Revised Course Curriculum

(2020-2022)

Department of Nuclear Science and Technology

CUMMULATIVE PICTURE OF COURSES REVISED FOR CURRICULUM (2020- 2022)

Sr. No.	Course Code	Course Name	Credit
1.	17NE501T	Introduction to Nuclear Physics and Engineering	**3**
2.	19NE502T	Energy and Environment	**3**
3.	19NE503T	Health Physics & Radiation Protection	**3**
4.	19NE511T	Elective-I Radiation and Radioisotope Applications – I/	**3**
5.	17NE 505T	Nuclear Instrumentation and Control	
6.	20MA503T	Advanced Numerical Methods and Computer Programming	**4**
7.	20MA 503P	Advanced Numerical Methods Lab	**1**
8.	16NE503P	Radiation Measurement Lab	**2**
9.	17NE 512T	Nuclear Reactor Engineering	**3**
10.	19NE 508T	Nuclear Safety, Security and Safeguard	**3**
11.	19NE 509T	Nuclear Material and Nuclear Fuel Cycle	**3**
12.	17NE 514T	Nuclear Heat Transfer and Thermal Hydraulics	**3**
13.	17NE 511T	Elective-II Radiation and Radioisotope Applications-II /	**3**
14.	17NE 512T	Design, Manufacturing and Testing of Nuclear Reactor Components)	
15.	16NE512P	Thermal Hydraulics Laboratory	**2**
Total			**36**

17NE 501T					Introduction to Nuclear Physics and Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce basic Nuclear Physics, Fission & Fusion process
- To demonstrate power reactors, research reactors and their fuels
- To teach basics of plasma physics, fusion energy and engineering design of fusion systems
- To introduce non-power applications of nuclear energy; Radiation and radioisotope

UNIT 1 Fission Physics and Reactors **12 Hrs.**

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 factor formula, Nuclear Fission reactors, power reactors, research reactors, advanced reactors.

UNIT 2 Fuels/Radioisotope Applications/Fuel Cycle/Reactor Applications **12 Hrs.**

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

UNIT 3 Fusion Energy **13 Hrs.**

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.

UNIT 4 Plasma for Societal Applications: **08 Hrs.**

Plasma production techniques, Paschen breakdown, Diffusion techniques - Plasma Nitriding and Implantation, Plasma based coatings – PVD and CVD, Waste disposal and energy recovery, plasma jet applications

Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Demonstrate nuclear engineering fundamentals and radiological sciences

CO2 - Understand neutron cross sections, multiplication factor and fission process

CO3 – Clarify and Categorize nuclear fuels and various reactor types.

CO4 – Learn fundamental of radiation and radioisotopes applications in various fields

CO5 - Compute simple problem based on decay constants and half-life

CO6 – Analyse and demonstrate importance of fusion energy, Plasma physics and its societal application.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A: 10 Questions from each unit, each carrying 4 marks 40 Marks

Part B: 2 Questions from each unit with internal choice, each carrying 10 marks 60 Marks

19NE 502T					Energy and Environment					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To learn basics of heat transfer and energy resources.
- To Explain the climate change and effects of non-conventional energy on environment
- To understand nuclear fission energy and its contribution to the climate change

UNIT 1 Basics of Heat Transfer **12 Hrs.**

Basics of Thermodynamics: Enthalpy, Entropy & Free energy; Conduction, Convection & Radiation

Conduction: Introduction; Derivation of generalized equation in Cartesian and cylindrical coordinates; One dimensional, steady state heat transfer equation 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 2 Energy System **10 Hrs.**

Carbon based energy system: Carbon cycle, greenhouse gases and global warming; Climate change – causes and consequences, Carbon capture, storage & Utilization.

Carbon-free energy options Renewable Energy: Solar, Wind & Biomass

Other Non-conventional Energy Sources: Geothermal; Fuel cell & Hydrogen fuels.

