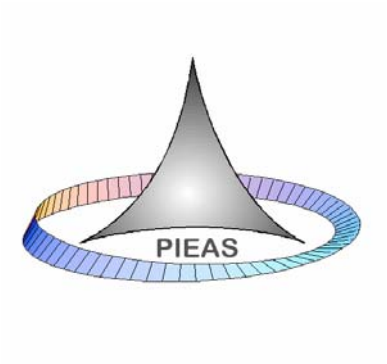
MS (Nuclear Engineering)



Department of Nuclear Engineering

Pakistan Institute of Engineering and Applied Sciences (PIEAS), Nilore, Islamabad 45650, Pakistan

Pakistan Institute of Engineering & Applied Sciences

Department of Nuclear Engineering

MS (Nuclear Engineering)
SEMESTER-WISE LAYOUT OF COURSES

NOTE: 'C' and 'O' stand for 'Compulsory' and 'Optional', respectively.

FIRST SEMESTER					
Sr.	**Course**	**Name of the course**	**Credits**	**Nature**	**Pre-requisite**
	NE-402	Introductory Nuclear Physics	2	C	Nil
	NE-403	Thermal Engineering Principles	3	C	Nil
	NE-501	Fundamentals of Nuclear Engineering	3	C	Nil
	NE-502	Radiation Interaction and Detection	4	C	Nil
	NE-503	Applied Mathematics-I	3	C	Nil
SECOND SEMESTER					
Sr.	**Course**	**Name of the course**	**Credits**	**Nature**	**Pre-requisite**
	NE-504	Radiation Measurement Laboratory	3	C	Nil
	NE-505	Nuclear Reactor Analysis	3	C	Nil
	NE-506	Nuclear Heat Transport	3	C	Nil
	NE-507	Radiological Engineering	3	C	Nil
	NE-511	Numerical Methods in Engineering	3	C	Nil
	NE-509	Special Topics in Nuclear Engineering-I	3	O	Nil
THIRD SEMESTER					
Sr.	**Course**	**Name of the course**	**Credits**	**Nature**	**Pre-requisite**
	NE-508	Nuclear Reactor Materials & Radiation Damage	3	C	Nil
	NE-510	Nuclear Power Plant Systems	3	C	Nil
	NE-601	Nuclear Engineering Laboratory	3	C	Nil
	NE-512	Fluid Dynamics	3	O	Nil
	NE-513	Nuclear Chemical Engineering	3	O	Nil
	NE-514	Materials Science	3	O	Nil
	NE-515	Materials Engineering	3	O	Nil

	NE-516	Mechanical Behavior of Materials-I	3	O	Nil
	NE-517	Feedback Control Systems	3	O	Nil
	NE-518	Applied Electronics	3	O	Nil
	NE-519	Principles of Plasma Physics	3	O	Nil
	NE-520	Optics and Laser Fundamentals	3	O	Nil
	NE-521	Vacuum Technology	3	O	Nil
	NE-522	The Finite Element Method	3	O	Nil
	NE-523	Special Topics in Nuclear Engineering-II	3	O	Nil
	NE-581	Nuclear Security	3	O	Nil
	NE-602	Reactor Thermal-Hydraulics	3	O	Nil
	NE-603	Nuclear Reactor Statics	3	O	Nil
	NE-604	Nuclear Fuel Management	3	O	Nil
	NE-605	Radiation Shielding	3	O	Nil
	NE-606	Applied Mathematics-II	3	O	Nil
FOURTH SEMESTER					
Sr.	**Course**	**Name of the course**	**Credits**	**Nature**	**Pre-requisite**
	NE-629	Reactor Operation and Experiments	3	C	Nil
	NE-697	MS Thesis Research	3	C	Nil
	NE-524	Structural Mechanics	3	O	Nil
	NE-525	Chemical Process Design	3	O	Nil
	NE-526	Radioisotope Applications	3	O	Nil
	NE-527	Environmental Engineering	3	O	Nil
	NE-528	Nuclear Proliferation and Safeguards	3	O	Nil
	NE-529	Project Management	3	O	Nil
	NE-530	Solid State Nuclear Track Detectors	3	O	Nil
	NE-531	Geological Aspects of Nuclear Materials	3	O	Nil
	NE-532	Seismic Aspects in Nuclear Power Plant Siting	3	O	Nil
	NE-533	Vacuum Technology Laboratory	3	O	Nil
	NE-582	Physical Protection Systems	3	O	Nil
	NE-607	Nuclear Reactor Dynamics	3	O	NE-603
	NE-608	Neutron Transport Theory	3	O	NE-505
	NE-609	Nuclear Reactor Safety	3	O	NE-603

	NE-610	Reliability and Risk Analysis	3	O	Nil
	NE-611	Nuclear Reactor Design	3	O	NE-603
	NE-612	Boiling Heat Transfer and Two Phase Flow	3	O	NE-602
	NE-613	Computational Fluid Dynamics	3	O	NE-512
	NE-614	Radioactive Waste Management	3	O	NE-605
	NE-615	Nuclear Chemical Plant Design	3	O	NE-513
	NE-616	Nuclear Reactor Materials	3	O	Nil
	NE-617	Degradation and Failure of Materials	3	O	NE-515
	NE-618	Mechanical Behavior of Materials-II	3	O	NE-516
	NE-619	Vacuum Metallurgy	3	O	NE-521
	NE-620	Cryogenic and Vacuum systems Design	3	O	Nil
	NE-621	The Boundary Element Method	3	O	NE-522
	NE-622	Laser Physics	3	O	NE-520
	NE-623	Laser System Technology and Applications	3	O	NE-520
	NE-624	Thermonuclear Engineering	3	O	Nil
	NE-625	Reactor Control and Instrumentation	3	O	Nil
	NE-626	Optimal Control Engineering	3	O	Nil
	NE-627	Computer System Management	3	O	Nil
	NE-628	Special Topics in Nuclear Engineering-III.	3	O	Nil
	NE-630	Control and Simulation Laboratory	3	O	Nil
	NE-631	Radiation Physics Laboratory	3	O	Nil
	NE-632	Engineering and Materials Laboratory	3	O	Nil

FIFTH SEMESTER

Sr.	Course	Name of the course	Credits	Nature	Pre-requisite
	NE-697	MS Thesis Research	9	C	Nil

