nucleon is nearly constant for all nuclei, and the radius measurement $c$ is about equal in fermis to 1.1 times the cube root of the mass number $A$. Absolute radius measurements can be made in favorable cases to an accuracy of about 1 percent and in many instances it is possible to determine differences between radii to an even higher accuracy. By direct comparison changes in radius between two isotopes or between two energy levels of the same nucleus have been determined to better than one part in 10,000. In other words, radius differences of less than .01 fermi have been detected!

*Scientific American,*
*August 1969.*

## Supplementary Text to Lesson 7

*The Control of Tape Speed*

In order to provide a measure of control over the velocity of the tape in the vicinity of the head, capstans, or rotating cylinders, were introduced near the head. In early machines a pinch roller pressed the tape against each capstan and constrained the tape to move at the circumferential velocity of the capstan. In order to prevent high-frequency oscillations capstans were loaded with a high-inertia drum, acting as a flywheel, that would not respond readily to small perturbations.

High-inertia systems with the velocity of the tape controlled in the vicinity of the heads by means of single or double capstans were quite satisfactory for sound recorders when the signals being recorded had fairly long wavelengths and correspondingly low frequencies. If one wanted good quality in the recording of signals of short wavelength and high frequency, however, or if one sought to record on one machine and play back on another, thereby requiring a recording that was compatible between machines, the control of tape speed with high-inertia capstans was inadequate. The solution to these difficulties was optical control. Light passing through one or more holes through the capstan produced a signal showing the speed of the capstan. That signal was compared with a reference signal to provide a means of regulating the speed of the capstan. Another technique is to record a control track on the tape. The velocity of the tape during playback is governed by the frequency recorded on the control track. In this way it is possible to compensate for variations in the speed of recording by introducing comparable variations in the speed of playback.

Even with these techniques of control it is possible for fluctuations in the velocity of a reel to be transmitted through the tape and to result in variations of velocity at the heads. It is therefore necessary to isolate a reel and its servomechanism from the corresponding capstan and its servomechanism.

*Scientific American,*
*November 1969.*

## Supplementary Text to Lesson 8

Since holography consists of recording an interference pattern, it has probably occurred to the reader that it bears an uncommonly close resemblance to interferometry, that traditional field of physical optics. This resemblance, of course, is not a coincidence. The only basic difference between holography and conventional interferometry is that in holography one generally records extremely complex interference patterns. Perhaps even more important, holography at its conception was meant to be a technique for recording wave fronts, in contrast to the more common use of interferometers for analyzing wave fronts.

As is often the case, one of the first areas to benefit from the new technique was the area that gave rise to it. So it was that holography was responsible for introducing a new range of powerful methods to interferometry. Interferometry has commonly been used for the precise measurement and comparison of wavelengths, for measuring very small distances or thicknesses (of the order of wavelengths of light), for detecting disturbances or inhomogeneities in optical mediums, for determining the refractive indexes of materials, and so on. To these functions the technique of holographic interferometry adds capabilities for studying phenomena that were formerly considered virtually inaccessible. Furthermore, holography makes interferometry less complicated by relaxing some of the exacting requirements that have attended this technique. For example, holography eliminates the necessity of using optical components of extremely high quality. This advantage is particularly useful when the phenomena under study take place in a closed vessel and must be measured interferometrically through windows. Holography makes it possible to distinguish the relevant information from the spurious, and thus it permits accurate interferometric experiments on any material and in almost any environment.

*Scientific American,*
*February 1968.*

## Supplementary Text to Lesson 9

Historically the recording of interference patterns throughout the volume of a photosensitive material is a very old subject. As early as 1891 the eminent French physicists Gabriel Lippmann discovered a way to store information throughout the volume of a photographic emulsion. By recording standing waves in an emulsion (produced by a beam of light reflected back on itself), he was able to develop an early form of color photography. This technique, although interesting, proved to be impractical and for many years remained merely a scientific curiosity. In 1962 Yu. N. Denisyuk of the U.S.S.R. combined the Lippmann technique of recording standing waves with the original techniques of holography to make volume holograms. With this technique he was able to record holograms of fairly simple subjects. Denisyuk's technique, like the original holographic technique, had several disadvantages; it was the advent of the separate reference beam that indicated the way to a more general applicability of volume holograms.

Holography has been the scene of considerable activity in the past few years. Considerable effort has been expended in the area of data-processing and related subjects. These areas are exceedingly interesting in themselves and may yet prove to be the pot of gold at the end of the holography rainbow. Except for a few isolated cases, however, these areas of holography are also the ones that are presenting the most severe problems. In the meantime there are many areas in which holography could be exploited to great advantage by an investment in the necessary adaptation of further development of the techniques already available.

*Scientific American,*
*February 1968.*

## Supplementary Text to Lesson 10

Acoustical imaging is of course not new; there are sonar devices that produce pictures similar to those on a radar screen. This type of imaging is currently employed in prospecting for oil and minerals. Similar scanning methods are also being used by physicians for the detection of brain tumors and for examining the unborn child. In these applications the sound usually has a frequency of between one million and 10 million cycles per second. Another conventional acoustical imaging technique employs what may be best described as an acoustical camera. In this method sound waves bounced off an object are focused with an accoustical lens onto an image converter that translates the pattern of sound intensity into a pattern of visible light.

The limiting feature of both of these conventional sound-imaging methods is that the images show only two dimensions. They are two-dimensional because the methods detect only the intensity (the square of the amplitude) of the sound waves in the sound images. What these methods are unable to record is phase information, that is, the arrival time of the crest of the wave from the object with respect to the arrival time of the crest of a reference wave of the same frequency. The most powerful feature of hologra-



phy is that phase information as well as intensity information is retained in the hologram and can subsequently be "played back" in the optical image, with the result that the optical image is three-dimensional. Thus in acoustical holography there is a total transfer of information from the acoustical wave field to the visible optical wave field.

