University of Dhaka

Department of Nuclear Engineering

Syllabus for the M.Sc. in Nuclear Engineering

Session: 2017-18 and Onwards

M.Sc. in Nuclear Engineering

Duration	: 1 year and 6 months: 3 semesters
Classes	: 14 active weeks/ semester
Preparatory Leave	: Maximum 2 (two) weeks
Semester Final Exam	: 2 (two)weeks/semester
Vacation	: Only the usual university's vacation will be applicable
Result Publications	: Within two months (from the last exam date)

Teaching of the courses:

For each 3.00 credits of a theory course, there will be 2 classes per week of 1.5 hours duration.

Total classes in a semester for each 3.0 credits of a theory course will be 14 active weeks

Admission

Students will be admitted to the department as per university rules.

Admission Requirements

Students having B. Sc. in Nuclear Engineering from University of Dhaka.

First semester:

Two (02) Compulsory Courses	= 6 credits
Two (02) Optional Courses	= 6 credits
Total	**= 12 credits**

Second semester:

Two (02) Compulsory Courses	= 6 credits
Two (02) Optional Courses	= 6 credits
Viva-Voce	= 2credits
Total	**= 14 credits**

Third semester:

Thesis	= 10 credits
Total	**= 10 credits**

Grand Total	**= 36 credits**

Grading System: The current UGC approved grading system applies as per university rules.

Marks	**Letter Grade**	**Grade Point**
80% and Above	A+	4.00
75% to < 80%	A	3.75
70% to < 75%	A-	3.50
65% to < 70%	B+	3.25
60% to < 65%	B	3.00
55% to < 60%	B-	2.75
50% to < 55%	C+	2.50
45% to < 50%	C	2.25
40% to < 45%	D	2.00
Less Than 40%	F	0.00

Marks Distribution

For a theory course:	Attendance	05%
	Assignment/Presentation	05%
	Incourse Examination	20%
	Final Examination	70%
	Total Marks	100%

For each 3 credits course, at least 2 Incourse examinations should be taken. One near the 5th/6th week and the other near the 11th/12th week.

Attendance

Students with 75% attendance and above in each course will be eligible to sit for the semester final examinations. Students having attendance >=60% and <75% will be considered to sit for the examination after paying the some required fines. Students having attendance below 60% will not be eligible to appear at the examination. The marks distribution for attendance is given below:

Attendance	**Marks**
90% and Above	5.0
85% to < 90%	4.5
80% to < 85%	4.0
75% to < 80%	3.5
70% to < 75%	3.0
65% to < 70%	2.5
60% to < 65%	2.0
Less Than 60%	0.0

Course Coordinator:

Whole of academic sessions will have a course coordinator. The coordinator will prepare class routine, monitor classes, arrange extra classes if necessary, ensure smooth functioning of the academic works, and help the Chairman (of the examination committee) in holding examinations and publishing results.

Class Representative:

Each batch/section of students will have two class representatives (one male and one female) to maintain liaison with the Course Coordinator regarding their class progress and problems.

Theory Courses Evaluation:

For a theory course the evaluation will be made on the basis of attendance, quiz/assignment/presentation, incourse exam and final exam. For any courses attendance, quiz/assignment/presentation, incourse exam will be evaluated by the teacher/s and the result must be submitted to the exam committee and controller of exam before commencement of semester final examination. The incourse exam scripts and evaluation marks must be shown to students before last class. For theoretical course final exam, generally there will be two examiners: course teacher will be the first examiner and the second examiner will be within the department or from a relevant department of University of Dhaka. If a suitable examiner is not found from University of Dhaka, a second examiner may be appointed from other universities with the prior permission from University. The average mark of two examiners will be considered as the mark obtained if the difference of theirs marks is less than or equal to 20%. In case of difference of marks between the two examiners is more than 20% the script will be evaluated by third examiner. Marks of nearest two examiners will two examiners will be taken for average. If the difference of third examiner from the first and second examiner become equal then mark obtained will be calculated from average of three examiners.

