Brief summary of lectures on discipline

" Basic principles of Modern Physics "

Lecture 1.

Nuclear physics is the field of physics that studies atomic nuclei and their constituents and interactions. Other forms of nuclear matterare also studied.[1] Nuclear physics should not be confused with atomic physics, which studies the atom as a whole, including its electrons.

Discoveries in nuclear physics have led to applications in many fields. This includes nuclear power, nuclear weapons, nuclear medicineand magnetic resonance imaging, industrial and agricultural isotopes, ion implantation in materials engineering, and radiocarbon dating in geology and archaeology. Such applications are studied in the field of nuclear engineering.

Particle physics evolved out of nuclear physics and the two fields are typically taught in close association. Nuclear astrophysics, the application of nuclear physics to astrophysics, is crucial in explaining the inner workings of stars and the origin of the chemical elements.

Lecture 2.

Electricity generation is the process of generating electric power from sources of primary energy. For electric utilities in the electric power industry, it is the first stage in the delivery of electricity to end users, the other stages being transmission, distribution, energy storage and recovery, using pumped-storage methods.

A characteristic of electricity is that it is not a primary energy freely present in nature in remarkable amounts and it must be produced. Production is carried out in power plants. Electricity is most often generated at a power station by electromechanicalgenerators, primarily driven by heat engines fueled by combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. Other energy sources include solar photovoltaics and geothermal power.

Lecture 3.

In this chapter, we will discuss the basic ingredients of nuclear physics. Section 1.1 introduces the elementary particles that form nuclei and participate in nuclear reactions. Sections 1.2 shows how two of these particles, protons and neutrons, combine to form nuclei. The essential results will be that nuclei have volumes roughly proportional to the number of nucleons, ∼ 7 fm3 per nucleon and that they have binding energies that are of order 8 MeV per nucleon. In Sect. 1.3 we show how nuclei are described as quantum states. The forces responsible for binding nucleons are described in Sect. 1.4. Section 1.5 discusses how nuclei can be transformed through nuclear reactions while Sect. 1.6 discusses the important conservation laws that constrain these reactions and how these laws arise in quantum mechanics. Section 1.7 describes the isospin symmetry of these forces. Finally, Sect. 1.8 discusses nuclear shapes.

Lecture 4.

A **nuclear reactor**, formerly known as an **atomic pile**, is a device used to initiate and control a sustained nuclear chain reaction. Nuclear reactors are used at nuclear power plants for electricity generation and in propulsion of ships. Heat from nuclear fission is passed to a working fluid (water or gas), which runs through steam turbines. These either drive a ship's propellers or turn electrical generators. Nuclear generated steam in principle can be used for industrial process heat or for district heating. Some reactors are used to produce isotopes for medical and industrial use, or for production of weapons-grade plutonium. Some are run only for research. As of April 2014, the IAEA reports there are 435 nuclear power reactors in operation, in 31 countries around the world.[1]

Lecture 5.

The complex merchant vessels, passenger ships and ships of war of the 1990s comprise tons of steel and aluminium as well as a variety of materials that range from the most common to the very exotic. Each vessel may contain hundreds or even thousands of kilometres of pipe and wire equipped with the most sophisticated power plants and electronic equipment available. They must be constructed and maintained to survive the most hostile of environments, while providing comfort and safety for the crews and passengers aboard and reliably completing their missions.

Ship construction and repair rank among the most hazardous industries in the world. According to the US Bureau of Labor Statistics (BLS), for example, shipbuilding and repair is one of the three most hazardous industries. While materials, construction methods, tools and equipment have changed, improved radically over time and continue to evolve, and while training and emphasis on safety and health have significantly improved the lot of the shipyard worker, the fact remains that throughout the world each year workers die or are seriously injured while employed in the construction, maintenance or repair of ships.

Despite advances in technology, many of the tasks and conditions associated with constructing, launching, maintaining and repairing today’s vessels are essentially the same as they were when the very first keel was laid thousands of years ago. The size and shape of the components of a vessel and the complexity of the work involved in assembling and outfitting them largely preclude any kind of automated processes, although some automation has been made possible by recent technological advances. Repair work remains largely resistant to automation. Work in the industry is very labour intensive, requiring highly specialized skills, which often must be utilized under less than ideal circumstances and in a physically challenging situation.

Lecture 6.

The core of a nuclear reactor is where the fuel is located and where nuclear fission reactions take place. The materials used to encase the fuel in fuel rods, to hold fuel rods together in fuel assemblies, and to hold fuel assemblies in place are all considered ‘core structural materials’, as are the materials used in control rods and core monitoring instruments and their supporting structures. For fusion reactors the core structural materials are the materials of the first wall, blanket and divertor. 2. The economics of current nuclear power plants is improved through increasing fuel burnups, i.e. the effective time that fuel remains in the reactor core and the amount of energy it generates. Increasing the consumption of fissile material in the fuel element before it is discharged from the reactor means less fuel is required over the reactor’s life cycle, which results in lower fuel costs, lower spent fuel storage costs, and less waste for ultimate disposal.

