Course Curriculum

(2019-2020)

Department of Nuclear Science and Technology

PROGRAMME LEARNING OBJECTIVES (PLOs):

1. Demonstrate an understanding of nuclear processes, and the application of general science and engineering principles to the analysis and design of nuclear and related systems of current and/or future importance to society.
2. Produce high quality nuclear and radiological engineering graduates in order to help meet the manpower needs of our state, region, nation and the international community.
3. Conduct nuclear and radiological engineering related research to help meet the needs of society.

PROGRAMME OUTCOMES (POs):

Postgraduate engineering programme are designed to prepare graduates to attain the following program outcomes:

1. The ability to apply knowledge of mathematics, science and engineering to the analysis of nuclear and other systems.
2. The ability to identify, formulate and solve nuclear engineering problems.
3. The ability to design integrated systems involving nuclear and other physical processes.
4. The ability to design and perform laboratory experiments to gather data, test theories, and solve problems.
5. The ability to learn and work independently, and to practice leadership and teamwork in and across disciplines.
6. The ability for effective oral, graphic and written communication.

Semester - I														
Sr. No.	**Course Code**	**Course Name**	**Teaching Scheme**					**Examination Scheme**					
			L	**T**	**P**	**C**	**Hrs/WK**	**Theory**			**Practical**		**Total Marks**
								MS	**ES**	**IA**	**LW**	**LE/Viva**	
1.	17NE501T	Introduction to Nuclear Physics and Engineering	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
2.	19NE502T	Energy and Environment	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
3.	19NE503T	Health Physics & Radiation Protection	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
4.	16NE503P	Radiation Measurement Lab	**0**	**0**	**4**	**2**	**4**				**40**	**60**	**100**
5.	16MA503T	Advanced Numerical Methods and Computer Programming	**3**	**1**	**0**	**4**	**3**	**25**	**50**	**25**			**100**
6.	16MA503P	Advanced Numerical Methods Lab	**0**	**0**	**2**	**1**	**2**				**40**	**60**	**100**
7.	19NE503T / 17NE 505T	Elective-I (Elective-I Radiation and Radioisotope Applications – I / Nuclear Instrumentation and Control)	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
Total			**15**	**0**	**6**	**19**	**21**						

Semester - II													
Sr. No.	**Course Code**	**Course Name**	**Teaching Scheme**					**Examination Scheme**					
			L	**T**	**P**	**C**	**Hrs/WK**	**Theory**			**Practical**		**Total Marks**
								MS	**ES**	**IA**	**LW**	**LE/Viva**	
1.	17NE 512T	Nuclear Reactor Engineering	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
2.	17NE 513T	Nuclear Safety, Security and Safeguard	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
3.	16NE 509T	Nuclear Material and Nuclear Fuel Cycle	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
4.	17NE 514T	Nuclear Heat Transfer and Thermal Hydraulics	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
5.	17NE 511T/ 17NE 512T	Elective-II (Radiation and Radioisotope Applications-II / Design, Manufacturing and Testing of Nuclear Reactor Components)	**3**	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**
6.	16NE512P	Thermal Hydraulics Laboratory	**0**	**0**	**4**	**2**	**4**				**40**	**60**	**100**
7.	17CE 527T	Successful Research Program Development	**2**	**0**	**0**	**2**	**2**						
Total			**17**	**0**	**4**	**19**	**21**						

L Lectures **P** Practical **MS** Mid-Semester Exam **IA** Internal Assessment
T Tutorials **C** Credits **ES** End-Semester Exam **LW** Lab Work

Semester - III			
Sr. No.	**Course Code**	**Course Name**	**Credits**
1.	MT611	Seminar	5
2.	MT612	Project	14
3.	MT613	Industrial Training	00

Semester - IV			
Sr. No.	**Course Code**	**Course Name**	**Credits**
1.	MT621	Seminar	5
2.	MT622	Project and Dissertation	24

17NE 501T	Introduction to Nuclear Physics and Engineering
Course Objectives	1. Basic Nuclear Physics, Fission & Fusion process 2. power reactors, research reactors and their fuels and applications 3. Basics of plasma physics, fusion energy and engineering design of fusion systems 4. Non-power applications of nuclear energy; Radiation and radioisotope applications
Course Outcomes	1. Demonstrate a fundamental understanding of microscopic and macroscopic cross-sections, and of the features of neutron cross sections. 2. Demonstrate a solid understanding of fission process, multiplication factor, nuclear fuels, and various reactor types. 3. Students will be having fundamental knowledge of radioisotopes applications in various fields. **4.** Students will be able to understand the importance of fusion energy, fusion systems and its prospects.

Fission Physics and Reactors

Atomic Structure and Isotopes, Binding Energy, Neutron Reactions, Interaction of Neutron with matter, Cross sections for neutron reactions, Fission Process, Mechanism of Nuclear Fission, Fission products, Fission energy, Critical Mass, Multiplication factor, Four & Six factor formula, Nuclear Fission reactors, power reactors, research reactors, advanced reactors.