List of Courses

NE-402	INTRODUCTORY NUCLEAR PHYSICS	1
NE-403	THERMAL ENGINEERING PRINCIPLES	1
NE-501	FUNDAMENTALS OF NUCLEAR ENGINEERING	2
NE-502	RADIATION INTERACTION AND DETECTION	2
NE-503	APPLIED MATHEMATICS-I	3
NE-504	RADIATION MEASUREMENT LABORATORY	3
NE-505	NUCLEAR REACTOR ANALYSIS	4
NE-506	NUCLEAR HEAT TRANSPORT	4
NE-507	RADIOLOGICAL ENGINEERING	5
NE-508	NUCLEAR REACTOR MATERIALS & RADIATION DAMAGE	5
NE-509	SPECIAL TOPICS IN NUCLEAR ENGINEERING-I	6
NE-510	NUCLEAR POWER PLANT SYSTEMS	6
NE-511	NUMERICAL METHODS IN ENGINEERING	7
NE-512	FLUID DYNAMICS	7
NE-513	NUCLEAR CHEMICAL ENGINEERING	8
NE-514	MATERIALS SCIENCE	8
NE-515	MATERIALS ENGINEERING	9
NE-516	MECHANICAL BEHAVIOR OF MATERIALS-I	9
NE-517	FEEDBACK CONTROL SYSTEMS	10
NE-518	APPLIED ELECTRONICS	10
NE-519	PRINCIPLES OF PLASMA PHYSICS	11
NE-520	OPTICS AND LASER FUNDAMENTALS	11
NE-521	VACUUM TECHNOLOGY	12
NE-522	THE FINITE ELEMENT METHOD	12
NE-523	SPECIAL TOPICS IN NUCLEAR ENGINEERING-II	13
NE-524	STRUCTURAL MECHANICS	13
NE-525	CHEMICAL PROCESS DESIGN	14
NE-526	RADIOISOTOPE APPLICATIONS	14
NE-527	ENVIRONMENTAL ENGINEERING	15

NE-528 NUCLEAR PROLIFERATION AND SAFEGUARDS 15
NE-529 PROJECT MANAGEMENT 16
NE-530 SOLID STATE NUCLEAR TRACK DETECTORS 16
NE-531 GEOLOGICAL ASPECTS OF NUCLEAR MATERIALS 17
NE-532 SEISMIC ASPECTS IN NUCLEAR POWER PLANT SITING 17
NE-533 VACUUM TECHNOLOGY LABORATORY 18
NE-581 NUCLEAR SECURITY 19
NE-582 PHYSICAL PROTECTION SYSTEMS 20
NE-601 NUCLEAR ENGINEERING LABORATORY 21
NE-602 REACTOR THERMAL-HYDRAULICS 21
NE-603 NUCLEAR REACTOR STATICS 22
NE-604 NUCLEAR FUEL MANAGEMENT 22
NE-605 RADIATION SHIELDING 23
NE-606 APPLIED MATHEMATICS-II 24
NE-607 NUCLEAR REACTOR DYNAMICS 24
NE-608 NEUTRON TRANSPORT THEORY 25
NE-609 NUCLEAR REACTOR SAFETY 25
NE-610 RELIABILITY AND RISK ANALYSIS 26
NE-611 NUCLEAR REACTOR DESIGN 26
NE-612 BOILING HEAT TRANSFER AND TWO PHASE FLOW 27
NE-613 COMPUTATIONAL FLUID DYNAMICS 27
NE-614 RADIOACTIVE WASTE MANAGEMENT 28
NE-615 NUCLEAR CHEMICAL PLANT DESIGN 28
NE-616 NUCLEAR REACTOR MATERIALS 29
NE-617 DEGRADATION AND FAILURE OF MATERIALS 29
NE-618 MECHANICAL BEHAVIOR OF MATERIALS 30
NE-619 VACUUM METALLURGY 31
NE-620 CRYOGENIC AND VACUUM SYSTEM DESIGN 31
NE-621 THE BOUNDARY ELEMENT METHOD 32
NE-622 LASER PHYSICS 32

NE-623 LASER SYSTEM TECHNOLOGY AND APPLICATIONS 33

NE-624 THERMONUCLEAR ENGINEERING 33

NE–625 REACTOR CONTROL AND INSTRUMENTATION 34

NE-626 OPTIMAL CONTROL ENGINEERING 34

NE-627 COMPUTER SYSTEM MANAGEMENT 35

NE-628 SPECIAL TOPICS IN NUCLEAR ENGINEERING-III 35

NE-629 REACTOR OPERATION AND EXPERIMENTS 36

NE-630 CONTROL AND SIMULATION LABORATORY 36

NE-631 RADIATION PHYSICS LABORATORY 37

NE-632 ENGINEERING AND MATERIALS LABORATORY 38

NE-697 MS THESIS RESEARCH 40

Course Contents

NE-402 INTRODUCTORY NUCLEAR PHYSICS

Compulsory	
Credits	2
Perquisite	Nil
Course Format	Two hours of lectures per week

Structure of the nucleus; Nuclear masses and binding energies; Nuclear forces; Nuclear models; Radioactivity and the laws of radioactive Transformations; Spectra, energetic, systematic and elementary theory of alpha, beta and gamma decay. Nuclear reactions; Q-value equation and its solution; Neutron induced reactions; Cross-sections and reaction rates; The nuclear fission reaction; Energetic of fission, Fission products; Prompt and delayed neutrons in fission; Theory of the fission process; Nuclear fusion.

References:

Krane, KS, Introductory Nuclear Physics, John Wiley, 1988.

Cottingham, W.N. and D.A Greenwood, An Introduction to Nuclear Physics, Cambridge University Press, 1986.

Cohen, B.L., Concepts of Nuclear Physics, McGraw-Hill, 1971.

Kaplan, L, Nuclear Physics, Addison-Wesley 1975.

NE-403 THERMAL ENGINEERING PRINCIPLES

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Derivation of energy equation; Application to heat transfer problems involving conduction, forced and free convection; Radiation heat transfer; Differential relation for a fluid particle; Boundary layer flows; Inviscid incompressible flows; Pumps; Dimensional Analysis; Introduction to Mass Transfer

References:

Holman, J.P., Heat Transfer, McGraw Hill, 1988.

Bird, R. B, Stewart, W. E, and Lightfoot, E. N, Transport Phenomenon, 2nd Ed., John Wiley, 2002

NE-501 FUNDAMENTALS OF NUCLEAR ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Role and importance of nuclear energy; Nuclear cross-sections. Reaction rates; Nuclear fission and chain reaction; Criticality conditions; Conversion and breeding, Reactor components and their characteristics; Classification and design features of research, production, and power reactors, Introduction to fast and fusion reactor systems; Different types of fuel cycles; Core and feed-material preparations; Uranium enrichment; Fabrication of fuel; Reprocessing of irradiated fuel; Process waste disposal. Reactor fuel requirements; Burnup studies of nuclear fuels; Fuel cycle performance of commercially available reactors; In-core fuel management and fuel management strategies.

References:

Lamarsh, J.R, Introduction to Nuclear Engineering, Addison-Wesley. 1983.

Glasstone, S. and A. Sesonske, Nuclear Reactor Engineering, D Van Nostrand. 1981.

Rahman, I.U. and P.S. Sheikh, Introduction to Nuclear Engineering, Krieger, 1981.