Life cycle Assessment of Carbon- based and Carbon-free energy options

UNIT 3 Environment Protection **8 Hrs.**

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

UNIT 4 **10 Hrs**

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.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1- Understand basic of thermodynamics and heat transfer

CO2- Demonstrate an overview of energy resources and energy consumption

CO3- Explain carbon and carbon free electricity production and heating system

CO4- Analyze Synergy between energy and environment with related environment issues.

CO5- Apply awareness of environmental protection and application of renewable energy.

CO6– Clarify Lifecycle Assessment of Nuclear Fission energy and its environmental impact

TEXT/REFERENCE BOOKS

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. S.P. Sukhatme, Solar Energy – Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi,
5. J. A. Duffie and W.A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley, New York, 1991
6. D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.
7. Rao S., Parulekar B.B., Energy Technology-Non conventional, Renewable and Conventional, Khanna Publishers, Delhi
8. Glynn Henry J., Gary W. Heinke, Environmental Science and Engineering, PearsonEducation, Inc, 2004.
9. Gilbert M. Masters, Introduction to Environmental Engineering and Science, 2nd Edition, Prentice Hall, 2003.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

19NE 503T					Health Physics & Radiation Protection					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To understand the various radiation sources.
- To explain interactions of radiation with matter and energy loss mechanism.
- To know various radiation detectors and measurement techniques.
- To learn the biological effect of radiation and radiation protection.

UNIT 1: Sources of Radiation and Radiation Interactions **10 Hrs.**

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 **12 Hrs.**

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 **12 Hrs.**

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 **8 Hrs.**

Fission product release and transport, Radiation shielding calculations, dispersion of radioactivity release.

Max. 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand the natural and man-made radiation sources.
CO2 – Summarize working of various radiation detectors and radiation interaction with matter.
CO3 - Solve problems of external and internal dose assessment.
CO4 - Formulate and solve problems relating to radiation protection.
CO5 - Understand risks of low and high-level radiation dose and limitations.
CO6 - Calculate shielding thickness required for various radiation sources.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

19NE 511T					Radiation and Radioisotope Applications-I					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To provides an insight about Nuclear isotopes production
- To explain basic of mutation and radiation induced mutation
- To understand the application of radioisotopes of in food preservation.

UNIT 1: RADIOISOTOPES FUNDAMENTAL AND PRODUCTION **10 Hrs.**

Introduction to Radioisotopes, Principles of Radioisotope production, Neutron induced reactions, Charged particle induced reactions, Radioisotope production in Reactors and accelerators, Radioisotope production in India, Introduction to applications of Radioisotopes in healthcare, Industry and environment, Agriculture and Food Technology and their production routes

UNIT 2: APPLIED BOTANY & MUTATION IN CROP IMPROVEMENT **10 Hrs.**

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 **10 Hrs.**

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 **10 Hrs.**

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

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain the various isotopes, their characteristics and production methods.

CO2 – Understand fundamental of applied botany and basic of mutation.

CO3 - Recognize the applications of radioisotopes and radiation techniques in agriculture.

CO4 – Summarize Radiation induced mutation for high yielding seeds and crops.

CO5 – Analyse the applications of radioisotopes and radiation techniques in food Preservation.

CO6 – Analyse and categorise the food for irradiation and its respective dose limits.

TEXT/REFERENCE BOOKS

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
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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A: 10 Questions from each unit, each carrying 4 marks 40 Marks

Part B: 2 Questions from each unit with internal choice, each carrying 10 marks 60 Marks

17NE 505T					Nuclear Instrumentation and Control					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To learn the instrumentation and control system used in nuclear power plant.
- To understand the basic of reactor dynamics & control
- To explain thermal feedback effects and effects of Xenon, fuel and moderator temperature, etc.

UNIT 1: Basics of Instrumentation and Control **08 Hrs.**

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 **10 Hrs.**

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 **10 Hrs.**

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

UNIT 4: Overview & Control of PHWR **12 Hrs.**

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

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain different instrumentation used for measurement and control in nuclear power plant.

CO2 - Describe the working principle of standard pressure, temperature, flow, and level sensors.

CO3 – Understand the basic of Control System, PID Control and its application in nuclear industry.