Fuels/Radioisotope Applications/Fuel Cycle/Reactor Applications

Nuclear Fuels for Research reactors and Power reactors (Metallic, Oxide, Carbide, Nitride etc.), Fuels for LWR, PHWR, FBR, Cladding material for thermal and fast reactors, Applications of Research Reactors (Production of Radioisotopes, Education and Basic Research, Characterization and Testing of materials), Application of radioisotopes in Food and Agriculture and food, Medicine and Healthcare, Gamma Radiography and as radio tracers

Fusion Energy

Introduction to Plasma and Nuclear Fusion, Basics of Plasma physics, Plasma Confinement, Magnetic Configurations, Fusion Experimental Reactor: Basic processes and main plant features, Overall plant design parameters, Fusion Experimental Reactor: Operation modes - Vacuum vessel and shield, Superconducting magnet system and cryostat vessel -Fuel cycle systems, Plasma facing components (Blanket, Divertor), Safety criteria and assessment, waste disposal, Overview on Magnetically Confined Fusion Facilities around the world, Overview on ITER experiment.

Textbooks and References:

1. J. R. Lamarsh and A. J. Baratta, Introduction to Nuclear Engineering 3rd Edition, Prentice Hall, 2001
2. Samuel Glasstone, Nuclear Reactor Engineering
3. Jeffrey P. Freidberg, Plasma Physics and Fusion Energy
4. John Wessen, Tokamaks

19NE502T	Energy and Environment
Course Objectives	Energy is the engine of growth, prosperity, and improved quality of life. In India, the demand of energy, in general and electricity in particular is anticipated to increase by a factor greater than 2 before 2050. Fossil energy will continue to dominate, the electricity market (using coal mainly) and transportation sector (mainly petrol & diesel), in the next few decades. The challenge in coming years, in India in particular, is to meet the increasing energy demands while curbing the emissions of CO2 and other Green House Gases (GHG) for environmental protection. This implies progressive reduction in our dependence to fossil fuels. Carbon- free renewable energy (solar & wind in particular) and nuclear fission energy will continue to contribute to the energy basket increasingly in order to meet the climate goal specified by the United Nations Framework Conventions on Climate change. It is therefore essential for all students (UG &PG) and research scholars in PDPU to have enhanced awareness on energy and environment. In the department of nuclear energy, the focus of the subject "Energy and Environment" should be linked with nuclear fission energy including nuclear power reactor and related fuel cycle technology.
Course Outcomes	At the end of semester students should able to 1. The environment as a framework for energy use and the exploitation of energy resources 2. An overview of energy recourses and energy consumption 3. Production methods for electric power and heating/cooling, and their consequences on the environment 4. District heating systems 5. Life cycle thinking and environmental impacts from energy production 6. Lifecycle Assessment of Nuclear Fission energy and its environmental impact

Unit I

Basics of Thermodynamics: Enthalpy, Entropy & Free energy

Basics of Heat Transfer: Conduction, Convection & Radiation

Conduction: introduction; Derivation of generalized equation in Cartesian and cylindrical coordinates; One dimensional, steady state heat transfer equations for slabs; One dimensional, steady state heat; transfer equations for cylinders, spheres use of electrical analogy; one dimensional transient heat conduction in solids

Radiation: Introduction; Concept of black and grey surfaces; various laws of radiation, heat exchange, between black and grey surfaces and enclosed body and enclosure; Radiation shield and their effects, use of electrical analogy methods

Unit II

a. **Carbon based energy system:** Carbon cycle, greenhouse gases and global warming; Climate change – causes and consequences, Carbon capture, storage & Utilization.
b. **Carbon-free energy options**
c. **Renewable Energy:** Solar, Wind & Biomass:
d. **Other Non-conventional Energy Sources:** Geothermal; Fuel cell & Hydrogen fuels.
e. **Life cycle Assessment of Carbon- based and Carbon-free energy options.**

Unit III

Environmental Protection, Pollution Control and Climate change: Clean air, water and land.

Unit IV

Nuclear Fission Energy (Carbon-free)

Lifecycle Assessment of Nuclear Fission energy.

Environmental Impact Assessment Methodology for siting of nuclear power plants and related fuel cycle facilities. Environmental Acts and Regulations pertaining to nuclear energy.