Graves, H.W., Jr., Nuclear Fuel Management, John Wiley, 1979

NE-502 RADIATION INTERACTION AND DETECTION

Compulsory	
Credits	4
Perquisite	Nil
Course Format	Four hours of lectures per week

Radiation sources; Interaction of radiation with matter, Basic principles of radiation detection; Design aspects of ionization chambers, Proportional and Geiger-Muller counters: Various types of scintillators; Scintillation detectors; Radiation spectroscopy using Scintillation detectors: Semiconductors; Various types of semiconductor detectors and their characteristics. Neutron sources; Neutron detection techniques and neutron spectroscopy. Basic electronic circuits and electronic equipment used in nuclear radiation detection systems; Measure of central tendency and dispersion; Concepts of sample space, events, random variables and probability; Probability distributions (discrete & continuous); Curve fitting and tests for goodness of fit; Errors and their propagation; Counting statistics.

References:

Knoll, G.F., Radiation Detection and Measurement, John Wiley, 1989.

Price, W J, Nuclear Radiation Detection, McGraw-Hill, 1964.

NE-503 APPLIED MATHEMATICS-I

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Double & Triple Integrals and Vector Calculus; Coordinate system transformation. Power series solution, Special functions; Bessel functions; Legendre polynomials; Laplace and inverse transforms, Solution of linear differential equations by the Laplace transform method.; Introduction to PDE's; Partial Derivatives and maxima & minima of multivariable functions.

References:

Kreyszig, E. Advanced Engineering Mathematics, John Wiley, 1988.

Kaplan, W., Advanced Calculus, Addison-Wesley, 1970.

Millar, K.S., Partial Differential Equations in Engineering Problems, Prentice-Hall, 1953.

NE-504 RADIATION MEASUREMENT LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of eight experiments must be performed from those listed below:

Calibration and use of health physics instruments including DRD, radguns, TLDs and neutron survey meter; Contamination survey and decontamination procedures. Verification of inverse square law and source strength measurements; Characteristics of a G.M. counter, dead time measurements, attenuation coefficient for beta particles and counting statistics. Characteristics of a NaI (TI) scintillation detector and pulse height spectrum of gamma sources; Characteristics of a surface barrier detector, alpha particle and fission fragment spectroscopy; Setting up of Ge (Li) or HPGe detector as a gamma ray spectrometer and X-ray fluorescence; Characteristics of a BF3 or He-3 detector and its use in measurement of albedo; Determination of attenuation coefficients and build-up factors of gamma rays in different materials. Measurement of half-lives; Determination of source strength using gamma-gamma or beta-gamma coincidence method; Study of the characteristics of an operational amplifier; Solution of linear differential equations and study of radioactive decay chain using an analogue computer.

References:

Nasir Ahmad, Experimental Radiation Detection, CNS-20, 1988.

Knoll, G.F., Radiation Detection and Measurements, John Wiley, 1989.

Price, W.J., Nuclear Radiation Detection, McGraw-Hill, 1964.

NE-505 NUCLEAR REACTOR ANALYSIS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Neutron slowing-down; Thermal neutron spectra; Neutron diffusion in non-multiplying media; The one-speed diffusion model of a nuclear reactor, Criticality calculations for bare and reflected homogeneous systems; Effects of heterogeneity reactor parameters; The multigroup diffusion method; Numerical solution of multigroup diffusion model; Use of computational codes for criticality calculation; The point reactor kinetics model; Temperature and void coefficient of reactivity, Fuel depletion; Fission product poisoning, Control rods; Introduction to neutron transport equation.

References:

Duderstadt, J.J. and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976.

Lamarsh, J.R, Introduction to Nuclear Reactor Theory, Addison-Wesley, 1966.

Ott, K.O. and W.A. Bazella, Introductory Nuclear Reactor Statics, American Nuclear Society, 1983.

Lamarsh, J.R, Introduction to Nuclear Engineering, Addison-Wesley, 1983.

NE-506 NUCLEAR HEAT TRANSPORT

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Thermodynamics of nuclear power plant; Reactor heat generation; Radial and axial temperature distribution in fuel elements; Temperature distribution in restructured fuel elements; Heat generation and conduction in thermal shields and fins; Numerical methods; Fluid flow and heat transfer in single phase coolants;; Introduction to two phase flow; Two phase flow models; Calculation of two phase pressure drop; critical flow phenomenon; Boiling heat transfer; Critical heat flux and core thermal design.

References:

Todreas, N.E. and M.S. Kazimi, Nuclear Systems Volt I, Hemisphere, 1990.

El-Wail, M.M., Nuclear Heat Transport, International Textbook, 1971

Rust, J.H., Nuclear Power Plant Engineering, Haralson, 1979.

NE-507 RADIOLOGICAL ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Radiation units; Natural and man-made radiation sources; Elementary biology and biological effects of radiation Standards of radiation protection; Calculation of exposure and dose. Attenuation coefficients and build-up factors gamma-rays; Shielding of sources with different geometrical shapes; Shields with internal sources; Multilayered Concept of removal cross-sections; Removal-attenuation and removal diffusion calculations; Principles of shielding. Safety features of nuclear power plants; Reactor sitting; Dispersion of effluents from nuclear facilities; Radiation doses from nuclear plants; Reactor accident risk analysis.

References:

Lamarsh, J.R, Introduction to Nuclear Engineering, Addison-Wesley, 1983.

Morgan, KZ. and J.E. Turner (eds.), Principles of Radiation Protection, Krieger, 1973.

Shapiro, J., Radiation Protection, Harvard University Press, 1981.

Jaeger, RG. Engineering Compendium on Radiation Shielding, Springer-Vela, 1970.

WASH-1400, Reactor Safety Study, USNRC, 1975.

NE-508 NUCLEAR REACTOR MATERIALS & RADIATION DAMAGE

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Atomic structure of materials, Diffusion in solids, Mechanical properties of materials, Phase diagrams (basic types and eutectoid reaction in plain-carbon steels) and strengthening of materials, Fabrication; casting, forming and welding, Failure of materials (fatigue, creep and corrosion), Introduction and application of non-destructive testing methods; Nuclear radiation effects, Fundamental radiation damage, Irradiation swelling. Reactor component materials, Reactor fuel; Uranium, its properties, Irradiation effects on Uranium, UO2 properties, its fabrication and swelling problem; Other fuels like Plutonium, Thorium; Structural metals; Zirconium properties and irradiation effects, Stainless steels, their properties and irradiation effects. Moderator, Coolant & Control materials, their material properties and irradiation effects. Reactor pressure vessel, steam generator, pressurizer, turbine, generators & piping, their material properties and irradiation effects. Irradiation damage control.

References:

Smith, W.F., Structure and Properties of Engineering Alloys, McGraw-Hill, 1981

Ma, B.M., Nuclear Reactor Materials and Applications, Van Nostrand, 1983.

Olander, D.R., Fundamental Aspects of Nuclear Reactor Fuel, US Dept. of Energy, 1976.

Barrett, C.R, W.D.Nix, and A.S.Tetelman, The Principles of Engineering Materials, Prentice-Hall, 1973

Shackelford, J.F., Introduction to Materials Science for Engineers, Macmillan, 1992

Van Vlack, L.H., Elements of Materials Science and Engineering, Addison-Wesely, 1985

Roberts, J.T.A., Structural Materials in Nuclear Power Systems, Plenum, 1981

NE-509 SPECIAL TOPICS IN NUCLEAR ENGINEERING-I

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

This is a course on advanced topics not already included in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The topic and contents of the course must be approved by the Board of faculty.

