AL-FARABI KAZAKH NATIONAL UNIVERSITY

Physics and Technics Faculty

Approved by the University scientific-methodical Council meeting
Protocol № 6 from June 27, 2014

Dean of the Faculty _____ A. Davletov

SYLLABUS

**Materials science**
For Computer science and software (5B070400)
Second year of Baccalaureate

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**Goal**

Form for students' the basic knowledge in domain of the analysis of atomic, molecular, nanoscale, poly- and monocrystalline as well as amorphous structure of matter, the behavior of conductive, insulating materials and intermediates in various fields: thermal, electrical, magnetic, under the influence of the deforming forces and various types of radiation, with elements of crystallography, structural and tensor analysis, quantum mechanics and classical methods of mathematical physics.

The main form of presentation of the course are lectures. For seminars given one hour per week. During seminars practical problems will solve on the topics of lectures for better securing the theoretical basis. Self study of students is homework tasks and reports on some small subjects. Solving of problems at seminars involves the use of the calculations and graphical interpretation of the results in Excel and Mathcad. Problems in this course are not taken from books of problems. They are direct result of scientific experiments. Sources of input data must be indicated in the problems. Most often, it is articles in scientific journals and the results of physical experiments, obtained by author of the course. As the model materials are taken for the treatment, i.e. well-studied, that problem answers are tabulated values of calculated parameters of materials. Lectures and self study of students held in the form of presentations.

**Competences (education results)**

Mastering of modern concepts, theories and calculations of the behavior of different materials in external force fields, such as temperature, electric and magnetic, understanding of the properties, processes at contact of two substances, familiarization with application of the material properties.

Structure and content of the course

| Weeks | Subjects | Hours | Grades |
|---|---|---|---|
| **Module 1 - The structure of materials** | | | |
| 1 | Lecture 1. Types of binding forces of atoms in molecules and crystal lattices. Internal structure of solids. Concept of electronegativity and interaction potential. Ionic, covalent, metallic, van der Waals, hydrogen bonds | 1 | 0 |
| | Seminar 1. Calculation of the interaction forces for real materials | 1 | 10 |
| | Self study 1. Binding energy. Types of polarizability. Hybridization of atomic orbitals | 1 | 3 |
| 2 | Lecture 2. Elements of statistical physics. Non-degenerate and degenerate ensembles. Maxwell-Boltzmann statistics. Distribution of quantum states of structural particle according Fermi-Dirac and Bose-Einstein | 1 | 0 |
| | Seminar 2. Problem Solving: degenerate and nondegenerate ensembles. Determining of the probability of filling by Fermi particles (electrons and holes) of certain energy levels in semiconductor materials and metals. Calculation of formation of Cooper pairs at the critical point and accumulating them in a Bose-Einstein condensate | 1 | 10 |
| | Self study 2. Distribution function of fermions. Distribution function for bosons | 1 | 3 |
| 3 | Lecture 3. Band theory of solids. Energy spectrum of crystals in space of wave vector. Schrödinger's equation for a crystal. Bloch function. Origin of the Brillouin zone. The concept of the effective mass. De Broglie waves | 1 | 0 |
| | Seminar 3. Solving problems: Contact phenomena. Calculation of the work function, contact potential difference, width of depletion region in semiconductors | 1 | 10 |
| | Self study 3. Temperature dependence of the energy band structure in the intrinsic and extrinsic semiconductors | 1 | 3 |
| 4 | Lecture 4. Reciprocal space. Construction of the Ewald sphere. Bravais lattices. Wigner-Seitz cell | 1 | 0 |
| | Seminar 4. Determination of the Miller indices of planes, directions and point in the lattices of different crystal systems | 1 | 10 |
| | Self study 4. Chirality. Symmetry. Solid solutions. Polymorphism | 1 | 3 |
| 5 | Lecture 5. Methods of investigation of crystal structure of solids. X-ray analysis. Bragg's law. Laue condition. | 1 | 0 |
| | Seminar 5. Calculation of X-ray and electron diffraction patterns of powder materials and single crystals | 1 | 10 |
| | Self study 5. Determination of crystallite size on the Scherrer formula | 1 | 3 |
| 6 | Lecture 6. Defects in materials. Schottky and Frenkel defects. Impurities. Radiation-induced defects. Displacement cascades | 1 | 0 |
| | Seminar 6. Calculation of ion-implanted structures | 1 | 10 |
| | Self study 6. Linear two-dimensional defects (dislocations, disclinations). Burgers vector. Grain boundaries | 1 | 3 |
| 7 | Lecture 7. Amorphous materials. Materials with nanostructure. Photonic crystals. Metamaterials | 1 | 0 |
| | Control work | 1 | 9 |
| | 1st Interim Control (IC) | - | 100 |
| | MidlTermExam | 2 | 100 |