Textbooks and References:

1. Engineering Thermodynamics by Moran and Shapiro
2. Engineering Heat Transfer by J P Holman
3. Fundamentals of Heat and Mass Transfer, Incropera, P.P. and Dewitt, D.P.
4. Heat Transfer by Frank Krieth
5. S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi, 1996
6. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley, New York, 1991
7. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000
8. D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.
9. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.
10. Rao S., Parulekar B.B., Energy Technology-Non conventional, Renewable and Conventional, Khanna Publishers, Delhi, 2005.
11. Glynn Henry J., Gary W. Heinke, Environmental Science and Engineering, PearsonEducation, Inc, 2004.5.
12. J. M. Fowler, Energy and the Environment, McGraw-Hill, 2Nd Edition, 1984.
13. Gilbert M. Masters, Introduction to Environmental Engineering and Science, 2nd Edition, Prentice Hall, 2003.

19NE503T	Health Physics & Radiation Protection
Course Objectives	Students should be able to understand 1. The decay systematic (decay laws, decay chains). 2. Various radiation sources. 3. Interactions of radiation with matter and energy loss mechanism. 4. Various radiation detection and measurement techniques. 5. Become familiar with elements of applied radiation protection through the study of specialized topics in health physics 6. Radiation shielding.
Course Outcomes	At the end of semester students should able to 1. Demonstrate applied competence in applying basic physics knowledge to analyze problems of radiation interactions. 2. Formulate simple first order kinetics problems relating to radiation protection problems. 3. Solve problems in external dose assessment, including simple shielding, using basic and standardized approaches. 4. Solve problems in internal dose assessment. 5. Show understanding of the risks of low and high level radiation dose and limitations in knowledge of these. 6. Working knowledge of various radiation detectors. **7.** Calculate shielding thickness required for various sources.

Unit 1: Sources of Radiation and Radiation Interactions
Fast electron sources, heavy charged particle sources, sources of electromagnetic radiation, Basic Principles of Radiation Interactions with matter, Stopping Power, Range of radiation sources.

Unit 2: Different types of Radiation Detectors
Radiation Detection Instruments, Gas Filled Detectors – Ionization Chamber, Proportional Counter, GM detection system, Scintillator Detectors, Semiconductor Detectors, counting statistics, Minimum Detectable Activity, Detector dead time and dead time measurement.

Unit 3: Introduction to Health Physics and Radiation Protection
Exposure and Absorbed Dose, Determination of Exposure and Limits for Internal and External Emitters, Dose Calculation, Biological Effects of Radiation and Radiation Protection Standards, Health Physics Instruments.

Unit 4: Nuclear Safety
Fission product release and transport, Radiation shielding calculations, dispersion of radioactivity release.

Textbooks and References:

1. G. F. Knoll, “Radiation Detection and Measurement”, John Wiley and Sons, New York
2. Nicholas Tsoulfanidis, “Measurement and Detection of Radiation”, Taylor & Francis
3. Jacob Shapiro, “Radiation Protection”, Harvard University Press

16NE503P	Radiation Measurement Laboratory
Course Objectives	1. Teach students how to perform basic radiation detection and measurement experiments. 2. Performing and analyzing realistic measurements through awareness of measurement limitations.
Course Outcomes	1. Perform laboratory and *in situ* measurements of gamma-emitting and other radionuclides. 2. Prepare professional, journal-style reports on experiments conducted. 3. Understand the importance of various radioisotopes and how to measure their strength.

List of Experiments

1. Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope.
2. Verification of Inverse Square Law for γ – rays.
3. Study of Nuclear counting statistics.
4. Linear and Mass attenuation coefficient using gamma source (for Aluminium).
5. Estimation of efficiency of G.M. detector using gamma and beta source.
6. Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage.
7. Study of Co-60 spectrum and calculation of resolution of detector in terms of energy.
8. Spectrum analysis of Cs-137 & Co-60 and to explain some of the features of Compton edge and backscatter peak.

Textbooks and References:

1. Lab Manuals for Geiger Muller and Gamma Ray Spectroscopy Experiments
2. G. F. Knoll, “Radiation Detection and Measurement”, John Wiley and Sons, New York
   Nicholas Tsoulfanidis, “Measurement and Detection of Radiation”, Taylor & Francis

19NE 503T	Radioisotope and Radiation Applications-I (Elective-I)
Course Objectives	This short course provides an insight about Nuclear Agriculture and food irradiation.
Course Outcomes	1. At the end of the course, the student should be able to know about various isotopes and their characteristics 2. The student will also be able to understand the applications of radioisotopes and radiation techniques in agriculture and food irradiation & Preservation.

