NUCLEAR ENGINEERING
(Professional Elective II)

I Semester

Course Code: 19ME2254

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Prerequisites: Heat Transfer

Course Outcomes: At the end of the course, the student shall be able to

CO1: Explain the basic concepts and processes taking place inside a nuclear reactor, such as nuclear fission, neutron production, scattering, diffusion, slowing down and absorption.
CO2: Summarize with concepts of reactor criticality, the relationship between the dimension and fissile material concentration in a critical geometry.
CO3: Discover Time dependent (transient) behaviour of power reactor in non-steady state operation and the means to control the reactor.
CO4: Discuss concepts of heat removal from the reactor core.
CO5: Inference reactor safety and radiation protection.

UNIT-I: **(10-Lectures)**

Basics of atomic and nuclear physics
Atomic and nuclear structure, Excited states and radiation, Nuclear stability and radioactive decay, Radioactivity calculations, Nuclear reactions, Binding energy, Nuclear models.
Interaction of radiation with matter
Neutron interactions, Neutron attenuation, Neutron flux, Energy loss in scattering collisions, Fission, ɣ ray interactions with matter, Charged particles.

Learning outcomes: At the end of this unit, the student will be able to

1. Define basic parameters to know the atomic and nuclear structure, nuclear stability and radioactive decay. (L1)
2. Apply basic principles to know the decay of radioactive nuclei. (L3)
3. Demonstrate how the nuclear radiation interacts with matter in the design of nuclear reactors. (L2)

UNIT-II: **(10-Lectures)**

Nuclear reactors and nuclear power
The fission chain reaction, Nuclear reactor fuels, Components of nuclear reactors, Power reactors and nuclear steam supply systems, Nuclear cycles, Isotope separation, Fuel reprocessing, Radioactive waste disposal
Neutron diffusion and moderation
Fick's law, The equation of continuity, The diffusion equation, Boundary conditions, Solutions of the diffusion equation, The diffusion length, The Group-Diffusion method, Thermal neutron diffusion, Two-group calculation of neutron moderation.

Learning outcomes: At the end of this unit, the student will be able to

1. Demonstrate non-nuclear and nuclear components of nuclear power plants. (L2)

2. Summarize various methods of radioisotope separation, radioactive fuel reprocessing and radioactive waste disposal. (L2)
3. Develop governing equations for mass diffusion of neutrons and solve governing equations with applicable boundary conditions. (L3)

UNIT-III: **(10-Lectures)**

Nuclear reactor theory
One-Group reactor equation, Slab reactor, The one-group critical equation, Thermal reactors, Reflected reactors, Multi-Group calculations, Heterogeneous reactors.
The time dependent reactor
Reactor kinetics, Control rods and chemical shim, Temperature effects on reactivity, Fission product poisoning, Core properties during lifetime.

Learning outcomes: At the end of this unit, the student will be able to

1. Design a nuclear reactor using one-group reactor equation and solve it to know the conditions for normal criticality. (L6)
2. Apply one-group reactor equation to know the radiation flux distribution in thermal and reflected reactors. (L3)
3. Apply principles of reactor kinetics to determine prompt neutron lifetime, critical state and jump. (L3)

UNIT-IV: **(10-Lectures)**

Heat removal from nuclear reactors
Heat generation in reactors, Heat flow by conduction, Heat transfer to coolants, Boiling heat transfer, Thermal design of a reactor.
Radiation protection
Radiation units, The biological effects of radiation, Calculations of radiation effects, Natural and man-made radiation sources, Standards of radiation protection, Computations of exposure and dose, Exposure from ɣ -ray sources.

Learning outcomes: At the end of this unit, the student will be able to

1. Apply basic thermodynamic principles to know the amount of heat removed by coolant from a nuclear reactor. (L3)
2. Design a cooling system to remove heat produced in a nuclear reactor by applying principles of heat transfer. (L6)
3. List out radiation units and biological effects of radiation and Identify various natural and man-made sources of radiation. (L1)

UNIT-V: **(10-Lectures)**

Radiation shielding
ɣ -Ray shielding, Infinite planar and disc sources, The line source, Internal sources, Multilayered shields, Principles of Nuclear reactor shielding, The reactor shield design, Shielding ɣ -rays, Coolant activation, Ducts in shields.
Reactor safety and environment

Principles of nuclear power plant safety, Dispersion of effluents from nuclear facilities, Radiation doses from nuclear plants, reactor siting, reactor accidents, Accident risk analysis, Environmental radiation doses.

Learning outcomes: At the end of this unit, the student will be able to

1. Determine the thickness and/or composition of shielding material required to reduce biological dose rates to predetermined levels. (L5)
2. Summarize the principles of nuclear power plant safety. (L2)
3. Demonstrate various methods for dispersion of nuclear effluents. (L2)

TEXT BOOKS:

1. R. Lamarsh, Anthony J. Barrata, *Introduction to Nuclear Engineering*, 4th Edition, Pearson Publisher, 2017.

REFERENCE BOOKS:

1. R. Lamarsh, *Introduction to Nuclear Reactor Theory*, 2nd Edition, Addison-Wesley, 1966.
2. James J. Duderstadt and Lewis J. Hamilton, *Nuclear Reactor Analysis*, 1st Edition, Wiley, 1976.