CO4 – Formulate and analyse the nuclear transfer function and reactor stability.

CO5 - Describe nuclear instrumentation system that is capable of covering the dynamic of PHWR.

CO6 – Solve simple problem of nuclear power plant control and dynamics

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

20MA503T					ADVANCED NUMERICAL TECHNIQUES AND COMPUTER PROGRAMMING					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	1	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

- To understand and acquaint the concept of various numerical methods.
- To develop numerical skills in solving problem of engineering interest.
- To enrich the concept of finite element techniques.
- To extract the roots of a polynomial equation.

UNIT 1 EIGEN VALUES EIGEN VECTORS AND INTERPOLATION **10 Hrs**

Eigen values and eigen vectors: Numerical evaluation of largest as well as smallest (numerically) Eigen values and corresponding Eigen vectors. Interpolation: Introduction, Newton Gregory Forward Interpolation Formula, Newton Gregory Backward Interpolation Formula, Central difference interpolation formula, Lagrange's Interpolation Formula for unevenly spaced Formula, Error in interpolation, Newton's Divided Difference Formula, cubic spline interpolation, surface interpolation.

UNIT 2 NUMERICAL SOLUTION NON LINEAR EQUATIONS AND POLYNOMIAL **8 Hrs**

Introduction, Solution of non-linear simultaneous equations, Descarte's Sign rule, Horner's method, Lin-Bairstow's method, Graeffe's root squaring method, Muller's method, Comparison of various methods.

UNIT 3 NUMERICAL SOLUTION OF ODEs AND PDEs **14 Hrs**

Taylor's method, Euler's method, Runge-Kutta methods of various order, Modified Euler's method, Predictor corrector method: Adam's method, Milne's method. Solution of Boundary value problems using finite differences. Finite difference approximation of partial derivatives, Classification of 2nd order PDEs, different type of boundary conditions, solutions of Elliptic, parabolic and hyperbolic equations of one and two dimensions, Crank- Nicholson method, ADI method.

UNIT 4 FINITE ELEMENT METHOD **8 Hrs.**

Introduction, Method of Approximation, The Rayleigh-Ritz Method, The Galerkin Method, Application to One dimensional and two dimensional problems.

Max:- 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – To apply a suitable numerical technique to extract approximate solution to the problem whose solution cannot be obtained by routine methods.

CO2 - To estimate the errors in various numerical methods.

CO3 - To analyse/ interpret the achieved numerical solution of problems by reproducing it in graphical or tabular form.

CO4 - To approximate the data generated by performing an experiment or by an empirical formula with a polynomial on which operations like division, differentiation and integration can be done smoothly.

CO5 - To evaluate a sufficiently accurate solution of various physical models of science as well as engineering interest whose governing equations can be approximated by nonlinear ODEs or PDEs or system of ODEs or PDEs.

CO6 - To design/ create an appropriate numerical algorithm for various problems of science and engineering.

TEXT/REFERENCE BOOKS

4. B.S. Grewal, Numerical Methods in Engineering and Science with Programs in C & C++,Khanna Publishers (2010).
5. S.S. Sastry, Introductory Methods for Numerical Analysis,4th Ed., Prentice Hall of India (2009).
6. M.K. Jain, S.R.K. Iyenger and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 5th Ed., New Age International (2007).
7. C F Gerald and P O Wheatley, Applied Numerical analysis, Pearson education, 7th edition, 2003.
8. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley publication, 9th edition. 2005
9. R.K. Jain & S.R.K. Iyenger, Advanced Engineering Mathematics, 3rd Ed., Narosa (2002).
10. S C Chapra, Raymond P. Canale, Numerical Methods for Engineers, Tata McGraw Hill Pub. Co. Ltd.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A : 4 questions of 6 marks each 24 Marks (40 min)

Part B: 4 questions of 10 marks each 40 Marks (80 min)

Part C: 3 questions of 12 marks each 36 Marks (60 min)

<table>
<tr><td colspan="5">16NE503P</td><td colspan="3">Radiation Measurement Laboratory</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="3">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
<tr><td>Continuous Evaluation</td><td>End Semester LE/Viva</td></tr>
<tr><td>0</td><td>0</td><td>4</td><td>2</td><td>4</td><td>25</td><td>25</td><td>50</td></tr>
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COURSE OBJECTIVES

- To Understand the basic science of radiation sources and their interactions with matter
- To learn the working principle of radiation detectors.
- To demonstrate the safety during perform radiation laboratory experiments.