UNIT 1: Radioisotopes Fundamental and production

Introduction to Radioisotopes, Production of Radioisotopes, Production of Radioisotopes in India, Reactor production of isotopes: Various steps, Charged particle induced nuclear reactions, Long lived and short loved fission products, Introduction of applications of Radioisotopes in healthcare and its productions, Radioisotopes used Industry and environment, Different Radioisotopes used in Agriculture and Food Technology;

UNIT 2: Applied botany & Mutation in crop Improvement

Morphology of flowering plants- Leaf, stem, root, inflorescence and flower; Reproduction in plants-Sexual and asexual; Pollination and fertilization-Seed and its structure;

Spontaneous and induced mutations, Effect of mutation on survival, Molecular basis of gene mutation, Mutagens, Factor affecting radiation effects, Mechanism of action of radiations, Principles of mutation breeding and its application, Procedure for mutation breeding,

UNIT 3 Genetic and biological basis of mutation

Mutation breeding for oligogenic and polygenic traits, Application and limitations of mutation breeding, Achievements

Consideration for induced mutation, When to use, selection of varieties, Choice of mutagen, Radiation induced mutation for development of high yielding seeds and crops, Mutagen and their doses, Induced mutation techniques for seed and vegetatively propagated crops;

UNIT 4: Food irradiation

Radiation processing of food products: working principles/source, dose determination and mapping, regulatory approvals,

Application of food irradiation: Low dose application: Insect disinfestation in cereals/pulses, Delayed ripening in fruits, Phytosanitary treatment of fruits and vegetables as an export compliance; Medium dose application; High dose application

Packing for radiation treated food; Wholesomeness of radiation processed food

Setting of a food irradiated plant; Basic Requirement and guidelines

Textbooks and References:

1. Fundamentals of Radiochemistry, D.D.Sood, A.V.R.Reddy, N.Ramamoorthy, Published by Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) (2010).
2. Essentials of Nuclear Chemistry, H.J.Arnikar, John Wiley (1990)
3. Nuclear and Radiochemisry, G.Friedlander, J.W.Kennedy, E.S.Macias and J.M.Miller, John Wiley & Sons (1981).
4. Practical applications of radioactivity and nuclear radiations – G.C. Lowenthal and P.L. Airey, Cambridge university press 2004
5. Fundamentals of nuclear science and engineering – J.Kennethshultis & Richard E.Faw
6. Fundamentals of Nuclear Science - Application in Agriculture, H. Chandrasekharan, Navindu Gupta
7. The application of nuclear energy to agriculture, C.C. Moh
8. Food Irradiation Technologies: Concepts, Applications and Outcomes, Isabel C F R Ferreira, Amilcar L Antonio, Sandra Cabo Verde

17NE 505T	Nuclear Instrumentation and Control (Elective-I)
Course Objectives	This short course provides an introduction to reactor dynamics& control including, critical operation in absence of thermal feedback effects and effects of Xenon, fuel and moderator temperature, etc.
Course Outcomes	1) At the end of the course, the student should be able toperform simple analysis of control systems, design Feedback controllers, such as PID controllers. 2) The student will also be able to understand basicinstrumentations and measurement techniques used in a nuclear power plant.

Unit 1: Basics of Instrumentation and Control

Measurements Concepts and Definitions , Pressure, Level, flow and Temperature Measurement, Control Theory and The Laplace Transform Mathematical Modelling and Dynamic behaviour, Transfer Functions and Closed Loop Control Systems, Block Diagrams

Unit 2: Control System Basics and PID Control

Basic Configuration of Control System, Transfer Function: Component Transfer Function, The Transfer Function in Feedback Control Systems, Stability and Performance:Evaluation of Stability,Evaluation of Control Performance, Design Method of Control Systems, Design Procedure, Evaluating Characteristics of the Control System, PID Control and Parameter Tuning Technique, PID Control, Tuning Methods of PID Control, Implementing the PID Control Rule, Design Examples: Design Specifications, Static Characteristics, Dynamic Characteristics, Control System Designing and Stability Margin, Evaluation of Control Characteristics.

Unit 3: Reactor Stability Study

Reactor Transfer Function, Transfer Function of Reactor with No Feedback, Transfer Function of High-Output Reactor Havingthe Feedback Reactivity, Design Example of Constant Output Control Systemof a High-Output Reactor, Nuclear Thermal-Hydraulic Stability, Xenon Stability

Unit 4:Overview &Control of PHWR

PHWR Reactor Transfer Function, Reactor Transfer Function; Temperature & Poisoning Feedbacks, Case Illustrations on Practical Plant Control Systems, Case Illustrations on Practical Control System Design Studies

Textbooks and References:

1. Y. Oka and K. Suzuki (eds.), Nuclear Reactor Kinetics and Plant Control,An Advanced Course in Nuclear Engineering
2. Nuclear reactor kinetics and control, Weaver. L.E. American Elsevier, 1968.
3. Nuclear reactor kinetics – Ash. M. Mcgraw Hill, New York, 1979

17NE 512T	Nuclear Reactor Engineering
Course Objectives	1. Teach students the fundamental behaviors of neutron populations in matter. 2. Teach students the neutron transport and diffusion process, slowing down of neutrons and transport calculations. 3. Teach students the essential elements of reactor kinetics behavior and reactor control. 4. To prepare students for nuclear reactor core design.
Course Outcomes	1. Students will be able to demonstrate a fundamental understanding of microscopic and macroscopic cross-sections, and of the features of neutron cross sections. 2. Students will be able to demonstrate a solid understanding of fundamental transport concepts such as neutron density, neutron scalar flux, neutron energy density. 3. Students will be able to analytically solve problems in neutron transport and diffusion in both non-multiplying and multiplying media. 4. Students will be able to utilize a diffusion theory based code to solve neutron transport problems. 5. Students will be able toutilize a Monte-Carlo based code to solve neutron transport problems.