Thesis Evaluation:

Thesis will be coordinated by the examination committee. Examination committee may include external expert to assess the defense. Thesis will be evaluated on the basis of 100% marks where there will be thesis defense 60% marks and thesis report will be evaluated by 40% marks. Two examiners will evaluate the thesis report and their average mark will be considered. In case of a difference of marks between the two examiners is more than 20% the thesis will be evaluated by third examiner. Marks of nearest two examiners will be taken for average. Examiners of the thesis report evaluation are appointed according to the rules of Faculty of Engineering and Technology, DU.

Examination Committee:

The examination committee consisting of 4 teachers will be proposed by the Academic Committee of the department. There will be an examination committee for whole academic year of one batch. Committee will consist of a Chairman, 2 internal members and an external member. The Course Coordinator should be one of the members of the committee. The committee may have the external member from DU or outside DU.

The Chairman of the examination committee, with the help of the committee members, will be responsible for getting questions from the respective course teachers, moderating the questions and printing them, holding examinations and publication of results. The exam committee will manage or coordinate all exam related activities as per university rules.

Tabulators:

The examination committee will appoint two tabulators. Course teachers/examiners will submit their grade-sheets in details.

The tabulators will enter the marks given by each course teacher/examiner in the tabulation sheets independently and tabulate the examination results.

The controller's office will publish the examination results at the end of every semester and issue the transcripts.

Requirements for the award of the Final Degree:

A student must earn required credits in a maximum period of three continuous semester starting from the date of admission in M. Sc. 1^{st} semester.

A student must obtain CGPA of atleast 2.5 to achieve M. Sc. in Nuclear Engineering degree without 'F' grade in any. There will be no option for grace.

The student can readmit for another three semesters. But a student may be allowed re-admission for a maximum of one time.

Improvement of Grades:

A student will be allowed a single earliest available chance to clear F grade/grades complying with the time requirement for the degree. A student will not be allowed for grade improvement if he or she passes and the final semester result is published.

A student may improve grade/grades of any course only once by reappearing at the examination with the immediate next batch if he/she obtains a grade less than or equal to C+ (GP=2.50) and the best grade that a student can achieve in case of grade improve is B+.

In addition to the usual fees, a fine, as per university rules, will be imposed for each course chosen for improvement.

A student will have to be mentally prepared to take the examination of a particular course chosen for improvement even if it is held on the same day of his/her other regular examination.

Other General Regulations:

For any matter covered in the above guidelines, existing rules of University of Dhaka will be applicable. Disciplinary and punishable actions will be applied according to the existing rules of the University of Dhaka.

Elaboration of Course Code:

N – Nuclear

E – Engineering

1st Digit – Represent year of the offered course

2nd Digit – Represent semester of the offered course

3rd and 4th Digit - Represent offered course number (Odd Number: Theory Course; Even Number: Viva Voce and Thesis Course.)

List of Courses

First Semester:

Course Code	Course Title	Credit
NE5101	Nuclear Reactor Analysis	3.00
NE5103	Advanced Thermal Hydraulics	3.00
NE5105	NEOP-1	3.00
NE5107	NEOP-2	3.00

Second Semester:

NE5201	Nuclear Reactor Safety and Accident Analysis	3.00
NE5203	Project and Risk Management and Economics of Energy	3.00
NE5205	NEOP-3	3.00
NE5207	NEOP-4	3.00
NE 5200	Viva Voce	2.00

Third Semester:

NE5300	Thesis	10.00
	Total	36.00

Optional courses:

NEOP	Advanced Nuclear Instrumentation and Control	3.00
NEOP	Plasma Physics of Fusion Energy	3.00
NEOP	Applications of Nuclear Technology	3.00
NEOP	Nuclear Energy Policy, Law and Liability	3.00
NEOP	Radiological and Environmental Impact of Nuclear Facility	3.00

FIRST SEMESTER: 12 Credits

Course Code: NE- 5101

Course Title: Nuclear Reactor Analysis

Credit: 3.00

Course Content:

Overview of Reactor Physics: Neutron transport and diffusion theory. One group and multi-group methods of neutron diffusion equations. Analytical and numerical solutions for neutron diffusion equations. Reactor equation and its solution. Point reactor kinetics. Reactor with reactivity feedback, Calculation of reactivity coefficients.