*Scientific American,*
*October 1969.*

## Supplementary Text to Lesson 11

It is uncertain whether or not tachyons might lose energy through processes other than Cerenkov radiation. One such possibility is that a single tachyon could decay into several tachyons, each of lower energy. If there were such other energy-loss mechanisms, the amount of Cerenkov radiation actually emitted might be smaller than the anticipated amount, and the value of the upper limit for the number of tachyons produced would be too low. For this reason, and because we are in general ignorant about possible interactions of tachyons with matter, it was thought desirable to search for tachyons in a manner independent of how they interact after being produced.

Such an experiment was performed recently by a group at Columbia University. The method used was a well-known one for searching for new elementary particles; it is called the missing-mass method. In this approach a large number of reactions among elementary particles are examined in a detecting apparatus (in our case a bubble chamber) in which the momentum and energy of the charged particles in the reaction can be measured. In some fraction of the reactions a number of neutral particles will be produced in addition to the charged particles observed. These neutral particles are usually not observed directly, and it is often not even known how many of them are produced. By applying the laws of the conservation of energy and momentum, however, it is possible to tell from the values measured for the charged particles whether or not any neutral particles have been produced, and also what the momentum and energy carried away by these particles are.

*Scientific American,*
*February 1970.*

## Supplementary Text to Lesson 12

In our experiment two reactions were studied. In one, negative $K$ mesons were allowed to come to rest and be captured by protons in a hydrogen bubble chamber. One neutral particle, a lambda hyperon, was produced and was detected through its decay in the bubble chamber into two charged particles. (The momentum and energy of the lambda particle can then be inferred from the measured values for the charged particles). In order to conserve energy and momentum other neutral particles had to be produced. These were usually a single neutral pion, or sometimes a neutral pion and a photon. The events had all been analyzed previously for other purposes, so that the momentum and energy of the charges were already measured. A plot of the missing mass squared was made for some 6,000 events involving the capture of a negative $K$ meson. It should be realized that in this case the missing energy and momentum are defined as the difference between the sum of the initial values for the $K$ meson and the proton, and the values for the emerging lambda particle, which, as indicated above, can be inferred from its decay products, even though it is neutral. In our first set of measurements a number of events were found with a negative missing mass squared, which suggested tachyon production. Caution, however, suggested that various tests be made before this conclusion could be accepted.

One test involved making sure that the $K$ mesons were really at rest when captured. If this were not the case, the missing mass squared would be incorrectly calculated for a given event, since in the calculation it was always assumed that the meson was at rest when captured. If the direction of the lambda particle were nearly the same as the actual direction of a $K$ meson captured in flight, then the missing mass squared could be measured as negative when it was really positive. Accordingly all events in which the angle between the $K$ meson and the lambda particle was less than 60 degrees were removed from the sample. For true tachyon-production events this should only reduce the number by the ratio of remaining events to total events, whereas it should eliminate all spurious negative-mass-squared events due to capture in flight. When this test was carried out, the number of events with negative missing mass squared was reduced to 23 from an original total of 101, indicating that most of the supposed tachyon events were actually captured in flight, producing ordinary particles.

*Scientific American,*
*February 1970.*



## Supplementary Text to Lesson 13

Both of the direct experimental searches for tachyons that have been carried out have therefore yielded negative results. Indirect arguments have also tended to restrict still further the possible interactions of tachyons. According to one of these arguments, if charged tachyons exist, the photon would not be a stable object but instead would decay within some time period into a pair of charged tachyons. We know that photons can travel for billions of years across intergalactic space without so decaying. This implies that if charged tachyons exist at all, then either their charge is many orders of magnitude smaller than that of the electron, which means that they interact very weakly with photons, or else their mass squared is very close to zero, which makes them difficult to distinguish from ordinary particles. Similar conclusions can be drawn from indirect arguments about the very small interactions of neutral tachyons.

The possibility that tachyons exist but do not interact at all with ordinary particles need not concern us, because if they do not interact with the objects that compose our measuring instruments, we have no possible way to detect them, and for our purposes it is the same as if they do not exist at all.

If we plausibly interpret the above results to conclude that tachyons cannot be produced at all from ordinary particles, we seem to be left with two possibilities. One remote possibility is that tachyons do interact with ordinary particles and can exchange energy with them but cannot be produced from them. This situation would strongly contradict all our experience with relativistic quantum theories of particles, and so it is improbable but perhaps not impossible. The hypothesis could be tested by searching for tachyons in natural phenomena, such as cosmic rays. A difficulty in carrying out such a search is that tachyons should lose energy rapidly and become hard to detect. The second possibility is that tachyons simply do not exist, and that nature has not filled the niche that is allowed by the theory of relativity. If this is the case, as now seems probable, we may not understand why it should be so until we reach a much deeper understanding of the nature of elementary particles than now exists.

*Scientific American,*
*February 1970.*

## Supplementary Text to Lesson 14

Because the crust of a neutron star should have considerable strength the star can maintain a shape that is slightly different from the shape of a rotating gaseous fluid bound by its own gravitational attraction. Presumably the crust solidified soon after the star was formed, when its rotation rate was close to maximum. As the rotation rate decreases there will be a reduction in centrifugal force and a consequent tendency for the star's shape to be more spheroidal than it was at first. The rigid crust, however, tends to resist this shape adjustment. It is rather difficult to estimate how much the crust can be stressed before it breaks.

It seems probable that the crust of a neutron star is strong enough to allow a maximum variation in surface position of somewhere between a hundredth of a centimeter and one centimeter. In other words, the fantastic gravitational pull of the star (100 billion times stronger at its surface than the gravitational pull of the earth) is very effective in keeping the shape of the star quite close to spherical. As a result no neutron-star mountains should be more than a few centimeters high, and even these might quickly melt. To climb a one-centimeter Everest on a pulsar, however, would take a man the energy of 100 lifetimes. Nevertheless, in spite of the very small geometrical distortions the crust could tolerate, some of the effects of such distortions may be observable.