Neutron Transport Concepts

One-speed neutron conservation, Calculation of neutron leakage, The diffusion equation, Solutions of the diffusion equation, Diffusion equation in non-multiplying media, Geometric buckling and the Spatial flux distribution, One group Critical equation for a Bare reactor, The slowing down of neutrons, elastic scattering, energy change in scattering, The average logarithmic energy decrement, Lethargy, neutron moderation with and without Absorption, Resonance absorption, Fermi Age Model, Two-group critical equations, reflected reactors, criticality measurements.

Nuclear Design Basics

Multigroup diffusion theory, Strategy for solving multigroup equations, Generation of group constants, Group fission source term, many group calculations, Few-group constants, Multiplication eigenvalue, Few-group diffusion equations, fast reactors, Fuel depletion calculations, Simplifying fuel depletion calculations, Fuel depletion isotopic behaviour, Fine mesh depletion calculations, nodal methods, Neutron transport equation, diffusion theory approximation.

Nuclear Reactor Kinetics and Control

One-Group model for bare reactors, prompt-neutron lifetime, step change in reactivity, stable reactor period, one group of delayed neutrons, reactivity and period, neutron flux after shutdown, Inhour formula, prompt-critical condition, effects of poisons on reactivity, Xenon poisoning during reactor operation, Xenon poisoning after shutdown, Xenon oscillations, Samarium poisoning, effects of temperature on reactivity, temperature coefficient of reactivity, Doppler effect, reactor stability analysis, reactivity feedback, fuel-moderator time constant, large increase in reactivity, Methods of control, effectiveness of control rods, control materials, range of control systems, control-rod worth evaluation, reactor operations.

Power Reactor Systems and Plant Operations

PWR; reactor vessel and core, control and safety systems, coolant circulation and steam generating systems, Advanced PWRs, BWR; Core and Vessel, Coolant Recirculation System, Control system, feed-water temperature and fuel cycle length, Heavy-Water moderated reactors; Design specifications and core features, heat removal, control system, safety features, Advanced CANDU, Generation IV reactors, Small Modular Reactors, Plant operational strategy, Plant control, Plant maintenance.

Textbooks/References

1. Samuel Glasstone & Alexander Sesonske, Nuclear Reactor Engineering – Vol-I and Vol-2, CBS Publishers, Fourth Edition, 2004.
2. J.J. Duderstadt and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976
3. J.R. Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley, 1966
4. G. I. Bell and S. Glasstone, Nuclear Reactor Theory, Reinhold, 1970

17NE 513T	Nuclear Safety, Security and Safeguard
Course Objectives	1. science and engineering as part of a comprehensive nuclear security and safety program 2. apply engineering techniques to design security systems and infrastructure at the State and facility level 3. understand the international security policy implications of technology developments 4. generate an estimate of nuclear security and safety threats **5.** perform quantitative measurements of nuclear and radiological materials and detect sources of radiation outside of regulatory control
Course Outcomes	1. Correlate and critically examine the legal and regulatory instruments that dictate how policy is implemented in relation to Nuclear Safety, Nuclear Security and Nuclear Safeguards. 2. Review and discuss the fundamental technologies associated with energy production and the nuclear fuel cycle, from its cradle to its grave. 3. Compare and contrast theoretical approaches to managing risk and critically discuss the essential characteristics of modern practice for evaluating and substantiating Nuclear Safety and dealing with threats to Nuclear Security. 4. Explain or debate how the development of nuclear technology has influenced nuclear safety and nuclear security in the civil nuclear industry. **5.** Expound and critically evaluate the means by which Nuclear Safety, Nuclear Security and non-proliferation safeguards arrangements are established, managed, monitored and controlled.

A : Nuclear Safety and Security

Unit 1: Nuclear Power Plant Safety

Nuclear Reactor Types, General background to nuclear reactor safety, Objectives and importance; Reactivity induced accidents; Coolant transients; Loss-of-coolant accidents; The role of intrinsic and engineered safety feature in transients and accident sequences; Design basis accidents; Fuel element behaviour during reactor transients; Accident containment; Release of radioactive materials within the containment and to the environment; Risk assessment for nuclear power plants.

Unit 2: Introduction to Nuclear Security and Material Security

Basic definitions, Goals and objectives; Basic elements of nuclear security; Threats to Nuclear Security & Assessment, case studies; Physical protection systems design concepts; Information security; Security culture: Concept and model; Insider threat and threat mitigation strategies, Human reliability program, Behaviour observation. Nuclear Material Transport Security, Deployable radiation detection technologies in nuclear security, vulnerability analysis of physical protection system at a facility, facility characterization and target identification.