Nuclear Reactor Calculations: Introduction to neutronics code. Nuclear data libraries. Fast spectrum calculation and fast group constant. Thermal spectrum calculation and thermal group constant. Criticality calculations for bare and reflected homogenous system. Cell calculation for heterogeneous core lattices. Calculation of core power distribution. Analysis of core composition changes. Plant dynamics and safety calculations.

Design Analysis of Nuclear Reactor: Overview of reactor core design. Design analysis for reactor safety features. Licensing requirements. Fuel system analysis. Principles and techniques of economic analysis to determine capital and operating cost. Systems design approaches. Optimization approaches.

Experimental Methods in Reactor Analysis: Reactivity measurement: Reactivity feedback and reactor dynamics, critical approach experiment, calibration of control rods, neutron source multiplication method, neutron source pull-out method etc. Fuel handling, inspection and storage. Reactor operating limits and conditions. Neutron flux measurement. Zero-Power critical experiments. Coordination of experiment and design.

References:

1. Nuclear Reactor Analysis, James J. Duderstat and Louis J. Hamilton, 1st ed. New York: Wiley, 1976. ISBN: 9780471223634
2. Nuclear Reactor Kinetics and Plant Control; Yoshiaki Oka, Katsuo Suzuki Editors, Springer, 2013, DOI 10.1007/978-4-431-54195-0, ISBN 978-4-431-54194-3
3. Nuclear Power Plant Design Analysis, Alexander Sesonske,1973, ISBN 0-87079-009-9

4. Nuclear Reactor Enginering, Glasstone and Sesonske, Third ed.
5. Introduction to Nuclear Reactor Theory, John R. Lamarsh, New York University
6. Nuclear Reactor Physics, Weston M. Stacey, Second Edition, ISBN 978-3-527-40679-1

Course Code: NE- 5103

Course Title: Advanced Thermal Hydraulics

Credit: 3.00

Course Content:

Review of Thermal hydraulic design: Thermal Design Approaches and Limitations, Fuel Rod Design, Preliminary Core Design, Hot-Channel Factor Evaluation for Conservative Core Design, Effect of Anticipated Operating Occurrences (AOOs) and Major Accidents on Core Design, Power Reactor Hydraulic Configurations, Boundary Conditions for the Hydraulic Problem.

Analysis of Core Performance: Analysis of Core Performance during Normal Operation, Effect of Core Flow Arrangement on Core Performance, Interaction of Thermal-Hydraulic Design with Other Areas, One-Dimensional Flow Equation formulations and solutions for single channel, multichannel and sub channel analysis, Conservation Equation analysis and solutions for multichannel and sub channel, Derivation of the Volume-Averaged Linear Momentum, Mass Conservation and Energy Conservation equations by the Porous Media Approach.

Analysis of Reactor Fuel Rod Assemblies: Laminar and Turbulent Flow in fuel Rods, Momentum and Heat Transfer in Laminar Flow Between Fuel Rods and Coolant region, The Equivalent Annulus Model Comparison of Laminar, Slug, and Turbulent Flow, Nusselt Numbers for Liquid Metals in Equivalent Annuli, Multi-region Analysis of Longitudinal Laminar Flow, Survey of Isolated Cell Problems Solved by the Distributed parameter method.

Thermal-Hydraulic Analysis of Selected Plant Components: Pipelines and Valves, Heat Exchangers, Steam Generators, Pumps, Turbines Sets, Steady-State Balance of Boiling Water Reactor.

Code Analysis: Relevant nuclear thermal hydraulics codes for analysis of nuclear reactor core performance.

References:

1. Neil E. Todreas, Mujid S. Kazimi, Nuclear systems II : Elements of Thermal Hydraulic Design.
2. L. S. Tong, Joel Weisman, Thermal Analysis of Pressurized Water Reactors, Third EditionAmerican Nuclear Society.
3. Henryk Anglart, Thermal-Hydraulics in Nuclear Systems.
4. Christopher Earls Brennen, Thermo-Hydraulics of Nuclear Reactors,Dankat Publishing Company.