*Scientific American, February 1971.*

## Supplementary Text to Lesson 15

The existence of a thick solid crust around a neutron star may have significant observable effects on pulsar behavior that are much subtler than the possible production of starquakes. In ways not yet understood the radio signals from pulsars are almost certainly generated by the magnetic field that rotates with the neutron star. Through this field the star couples to the medium around it and "feels" the torque that gradually decreases its rotation rate. The fact that the magnetic field threads through the rigid crust of the rotating neutron star and is anchored to it rather than to the gaseous-liquid matter found in the outer layers of less dense stars may be quite relevant to the precisely maintained periods of pulsars. The magnetic field cannot drift with respect to the stellar surface (as sunspots do), so that the field and its effects can remain unchanged after tens of millions of rotations.



Because crust rigidity can slightly distort the shape of a rotating neutron star it can cause a slow stellar wobble like that of a slightly aspherical spinning top. Peter Goldreich of the California Institute of Technology has pointed out that an extremely small wobble would be sufficient to keep the stellar magnetic field from roughly aligning itself along the stellar exis of rotation as the spinning star gradually slows up. An aligned field would not vary in the aspect it presents to us as the star rotates, so that it would be difficult to understand why the pulsar's signal changes so much during each rotation. (The necessary minimum shape distortion from crust rigidity to prevent alignment is only about $10^{-5}$ centimeter.)

A complete interpretation of pulsar observations will probably depend in part on a more reliable and detailed description of properties of neutron star crusts than is currently available. To know how the star can be expected to wobble, how it may stabilize its magnetic field and when its crust may crack, it will be necessary to learn more about crustal strength and ductility and how the crust relaxes under stress. All of this suggests that the twinkling pulsar—with its jewel-like crust surrounding a superfluid core that in turn can possess a center with unknown properties — may have the most remarkable architecture of any object in the universe.

*Scientific American, February 1971.*

## Supplementary Text to Lesson 16

How far things went in the pursuit of the consequences of the counter-Euclidean hypothesis is shown by the following statement in Aristotle's *De caelo*: "If it is impossible for the triangle to have the sum of its angles equal to 2R, then the side of the square is commensurable with the diagonal". Here is a powerful and beautiful theorem that is not to be found in either Saccheri or Lambert, and not in the modern creators of non-Euclidean geometry. From the general counter-Euclidean hypothesis it follows that the diagonal of the square could be commensurable to its side. Failing to find among the consequences of the general counter-Euclidean hypothesis the absurd conclusion "Parallels meet", the Greek geometers probably attempted to obtain from the same hypothesis another absurd conclusion: "The diagonal of the square is commensurable with its side". (That is, the ratio of the diagonal to the side is a rational number.) They knew that from this would follow the contradiction that the same number is both odd and even. Unfortunately, in order to deduce the impossible conclusion "Odd is even", it is necessary to have recourse to the Euclidean proposition "The sum of the angles of the triangle is equal to 2R". Thus the absurd conclusion "Odd is even" cannot be reached from the counter-Euclidean hypothesis alone.

*Scientific American,*
*November 1969.*

## Supplementary Text to Lesson 17

Liquid metals are very interesting. They present challenging unsolved problems to the physicist: how to describe dense disordered systems, and how to account for the properties of "free" electrons in these systems.

In order to gain perspective on the complexity of the first of these problems, consider the following analogy to the liquid state. Suppose all the people in the world (some three billion of them) were to be assembled on a flat square of land measuring about 25 miles on a side. Surprisingly, it turns out that on the average each person would be an arm's length from his closest neighbors. Each one is given a single instruction: to move, and to keep moving, as fast as possible, regardless of direction. Not unexpectedly the result will be chaos. People will mill about in an agitated fashion trying (but failing) to avoid running into one another. This, apart from the lack of a third dimension, is roughly analogous to the chaotic motion of a large number of atoms in a liquid. How does one analyze such a motion?

*Scientific American,*
*July 1969.*

## Supplementary Text to Lesson 18

A new and exciting development is the study of the effects of imminent phase changes and phase separations on the transport properties of liquid metals and alloys. We know that in general metals solidify when they are cooled below their melting points. We also know that some mixtures of metals are completely miscible above a certain temperature and immiscible below it. Just before these transitions the ions must begin to exhibit "critical fluctuations" in their motion, or excursions that mirror the onset of the phase changes. As a result the transport phenomena must also exhibit these effects; such "critical phenomena" are proving to be an interesting field of study in the liquid metallic state.

The explanation of the transport properties of liquid metals exposes a fundamental distinction between metallic and liquid properties. The liquid properties can be reasonably well accounted for by the methods of classical physics. To explain the metallic properties, however, we need quantum theory. This remains true even in those metals whose electron mean free paths turn out to be just two or three angstroms. This particular problem — the nature and distribution of electronic states in strongly scattering systems — is one that is receiving considerable theoretical attention.

*Scientific American,*
*July 1969.*

## Supplementary Text to Lesson 19

Someday liquid crystals may become the picture-producing element in the most ubiquitous display device of all: the television receiver. Engineers have long sought a display concept that would enable them to build a television receiver that would operate on very little power and would do away with the bulky equipment behind the picture screen. These ground rules suggest that the operation of the picture screen would be based not on the electron beam of a cathode ray tube but on solid-state devices such as transistors and semiconductor diodes. The dynamic-scattering mode in nematic liquid crystals could easily be made to produce images by impulses from such circuitry.

Test patterns of such images have in fact been broadcast and received. The turbulence-controlling electrodes, however, were activated by a scanning electron beam. The organization and operation of the hundreds of thousands of light-reflecting elements and the associated solid-state components required for a flat display unit remain a difficult technical problem. The cost of a technically satisfactory solution is also a difficult problem. These and other difficulties must be overcome if liquid-crystal display devices are to perform all the diverse services of which they appear capable. One point is clear: a new kind of device is ready to join light-generating electron tubes and other devices as a part of display technology.