Unit 3: Legal and International Issues on 3S

Legal Framework, International/Multilateral covenants, Domestic Legislation, Liability Regime, Nuclear Information Management, Nuclear Terrorism, Social Acceptance/Public perception, Corporate Social Responsibility, Nuclear Security Summit.

Unit 4: Radiological safety analysis
Nuclear Safeguard, Nuclear material accountancy and inventory control of radioactive material.
Emergency preparedness, Nuclear Forensics

Textbooks and References:

1. Lewis, E.E., Nuclear Power Reactor Safety, John Wiley, 1977.
2. Thomas, T.J. and J.G. Berkeley (eds.), The Technology of Nuclear Reactor Safety Vol. 1, M.I.T. Press, 1964.
3. Jones, O.C., Nuclear Reactor Safety Heat Transfer, Hemisphere Pub., 1981.
4. McCormick, N.J., Reliability and Risk Analysis: Methods and Nuclear Power Applications, Academic, 1981.
5. The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Rev.4(Corrected), IAEA, Vienna
6. Development, Use and Maintenance of the Design Basis Threat, IAEA Nuclear Security Series No. 10, IAEA, Vienna
7. Nuclear Security Culture, IAEA Nuclear Security Series No. 7, IAEA, Vienna (2008).
8. James Doyle, Nuclear Safeguards, Security and Nonproliferation, Butterworth-Heinemann, 2008.
9. Fry, M.P., P. Keatinge and J. Rotblat (Eds.): Nuclear Nonproliferation and the Nonproliferation Treaty, Springer-Verlag, 1990.
10. The Nuclear Fuel Cycle, ANS Text book by Nicholas Tsoulfanidis, 2013, ISBN 978-0-89448-460-5.
11. Design and Evaluation of Physical Protection Systems by Mary Lynn Garcia, Second Edition, Sandia National Laboratories, Butterworth-Heinemann (BH)
12. An Introduction to The Nuclear Fuel Cycle and Nuclear Safeguards by Donald R. Joy, Jai Corporation, Fairfax, Virginia.
13. Industrial Safety Management – L.M.Deshmukh - Tata McGraw-Hill Publishing Company Ltd, New Delhi – ISBN 0-07-061768-6
14. Chemical Process Safety – Daniel A.Crowl and Joseph F.Louvar – Pearson Education Inc – ISBN 978-93-325-2405-7
15. Industrial Safety and Human Behaviour – H.L.Kaila – AITBS Publishers, India – ISBN 978-81-7473-453-2
16. What Went Wrong – Trevor A Kletz – Elseveir – ISBN 978-18-5617-531-9
17. Incidents that define process safety – John Atherton and Frederic Gil, CCPS – John Wiley and Sons – ISBN – 978-0-470—12204-4
18. Electrical fires and failures – A.A.Hattangadi – Tata McGraw Hill – ISBN 0-07-463165-9
19. Lee’s Loss prevention in process industries – Frank P Lees - Elseveir - ISBN 978-0-12-397189-0

16NE509T	Nuclear Materials and Nuclear Fuel Cycle
Course Objectives	1. Various process in front end of the fuel cycle 2. Various fuel types in different reactors 3. performance of various fuels 4. Fuel failures and their mitigation 5. Various process in back end of the fuel cycle 6. Various reprocessing process 7. Radioactive waste management 8. Disposal of radioactive wastes
Course Outcomes	1. Demonstrate various enrichment processes 2. Identify the suitable fuel for a particular reactor 3. Explain the demand and supply of Nuclear fuel 4. Explain the difference between various fuels 5. Demonstrate PUREX and other reprocessing processes 6. Explain recycling of nuclear fuels 7. Demonstrate fast reactor fuel cycle 8. Identify the challenges associated with fast reactors

Unit 1: Introduction and Front End of Fuel Cycle

Nuclear power Reactor Types (LWR, PHWR, FBR), Basic raw material for nuclear fuel (Natural Uranium and Thorium resources, their supply and demand), Uranium Mining, Milling, Refining, Conversion and Enrichment, Processing of Thorium ore, Manufacturing technology of uranium oxide, mixed uranium plutonium oxide and thorium based mixed oxide fuels, zirconium and zirconium alloy technology

Unit 2: Water cooled Nuclear fuel performance

PHWR fuel, PWR fuel, BWR fuel, accident tolerant fuel for LWR, post irradiation examination of fuel, non-destructive evaluation of fuel, fuel defect and failure mitigation

Unit 3: Back End of Fuel Cycle

Interim storage of spent fuel at reactor and away from reactor, wet and dry storage, Reprocessing options (partitioning and transmutation), PUREX and Advanced PUREX process, dry reprocessing routes, plutonium recycling in LWR and PHWR, thorium fuel cycle,

Unit 4: Fast reactor fuel and High active waste management and permanent disposal

conventional and advanced FBR fuel and fuel cycles, Mixed Uranium Plutonium oxide, monocarbide, mononitride and U-Pu-Zr metallic fuel for fast reactors, electro-refining and electro-wining of FBR fuels, proliferation resistant fuel, waste treatment and disposal in once through fuel cycle, vitrification and synroc for immobilization of high level waste, long term storage of high active waste and their permanent disposal in underground repository.