SECOND SEMESTER: 12 Credits

Course Code: NE- 5201
Course Title: Nuclear Reactor Safety and Accident Analysis
Credit: 3.00
Course Content:

Concepts of Nuclear Power Plant Safety: Elements of Reactor Safety; Defense in Depth; Safety Systems and their Functions, Reactor Protection System; Safety of Specific Plant.

Reactor Safety Analysis: Operational States of NPP; Concept of Nuclear Accident and Incident; Classification of Initiating Events; Classification of Nuclear Accident; INES Scale; Upset Condition, Emergency Condition, Design Basis and Beyond Design Basis Accidents in NPP. Root Cause Analysis of Severe Accident; Progression and Consequences of Three Mile Island, Chernobyl and Fukushima Daiichi Nuclear Accident. Types of Accident Analysis; Analysis Methods; Acceptance Criteria; Reactor Safety Analysis: Deterministic and Probabilistic; Radiological Assessment; Quantitative Risk Assessment; Probabilistic Risk Assessment; Nuclear Safety Criteria, Regulatory Framework and Safety Document.

Phenomenology in Propagation of Severe Accidents : Classification of Severe Accidents Phenomena into Three Levels of Scientific Knowledge: High, Medium and Low; Nuclear Fuel Degradation; Relocation of Melted Fuel; In-Vessel Melt Retention; Ex-Vessel Corium Cooling; Reactor Vessel Failure Mechanisms; Early and Late-Phase Containment Failure; Hydrogen Generation, Transport and Explosion; Physics and Chemistry of Source Term; Fission Product Behavior and Transport.

Numerical Simulations of Severe Accident Phenomena: Classification of Severe Accident Computer Codes (Integral Codes, Mechanistic Codes), Requirements for Modelling Severe Accident Phenomena, Verification and Validation of Computer Codes, Selection of the Approach and Code to be Used, Determination of the Methodology, Input Data Preparation, Preparation of Scenarios, Execution of the Calculation, Checking of Results.

Technological Challenges in Propagation of Severe Accidents and Mitigation of their Consequences: Active and Passive Core Cooling, Active and Passive Containment Cooling, Containment Pressure Venting and Prevention of Hydrogen Explosions, Emergency Preparedness and Response, Decommissioning and Waste Management after Severe Accidents, Severe Accident Management: IAEA Safety Standards and Guidelines, IAEA Activities.

References:

1. Nuclear safety, Gianni Petrangeli, 2006, 1st edition, ISBN: 978-0-7506-6723-4
2. Nuclear Reactor Physics, Weston M. Stacey, Second Edition, ISBN 978-3-527-40679-1, Chapter 8
3. Joint ICTP-IAEA 1st Course on Scientific Novelties in Phenomenology of Severe Accidents in Water-Cooled Reactors (Lectures notes)
4. Introduction to Nuclear Power, Hewit & Collier, 2nd ed. Chapter 4-6.
5. Nuclear Reactor Enginering, Glasstone and Sesonske, Third edition, Chapter 11
6. Introduction to Nuclear Engineering, John R. Lamarsh, Anthony J. Baratta, Third Edition, Chapter 11, ISBN 0-201-82498-1.
7. Accident Analysis for nuclear Power Plant, IAEA Safety Report Series No. 23.
8. Approaches and Tools for Severe Accident Analysis for Nuclear Power Plants, IAEA Safety Report Series No. 56.

Course Code: NE- 5203

Course Title: Project , Risk Management and Economics of Energy

Credit: 3.00

Course Content:

Planning for Nuclear Power Projects

Types of generation resources, Supply and demand sides, Economics of electricity, Nuclear Power Option, Model for energy system analysis. Requirement for nuclear power programme planning.

Introduction of Project Management

Management principles; Management of project planning, financing and implementation; Project evaluation techniques including ratio analysis, break-even analysis, liquidity analysis, and sensitivity analysis; Public sector project approval process.

Project Management in Nuclear Power Plant (NPP), Basic considerations in managing the first Nuclear NPP project. Milestone approaches for nuclear infrastructure development.