*Scientific American, April 1970.*

## Supplementary Text to Lesson 20

Perhaps the most startling discovery made in astronomy this century is that the universe is populated by billions of galaxies and that they are systematically receding from one another, like raisins in an expanding pudding. If galaxies had always moved with their present velocities, they would have been crowded on top of one another about 10 billion years ago. This simple calculation has led to the cosmological hypothesis that the world began with the explosion of a primordial atom containing all the matter in the universe. A quite different line of speculation argues that the universe has always looked as it does now, that new matter is continuously being created and that new galaxies are formed to replace those that disappear over the "horizon".

On either hypothesis it is still necessary to account for the formation of galaxies. Why does matter tend to aggregate in bundles of this particular size? Why do galaxies comprise a limited hierarchy of shapes? Why do spiral galaxies rotate like giant pinwheels? Astrophysicists are trying to answer these and similar questions from first principles. The goal is to explain as many aspects of the universe as one can without invoking special conditions at the time of origin. In most of what follows we shall assume a cosmological model in which the universe starts with a "big bang". When we have finished, the reader will see, however, that some form of continuous creation of matter may not be ruled out.

*Scientific American, June 1970.*

## Supplementary Text to Lesson 21

One prediction of the CPT theorem is that all elementary particles have antiparticles with opposite charge but with exactly the same mass and lifetime. After the Princeton observation a number



of new experiments were performed with the aim of providing extremely refined tests of this CPT prediction. A good deal of evidence has now been accumulated. At least within the limits of refinement of the tests there is no reason to doubt the validity of the CPT theorem. Physics is therefore left with the inference that time-reversal invariance is violated somewhere in physical processes. It is most important to move beyond inference to direct experimental confirmation.

The desire to find symmetries in nature goes back to the earlies days of science. Since ancient times the ideal has persisted that nature is simple, symmetrical and beautiful; heavenly bodies, for example, were regarded as perfect spheres, moving in perfect circles in perfect harmony with one another. The development of science, however, has been accompanied by the slow realization that nature is not this simple, although it is no less beautiful. (Is an ellipse less attractive than a circle?) Similar desires for symmetry have also affected our concepts of space and time. To assume that nature is indifferent to left or right, plus or minus and the flow of time forward or backward may be attractive, but we must be careful. Beauty in nature, as in art, need not imply exact symmetry; the lamp in the middle of the picture window is not the ultimate in interior decoration.

*Scientific American, October 1969.*

## Supplementary Text to Lesson 22

Although there are as many molecules arriving at the top plate as there are molecules leaving it, those that move down take with them more kinetic energy that those that move up. If follows that there is a net flow of random kinetic energy downward, in short, a heat flow. The theory of this phenomenon was worked out early in the development of the kinetic theory of gases; the thermal conductivity was correctly related to the mean free path, the average speed of the molecules and the specific heat of the gas. Thermal conductivity is a gas, then, is a fairly well-understood phenomenon. What about thermal conductivity in a solid?

Here we shall be concerned only with electrically nonconducting solids. In metals and semiconductors electrons can also conduct heat, and this makes the analysis of heat flow in these materials much too complex to consider here. In any event, second sound has not been observed in these materials.

In order to understand the flow of heat in solids one must examine the details of how thermal energy manifests itself in crystalline solids, such as diamond or solid helium. The most characteristic feature of these solids is their regularity. When a theoretical physicist sets out to calculate some property of a crystalline solid, his first approximation is that the solid is a completely regular array of atoms held together with forces that act much like springs. The atoms are not at rest but are vibrating slightly around their fixed sites in the crystal lattice.

*Scientific American, November 1969.*

## Supplementary Text to Lesson 23

Although the experimental results pertaining to Type II superconductors could be explained by Abrikosov's theory, many physicists did not accept his picture of the mixed state in Type II superconductors. It was for this reason that we began in 1966 to consider the possibility of photographing the flux-line lattice; if such a visualization were possible, we thought it would be a rather convincing proof of Abrikosov's theory. A crude estimate of the necessary resolving power made it clear that the individual flux lines were too small to be resolved by a conventional optical microscope. We realized that direct observation of a superconducting specimen in an electron microscope would not be feasible either, because the predicted magnetic flux of a vortex would be too small to cause a detectable deflection of the electrons. Therefore we decided to divide the problem into two steps. In the first step we made a "negative" of the flux-line lattice in a conventional liquid-helium cryostat; in the second step we viewed the negative with a high-power electron microscope at room temperature.

*Scientific American, March 1971.*

## Supplementary Text to Lesson 24

A typical electron micrograph clearly shows the anticipated triangular flux-line lattice. One of the first questions we wanted to answer was whether or not the flux lines actually carry just one



quantum of magnetic flux, as had been predicted by Abrikosov. We therefore estimated the number of flux lines present in the specimen from the micrographs and compared the result with the total magnetic flux in the specimen. Within the experimental error Abrikosov's prediction could be confirmed: each line carried one quantum of magnetic flux.

All our micrographs represent a cut across the flux-line lattice and in many respects resemble a two-dimensional model of a crystal lattice. It is thus not unreasonable to expect that for many properties of real crystals, such as grain boundaries, one should find an analogy in the flux-line lattice. This turned out to be the case. For example, the closely packed rows of flux lines are not always aligned in the same direction throughout the entire specimen; instead they often change direction abruptly along a "grain boundary".

*Scientific American, March 1971.*

## Supplementary Text to Lesson 25

Hydrodynamicists distinguish between two kinds of viscosity. When the viscosity can be ascribed to the interplay among the individual particle constituents of a fluid, it is labeled molecular viscosity. On all larger scales, where viscous effects arise from the interaction of macroscopic "parcels", or masses, of a fluid, one speaks of turbulent, eddy or virtual viscosity.

The explanation of molecular viscosity had its origins in a suggestion by Isaac Newton that in ordinary fluids the drag, or stress, per unit area of one layer of a fluid on its immediate neighbor is proportional to the shear in the fluid. Shear is formally defined as the spatial rate of change in the speed of flow in a direction perpendicular to the mean fluid motion. Subsequently James Clerk Maxwell and others made the assumption that viscous effects originate in molecular motions.