NE-510 NUCLEAR POWER PLANT SYSTEMS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Layout of nuclear power plants; Containment buildings; Primary containment vessels; Structure of reactor core; and mechanical stress in various structures. Description and analysis of power plant systems and components including steam generator, steam dryer and separator, pressurizer, reheater, heat exchanger, condenser, demineralizer, pumps ,turbine, generator, cooling tower; Auxiliary cooling systems. Fuel handling mechanisms; Control and mechanisms; Radwaste systems; Electrical Systems; Reactor grid interface and load following. Basic considerations in nuclear plant design; Components of nuclear power cost; Economic comparison of nuclear and fossil fueled plants; Dual and multipurpose nuclear plants; Future trends in nuclear power cost.

References:

Rust, J. H., Nuclear Power Plant Engineering, Haralson, 1979.

El-Wakil, M.M., Nuclear Energy Conversion, International Text Book, 1982

Pedersen, E.S., Nuclear Power, Ann Arbor Science, 1978.

El-Wakil, M.M., Power Plant Technology, McGraw-Hill, 1984.

Lish, K.C., Nuclear Power Plant Systems & Equipment, Industrial Press Inc., 1972.

NE-511 NUMERICAL METHODS IN ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Lagrange interpolation; Cubic Spline interpolation; Solution of systems of linear and non-linear algebraic equations: Gaussian quadrature; eigenvalues, eigenvectors: solution of ODE's, higher order differential equations and systems of first order ODE's: Partial differential equations: Software Package applications.

References:

Faires, J.D. and RL Burden, Numerical Methods, Prindle, Weber and Schmidt, 1993.

Burden, RL, et.al., Numerical Analysis, Prindle, Weber and Schmidt, 1993.

Brebbia, C.A. and AJ. Ferrante, Computational Methods for the Solution of Engineering Problems, Pentech, 1986.

NE-512 FLUID DYNAMICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Fluid properties and definitions; Fluid flow concepts and basic equations; Bernoulli equation and its applications; Navier Stokes equations; Similitude and dimensional analysis, Laminar and turbulent flow, Boundary layer theory, Pressure and flow measurements; Analysis of steady closed-conduit flows.

References:

Sabersky, RH, A J.Acosta and E.G.Hauptmann, Fluid Flow, Macmillan, 1971.

Schlichting, H, Boundary Layer Theory, McGraw-Hill, 1979.

Streeter, V.L. and E.B.Wylie, Fluid Mechanics, McGraw-Hill, 1975.

NE-513 NUCLEAR CHEMICAL ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Chemical engineering and nuclear power-industry, Decay chains; Growth and decay of fission products in and out of reactor, Build-up of heavy actinides. Nuclear fuel cycles; Feed requirements; Burn-up and reactivity changes for mix and unmixed fuel; Plutonium recycle. Nuclear fuel reprocessing; Solvent extraction; McCabe-Thiele diagrammatic solution of problems in separation processes; Equipment for reactor materials processing; Hafnium and zirconium; Important isotopes, their uses and methods of separation; General cascade theory; Ideal, close-separation and squared-off cascades; Separative duty and separation potential; Enrichment costs; Heavy water production, its analysis and process optimization; Uranium enrichment process, its analysis and optimization.

References:

Benedict. M., T.H. Pigford, and H.W. Levi, Nuclear Chemical Engineering, McGraw-Hill, 1981.

Pratt, H.RC., Countercurrent Separation Processes, Elsevier, 1967.

Flagg, J.F. (ed.), Chemical Processing of Reactor Fuels, Acadenuc, 1961.

London, H., Separation of Isotopes, Newnes, London, 1963.

Villani, S., Isotope Separation, American Nuclear Society, 1976.

Becker, E.W., Production of Heavy Water, IAEA, Vienna, 1961.

Low Temperature Heavy Water Plant, USAEC report, NYO-889, 1951.

NE-514 MATERIALS SCIENCE

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Electronic structures of atoms; Interatomic bonding and coordination; Crystalline and amorphous solids; Crystal systems; Crystallographic notations; Point defects; Line defects; Planar defects; First law of thermodynamics; Second law of thermodynamics; Free energy and equilibrium; Phases and mixtures; Phase transformations in one component system; Phase transformations in multi component systems; Liquid-solid transformations; Solid-solid transformations; Elasticity and plasticity; Tensile test and important mechanical properties; Plastic deformation by dislocations; Structural materials; Conducting materials; Magnetic, dielectric and optical materials; Composites.

References:

Barrett, C.R, W.D. Nix, and A.S. Tetelman, The Principles of Engineering Materials, Prentice-Hall, 1973.

Shackelford, J.F., Introduction to Materials Science for Engineers, Macmillan, 1992.

Van Vlack, L.H., Elements of Materials Science and Engineering, Addison-Wesley, 1985.

Avner, S.H., Introduction to Physical Metallurgy, McGraw-Hill, 1974.

Guy, A G., Introduction to Materials Science, McGraw-Hill, 1972.

NE-515 MATERIALS ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Thermodynamics and kinetics; Blast furnace smelting of iron; Bessemer converter processes; Open hearth process; Electric furnace steel-making; Oxygen steel-making; Oxidation refining; Zone refining; Advanced techniques of rector grade steel-making; Hydrometallurgy of uranium and nickel; Metal casting; Cold and hot metal forming; Rolling of rods and slabs; Forging; Extrusion; Welding techniques and associated heat treatments; Powder production; Powder compaction and sintering; Pellet production; Hardening heat treatment of steel and hardenability; Techniques of grain refinement and precipitation hardening; Defects induced by various manufacturing techniques; Non-destructive testing

References:

Phelke, RD., Unit Processes of Extractive Metallurgy, Elseveir, 1984.

Dieter, G.E., Mechanical Metallurgy, McGraw-Hill, 1986.

Heine, RW., C.R Loper, P.C. Rosenthal, Principals of Metal Casting, McGraw-Hill, 1967.

Warr4 J.RW., Concise Chemical Thermodynamics, Van Nostrand, 1969.

Gaskell, D.R, Introduction to Metallurgical Thermodynamics, McGratv-Hill Kogakusha, 1973.

Hull, J.B. and V.B. John, Non-Destructive Testing, Macmillan Education, 1988.

NE-516 MECHANICAL BEHAVIOR OF MATERIALS-I

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Engineering stresses and strains; True stresses and strains; Methods of obtaining stress-strain curves; Procedures performing tension, compression, and hardness experiments; Types and design of test specimens used in tension; compression experiments; Stress concentration factor, Failure theories; Definition of homologous temperature and importance in engineering, Creep and relaxation; Monotonic stress-strain behavior of materials; Cyclic stress-strain behavior of materials; Methods of obtaining

stress-strain hysteresis loops; Cyclic strain hardening and softening; Coffin Manson law; Fatigue and its importance in design and damage analysis; Low cycle fatigue; High cycle fatigue; Effect different types of wave Shapes, environment, temperature, etc. on fatigue; Introduction to fracture mechanics; Modes of fracture; Stress intensity factor.