Nuclear Power Project Cycle and Implementation

Stages of Nuclear Power Development, NPP Siting and site evaluation, environmental considerations; Conceptual design and Detailed design of NPP, Safety analysis reports, Construction management, Plant commissioning and acceptance testing, Decommissioning of NPP.

Regulatory control and licensing; Quality assurance, quality control and quality surveillance; Staffing for plant operation and maintenance.

Contracts and Contract management

Legal principles & overview of contract law, Types of contracts; Contract administration; Technical bid evaluation and award of contracts; Contract Strategy. Number and scope of contracts and sub-contracts. Responsibilities and risks, Terms of Payment. Incentives and damages terms, scheduling of the project and challenges of schedule management.

Funding and financing of nuclear power project, Financing Models for Nuclear Power Plants, Financing approach to a new build NPP in the developing country.

Public Communication and Major Social Issues

Public communication, Surveys the major social challenges for nuclear energy. nuclear power and climate change; challenges associated with ensuring nuclear safety; the effects of nuclear accidents; the management of nuclear waste; and political challenges to the safe and economic regulation of the nuclear industry.

References:

1. A Guidebook-Nuclear Power Project Management: Technical Reports Series No. 279, IAEA, Vienna, 1988
2. Management Stategies for Nuclear Power Plant Outages: Technical Reports Series No. 449, IAEA, Vienna, 2006
3. Project management in Nuclear Power Plant Construction: Guidelines and Experience: IAEA NUCLEAR ENERGY SERIES No. NP-T-2.7, IAEA, Vienna, 2012
4. Managing the First Nuclear Power Plant Project: IAEA-TECDOC-1555, IAEA, Vienna, 2007

Optional Courses:

Course Code: NEOP
Course Title: Advanced Nuclear Instrumentation and Control
Credit: 3.00
Course Content:

Concepts of Control System: Open and closed loop feedback control system. Block diagram, equation of motion, degrees of freedom, Dynamic responses of the system (transfer function, frequency response function, Laplas transformation), characterization of responses, stability analysis (root locus, Nyquist diagram, Asymptotic bode diagram, polar plot). Study of closed loop controller, such as PID controller tuning method (Ziegler–Nichols). Basic practice in Matlab and Simulink.

Sensors, Actuation and Microprocessor: Study of various sensors and transducers. Boolean algebra, logicgates and circuit analysis. Thermocouple, accelerometer, thermistor, pressure, flow-liquid level transducers, load cells, gas detector, radiation detector, HPGE detector, valves. Signal and noise detection will be studied along with data acquisition, conditioning and display. Electrical, mechanical, pneumatic and hydraulic systems. Microprocessor basic, ADC, assembly language and programmable logic controller (PLC), construction of ladder diagram and functional block programming method. Internal relays, timers, counters, I/O systems and data logging, Basic practice in LabVIEW.

Measurement and instrumentation systems: Basic of signal processing and display. Regulating and correction elements by means of actuators. Calibration methods.

Nuclear Electronics and Radiation Measurement: Pulse Generators, Pulse height and shape discriminations, Function Generators, Testing of High Voltage Supply, Testing of Photomultiplier tube, Measurement of Noise. Radiation Detectors (Gas Filled Detectors, Scintillation Detector, Semiconductor Detectors), Radiation spectroscopy, Radiation Dosimeter, Radiation Survey meter, Area radiation Monitor, Digital Soil PH Meter, Magnetic Field detector, Fluid Sensor cum system controller.

Nuclear I&C Systems: in-core instrumentation (neutron and temperature monitoring, flux mapping), ex-core instrumentation (detector locations, operational logarithmic and linear power channels, safety channels), rod position indicating system, reactor protection system (scram logic, operating modes and system interfaces), rod control system (rod drive mechanism, signal processing and logic, system interrelations), S/G control system, NPP control rooms.

References:

1. Mechatronics Electronic control systemsin mechanical and electrical engineering, Sixth Edition, William Bolton
2. Programmable Logic Controllers, Sixth Edition, W. Bolton
3. INSTRUMENTATION AND CONTROL, SYSTEMS SECOND EDITION, WILLIAM BOLTON
4. Vladimir Polushkin, Nuclear Electronics: Superconducting Detectors and Processing Techniques, 2004, Wiley.