They hypothesized that a fluid resists shear because its molecules do not travel precisely parallel to one another but, as a result of random collisions, are impelled at random angles across the mean direction of flow. In this way faster-moving molecules drift into slower-moving regions and vice versa. On balance, the number of molecules moving in one direction across a hypothetical plane dividing two regions of different average flow rates must equal the number moving in the opposite direction. The viscous effect across the plane is associated with the difference in the downstream momentum carried by the molecules moving in opposite directions. Molecules originating in the slower part of the stream tend to carry less of this momentum than those originating in the faster part. As a result the momentum tends to reach an average value and thereby lessens the shear.

*Scientific American,*
*July 1970.*

## Supplementary Text to Lesson 26

The displacement of fringes must of course be read out in some form. In order for the readout system to follow displacements of more than a few fringes it is provided with a limiting switch that interrupts the fringe-following mechanism after it has traveled a distance of a fringe or so. After the mechanism has been interrupted it returns to an equilibrium point and picks up the adjacent fringe. Because the mechanism must traverse the distance between the fringe it has been following and the next fringe there is a discontinuity in the recorded curve corresponding to a displacement of the ground that shifts the fringes by half a wavelength. This conveniently and continuously calibrates the system. The direction of the discontinuity in the curve reveals the direction in which the ground is moving.

In principle this kind of readout system can record any amplitude of earth motion. When motions are recorded on a reel of paper, for instance, the shape of the curve traced corresponds to the movement of the fringe-following mechanism. When the mechanism returns to pick up the next fringe, the tracer returns to its starting place also and begins a new curve. If the mechanism had no limiting switch, the curve representing the movement of fringes would have to be continuous because the tracer would have no way of returning to an equilibrium point. Such an arrangement would make the recording system impossibly cumbersome. A system capable of simultaneously recording earth strains with an amplitude of one part in $10^{12}$ and earth tides with an amplitude of five parts in $10^{8}$ would need a paper recording strip 20 meters wide! Similar considerations apply to magnetic tape, which can accommodate only about four orders of magnitude of signal change.

*Scientific American,*
*December 1969.*



## Supplementary Text to Lesson 27

Some of the events recorded at the Kern River site are caused by earthquakes and some by underground explosions in Nevada. With only one instrument — a strain meter with two arms at right angles — one can determine the location and magnitude of the event. The distance can be determined from the difference in arrival time of the pressure waves and the shear waves. The direction can be determined from the relative strength of the pressure waves at each interferometer arm. The absolute amplitude of the pressure or shear waves reveals the magnitude of the events. Explosions can often be distinguished from earthquakes because their shear waves are comparatively weak campared with their pressure waves.

An 800-meter Michelson strain meter is being operated by Ralph H. Lovberg and Janathan Berger of the University of California at San Diego. The interferometer mirrors and the readout system are mounted on pillars set 10 feet in the ground to minimize the effects of thermal strain. Small buildings shield the pillars from the wind and uneven solar heating. The long vacuum pipe that encloses the optical paths runs aboveground. This calls for an ingenious system to compensate for thermal expansion and contradiction, which amounts to several inches at the air gaps between the pipes and the interferometer mirrors. A variation on the Michelson instrument has been developed by Anthony F. Gangi. His interferometer consists of an arm, one meter in length, that is fixed to bedrock and a second arm whose length is adjusted by a mechanism that keeps it equal to the length of the first arm, so that the interference pattern remains stationary. The ground displacement is therefore proportional to the voltage needed to change the length of the adjustable arm.

*Scientific American,*
*December 1969.*

## Supplementary Text to Lesson 28

It should now be clear that information bearing on the value of any specific constant can come from several different experiments. Stated another way, there are many different routes one can follow (both direct and indirect) in order to obtain a value for a particular constant. In general each route will give a slightly different value. The best way to handle such a situation is by a mathematical approach known as the least-squares technique. This method provides a self-consistent procedure for calculating "best" compromise values of the constants from all the available measurements. For a given set of data it automatically takes into account all the possible routes for obtaining values for each of the constants being calculated. It then determines a single final value for each constant by automatically weighting the values of the constant obtained from the various routes according to their relative reliability or uncertainty. The uncertainty for each route is determined from the uncertainties of the individual measurements comprising the original set of data.

The most recent critical analysis and least-squares adjustment of the constants were carried out by the present authors in 1969. Since the application of the least-squares technique to the fundamental constants is the backbone of the field.

*Sciencific American,*
*October 1970.*

### Supplementary Text to Lesson 29

*Lorentz Invariance*

A theory based on the equations of motion, in which the time is treated differently from the space coordinates, is not manifestly Lorentz invariant. This does not imply that the theory is wrong. We require the results of the theory to be Lorentz invariant, and we would have to prove that they are Lorentz invariant before the theory could be accepted as correct. The proof might be quite an involved one, but that would not matter.

Further it may be that the requirement of Lorentz invariance applies only to a complete theory that takes into account all the particles of physics and all the interactions among them. An incomplete theory, restricted only to certain particles, need not then be a Lorentz invariant theory. Present-day theories are all incomplete. Quite likely we do not yet know all the elementary particles that exist. There may not be a need to insist on Lorentz invariance for present-day theories.

If one believes that equations of motion should apply to high-energy physics, the natural way to proceed would be to take the equations that are successful for low-energy phenomena and try to develop and generalize them to make them apply to higher and higher energies. There is no need to require accurate Lorentz invariance during the procedure. We should require approximate Lorentz invariance in the application to the lower energies, and should strive gradually to increase the accuracy.



There is here an essential difference in the mode of approach from the S-matrix theory. In the latter, one has Lorentz invariance holding initially and at all stages of the development.

*Physics Today,*
*April 1970.*

### Supplementary Text to Lesson 30

The difference in the pressure of the saturated vapors associated with an identical chemical composition led to what appeared to be the only possible conclusion, that a difference of the structure in the secondary and primary normal columns must serve as the origin of this effect. The assumption, which later turned out to be only half true, was first confirmed by Fedyakin by showing that on being heated by about 20 to 50 degrees the secondary columns of water expanded one and a half times faster than the primary columns, in spite of the fact that the experiments were carried out in capillaries with a radius of approximately one micron.