Textbooks and References:

1. M.Benedict: Nuclear Chemical Engineering
2. Cochran R. G. and N. Tsoulfanidis. *The Nuclear Fuel Cycle: Analysis and Management*. 2nd ed. La Grange Park, IL: ANS, 1993.

16NE 509T	Nuclear Heat transfer and Thermal Hydraulics
Course Objectives	Students should be able to understand 1. Application of Heat transfer and designing of Heat transfer accessories 2. The energy balances in fins and Heat exchangers and thermodynamic cycles 3. Calculation of the spatial distribution and the time evolution of the power production in a fission reactor 4. The basics on critical heat flux and Two phase heat transfer 5. The thermal hydraulic processes involved in the Nuclear reactor 6. Thermal fluxes and the coolant and fuel state in a fission reactor
Course Outcomes	At the end of semester students should able to 1. Capability of formulating and designing heat transfer accessories 2. Understanding of steam thermodynamic cycles 3. Understanding of thermal hydraulics processes and fluid flow mechanisms in reactor systems 4. Formulate, analyze and solve simple problems of heat transfer in reactor systems and safety measures 5. Describe the thermal hydraulics processes that take place in a nuclear power plant

Unit 1:

Regimes of heat transfer: conduction, convection, radiation; Single phase fluid flow and heat transfer; Pressure drop in straight channels: friction factor, equivalent diameter, friction relationships; changes in cross section.

Natural convection, forced convection, Free convection, Laminar and turbulent flow heat transfer, Heat Transfer through extended surfaces, Fin effectiveness and fin efficiency.

Unit 2:

Transient heat flow- lumped heat analysis; Heat exchanger classification and application, Thermal design and analysis of heat exchanger, effectiveness of heat exchanger.

Steam generators and condensers, Properties of steam; Thermodynamic Cycles: Rankine cycle; Joule cycle, Sterling cycle; Otto, Diesel and Dual cycles.

Unit 3:

Overview of Nuclear Reactor Systems; Power Cycles;; Fuel element grids, Heat Generation in Reactors, Energy Release and Deposition, Heat Generation Parameters, Heat conduction in Fuel Elements, Heat Conduction analysis for different geometries; Radial and axial temperature distribution in fuel elements; Temperature distribution in restructured fuel elements. Power Profiles in Reactor Core, Thermal analysis of Fuel Elements, Radial and axial temperature distribution in fuel elements; Pressure drop in straight channels; nuclear reactor safety: Coolant transients, Loss-of-coolant accidents.

Unit 4:

Introduction to two phase flow; Analysis of boiling and condensation phenomena; Heat transfer rates in pool and flow boiling; Flow Regimes, void-quality analysis, Flow instability, Critical flow; Coolant Channel Orificing, Hot Spot and Hot Channel Factors; Calculation of two phase pressure drop, Critical heat flux, reactor thermal design, Simulation of reactor thermal hydraulics

Textbooks and References:

1. Cengel, Ghajar; Heat and Mass Transfer; TMH publication
2. Nag, Heat and Mass Transfer; TMH publication
3. N.E. Todreas and M.M. Kazimi, Nuclear Systems, vol 1: Thermal-Hydraulic Fundamentals, Hemmisphere Pub. Co., 1990
4. Incropera, F. P. and DeWitt, Fundamentals of Heat and Mass Transfer, 5th edition, J. Wiley & Sons, 2002.
5. M. M. El-Wakil, Nuclear Heat Transport
6. Lahey, Jr, R.T. & Moody, F.J, the Thermal-Hydraulics of a Boiling Water Nuclear Reactor.

16NE512P	Thermal Hydraulics Laboratory
Course Objectives	Students should be able to understand 1. The basic heat transfer mechanism 2. The heat conduction, convection process 3. The boiling and condensation process 4. Thermal conductivity of liquids
Course Outcomes	At the end of semester students should able to 1. Demonstrate the heat generation and transfer process in nuclear reactors. 2. Calculate the Critical Heat Flux (CHF) and its importance. 3. Understand the two phase heat transfer process. 4. Demonstrate that how efficiently heat can be transferred in a nuclear power plant. **5.** Understand the practical aspects of various heat transfer equipment.