5. Hai Hung Chiang, Electronics for Nuclear Instrumentation: Theory and Application, 1985, Krieger Pub Co.
6. Rachel A. Powsner, Matthew R. Palmer, Edward R. Powsner, Essentials of Nuclear Medicine Physics and Instrumentation, Wiley.
7. Nuclear Power Plant Instrumentation and Control Systems for Safety and Security edited by Yastrebenetsky, Michael, 2014, IGI Global. USA.

Course Code: NEOP

Course Title: Plasma Physics of Fusion Energy

Credit: 3.00

Course Content:

Overview of magnetic fusion. Plasma properties necessary for a fusion reactor.

Basic definition of plasma and its characteristics. Shielding DC electric fields in a plasma --- the Debye length. Derivation of Debye length. The concept of quasi neutrality of plasma. Shielding of AC electric fields in plasma. Derivation of electron plasma frequency. Collective behavior in plasma.

Single Particle Motion in Electric and Magnetic Fields. (a) Motion in uniform fields. (b) Motion in oscillating fields. (c) Curvature and grad-B drifts. (d) Ponderomotive force. (e) General treatments: method of averaging, guiding center motion and drifts, invariance of the magnetic moment, Poincare invariants, adiabatic invariants. (f) Examples: magnetic mirrors, Van Allen Radiation Belts, Fermi acceleration, etc.

Collision processes. Coulomb collision between charged particles in plasma. Applications of collision analysis:energetic (‘runaway’) electrons, collision time, energy equilibrium.

Fluid Description of Plasma. Relation of plasma physics to ordinary electromagnetics. The fluid equation of motion, fluid drift perpendicular to B**,** fluid drifts parallel to B.

Magnetohydrodynamics (MHD). MHD model, Alfven theorem, Diffusion of a B-field, MHD waves.

Diffusion and Resistivity. Diffusion and mobility in weakly ionized gases, decay of a plasma by diffusion, steady state solutions, recombination, diffusion across a magnetic field, diffusion in fully ionized plasmas, solution of the diffusion equation.

Theory of Plasma. Kinetic theory of plasmas, Boltzmann Vlasov equation, Drift Kinetic equation, Linearization of the Vlasov model, Linear electrostatic response, Landau damping, Stability methods.

Present status and challenges of fusion research for energy production

References:

1. Francis F. Chen, *Introduction to Plasma Physics and Controlled Fusion*. Springer; 2nd Ed., 1984
2. Jeffrey P. Freidberg, *Plasma Physics and Fusion Energy*, 2007
3. Francis F. Chen, *An Indispensable Truth. How Fusion Power Can Save the Planet*. Springer, 2011
4. Lyman Spitzer Jr., *Physics of Fully Ionized Gases*, 2nd Revised Edition, Dover Publications, 1962
5. John Wesson, *Tokamaks*, Oxford Univ. Press, USA, 4th edition, 2011
6. Mitsuru Kikuchi, Karl Lackner, and Minh Quang Tran, *Fusion Physics*, IAEA, Vienna 2012
7. Leslie C. Woods, *Theory of Tokamak Transport*, Wiley-VCH Verlag GmbH & Co. KGaA, 2006
8. Jeffrey P. Freidberg, *Ideal MHD*, Cambridge University Press, 2014 (updated version of 1987 Ed.)
9. Richard Fitzpatrick, *Plasma Physics An Introduction*, CRC Press, 2015
10. Peter C. Stangeby, *The Plasma Boundary of Magnetic Fusion Devices*, Taylor & Francis, 2000
11. Dwight Nicholson, *Introduction to Plasma Theory*, John Wiley & Sons, 1983
12. K. Nishikawa, M. Wakatani, *Plasma Physics*, 3rd Edition, Springer
13. Richard D. Hazeltine, Francois L. Waelbroeck, *The framework of plasma physics*, Perseus Book

Course Code: NEOP

Course Title: Applications of Nuclear Technology

Credit: 3.00

Course Content:

Nuclear Technology in Industry and Research:

Production of Radioisotopes, Tracer Applications of Radioisotopes: leak detection, flow rate measurements, labeling of chemical reagents with radionuclides to study complex chemical reactions, etc., **Tracer Dilution Techniques:** blood volume measurement, mixing time of two fluid, residence times.**Application of the effects on radiation by matter: Radiography:** X-ray and gamma- ray radiography, neutron radiography, beta radiography,thickness gauging,density gauges, liquid level gauges etc. **Application of the effects in matter by radiation:** food preservation, sterilizing, insect control, etc., **Neutron activation analysis, Neutron Scattering, Nondestructive testing (NDT):** nuclear material testing and inspection, **Technology of Hydrogen Production andWater desalination.**

Nuclear Medicine:

Diagnostic Techniques: Use of X-rays**,** SPECT imaging**,** PET imaging, Hybrid Imaging: SPECT/CT and PET/CT, NMR, MRI, diagnostic uses of radioisotopes**, Therapeutics:** fundamental radiobiology and its applications to radiation oncology, X-rays therapy, hadron therapy, brachytherapy, quality assurance, computers in treatment planning, in vitro applications: RIA, molecular biology techniques using radionuclide methods**.**

Accelerators in Applied Research and Technology:

Accelerator based fundamental research, application of accelerator in medical and industry.

Applications in Agriculture and Food Processing:

Pest control, Crop Production Enhancement, Improving Animal Health, Food Processing, Food Irradiation, Sterilization, Eradication of Pests.

Geological aspects of Nuclear Materials:

Mineralogy of nuclear materials, Geographical distribution of nuclear minerals in world, Exploration & exploiting of nuclear minerals, Geochemical analysis and their interpretation, mining and economics of commercial exploration of nuclear deposits, radiation safety aspects of mining and environment.

References:

1. J. Kenneth Shultis&Richard E. Faw, Fundamentals of Nuclear Science And Engineering, Kansas State University Manhattan, Kansas, U.S.A.
2. Simon R. Cherry, James A. Sorenson &Michael E. Phelps, Physics in Nuclear Medicine, 4th edition, Elsevier, ISBN: 978-1-41605198-5
3. Yves Lemoigne& Alessandra Caner, Radiotherapy and Brachytherapy,European Scientific Institute Site d'Archamps France, Spriger, ISBN 978-90-481-3096-2 (PB)
4. NamiraNegm, TransferofNuclearTechnology under International Law, ISBN 9789004175273
5. Lamarsh, John R., and Anthony J. Baratta. Introduction to Nuclear Engineering. 3rd ed. Englewood Cliffs, NJ: Prentice Hall, 2001. ISBN: 9780201824988.
6. B H Brown, R H Smallwood, D C Barber, P V Lawford and D R Hose, Medical Physics and Biomedical Engineering, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK, ISBN: 0750303670 (hbk),
7. Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt Jr., John M. Boone, The Essential Physics of Medical Imaging, Third Edition, Lippincott Williams & Wilkins, ISBN-13: 978-0781780575
8. Manson Benedict, Thomas H. Pigford, Hans Wolfgang Levi, Nuclear Chemical Engineering, 2nd Edition

Course Code: NEOP

Course Title: Nuclear Energy Policy, Law and Liability

Credit: 3.00

Course Content:

Elements of Nuclear Law and Nuclear Energy Policy:

Nuclear Law and the Legislative Process: Basic Structure of a Nuclear Law or Laws, Relation of Laws and Regulations, Objective and Principles of Nuclear Law, Legislative Process for Nuclear Law, Security Culture and Safety Culture in Nuclear Law. **The Regulatory Body**: Designating the Regulatory Body, Independence and Separation of Regulatory Functions, Advisory Bodies and External Support. **Regulatory Activities:** Notification, Licensing Legislation, Inspection and Enforcement Legislation, Model Provisions on Appeals of Regulatory Decisions. National Laws and Regulation for Practice of Nuclear Energy, IAEA Policy and Regulations.