Lecture 7.

The IAEA promotes and supports the establishment of comprehensive regulatory frameworks to ensure the safety of nuclear installations throughout their lifetime.

These regulatory frameworks consist of relevant legislation, regulations and guidance and a robust leadership and management programme for safety. It is essential to ensure that an operational and effectively independent regulatory body is established and maintained for the regulatory control of nuclear installations. This body needs sufficient resources and suitably qualified and competent staff that are enabled to fulfil their regulatory responsibilities and functions.

The IAEA's Safety Standards and the Code of Conduct on the Safety of Research Reactors lay out the international requirements and recommendations for enhancing existing or developing regulatory systems for the control of nuclear installations throughout their lifetime until they are released from regulatory control, and any subsequent period of institutional control. The Convention on Nuclear Safety also provides to its contracting parties a set of obligations, including those relative to their legislative and regulatory framework and regulatory bodies.

Lecture 8.

Nuclear propulsion includes a wide variety of propulsion methods that fulfill the promise of the Atomic Age by using some form of nuclear reaction as their primary power source. The idea of using nuclear material for propulsion dates back to the beginning of the 20th century. In 1903 it was hypothesised that radioactive material, radium, might be a suitable fuel for engines to propel cars, boats, and planes.[1] H. G. Wells picked up this idea in his 1914 fiction work *The World Set Free*

Research into nuclear-powered aircraft was pursued during the Cold War by the United States and the Soviet Union as they would presumably allow a country to keep nuclear bombers in the air for extremely long periods of time, a useful tactic for nuclear deterrence. Neither country created any operational nuclear aircraft. One design problem, never adequately solved, was the need for heavy shielding to protect the crew from radiation sickness. Since the advent of ICBMs in the 1960s the tactical advantage of such aircraft was greatly diminished and respective projects were cancelled. Because the technology was inherently dangerous it was not considered in non-military contexts. Nuclear-powered missiles were also researched and discounted during the same period.

Lecture 9.

Spent nuclear fuel, occasionally called **used nuclear fuel**, is nuclear fuel that has been irradiated in a nuclear reactor (usually at a nuclear power plant) to the point where it is no longer useful in sustaining a nuclear reaction.

After uranium fuel has been used in a reactor for a while, it is no longer as efficient in splitting its atoms and producing heat to make electricity. It is then called "spent" nuclear fuel. About one-fourth to one-third of the total fuel load is spent and is removed from the reactor every 12 to 18 months and replaced with fresh fuel. The spent nuclear fuel is high-level radioactive waste.

The NRC regulates all commercial reactors in the United States, including nuclear power plants that produce electricity, and university research reactors. The agency regulates the possession, transportation, storage and disposal of spent fuel produced by the nuclear reactors.

Spent nuclear fuel is highly radioactive and potentially very harmful. Standing near unshielded spent fuel could be fatal due to the high radiation levels. Ten years after removal of spent fuel from a reactor, the radiation dose 1 meter away from a typical spent fuel assembly exceeds 20,000 rems per hour. A dose of 5,000 rems would be expected to cause immediate incapacitation and death within one week.

Lecture 10.

An **electrostatic nuclear accelerator** is one of the two main types of particle accelerators, where charged particles can be accelerated by subjection to a static high voltage potential. The static high voltage method is contrasted with the dynamic fields used in oscillating field particle accelerators. Owing to their simpler design, historically these accelerators were developed earlier. These machines are operated at lower energy than some larger oscillating field accelerators, and to the extent that the energy regime scales with the cost of these machines, in broad terms these machines are less expensive than higher energy machines, and as such they are much more common. Many universities worldwide have electrostatic accelerators for research purposes.

Lecture 11.

The fourteenth International Conference on the Application of Accelerators in Research and Industry was held in November, 1996 in Texas, USA. The United States Department of Energy was one of the sponsors of this conference. The conference was widely attended by accelerator scientists throughout the world. The topics discussed included a wide range of applications spanning the fields from Art History to Zoology. An overview of the Design Project for the National spallation Neutron Source was presented in one of the plenary sessions, as was a summary of Accelerated Beams of Radioactive Ions. Accelerator based Atomic Physics had the most sessions. The subject of accelerator Technology covered topics such as new accelerators, beam handling systems, ion sources, detector, spectrometers, and magnets etc. Radioactive Beams and Nuclear Physics were also topics of several sessions. New Research Opportunities for Nuclear structure, Nuclear Astrophysics, Material Science, and the future facilities and applications of Accelerated Beams of Radioactive ions were discussed. These proceedings represent the papers presented at this exciting conference which summarized the State of the Art technology of Accelerator applications in research and Industry.

Lecture 12.

The future of humankind is present today within the bodies of living people, animals and plants -- the whole seedbearing biosphere. This living biosystem which we take so much for granted has evolved slowly into a relatively stable dynamic equilibrium, with predictable interactions between plants and animals, between microscopic and macroscopic life, between environmental pollutants and human health. Changes in the environment disturb this balance in two ways: first, by altering the carefully evolved seed by randomly damaging it, and second, by altering the habitat, i.e. food, climate or environment, to which the seed and/or organism has been adapted, making life for future generations more difficult or even impossible.