References:

Bannantine, J.A., J.J. Comer, and J.L. Handrock Fundamentals of Metal Fatigue Analysis, Prentice-Hall, 1990.

Broek D., Elementary Engineering Fracture Mechanics, 4th Ed., Martinus Nijhoff, 1986.

Shigley, J.E., and L.D. Mitchell, Mechanical Engincering Design, McGraw-Hill, 1983.

Eisenberg, M.A., Introduction to the Mechanics of Solids, Addison-Wesley, 1980.

NE-517 FEEDBACK CONTROL SYSTEMS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Transfer functions, block diagrams, and signal-flow graphs; Mathematical modeling of physical systems; State-variable analysis of linear dynamic systems; Stability of linear control systems; Time-domain analysis of control systems; Root-locus technique; Frequency-domain analysis of control systems; Time-domain design of control systems; Frequency domain design of control systems.

References:

Kuo, B.C., Automatic Control Systems, Prentice-Hall, 1991.

Ogata, K, Modern Control Engineering, 2nd Ed., Prentice-Hall, 1990.

Doyle, J.C., B.A. Francis, and A R Tannenbaum, Feedback Control Theory, Macmillan, 1992.

NE-518 APPLIED ELECTRONICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Discrete electronic components; Linear integrated circuits; Digital integrated circuits and applications; Basic pulse circuits; Counting and storage circuits; Amplifier types and specifications; Pulse height and

shape discriminators; Timing circuits; Cables and accessories; Microprocessors; Data acquisition methods; Data conversion and transmission; Optic displays; Data acquisition modules: NIM, VME, Fast Bus, and CAMAC.

References:

Nicholson; P.W., Nuclear Electronics, John Wiley, 1974.

Delaney, C.F.G., Electronics for the Physicist, Ellis Harwood, 1980.

Knoll, GF., Radiation Detection and Measurement, John Wiley, 1989.

Malvino, AP., Electronic Principles, McGraw-Hill, 1984.

NE-519 PRINCIPLES OF PLASMA PHYSICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Fundamental concepts of plasma physics; Occurrence and generation of plasmas with applications to thermonuclear fusion, gas lasers, and astrophysics; Electromagnetic theory and plasma behavior, plasma fluid model; MHD approximation; Kinetic theory; Wave propagation in cold and warm plasmas; Landau damping; Simple equilibrium and stability analysis; Explosion, implosion.

References:

Chen, F.F., Introduction to Plasma Physics and Controlled Fusion, Plenum, 1984.

Stacey, W. M., Jr., Fusion Plasma Analysis, John Wiley, 1981.

Kettani, M. A., and M.F. Hoyaux, Plasma Engineering, Butterworth and Co., 1973.

Linhart, J.G., Plasma Physics, Euratom 1969.

Schmidt, G., Physics of High Temperature Plasmas, Academic, 1979.

Krall, N.A. and A.W. Trivelpiece, Principles of Plasma Physics, McGraw-Hill, 1973.

NE-520 OPTICS AND LASER FUNDAMENTALS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Light sources and their characteristics; Optical materials; Geometrical optics; Maxwell's equations; The wave equation and boundary conditions; Wave properties; Optical instruments; Non-linear optics; Crystal

physics; Electro-optic effect, processes, materials, techniques and applications; Light transmission optics; Fiber transmission.

Introduction to lasers; Parts of a laser system; Types of lasers; Stimulated emission; Spontaneous emission; Pumping types and applications; Pumping threshold; Output power, Introduction to resonators; Longitudinal/Transverse modes and mode selection; Laser amplifiers.

References:

Jenkins, A. & H.E. White, Fundamentals of Optics, McGraw-Hill, 1976.

Lengyel, B. A., Lasers, John Wiley, 1971.

Verdyen, J. T., Laser Electronics, Prentice-Hall, 1981

Siegman, A.E., lntroduction to Lasers and Masers, McGraw-Hill, 1971.

NE-521 VACUUM TECHNOLOGY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Introduction to vacuum; Basic terms, definitions and units; Rarefied gas theory for vacuum technology; Physical state of matter; General gas laws; Motion of molecules in rarefied gases; Pressure and mean free path; Transport phenomenon in viscous state; Transport phenomenon in molecular state; Thermal diffusion and energy transport; Gas flow at low pressure; Physico-chemical phenomena in vacuum techniques. Types and working principles of various vacuum pumps for low, medium, high and ultrahigh vacuum regions; Measurement of pumping speed; Vacuum systems design; Devices for measurement of vacuum; Vacuum seals of various types; Leak detection in vacuum systems by search gas overpressure and vacuum methods, Mass spectrometer and tesla coil; Accessories such as pressure switching units; Traps of various types; Protective devices.

References:

Roth, &, Vacuum Technology, North-Holland 1976.

Van Atta, Vacuum Science and Engineering, McGraw-Hill, 1965.

Harris, N.S., Vacuum Technology, Edwards High Vacuum, Sussex, 1975.

Vacuum Technology, its Foundation, Formula & Tables, Leybold Heraeus, 1970.

NE-522 THE FINITE ELEMENT METHOD

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Basic concepts and general applicability of the finite element method; Solution of FEM equations; General procedure of FEM; Direct, variational and weighted residual approaches; Detailed study of two and three dimensional finite elements; Higher order and isoparametric element formulations; Numerical integration and its use for FEM; Engineering applications of FEM

References:

Rao, S.S., The Finite Element Method in Engineering, Pergamon, 1980

Heubner, KH, The Finite Element Method for Engineers, Wiley-Interscience, 1975

NE-523 SPECIAL TOPICS IN NUCLEAR ENGINEERING-II

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

This is a course on advanced topics not already included in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The topic and contents of the course must be approved by the Board of faculty.

NE-524 STRUCTURAL MECHANICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Basic concepts of mechanical structures and strength of materials; Stress at a point; Stress equations of equilibrium; Laws of stress transformations; Principal stresses and strains; Compatibility; field equations; Airy's stress function in Cartesian and polar coordinates; Stress analysis of different mechanical structures; Thermal stresses; Introduction to plastic problems and simple case studies.

References:

Dally, J.W., and W.F. Riley, Experimental Stress Analysis, McGraw-Hill, 1978.

Gill, S.S., The Stress Analysis of Pressure Vessels and Pressure Vessel Components, Pergamon, 1970.

Hasselman, D.P.H., and RA. Heller (eds.), Thermal Stresses in Severe Environments, Plenum, 1980.

NE-525 CHEMICAL PROCESS DESIGN

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Design of absorption & distillation columns, cooling towers, knockout drums, heat exchangers and liquid extract columns; Study of water treatment plants with particular emphasis on ion exchange columns and reverse osmosis process; applications Industrial applications of compressors and pumps including design calculations; Study of process flow, piping instrumentation and layout diagrams; Brief study of process control.