Nuclear and Radiation Safety:

Safety of Nuclear Facilities: Safety Requirements for Power Reactors, Role of the Regulatory Body and Operating Organization, Conditions for a Licence, Research and Test Reactors.Activities and Facilities Requiring a Licence for the Mining and Milling of Nuclear Materials as well as for Radioactive Waste and Spent Fuel Management, Conditions for the Issuance of a Licence, Special Issuses. Responsibility of Licencee, Managemnt Requirements. **Transport of Radioactive Material:** Legal Means of Ensuring the Safe Transport ofRadioactive Material, Change of Jurisdiction During International Transport, Transboundary Movement of Spent Fuel and Radioactive Waste. **Emergency Preparedness and Response**: Goals and Elements, Implementation of Emergency Preparedness, Obligations Under Public International Law and Relevant Conventions.

Nuclear Liability and Coverage: International Nuclear Liability Conventions, Nuclear Liability Principles, Liability for Nuclear Damage Occurring During Transport, Liability for Other Radiation Damage, Damage Coverage.

Non-Proliferation, Physical Protection and Illicit Trafficking: Key Elements of Safeguards Legislation, Key Elements of Nuclear Export and Import Control Legislation, CPPNM,UNSCR 1540, 1371, Key Elements of Physical Protection Legislation, Basic Elements of Nuclear Security Legislation, Model Provisions on Nuclear Security, Physical Protection and Illicit Trafficking, Offences Relating to Nuclear Security.

References:

1. Handbook on Nuclear Law, Carlton Stoiber, Abdelmadjid Cherf, Wolfram Tonhauser, Maria De Lourdes Vez Carmona, International Atomic Energy Agency, Vienna, 2003
2. Handbook on Nuclear Law, Implementing Legislation; Carlton Stoiber, Abdelmadjid Cherf, Wolfram Tonhauser, Maria De Lourdes Vez Carmona, International Atomic Energy Agency, Vienna, 2010.
3. The Structure and content of agreements between the agency and states required in connection with the treaty on the nonproliferation of nuclear weapons, INFCIRC/153(Corrected), International Atomic Energy Agency, Vienna, 2016.
4. Model protocol additional to the agreements between state(s) and the IAEA for the application of safeguards, INFCIRC/540(Corrected), International Atomic Energy Agency, Vienna, 2016.

Course Code: NEOP

Course Title: Radiological and Environmental Impact of Nuclear Facility

Credit: 3.00

Course Content:

Radiation Hazards, Radiation Protection and Standards: Quantitative effects of radiation on the human species, Calculation of exposure, dose and radiation effects, Protection from Radiation Hazards. Standards for occupationally exposed individuals and general population.

Radiation Doses from Nuclear Plants: External dose from Plume: gamma rays and Beta rays, Internal Dose from Inhalation and Ingestion, Dose from Ground-deposited Radionuclides in normal and abnormal condition, Leakage from Buildings, Direct gamma-ray Dose, Population Doses.

Radiological Dispersion: Dispersion of Effluents from Nuclear Facility: Meteorology of Dispersion, Plume formation, Diffusion of Effluents (Gaussian Model), Deposition and Fallout, The wedge Model, Release from Buildings. Dispersion calculations for single fuel failure and multiple fuel failure.

Radionuclide Transport Model: Primary contamination and the source term; groundwater transport model; accumulation of radionuclides at offsite locations and in food: accumulation in offsite surface soil, accumulation of radionuclides in surface water, accumulation in plants, fish and aquatic foods, meat and milk; exposure pathways.

Impact of Thermal Discharge: Cooling requirements of NPP, general effects of the condenser cooling system, aquatic ecosystem, effects of temperature and entrainments on aquatic ecosystem, aquatic ecological monitoring, and regulation of thermal discharge.

Environmental impact assessment: Principles and objectives**,** Requirements, Radiological risk assessment, Continuous dose monitoring system for NPP: Onsite and Offsite, Feedback from environmental monitoring.

References:

1. Introduction to Nuclear Engineering, John R. Lamarsh, Anthony J. Baratta, Third Edition, Chapter 4, ISBN 0-201-82498-1.
2. Nuclear Reactor Enginering, Glasstone and Sesonske, Third ed.
3. Nuclear safety, Gianni Petrangeli, 2006, 1st edition, ISBN: 978-0-7506-6723-4
4. User Manual, RESRAD OFFSITE, Version 2, Argonne national laboratory.