Although examples of maladaptation in nature and resulting species extinction abound, our focus here is on human seed, the sperm and ovum, and the effect on it and on the human habitat resulting from increasing ionising radiation in the environment.

Lecture 13.

Ionizing radiation (**ionising radiation**) is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Ionizing radiation is made up of energetic subatomic particles, ions or atoms moving at high speeds (usually greater than 1%

of the speed of light), and electromagnetic waves on the high-energy end of the electromagnetic spectrum.

Gamma rays, X-rays, and the higher ultraviolet part of the electromagnetic spectrum are ionizing, whereas the lower ultraviolet part of the electromagnetic spectrum, and also the lower part of the spectrum below UV, including visible light (including nearly all types of laser light), infrared, microwaves, and radio waves are all considered *non-ionizing radiation*. The boundary between ionizing and non-ionizing electromagnetic radiation that occurs in the ultraviolet is not sharply defined, since different molecules and atoms ionize at different energies. Conventional definition places the boundary at a photon energy between 10 eV and 33 eV in the ultraviolet (see definition boundary section below).

Typical ionizing subatomic particles from radioactivity include alpha particles, beta particles and neutrons. Almost all products of radioactive decay are ionizing because the energy of radioactive decay is typically far higher than that required to ionize. Other subatomic ionizing particles which occur naturally are muons, mesons, positrons, and other particles that constitute the secondary cosmic rays that are produced after primary cosmic rays interact with Earth's atmosphere.[1][2] Cosmic rays are generated by stars and certain celestial events such as supernova explosions. Cosmic rays may also produce radioisotopes on Earth (for example, carbon-14), which in turn decay and produce ionizing radiation. Cosmic rays and the decay of radioactive isotopes are the primary sources of natural ionizing radiation on Earth referred to as background radiation. Ionizing radiation can also be generated artificially using X-ray tubes, particle accelerators, and any of the various methods that produce radioisotopes artificially.

Lecture 14.

Peaceful nuclear explosions (**PNEs**) are nuclear explosions conducted for non-military purposes, such as activities related to economic development including the creation of canals. During the 1960s and 1970s, both the United States and the Soviet Union conducted a number of PNEs.

Six of the explosions by the Soviet Union are considered to have been of an applied nature, not just tests.

Subsequently the United States and the Soviet Union halted their programs. Definitions and limits are covered in the Peaceful Nuclear Explosions Treaty of 1976.[1][2] The Comprehensive Nuclear-Test-Ban Treaty of 1996 prohibits all nuclear explosions, regardless of whether they are for peaceful purposes or not.

In the PNE Treaty, the signatories agreed: not to carry out any individual nuclear explosions having a yield exceeding 150 kilotons; not to carry out any group explosion (consisting of a number of individual explosions) having an aggregate yield exceeding 1,500 kilotons; and not to carry out any group explosion having an aggregate yield exceeding 150 kilotons unless the individual explosions in the group could be identified and measured by agreed verification procedures. The parties also reaffirmed their obligations to comply fully with the Limited Test Ban Treaty of 1963.

The parties reserve the right to carry out nuclear explosions for peaceful purposes in the territory of another country if requested to do so, but only in full compliance with the yield limitations and other provisions of the PNE Treaty and in accord with the Non-Proliferation Treaty.

Articles IV and V of the PNE Treaty set forth the agreed verification arrangements. In addition to the use of national technical means, the treaty states that information and access to sites of explosions will be provided by each side, and includes a commitment not to interfere with verification means and procedures.

The protocol to the PNE Treaty sets forth the specific agreed arrangements for ensuring that no weapon-related benefits precluded by the Threshold Test Ban Treaty are derived by carrying out a nuclear explosion used for peaceful purposes, including provisions for use of the hydrodynamic yield measurement method, seismic monitoring and on-site inspection.

The agreed statement that accompanies the treaty specifies that a "peaceful application" of an underground nuclear explosion would not include the developmental testing of any nuclear explosive.[3]

Lecture 15.

Future electricity demand will depend to some extent on the country’s role from 2019 in the Eurasian Economic Community energy market. Also the State Grid Corporation of China (SGCC) is planning transmission links from China. The state-owned Kazakhstan Electricity Grid Operating Company (KEGOC) was set up in 1997. The question of nuclear power in Kazakhstan has been discussed for many years, notably since 2006 with Russia, and a national nuclear strategy is expected in 2018.

Kazatomprom is the national atomic company set up in 1997 and owned by the government. It controls all uranium exploration and mining as well as other nuclear-related activities, including imports and exports of nuclear materials. It announced in 2008 that it aimed to supply 30% of the world's uranium by 2015 (it produced 39% in fact), and through joint ventures: 12% of the uranium conversion market, 6% of enrichment, and 30% of the fuel fabrication market by then.