References:

Chopey N.P. and T.G. Hicks (eds.), Handbook of Chemical Engineering Calculations, McGraw-Hill, 1984.

Ludwig, E.E., Applied Process Design for Chemical and Petrochemical Plants, Gulf Publishing Co., 1983.

McKetta, Encyclopedia of Chemical Process and Design

NE-526 RADIOISOTOPE APPLICATIONS

Compulsory	
Credits	3
Perquisite	NE-605
Course Format	Three hours of lectures per week

Introduction and historical perspective; Neutron activation engineering and its applications in various fields; Design and construction of radioisotope power sources; Radio gauging and ionization applications; Radioactive tracer techniques; Radiography and other isotopes for irradiators; Applications of large radiation sources; Analysis of economics of gamma irradiation systems.

References:

Eichholz, G.G. (ed): Radioisotope Engineering, Marcel Dekker Co., 1972.

Ely, RL. and RP. Gardner: Nuclear Measurement Methods in Engineering.

Kehl, J., Zentuer, D. and R.R. Lukens: Radioisotopes Applications in Engineering, Van Nostrand

Domanus, J.C.: Practical Neutron Radiography; Kluwer Academic, 1992.

NE-527 ENVIRONMENTAL ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Environmental systems; Dynamics of environmental cycles; The human-environment interaction; Pollution from natural sources and from human activities; Radioactive effluents from nuclear power plants and other related nuclear industries; Effects of pollutants. Dispersion of pollutants released to the atmosphere, water bodies and soil; Reconcentration of pollutants in the food chain and critical pathways to man; Sampling and monitoring of pollutants in various matrices Methods of pollution control; Economics of pollution control; Risk-benefit analysis of environmental hazards; Regulations governing pollution emission; Preparation of environmental impact statements; Social aspects of environmental hazards.

References:

Masters, G.M.: Introduction to Environmental Science and Technology, John Wiley, 1974.

Eichholz, G.G.: Environmental Aspects of Nuclear Power, Ann Arbor Science, Inc., 1976.

Strauss, W.: Air Pollution Control, Part I and II, Wiley-Interscience, 1971 & 1972.

Eisenbud, M.: Environmental Radioactivity, Academic, 1973.

Williamson, S.J.: Fundamentals of Air Pollution, Addison-Wesley, 1973.

Inhaber, H.: Energy Risk Assessment, Gordon &Breach Science Pub., 1982.

NE-528 NUCLEAR PROLIFERATION AND SAFEGUARDS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Nuclear power and associated industry; Nuclear power and status of some developed and developing countries; Types of nuclear weapons and their effects; Nuclear weapons proliferation; Nuclear strategic doctrines; Global security and nuclear proliferation; Nuclear arms control and disarmament; Nuclear terrorism; Transfer of nuclear technology and role of exporting countries; IAEA and nuclear safeguards.

References:

Fry, M.P., P. Keatinge and J. Rotblat (Eds.): Nuclear Nonproliferation and the Nonproliferation Treaty, Springer-Verlag, 1990.

SIPRI: World Armaments and Disarmament, Oxford University Press,1993.

Singh, N. and E.Mc Whinney: Nuclear Weapons and Contemporary International Law, Martinus Nijhoff, 1989.

Leventhal, P. and Y. Alexander (Eds.): Preventing Nuclear Terrorism, Lexington Books, 1987.

Glasstone, S. and P.J. Dolan: The Effects of Nuclear Weapons, US DOP and AEC, 1977.

London, J. and G.F. White: The Environmental Effects of Nuclear War, Westview Press, 1984.

NE-529 PROJECT MANAGEMENT

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

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 cycle; Siting and environmental considerations; Regulatory control and licensing; Safety analysis reports; Regulatory bodies; Public information.

Types of contracts; Contract administration and tendering; Technical bid evaluation and award of contracts; Project implementation; Network analysis; Quality assurance, quality control and quality surveillance; Plant acceptance testing; Staffing for plant operation and maintenance.

References:

Khan, A.Q.: Project Management, CNS, 1993.

Pederson, E.S.: Nuclear Power, Volume 2, Ann Arbor, 1978.

Hajek, V.G.: Management of Engineering Projects, McGraw-Hill, 1984.

Baumgartener, J.S.: Project Management, R.D.Irwin,1963

NE-530 SOLID STATE NUCLEAR TRACK DETECTORS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Introduction to nuclear track detectors; Interaction of charged particles with matter, Track formation mechanisms; Radiation damage in solids; Track forming particles; Track formation models; Bulk, track and electrochemical etching, Track etching recipes and geometry, Thermal fading of latent damage trails; Use of track detectors in particle identification; Neutron and radon dosimetry with track detectors; Methods of track image enhancement; Spark counters; Electrical breakdown devices; Scintillator-filled etch pit counting; Automatic and semi-automatic image-analysis systems; Fission track dating.

References:

Durrani, S.A and RK Bull, Solid State Nuclear Track Detection Principles, Methods and Applications, Pergamon, 1987.

Fleischer, RL., et al., Nuclear Tracks in Solids, University of California Press, 1975.

Proceedings of the 13th International Conference on SSNTD, Rome, Italy, 1986.

Etched Track Neutron Dosimetry, Proceedings of a Workshop held at Harwell (U.K). Radiation Protection Dosimetry, Vol. 20 Nos. 1-2. 1987.

NE-531 GEOLOGICAL ASPECTS OF NUCLEAR MATERIALS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Mineralogy of nuclear materials including uranium, thorium, zirconium, beryllium, alum inurn, rare earths, lithium, titanium, niobium and tantalum; Geo-chemical distribution of nuclear minerals in natural environments; Geologic occurrences of commercial deposits in the world and in Pakistan; Concepts of geological and geochemical processes responsible for the formation of nuclear minerals deposits Geological principles for search of nuclear minerals; Radiometric, geophysical, geochemical and drilling techniques for exploration of nuclear minerals deposits; Mining geology; Economic evaluation of ore reserves; Mining methods for commercial exploitation of nuclear mineral deposits; Development of prospect and planning for exploitation of mineral sources; Radiation safety aspects of mining and environment.

References:

Gilluly, Principles of Geology, Toppan Co., Ltd., Tokyo.

Durrance, E.M., Radioactivity in Geology, Principles and Applications, Ellis Harwood, 1987.

Heinrich, E.W., Mineralogy and Geology of Radioactive Raw Materials, McGraw-Hill, 1958.

Beus, A.A., Geochemistry of Beryllium and Genetic types of Beryllium Deposits, W.H. Freeman & Co., 1966.

Boyle, R.W., Geochemical Prospecting for Uranium and Thorium Deposits, Elsevier, 1982.