It was at about this time that the scientists joined forces to undertake further systematic investigation of this phenomenon at the Department of Surface Phenomena of the Institute of Physical Chemistry in Moscow. We were soon able to report an important finding: The secondary columns observed earlier by Fedyakin had a viscosity that was several times larger than that of the primary columns. In order to measure the viscosity the columns were set in motion by a given decrease in pressure. The velocity of a column's movement is inversely proportional to its length and viscosity. Therefore by knowing the length of the liquid column and its velocity of motion one can readily calculate the viscosity.

*Scientific American,*
*November 1970.*

### Supplementary Text to Lesson 31

The apparatus used by Wheatley and his co-workers for their Pomeranchuk experiments contains essentially three concentric compartments. The outermost part is the mixing chamber of a helium-3/helium-4 dilution refrigerator used for precooling, the middle part is for liquid helium 4 employed for compressing the helium 3 after the plug has been formed in the helium-3 inlet tube, and the innermost part is the Pomeranchuk cell itself. The construction materials are epoxy resin and copper-nickel tubes. The upper, flexible-wall part of the helium-3 cell is made by rolling nearly flat one end of a copper-nickel tube. The salt pill of a cerium-magnesium-nitrate magnetic thermometer is placed at the bottom of the helium-3 cell for measuring the temperature.

When the experiment is started, the assembly is first precooled to about .1 degree K. With the helium-3 pressure slightly below 28.9 atmospheres and with the helium-4 pressure at about .1 atmosphere. More liquid is then slowly admitted to the helium-3 cell until the pressure increases enough for the plug to form. Next, the assembly is cooled by means of the dilution refrigerator to about .025 degree. This phase of the experiment requires two or three days because of the very poor thermal contact between the mixing chamber and the helium-3 cell at low temperatures. Increasing the pressure of the helium 4 from an outside gas supply is then started at a rate of approximately .1 atmosphere per minute, causing the helium-3 cell to be «squeezed» and the pressure of the helium 3, initially at about 29 atmospheres, to begin to increase. As soon as the melting curve is reached at about 33 atmospheres the Pomeranchuk effect starts to operate. At first the temperature decreases almost linearly with increasing helium-4 pressure. Eventually the rate of cooling becomes slower because the entropy of the solid helium 3 is rapidly decreasing below .004 degree; finally the temperature stops going down. Owing to the poor thermal contact between the mixing chamber and the helium-3 cell there is no need for any heat switch between these two parts of the assembly.

*Scientific American, December 1969.*

## Supplementary Text to Lesson 32

After the starting temperature $T_1$, near 10 millidegrees, has been reached by a dilution refrigerator or by electronic demagnetization, the nuclear stage is magnetized by increasing the external field from zero to 60,000 gauss in about 30 minutes. The temperature is kept constant at $T_1$ by conducting the heat of magnetization away to the precooling stage through a superconducting heat switch.

The nuclear stage is then thermally isolated by turning the heat switch to its «off» position. Next, demagnetization is started by reducing the field in about 30 minutes from 60,000 gauss to 600 gauss. This



is done adiabatically, the theoretical temperature $T_2$ that is reached in this way is about .1 millidegree. Still lower temperatures, in the microdegree range, could be obtained by reducing the magnetic field even further, this was actually done by Kurti and his co-workers in their pioneering experiments in 1955. A serious difficulty was encountered, however: the system warmed back to its starting temperature $T_1$ in about two minutes, which is too short a time for performing useful experiments.

*Scientific American, December 1969.*

## Supplementary Text to Lesson 33

The only difficulty with the field-emission source is that it requires a vacuum in the range of $10^{-10}$ torr. Such a vacuum is some 10,000 times higher than the vacuum needed in transmission electron microscopes. Fortunately high-vacuum technology has reached the point where it is not too difficult to construct a field-emission chamber that will attain and hold the necessary vacuum.

We found we were able to achieve an electron beam of the desired intensity by applying only about 3,000 volts to the tungsten point. Upward of 25,000 volts are needed, however, for adequate penetration of typical specimens. To give the beam the needed extra energy we had to develop electron guns of novel design that would introduce a minimum of aberrations.

We found as a somewhat accidental outcome of this work that the electron-acceleration system will produce a real image of the field-emission source on the other side of the electron gun. Taking everything into account, we found that the system can produce a focused spot about 100 angstroms in diameter only four centimeters away from the gun. This made it possible for us to build a scanning microscope with a resolution of 100 angstroms, which is equal to the resolution of the best commercial instruments. Moreover, the field-emission beam is so intense that our microscope can produce pictures in a fraction of the time required by other instruments.

*Scientific American, April 1971.*

## Supplementary Text to Lesson 34

We are now in a position to estimate the visibility of single atoms. To deal with a realistic case we shall consider a single heavy atom, uranium (Z-92), supported by a thin film of carbon (Z-6). We should like to know the strength of the signals expected in the two detectors when the spot of electrons is focused on the uranium atom and when the spot is on carbon atoms alone. We have found that the thinnest carbon film we can make is 20 angstroms thick. This means that a spot five angstroms in diameter will cover some 55 atoms of carbon. Working through the calculations for the average value of Z in the two cases, one finds that when the uranium atom is present, the ratio of the two scattering signals is 1.68 times larger than it is when the uranium atom is absent. Such a relatively high ratio implies that a single atom of uranium should be readily visible. In theory it should show up as a spot five angstroms in diameter (the size of the focused beam) with a brightness 68 percent higher than the brightness of the carbon film that surrounds it. In practice, of course, there are many sources of noise in the signals that could lessen the contrast and even produce spurious spots resembling the ones made by uranium. For example, such noise can be generated when the electrons are diffracted by the microstructure of the carbon film. We were confident, however, that when all sources of noise had been accounted for our instrument would reveal individual heavy atoms.