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.
9. Gamma scanning for blockage detection in pipe lines.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Demonstrate gamma-emitting and other radiation sources.
CO2 - Understand the physical mechanisms of radiation interactions in materials.
CO3 - Analysing radiation measurements methods with limitations.
CO4 - Apply the use of the major detector types applicable for specific radiations.
CO5 - Estimate uncertainties in measurements and statistical models of random processes.
CO6 – Formulate and analyse data acquisition and scientific results.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 25 **Exam Duration: 2 hrs**

Lab examination/ quiz	10 Marks
Viva	15 Marks

17NE 512T					Nuclear Reactor Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To learn the fundamental behaviors of neutron populations in matter.
- To demonstrate the essential elements of reactor kinetics behavior and reactor control.
- To implement basic of reactor physics for reactor design.

UNIT 1 Neutron Transport Concepts **13 Hrs.**

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.

UNIT 2 Nuclear Design Basics **13Hrs.**

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.

UNIT 3 Nuclear Reactor Kinetics and Control **14 Hrs.**

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.

UNIT 4 Power Reactor Systems and Plant Operations **14 Hrs.**

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. **Max. 40 Hrs.**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Demonstrate fundamental transport concepts such as neutron density, neutron energy density.
CO2 - Apply diffusion theory-based code to solve neutron transport problems.
CO3 - Solve problems in neutron transport and diffusion in both non-multiplying and multiplying media.
CO4 – Understand the reactor kinetics, the parameter of reactor dynamics and control.
CO5 – Analyze transport calculations and reactor core design.
CO6 – Evaluate the operation and safety of present and advanced power reactor.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

19NE 508T					Nuclear Safety, Security and Safeguard					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To apply engineering techniques for nuclear security systems design.
- To understand the national and international nuclear safety and security policy.
- To explain different techniques of nuclear safety and security analysis.

UNIT 1 Nuclear Power Plant Safety **12 Hrs.**

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 **10 Hrs.**

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 **10 Hrs.**

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 Nuclear Safeguards **08 Hrs.**

Special Nuclear Materials, Nuclear Non-proliferation, Nuclear material accounting and Control, Material unaccounted for (MUF), Physical inventory taking and verification, IAEA and domestic safeguards, Nuclear Forensics

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1- Explain the difference between safety, security and safeguards and their effective integration.

CO2- Debate on nuclear safety and nuclear security in the civil nuclear industry.

CO3 -Analysis of deterministic and probabilistic basis for system reliability and failures.

CO4 - Demonstrate national and international nuclear regulatory frameworks and licensing conditions.

CO5- Conduct threat assessments and apply physical protection measures to mitigate design basis threats.

CO6 - Develop detailed understanding of nuclear safeguard and several nuclear accidents.

TEXT/REFERENCE BOOKS

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
3. Jones, O.C., Nuclear Reactor Safety Heat Transfer, Hemisphere Pub., 1981.
4. The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Rev.4(Corrected), IAEA, Vienna
5. Development, Use and Maintenance of the Design Basis Threat, IAEA Nuclear Security Series No. 10, IAEA, Vienna
6. Nuclear Security Culture, IAEA Nuclear Security Series No. 7, IAEA, Vienna (2008).
7. James Doyle, Nuclear Safeguards, Security and Nonproliferation, Butterworth-Heinemann, 2008.
8. Fry, M.P., P. Keatinge and J. Rotblat (Eds.): Nuclear Nonproliferation and the Nonproliferation Treaty, Springer-Verlag
9. The Nuclear Fuel Cycle, ANS Text book by Nicholas Tsoulfanidis, 2013, ISBN 978-0-89448-460-5.
10. Design and Evaluation of Physical Protection Systems by Mary Lynn Garcia, Second Edition, Sandia National Laboratories
11. An Introduction to The Nuclear Fuel Cycle and Nuclear Safeguards by Donald R. Joy, Jai Corporation, Fairfax, Virginia.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