NE-532 SEISMIC ASPECTS IN NUCLEAR POWER PLANT SITING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Earth, earthquakes and review of basic concepts; Seismic source mechanism; Elementary seismic waves; Seismic wave velocity and other source parameters and their determination; Seismic instrumentation; Analysis of instrumental seismic data. Geologic/seismic criteria for siting nuclear power plants; Identification of the seismotectonic structures and provinces; Estimating the maximum earthquake. Near field acceleration and source modeling; Deterministic and probabilistic methods for evaluating design basis ground motion; Techniques for estimating strong ground motion. Recorded strong ground motion; Peak ground acceleration, velocity and displacement; Duration of shaking and spectral characteristics; Local effects; Soil conditions; Attenuation; Estimating of Response; Spectra from recorded peak ground acceleration.

References:

Hensen RJ. (ed.), Seismic Design for Nuclear Power Plants. MIT Press,1970.

Bullen K.E. & B.A. Bolt, An Introduction to Seismology, Cambridge University Press, 1985.

Lomnitz C. and E. Rosenblueth (eds.), Seismic Risk and Engineering Decisions, Elsevier, 1976.

IAEA, Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting, Safety Series No.50-SG-Sl (Rev. 1), 1991.

IAEA, Seismic Design and Qualification for Nuclear Power Plants, Safety Series No.50-SG-D15, 1992.

IAEA, Safety Aspects of Foundations of Nuclear Power Plants, Safety Series No.50-SG-S8? 1982.

USNRC (1988), Seismic and Geologic Siting Criteria for Nuclear Power Plants, 10 CFR part 100, Appendix A, Federal Register, Vol. 38 No. 31282.

NE-533 VACUUM TECHNOLOGY LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of six experiments will be performed from the following list:

The examination of an oil-sealed mechanical rotary pump; Measurement of pumping speed and the effect of connecting times.

Examination of an oil-vapour diffusion pump, Measurement of different gases and measurement of effective pump speed in the system due to component conductance.

Examination of differences between real and virtual leaks and the use of thermal conductivity gauge as a leak detector and over pressure leak detection technique.

Comparison of the U-tube with capsule dial and McLeod gauges, Comparison of Pirani and McLeod gauges, Comparison of hot cathode and cold cathode ionization gauges.

Study of the crystal structure using X-ray diffraction techniques.

Out gassing characteristics of various material under vacuum.

The calibration of vacuum gauges.

Partial pressure gas analysis.

Production and monitoring of thin films.

Electron Microscope specimen preparation by various techniques.

Study of freeze drying process.

References:

Roth, A., Vacuum Technology, North-Holland, 1976.

Van Atta, Vacuum Science and Engineering, McGraw-Hill, 1965.

NE-581 Nuclear Security

Optional	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Introduction to nuclear safety and security; National infrastructure for nuclear security; Knowledge of national/international nuclear laws; International conventions & treaties on nuclear safeguards; Introduction to International Atomic Energy Agency (IAEA)'s safeguards system: types, requirements, implementation, verification and evaluation; Categorization, applications, vulnerability, security of radioactive materials and facilities; Basics of nuclear materials accounting and control; Overview of an export control system; National/International control lists; Introduction to international nuclear security initiatives; Introduction to border monitoring systems, types, assessment, localization and identification, verification of alarms; Illicit trafficking of nuclear materials; Causes of nuclear terrorism; Nuclear security emergency: types, preparedness and response to radiological emergency and emergency monitoring, Introductory principles of nuclear forensics; Mobile Emergency Support Team (MEST); Functions of nuclear security emergency coordination centre. Class demonstration of nuclear security equipment is also included.

References:

James E. Doyle (editor), Nuclear Safeguards, Security and Nonproliferation, Butterworth-Heinemann, New York, 2008.

Sarah J. Diehland, and James Clay Moltz, Nuclear Weapons and Nonproliferation: A Reference Handbook, ABC CLIO Publishers, Oxford, England, 2002.

Randall Forsberg, William Driscoll, Gregory Webb , and Jonathan Dean, Nonproliferation Primer: Preventing the Spread of Nuclear, Chemical, and Biological Weapons, The MIT Press, Cambridge, London, 1995.

International Atomic Energy Agency, Code of Conduct on the Safety and Security of Radioactive Sources, IAEA/CODEOC/2001, IAEA, Vienna, 2001.

International Atomic Energy Agency, Guidance on Import and Export of Radioactive Sources, IAEA/CODEOC/IMP-EXP/2005, IAEA, Vienna 2005.

International Atomic Energy Agency, Handbook on Nuclear law, IAEA, Vienna, 2003.

International Atomic Energy Agency, IAEA Nuclear Security Series No. 1 to 11, IAEA, Vienna, 2009.

PNRA, Regulations on Licensing of Nuclear Installations, PAK/909, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, October, 2001.

PNRA, Regulations on Radiation Protection, PAK/904, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, October 2004.

PNRA, Regulations on Safety of Nuclear Power Plants/Operations, PAK/913, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, December 2004.

NE-582 Physical Protection Systems

Optional	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Introduction to objectives of Physical Protection System; Categorization of nuclear materials; Design basis threat (DBT) definition and target identification; Design of a physical protection systems; Intrusion sensors and alarm assessment; Display and communication; Access control system and delay barriers; Response force communication; Vital area identification; Techniques for analysis and evaluation of a physical protection system; Software for analysis and evaluation: EASI Model and SAVI; Adversary Sequence Diagram; Physical protection requirements to protect the nuclear materials and facilities; Idea of security envelop and application of graded approach; Regulatory process and national laws; Development, assessment/evaluation and implementation of a physical protection plan; Quality assurance policy/program for adequate PPS; Enforcement; Grading the levels of violations, prosecution, identification of Non-Compliances, Regulatory Practices. Case studies regarding physical protection systems.

References:

Mary Lynn Garcia, *The Design and Evaluation of Physical Protection Systems*, Butterworth-Heinemann, USA, November 2000.

IAEA, *The Physical Protection of Nuclear Materials and Nuclear Facilities*, INFCIRC/225/rev4, International Atomic Energy Agency, Austria, June 1999.

Mary Lynn Garcia, *Vulnerability of Physical Protection Systems*, Butterworth-Heinemann, USA, November 2006.

Robert L. Benard, *Intrusion Detection Systems*, 2nd Edition, Butterworth-Heinemann, USA, 1998.

IAEA, *Handbook on the Physical Protection of Nuclear Materials and Nuclear Facilities*, IAEA-TECDOC-1276, International Atomic Energy Agency, Austria, March 2002.

PNRA, Regulations on Licensing of Nuclear Installations, PAK/909, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, October, 2001.

PNRA, Regulations on Radiation Protection, PAK/904, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, October 2004.

PNRA, Regulations on Safety of Nuclear Power Plants/Operations, PAK/913, Pakistan Nuclear Regulatory Authority (PNRA), Islamabad, Pakistan, December 2004.

NE-601 NUCLEAR ENGINEERING LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of six experiments must be performed from the following list: '

Study of PARR-1 systems and approach to criticality.

Calibration of control rods in PARR-1&2.

Neutron flux mapping in the thermal column or core of PARR-1

Determination of statistical weights in a reactor core.

Determination of neutron total cross-section by transmission method.

Determination of neutron diffusion parameters.