*Scientific American,*
*April 1971.*

## Supplementary Text to Lesson 35

We believe we can explain why the spacing of the atoms is not absolutely correct. We know from other experiments that the 30,000-volt electron beam can easily damage structures as fragile as molecules. In fact, we are certain that the original organic molecule is destroyed before its picture is ever taken; we can see the heavy atoms moving around on the carbon film to some extent as we irradiate them. Motions of about five angstroms are readily observable.

The second most noticeable feature of the pictures is that most of the bright spots are aggregations of more than one heavy atom. Evidently as the solution containing the heavy atoms dries on the carbon film there is a tendency for the liquid to collect in microscopic puddles before the last of the water evaporates. This effect indicates that one must be cautious in interpreting pictures of single atoms.

What remains is to harness the technique for solving real problems. One of the most challenging and suitable is the problem of determining the sequence of bases in molecules of DNA (deoxyribonucleic acid). Each gene of a living organism is a length of DNA incorporating anywhere from a few hundred to a few thousand bases; the hereditary material in even the simplest organism consists of thousands of genes. To unravel the complete base sequence in the DNA of a bacterium by conventional chemical methods seems an almost hopeless task. An alternative route brought into view by our microscope is the possibility of finding a specific heavy-atom stain for each of the four different bases that serve as «letters» in the message encoded by DNA. The dream would be to stain a molecule of DNA from a particular organism and read off the encoded message by simply looking at the pattern of spots made in the high-resolution scanning electron microscope.

*Scientific American,*
*April 1971.*

## Supplementary Text to Lesson 36

The Nuclear Physics Institute has provided a centre for much more than colliding beam research. Advanced thermonuclear research is in progress in which shock waves are used to heat the plasma and a medical proton accelerator of high energy has been developed for use against tumors. The range of work at the other research institutes is equally wide. One of these institutes concerns itself exclusively with catalysis. The institute's *forte* has been the development of computer models of chemical processes which have made it possible to improve conventional production schemes without having to build laboratory scale pilot plants. The work is done on digital computers and on the Leningrad built MN-14 — the largest Soviet analogue machine. Again it has been the critical size of Akademgorodok which has enabled this work to proceed so swiftly — in few other places could the combined effort of mathematicians, computer specialists, chemists, thermodynamicists and other scientists be called upon to operate together at short notice and with adequate computer time.

Although this institute has its own computers, the larger calculations are done at the Institute of Computer Sciences. This has five computers — three M-20s, a small digital machine, one M-22 (medium size) and one BESM-6, the largest Soviet digital machine and one which is competitive with the best on the American market. As well as providing computer facilities for other institutes this centre carries out its own research programme with the help of more than 40 scientists at post Ph. D. level. Mathematical geophysics is being developed in an effort to provide a system of identifying minerals in particular areas simply by feeding the results of gravimetric and magnetic aircraft surveys into the programmed computer.

*Science,*
*August 1967.*

## LIST OF WORDS

## LIST OF IRREGULAR VERBS

arise, arose, arisen
be, was/were, been
bear, bore, born
become, became, become
begin, began, begun
bend, bent, bent
bind, bound, bound
break, broke, broken
bring, brought, brought
build, built, built
burn, burnt, burnt
choose, chose, chosen
come, came, come
cost, cost, cost
cut, cut, cut
deal, dealt, dealt
do, did, done
draw, drew, drawn
drive, drove, driven
fall, fell, fallen
feel, felt, felt
find, found, found
fly, flew, flown
forbid, forbade, forbidden
freeze, froze, frozen
get, got, got
give, gave, given
go, went, gone
have, had, had
hit, hit, hit
hold, held, held
keep, kept, kept
know, knew, known
lead, led, led
learn, learnt, learnt
leave, left, left
let, let, let
lie, lay, lain
lose, lost, lost
make, made, made
mean, meant, meant
put, put, put
ride, rode, ridden
rise, rose, risen
run, ran, run
say, said, said
see, saw, seen
seek, sought, sought
set, set, set
shine, shone, shone
show, showed, shown
stand, stood, stood
strike, struck, struck
speak, spoke, spoken
spend, spent, spent
spread, spread, spread
take, took, taken
teach, taught, taught
tell, told, told
think, thought, thought
understand, understood, understood
write, wrote, written

# LIST OF PROPER NAMES

Al Hazan [ˈælˈheizən]
Alväger Torsten [ˈælvəgə ˈtɔstən]
Ampère [ˈæmpεə]
Anaximander [əˈnæksəˌmændə]
Anaximenes [əˈnæksəˈmi:nəz]
Aristotle [ˈæristɔtl]
Ashcroft [ˈæʃkrɔft]
Avogadro [ˌævəˈga:drou]
Baranger Michel [ˈbærəndʒə miˈʃæl]
Bardeen John [ba:ˈdi:n ˈdʒɔn]
Beltrami Eugenio [bəlˈtræmi ju(:)ˈdʒi:njə]
Benioff Hugo [ˈbeniəf ˈhju:gou]
Berger Jonathan [ˈbə:dʒə ˈdʒɔnəθ(ə)n]
Bertman [ˈbə:tmən]
Bilaniuk Olexa-Myron [biləˈnjuk əˈleksə ˈmai(ə)rən]
Bolyai Johann [ˈbɔləi dʒo(u)ˈæn]
Boscovich Roger Joseph [bəsˈkɔvitʃ ˈrɔdʒə ˈdʒouzif]
Cavendish [ˈkævəndiʃ]
Chandrasekhar Subrahmanyan [ˈtʃændrəˈsekhə ˌsebrəməˈnjæn]
Clarke Robin [ˈkla:k ˈrɔbin]
Cooper [ˈku:pə]
Copernicus [kouˈpə:nikəs]
Coulomb Charles [ˈku:lɔm ˈtʃa:lz].
Crewe Albert [ˈkru: ˈælbə(:)t]
De Broglie Prince Louis [dəˈbrɔ:ˈgli:ˈprins ˈlu:i]
Democritus [diˈmɔkrətəs]
Descartes René [deiˈka:t rəˈne]
Devons Samuel [ˈdevnz ˈsæmjuəl]
Dicke Robert [ˈdik ˈrɔbət]
Dirac Paul [diˈræk ˈpɔ:l]
Doppler [ˈdɔplə]
Eggen Olin [ˈegən ˈoulin]
Einstein Albert [ˈainˌstain ˈælbə(:)t]
Empidocles [emˈpedəˌkli:z]