| Module 2 – Material properties | | | |
|---|---|---|---|
| 8 | Lecture 8. Thermodynamic interaction of materials. Phase states. Phase diagrams of binary systems. Variability of system. Electrochemical potential. Gibbs phase rule | 1 | 0 |
| | Seminar 8. Calculation and construction of phase diagrams of binary systems | 1 | 10 |
| | Self study 8. Phase diagrams of binary systems with chemical compounds. Congruent transformation in alloys. Syntectic bynary diagrams. Monotectic phase diagrams. Limit cases | 1 | 3 |
| 9 | Lecture 9. The mechanical properties of materials: elasticity, plasticity, hardness, creepage | 1 | 0 |
| | Seminar 9. Finding of the mechanical characteristics of materials on the stress-strain diagram. The calculation of alloys hardness and materials microhardness by Vickers and Brinell methods | 1 | 10 |
| | Self study 9. Elastic moduli and their relationship. Shear characteristics. Work hardening. Superplasticity. Bending characteristics. Torsion features | 1 | 3 |
| 10 | Lecture 10. Thermal properties of materials. Dulong-Petit, Joule-Kopp, Einstein, Debye heat capacity models. Phonons. Thermal conductivity. Thermal expansion of solids | 1 | 0 |
| | Seminar 10. Calculation of the specific heat, thermal conductivity, thermal expansion, Debye temperature of given materials in the Mathcad program | 1 | 10 |
| | Self study 10. Normal lattice vibrations. Normal oscillator. Phonon statistics | 1 | 3 |
| 11 | Lecture 11. The electrical properties of materials. Electrical conductivity of metals and semiconductors. Mobility of charge carriers in semiconductors. Temperature dependence of the mobility and conductivity. | 1 | 0 |
| | Seminar 11. Calculation of the electrical conductivity of metals, comparison with tabulated values. Calculation of the electrical conductivity and mobility semiconductors | 1 | 10 |
| | Self study 11. Wiedemann-Franz law. Polarization of dielectrics. Phenomena in strong electric fields. Zener tunneling effect and Gunn effect | 1 | 3 |
| 12 | Lecture 12. Phenomenon of superconductivity. Barden-Cooper-Schrieffer theory. Meissner effect. The concept of phase transition. Superconductivity 1, 2 and 1.5 types. Abrikosov vortices | 1 | 0 |
| | Seminar 12. Calculation of the current density in superconductors, specific heat jump at the critical point, levitation conditions, parameters of Josephson junctions in Mathcad software | 1 | 10 |
| | Self study 12. Josephson effects. HTSC ceramics. SC wires. SQUID | 1 | 3 |
| 13 | Lecture 13. The magnetic properties of the materials. Magnetization Rayleigh law. Magnetic hysteresis. Ferro-, para- and diamagnetics | 1 | 0 |
| | Seminar 13. Analysis of magnetic materials parameters from magnetic hysteresis | 1 | 10 |
| | Self study 13. Hard and soft magnetic materials. Ferrimagnets and antiferromagnets. Magnetic resonance. Superparamagnetism. Types of magnetoresistance | 1 | 3 |
| 14 | Lecture 14. The interaction of light with matter. Optical phenomena in materials | 1 | 0 |
| | Seminar 14. Determination of skin layer depth in metals under irradiation with monochromatic light, calculation of the plasma | 1 | 10 |

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|---|---|---|---|
| | frequency of semiconductors, comparison with the tabulated data, calculation of the band gap of semiconductors and dielectric films from the transmission and reflection spectra in Excel | | |
| | Self study 14. Photoconductivity of semiconductors. Luminescence. Ruby laser | 1 | 3 |
| | Control work | 1 | 9 |
| | 2nd Interim Control (IC) | - | 100 |
| Final Exam (FE): written, 2 theoretical questions, 1 problem | | 2 | 100 |