19NE 509T					Nuclear Material and Nuclear Fuel Cycle					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To demonstrate various process of fuel cycle.
- To explain various fuel types in different reactors and performance.
- To understand various reprocessing process.
- To explain various enrichment processes.

UNIT 1 Introduction and Front End of Fuel Cycle 10 Hrs.

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 10 Hrs.

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 10 Hrs.

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 10 Hrs.

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.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Identify the suitable fuel for a particular reactor.

CO2 - Explain the various type of fuels used in nuclear reactor.

CO3 - Explain front end and back end of fuel cycle.

CO4 - Demonstrate PUREX and other reprocessing processes.

CO5 - Demonstrate fast reactor fuel cycle and Identify the challenges associated with fast reactors.

CO6 – Explain Radioactive waste management.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A: Short term Questions from each unit with internal choice 50 Marks

Part B: Long term questions from each unit with internal choice 50 Marks

17NE 514T					Nuclear Heat transfer and Thermal Hydraulics					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**-**	**-**	**3**	**3**	**25**	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

- 1 To impart the knowledge of fundamentals of heat transfer and analysis of various heat transfer systems
- 2 To Evaluate the performance of various heat transfer and thermodynamic systems and identify its application
- 3 To learn properties of steam and analyse its applications in Rankine cycle and other applications
- 4 To understand nuclear reactor system design and its thermal hydraulics applications

UNIT 1: Regimes of heat transfer and Extended surfaces **(10L)**

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, steam and thermodynamic cycles **(12L)**

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 **(13L)**

Power Cycles; Critical heat flux and core thermal design; Fuel element grids, Heat Generation in Reactors, Energy Release and Deposition, Heat Generation Parameters, Power Profiles in Reactor Core, Thermal analysis of Fuel Elements,; nuclear reactor safety: Coolant transients, Loss-of-coolant accidents.

UNIT 4: Introduction to two phase flow **(10L)**

Analysis of boiling and condensation phenomena; Heat transfer rates in pool and flow boiling; Critical Heat Flux; Two phase flow: basic concepts, Flow Regimes, void-quality analysis, pressure losses; Flow instability, Critical flow; Calculation of two phase pressure drop, 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

Lecture: 45 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1: Application of Heat transfer and designing of Heat transfer accessories
CO2: The energy balances in fins and Heat exchangers and thermodynamic cycles
CO3: Capability of formulating and designing heat transfer accessories
CO4: Understanding of steam thermodynamic cycles
CO5: Understanding of thermal hydraulics processes and fluid flow mechanisms in reactor systems
CO6: Formulate, analyze and solve simple problems of heat transfer in reactor systems and safety measures

TEXT/REFERENCE BOOKS

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.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

17NE 511T					Radiation and Radioisotope Applications – II [Elective-I]					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To demonstrate various applications of radioisotope and radiation techniques in Industry.
- To explain radiation and radioisotopes in medical field.

UNIT 1 Basics of radiotracer and isotopes techniques **10 Hrs.**

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 **10 Hrs.**

Gamma or X-ray Radiography, Industrial tomography, Gamma scanning, Nucleonic gauges in industry, Radiation processing applications, Sewage sludge hygienization, Radiation induced polymerization, Radiation grafting and material modification, Value addition to precious stones by radiation.

UNIT 3 Applications of Radiation Technology in Healthcare **10 Hrs.**

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 **10 Hrs.**

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

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understand radiation techniques like RTD and its application

CO2 - Explain various applications of radiotracer techniques in chemical and petroleum industry

CO3 – Apply non-destructive techniques in Industry and know the material modification

CO4 - Understand various applications of radioisotope and radiation healthcare.