List of Experiments:

1. To calculate the heat loss from a lagged pipe
2. The determination of the thermal conductivity of fluids
3. To determine heat transfer coefficient for a vertical tube losing heat by natural convection
4. To study the heat transfer coefficient by forced convection heat transfer
5. To study the two phases heat transfer
6. To study Dropwise and Filmwise condensation process
7. To measure the critical heat flux of a Nichrome wire
8. To find the effectiveness of the different types of heat exchanger

Textbooks and References:

1. Lab Manuals
2. Incropera, F. P. and DeWitt, Fundamentals of Heat and Mass Transfer, 5th edition, J. Wiley & Sons, 2002.

16NE511T	Radioisotope and Radiation Applications (Elective-II)
Course Objectives	This short course provides an insight about various applications of Radioisotope and radiation techniques in Industry and Medical field.
Course Outcomes	1) At the end of the course, the student should be able to know about various isotopes and their characteristics 2) The student will also be able to understand the applications of radioisotopes and radiation techniques in industry, healthcare and sewage sludge hygienization.

UNIT 1: Applications of Radioisotopes in Industry

- Radiotracer techniques and their applications
- Isotope techniques for waters resources management
- Radiometry (Column scanning)
- Mixing Time/Blending Time Measurements Using Radiotracer Technique
- Residence Time Distribution (RTD) and its Applications Industry
- RTD Investigations in Petroleum Industry

UNIT 2: Applications of Radioisotopes in Industry

- Gamma or X-ray Radiography
- Industrial tomography
- Nucleonic gauges in industry
- Radiation processing applications
- Sewage sludge hygienization
- Material Modification

UNIT 3: Applications of Radiation Technology in Healthcare

- Production of radioisotopes in nuclear reactor and cyclotron
- Principle, construction and use of radionuclide generators
- Nuclear medicine and radiopharmaceuticals (Diagnostic and Therapeutic)
- Formulation and quality control of radiopharmaceuticals
- Some important organ-specific diagnostic radiopharmaceuticals

UNIT 4: Biomedical Applications of Radioisotopes and Radiation Technology

- Imaging techniques - SPECT, PET and hybrid imaging
- Concepts of brachytherapy and teletherapy, Neutron Therapy
- Medical Tracer applications**,**
- Targeted radionuclide therapy using radiopharmaceuticals,
- Concept of theranosis and personalized medicine
- Blood Irradiator
- Sterilizations of medical products

Textbooks and References:

i. Charlton, J.S., 1986. Radioisotope tracer techniques for problem solving in industrial plants. LeonardHill, Glasgow, London.

ii. Practical applications of radioactivity and nuclear radiations – G.C. Lowenthal and P.L. Airey, Cambridge university press 2004

iii. Fundamentals of nuclear science and engineering – J.Kennethshultis & Richard E.Faw

iv. Radiotracer generators for industrial applications – IAEA radiation technology series no.5, 2013

v. International Atomic Energy Agency, 2004. Radiotracer Applications in Industry-A Guidebook, Technical Reports Series No. 423, IAEA, Vienna 281p.

vi. IAEA, 2008. Residence time distribution method for industrial and environmental applications. IAEA, Vienna, Austria.

vii. Thyn, J., Zitny, R., Kluson, J. and Cechak, T., 2000, Analysis and Diagnostics of Industrial Processes by Radiotracers and Radioisotope Sealed Sources, Vol. 1, CVUT, Praha, pp. 329.

viii. Pant, H. J., Kundu, A. and Nigam, K. D. P., 2001. Radiotracer applications in chemical process industry, Reviews in Chemical Engineering, Vol. 17, pp.165-252.

16NE512T	Design and Manufacturing of Nuclear Reactor Components (Elective-II)
Course Objectives	1. Course covers the structural components in nuclear power plant systems and structural design requirements 2. It combines mechanics techniques with models of material to determine adequacy of component design 3. Considerations include mechanical loading, , inelastic behavior, 4. Manufacturing processes for different components
Course Outcomes	At the end of semester students should able to, 1. Design the structural components of nuclear reactors 2. Estimate induced stresses and compare against standards

Machine Design
Principles of machine design, Design and Drawing practices, Sealing methods, Advanced manufacturing techniques, Design Approach, Design Rules and stress limits

Design of Pressure Vessel and piping
Design for pressure vessel and piping as per ASME codes, Seismic qualifications

Manufacturing of nuclear components
Pressure vessel, calandria, steam generator, pressurizer, coolant channels, header, fuelling machine, control rod mechanisms, etc.

Textbooks and References:

1. Pressure Vessel Design Manual by Dennis R. Moss
2. Theory and Design of Pressure Vessels by Harvey, John F.
3. Structural Materials in Nuclear Power Systems by Roberts, J. T. Adrian
4. Fracture and Fatigue Control. 2nd ed. by J. M. Barsom and S. T. Rolf
5. Process equipment design by brownell and young
6. ASME codes Section III and section –VIII
7. American standard codes for pressure piping B31.1