Total GPA: $\frac{1^{st}\,IC + 2^{nd}\,IC}{2} \times 0{,}6 + 0{,}1MT + 0{,}3FE$

Each student should have about 15 grades every week. To compensate the missing grades in next week will impossible

References

Basic


1 Callister W. D. Fundamentals and Materials Science and Engineering/An Interactive. -2001. – 1619 p.
2 Kittel Ch. Introduction in Solid State Physics. – 1996. – 675 p.
3 Ashcroft N. W., Mermin N. D. Solid State Physics. – 1976. - 826 p.
4 Shackelford J. F., William A. Materials science and engineering handbook. – 2001. – 1928 p.
5 Anderson J. C., Leaver K. D., Leevers P., Rawlings R. D. Materials Science for Engineers. – 2009. – 889 p.
6 Ohring M. Engineering materials science. - 2009. - 850 p.
7 Brewster H. D. Solid State Physics. – 2009. - 286 p.
8 Methods for Phase Diagram Determination, edited by Zhao J.-C., ELSEVIER. - 505 p.
9 Phase diagrams. Understanding the basics, edited by Campbell F. C., ASM International. – 2012. - 462 p.
10 Шевченко О. Ю. Основы физики твердого тела. – С.-Петербург. – 2010. – 76 с.
11 Епифанов Г. И. Физика твердого тела. – М.: ВШ. – 1977. – 288 с.
12 Давыдов А. С. Теория твердого тела. – М.: Наука. – 1976. – 637 с.
13 Павлов П. В., Хохлов А. Ф. Физика твердого тела. – М.: Высшая школа. – 2000. – 494 с.
14 Зиненко В. И., Сорокин Б. П., Турчин П. П. Основы физики твердого тела. – М.: Изд. Физ. Мат. Лит. – 2001. – 333 с.


Aditional


1 Краткий справочник физико-химических величин. Под ред. Мищенко А. А. – Л.: Химия. – 1974. – 200 с.
2 Гинзбург И. Ф. Введение в физику твердого тела. Часть I. – Новосибирск. – 2003. – 218 с.


Map of methodical support of the discipline

| Grade | Equivalent (GPA) | % | Grade in traditional system |
|---|---|---|---|
| A | 4 | 95-100 | "Excellent" |
| A- | 3,67 | 90-94 | |
| B+ | 3,33 | 85-89 | "Good" |

| | | | |
|---|---|---|---|
| B | 3 | 80-84 | |
| B- | 2,67 | 75-79 | |
| C+ | 2,33 | 70-74 | " Satisfactory" |
| C | 2 | 65-69 | |
| C- | 1,67 | 60-64 | |
| D+ | 1,33 | 55-59 | |
| D | 1 | 50-54 | |
| F | - | 0-49 | "Failing" (no-go mark) |
| I | - | - | "Incomplete" |
| W | - | - | "Withdrawal" |
| AW | - | - | "Administrative Withdrawal |
| AU | - | - | " Auditing – Discipline listened" |
| P/NP | - | 65-100/0-64 | "Pass / No Pass" |

In grading the performance of the student during the semester is taken into account the following: attendance, active and productive participation in practical classes, study of basic and additional literature, fulfillment of the SSS, timely submission of all homeworks. For the late presentation of three SSS rating of AW.

The policy of academic behaviour and ethics
Be tolerant and respect other people's opinions. Objection was formulated in the correct form. Plagiarism and other forms of cheating are not allowed. Prompting and copy off from someone are not allowed during the delivery of the SSS, intermediate control and final exam, copying problems solved by others, passing the exam for another student. A student convicted of falsification of any information of the course will receive a final grade of «F».

Help: For advice on the implementation of independent work (SSS), their delivery and protection, as well as additional information on the studied material, and all other emerging questions for course please contact the instructor during his office hours.

Recommended at a meeting of the Department
Protocol # 36 from June 10, 2014

Head of Department
of Solid State Physics and Nonlinear Physics O. Yu. Prikhodko

Teacher A. A. Migunova