CO5 – Apply and analyse the radioisotopes application in biomedical industry.

CO6 – Evaluate the safety system and protection during working with radiation and radioisotopes in industry.

TEXT/REFERENCE BOOKS

1. Charlton, J.S., 1986. Radioisotope tracer techniques for problem solving in industrial plants. LeonardHill, Glasgow, London.
2. Practical applications of radioactivity and nuclear radiations – G.C. Lowenthal and P.L. Airey, Cambridge university press
3. Fundamentals of nuclear science and engineering – J.Kennethshultis & Richard E.Faw
4. Radiotracer generators for industrial applications – IAEA radiation technology series no.5, 2013
5. International Atomic Energy Agency, 2004. Radiotracer Applications in Industry-A Guidebook, Technical Reports Series No. 423, IAEA, Vienna 281p.
6. IAEA, 2008. Residence time distribution method for industrial and environmental applications. IAEA, Vienna, Austria.
7. 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.
8. 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.
9. A concise guide to nuclear medicine by Abdelhamid H Elgazzar and Soud Alenezi 2nd edition, Springer 2020
10. R.D. Lele, Principles and Practice of Nuclear Medicine, Arnold-Heinemann, New Delhi (1984)
11. H.N. Wagner Jr., Z. Szabo, J.W. Buchanan, Principles of Nuclear Medicine, 2nd Edition (1995).

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

17NE 512T					Design and Manufacturing of Nuclear Reactor Components [Elective-II]					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To explain structural components in nuclear power plant and structural design requirements
- To understand manufacturing processes of different nuclear power plant components

UNIT 1 Machine Design 10 Hrs.

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

UNIT 2 Design of Pressure Vessel and Piping 11 Hrs.

Introduction to materials being used in critical nuclear reactor equipment and their properties, German code KTA for PHWR equipment design; Design for pressure vessel and piping as per ASME codes, Seismic qualification

UNIT 3 Manufacturing of Nuclear Components 12 Hrs.

Pressure vessel, Calandria, Coolant channels, Header, Steam generator, Pressurizer, Fuelling machine

UNIT 4 Design of Secondary side and safety system Components 12 Hrs.

Control rod mechanisms, Turbine, Condenser, reheaters, Deaerator, cooling tower etc.

Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Design the structural components of nuclear reactors

CO2 - Estimate induced stresses and compare against standards

CO3 - Demonstrate the models of material to determine adequacy of component design

CO4 – Apply ASME code for pressure vessel design.

CO5 – Evaluate the parameter for steam generator and coolant channel manufacturing.

CO6 - Analyse different Safety system and secondary side component of nuclear power plant.

TEXT/REFERENCE BOOKS

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

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: Questions from each unit with internal choice, each carrying 20 marks 100 Marks

16NE512P					Thermal Hydraulics Laboratory		
Teaching Scheme					Examination Scheme		
L	T	P	C	Hrs/Week	Practical		Total Marks
					Continuous Evaluation	End Semester LE/Viva	
0	0	4	2	4	25	25	50

Course objectives:

- **To analyse, differentiate** and **evaluate** different modes of heat transfer through various mediums.
- **To evaluate** steady and transient state properties of heat transfer mediums.
- **To calculate and compare** the performance of heat exchangers.
- **To demonstrate** boiling and condensation regimes

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

Course Outcomes (COs): On completion of the course, students will be able to

CO1 - Understand and **evaluate** different modes of heat transfer.
CO2 - Understand and **analyse** conductivity of different materials.
CO3 - Examine the performance of heat exchangers.
CO4 – Evaluate the convective heat transfer coefficient
CO5 - Demonstrate film wise and dropwise condensation and **evaluate** their performance.
CO6 -Interpret and **evaluate** critical heat flux (CHF)

Resources/Text/Reference books

1. Heat Trasfer by P K Nag
2. Heat transfer by Yungus A. Cengel.

End Semester Lab Examination

Max. Marks: 25 **Exam Duration: 2 hrs**

Quiz/Experiment	10 Marks
Viva	15 Marks