Epicurus [ˌepiˈkjuərəs]
Essmann Uwe [ˈesmən ˈju:w]
Euclid [ˈju:klid]
Fahrenheit [ˈfærənhait]
Faraday Michael [ˈfærədei ˈmaikl]
Feinberg Gerald [ˈfeinbəg ˈdʒerəld]
Forward Robert [ˈfɔ:wəd ˈrɔbət]
Fultz Stanley [ˈfʌlts ˈstænli]
Gabor [ˈgeibə]
Galilei Galileo [ˌgæləˈleiˌi: ˌgæləˈleiou]
Gangi Anthony [ˈgændʒi ˈæntəni]
Gell-Mann Murray [ˈgelmən ˈmʌri]
Gauger Joleroy [ˈgɔ:dʒə ˈdʒoulrɔi]
Gauss Carl Friedrich [ˈgæus ˈka:l ˈfri:draik]
Gaut Normann [ˈgɔ:t ˈnɔ:mən]
Gersonides [ˈdʒə:sənaidz]
Hartmann Lillian [ˈha:tmən ˈliljən]
Heilmeier [ˈhailmaiə]
Hertz Heinrich [hə:ts ˈhainrik]
Hofstadter Robert [ˈhɔfʃtʌtə ˈrɔbət]
Holliday Lesli [ˈhɔlidei ˈlesli]
Joule James [ˈdʒu:l ˈdʒeimz]
Kelvin Lord [ˈkelvən ˈlɔ:d]
Khayyam Omar [ˌkaiˈja:m ˈouma:]
Kock Winston [ˈkɔk ˈwinstən]
Kopal Zdenek [ˈkoupəl ˈzdenək]
Kreisler Michael [ˈkreislə ˈmaikl]
Kurti [ˈkə:ti]
Lambert Johann Heinrich [ˈlæmbət dʒo(u)ˈæn ˈhainrik]
Langenberg Donald [ˈlændʒənbə:g ˈdɔnld]
Leucippus [ˈlu:səpəs]
London Heinz [ˈlʌndən ˈhaints]
Lounasmaa [ˈlaunəsmə]
Lucretius [lu:ˈkri:ʃjəs]
Lovberg Ralph [ˈlʌvbə:g ˈrælf]
Lynden-Bell Donald [lindən ˈbel ˈdɔnld]
Maxwell James Clerk [ˈmækswəl ˈdʒeimz ˈkla:k]
Meissner [ˈmeisnə]
Mendelssohn Kurt [ˈmendəlsən ˈkə:t]
Mendoza [menˈdouzə]
Metherell Alexander [ˈmeðərəl ˌæligˈza:ndə]
Millikan Robert [ˈmilikən ˈrɔbət]
Nasreddin [ˈnæsrədin]
Oatley [ˈoutli]
Ochsenfeld [ˈɔksənfəld]
Onnes Kamerlingh Heike [ˈɔnəs ˈkʌməliŋ ˈheik]
Overseth Oliver [ˈouvəsəθ ˈɔlivə]
Parker William [ˈpa:kə ˈwiljəm]

Pauli Wolfgang ['pauli 'wɔlfgæŋ]
Peebles ['pi:blz]
Plato ['pleitou]
Proclus ['prouklǝs]
Ptolemy Claudius ['tɔlimi 'klɔ:djǝs]
Rayleigh ['reili]
Rees Martin ['ri:s 'ma:tin]
Riemann Georg ['ri:mǝn gǝ'ɔrg]
Ruderman Malvin ['rudǝmǝn 'mælvin]
Ruska Ernst ['rʌskǝ 'ǝ:nst]
Saccheri Girolamo [sǝ'tʃeri dʒirǝ'leimou]
Sachs Mendel ['za:ks 'mendǝl]
Sandage Allan ['sændidʒ 'ælǝn]
Sandiford David ['sændifǝd 'deivid]
Silk Joseph ['silk 'dʒouzif]
Sorensen Raymond ['sɔrǝnsǝn 'reimǝnd]
Starr Victor ['sta: 'viktǝ]
Stroke George ['strouk 'dʒɔ:dʒ]
Sudarshan George ['sʌdǝʃǝn 'dʒɔ:dʒ]
Taylor Barry ['teilǝ 'bæri]
Thales ['θeili:z]
Toth Imre ['tɔθ 'imrǝ]
Träuble Hermann ['trɔiblǝ 'hǝ:mǝn]
Tzara ['za:rǝ]
Vali Victor [vǝ'li: vik'tɔr]
Van Horn Hugh ['væn 'hɔ:n 'hju:]
Wallis John ['wɔlis 'dʒɔn]
Wheatley ['wi:tli]
Yang ['ja:ŋ]
Yount David ['jʌnt 'deivid]

CONTENTS

**Ирина Дмитриевна Лепешова, Татьяна Иосифовна Савощенко**

УЧЕБНИК АНГЛИЙСКОГО ЯЗЫКА ДЛЯ СТУДЕНТОВ
СТАРШИХ КУРСОВ ФИЗИЧЕСКИХ ФАКУЛЬТЕТОВ

Тематический план 1973 г. № 79

Редактор *Л. Н. Панадина*
Переплет художника *В. И. Воробьева*
Технический редактор *И. Л. Тимашева*
Корректор *Г. А. Зломанова*

Сдано в набор 20/IX—1972 г. Подписано к печати 7/III—1973 г. Формат 60×90/16. Бумага тип. № 3. Физ. печ. л. 23,5 Уч.-изд. л. 21,21. Изд. № 1941. Зак. 482: Тираж 20 000 экз: Цена 69 коп.

Издательство Московского университета
Москва, К-9, ул. Герцена, 5/7.
Типография Изд-ва МГУ. Москва, Ленинские горы.