A short-term course on “Basics of Nuclear Technology”

1. Course Objectives

The nuclear technology, in its totality, encompasses a wide variety of subjects, namely, basic nuclear physics, reactor physics, thermal hydraulics, radiation safety, materials science, process engineering, control engineering and power plant engineering. To gain a mastery of the entire spectrum of these subjects definitely requires full-fledged courses in undergraduate and graduate levels. Such courses are offered by a number of universities for students majoring in Nuclear Engineering. There is, however, a need for engineers and scientists of many other disciplines to have a general understanding of the basics of nuclear energy which provides 11% of world’s electrical energy today and has a potential for meeting the base load requirements of electricity for several centuries, complementing renewable energy sources, such as solar and wind, which suffer due to their intermittency. The mandate of reduction of green house gases for mitigating climate change in the planet is driving every nation, particularly those developing rapidly, towards a non-carbon economy. Therefore, opinion makers of tomorrow require a basic understanding of the nuances of different energy technologies. The proposed course is so designed that those attending will be introduced to the fundamentals of nuclear energy production, will find answers to the frequently asked questions related to radiation and safety, will appreciate how different technology challenges in design and construction of nuclear reactors were solved and will get exposed to aspects such as design of nuclear fuel and their in-service performance, reprocessing of spent fuel and handling of radioactive waste. In order to highlight the complexities of the technologies involved some of the important concepts will be discussed rigorously. Having attended this course, participants will acquire a broad background which will enable them to make proper judgement in connection with different energy options and to advance their knowledge by self-learning through various available sources.

2. Outlines of lectures

(Five lectures, two hours each)

Lecture 1: Reactor Physics Fundamentals

Binding energy of nucleons, Stable and unstable nuclei and radioactivity, Cross sections of nuclear processes, Energy release from fusion and fission reactions, Chain reaction, Uncontrolled fission, Moderation of neutron energy, Delayed neutrons, Doppler effect, Concept of criticality, Four factor formula, Diffusion equation and steady state in neutron population, Multigroup (energy) calculations, Concept of reactivity, Kinetics of neutron multiplication, Effect of temperature, fission product poisoning and fuel burn-up on reactivity, Function of control elements in controlling neutron population, Homogeneous and heterogeneous nuclear reactors.

Lecture 2 : Descriptions of Nuclear Reactors, Functions of Reactor Components and Methods of Heat Removal

Descriptions of currently operating water cooled reactors – Pressurised and Boiling Water Reactors (PWRs & BWRs) and Pressurised Heavy Water Reactors (PHWRs), Comparison of vessel type and tube type reactors, Nuclear reactor components-fuel, cladding, moderator, coolant, control system, pressure vessel/ pressure tube, containment, radiation shield – and their functions, Design of fuel elements and coolant channels, Thermal hydraulics of coolant circuit, Control of reactor power, Control and shut off mechanisms, High temperature reactors-gas cooled and liquid metal/molten salt cooled, Coupling of thermal hydraulics and neutronics.

Lecture 3 : Nuclear Power Plants and their Safety

Subsystems of nuclear power plants- Core of a reactor, Steam Generators, Turbines, Pressurisers, Emergency core cooling systems, Multiple tiers of safety, Reactivity control for core safety, Adequate cooling of the core during operating and shut down conditions, Effective containment of radioactivity, Passive safety features, Analysis and consequences of three worst accidents, Probabilistic and deterministic safety analysis.

Lecture 4 : Nuclear Fuel Cycle

Open and closed fuel cycle, Front and back end of fuel cycle, Isotope enrichment, Heavy water production, Nuclear fuel -metallic, ceramic, dispersion type fuel, Spent fuel reprocessing, Nuclear waste management.

Lecture 5 : Fast Reactors and Emerging Reactor Designs

Fertile to fissile breeding, Fast breeder reactor technology, Molten salt reactor, Small and medium sized reactors, High temperature reactor -hydrogen production, Nuclear power from thorium, Long term sustainability of nuclear power.

3. Recommended Books

i) 'Nuclear Reactor Engineering'- Samuel Glasstone and Alexander Sesonske

(ii) ' Introduction to Nuclear Engineering' - John R. Lamarsh

(iii) ' Introduction to Nuclear Reactor Theory' - John R. Lamarsh