Determination of attenuation coefficient and build-up factor for single and multilayered shields.

Study of nuclear power plant transients on a PWR simulator.

Experimental study of basic heat transfer and fluid flow phenomena.

Experimental study of two-phase heat transfer.

Study of reactor kinetic equations using an analogue computer.

Digital data acquisition/analysis using logic analyzer and design of digital counters.

Data acquisition using PCs.

References:

Nasir Ahmad and Tahir Mahmood, Experiments in Reactor Physics and Reactor Shielding, CNS-12, 1982.

Profio, A.E., Experimental Reactor Physics, John Wiley, 1976.

Holman, J.P., Experimental Methods for Engineers, McGraw-Hill, 1984.

Kreith, F., Principles of Heat Transfer, Intext Press Inc., 1976.

Dally, J.W. and W. F. Riley, Experimental Stress Analysis, McGraw-Hill, 1978.

NE-602 REACTOR THERMAL-HYDRAULICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Thermodynamic analysis of nuclear power plants: non-flow, steady and unsteady flows; Thermal analysis of fuel elements; Numerical methods of analysis and use of computer codes for analysing steady-state and transient conditions; Thermal design and analysis of heat exchanger, steam generators and condensers.

References:

Todreas, N.E. and M.S. Kazimi, Nuclear Systems Vol. I, Hemisphere, 1990.

El-Wakil, M.M., Nuclear Heat Transport, International Text Book, 1971

Rust, J.H., Nuclear Power Plant Engineering, Haralson, 1979.

NE-603 NUCLEAR REACTOR STATICS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

The neutron transport equation; Introduction to numerical solution methods for the transport equation; The diffusion approximation. The Multigroup diffusion model; Numerical solution of the multigroup diffusion equation; Multigroup perturbation theory. Fast spectrum calculations and fast group constants; Thermal spectrum calculations and thermal group constants; Cell calculations for heterogeneous core lattices; Calculation of core power distribution.

References:

Duderstadt, J.J., and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976.

Henry, AF., Nuclear Reactor Analysis, The M LT. Press, 1975.

Stamm'ler, RJ. and M J. Abbate, Methods of Steady State Reactor Physics in Nuclear Design, Academic, 1983.

Carmignani, B., Reactor Statics Modules, ICTP, 1980.

NE-604 NUCLEAR FUEL MANAGEMENT

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Different types of fuel cycles; Objectives, variables and constraints of fuel management; Selection of fuel reload fraction; Behavior of reactivity variation with fuel management parameters; Fuel and control arrangements in the core loading schemes; Methods of reactivity control; Fuel depletion analysis; Burn-up

studies of nuclear fuels; Fuel cycle economics; Fuel management for CANDU reactors; Various current developments in fuel management.

References:

Graves,-H.W., Jr., Nuclear Fuel Management, John Wiley, 1979.

Duderstadt; J.J, and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976.

Silvennoinen, P., Reactor Core Fuel Management, Pergamon 1976.

Frost, B.RT., Nuclear Fuel Element, Pergamon, 1982.

IAEA, Operational Physics of Power Reactors, ICTP, Trieste, 1982.

ANS proceedings of The Topical Meeting on Advances in Fuel Management, 1986.

NE-605 RADIATION SHIELDING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Isotropic and anisotropic shields for extended radiation sources; Calculational methods used in shielding; Effects of ducts and voids in shields; Streaming and backscattering of radiation; Heat generation by radiation in shields. Materials for shielding and their nuclear, physical, and mechanical properties and technology; Shield design and engineering research and power reactors; Large radiation sources; Transport containers; Reprocessing plants; Waste storage facilities and shielded cells; Experimental facilities for shielding studies.

References:

Chilton, A B., Shultis, J. K. and R E. Faw, Principles of Radiation Shielding, Prentice-Hall, 1984

Schaeffer, N. M. (ed), Reactor Shielding for Nuclear Engineers, Technical Information Center, USAEC, 1973

Goldstein, H., Fundamental Aspects of Reactor Shielding, Pergamon, 1959.

Rockwell, T., Reactor Shielding Design Manual, Springfield National Technical Information Services 1956.

Jaeger, RG. and E.P. Blizard (eds.), Engineering Compendium on Radiation Shielding Vol. 1, 11 and, 111, Springer- Verlag, 1970.

NE-606 APPLIED MATHEMATICS-II

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Complex numbers; Analytic functions; Cauchy-Riemann equations; Cauchy integral formula; Residue theorem; Contour integration; Introduction to the calculus of variations; Euler-Jacobi equations. Orthogonal functions; Fourier series and its convergence; Dirichlet's conditions; Complex Fourier series; Fourier transform theorems; Discrete data systems; Z-transform theorems; Limitation of the Z-transform method; Solution of difference equations by the Z-transform method.

References:

Churchill, RV. and J.W. Brown, Complex Variables and Applications, McGraw-Hill, 1984.

Churchill, RV. and J.W. Brown, Fourier Series and Boundary Value Problems, McGraw-Hill, 1978.

Cadzo, J. A., Discrete Time Systems: An Introduction with Interdisciplinary Applications, Computer Applications in Electrical Engg. Series, 1973.

Jury, E.I., Theory and Application of the Z-Transform Method, Krieger, 1986.

Brace well, Ron, The Fourier Transform and its Applications, McGraw-Hill, 1978.

NE-607 NUCLEAR REACTOR DYNAMICS

Compulsory	
Credits	3
Perquisite	NE-603
Course Format	Three hours of lectures per week

The time-dependent neutron diffusion equations; Step reactivity input and response; Frequency response and transfer functions; Reactivity oscillations; Ramp reactivity input and response; Arbitrary reactivity variations. Integral equations for point reactor dynamics; Numerical methods for the solution of dynamics equations; Reactivity feedback; The Nordheim Fuchs model; The Fuchs ramp input model; Small reactivity excursions; Excursions near prompt critical Complex shutdown mechanisms for reactors. The transport equation for space-dependent neutron dynamics; Multi-mode dynamics equations; Numerical methods for the solution of space dependent dynamics equations.

References:

Hetrick, D.L., Dynamics of Nuclear Reactors, The University of Chicago Press, 1971.

Ott, K.O. and RJ. Neuhold, Introductory Nuclear Reactor Dynamics, American Nuclear Society, 1985.

Murray, RL. et. al, Reactor Kinetics Computer Modules, N.C. State University, 1977.

Ash, M., Nuclear Reactor Kinetics, McGraw-Hill, 1979.

Lewins, J., Nuclear Reactor Kinetics and Control, Pergamon, 1977.

NE-608 NEUTRON TRANSPORT THEORY

Compulsory	
Credits	3
Perquisite	NE-505
Course Format	Three hours of lectures per week

Development of neutron transport theory, The one-speed neutron transport equation and its solution by analytical methods; Reciprocity relations and collision probabilities. Numerical solution of the one-speed transport equation spherical harmonics expansion, discrete-ordinates method, finite element technique and integral transport methods.

Multigroup methods for the solution of the energy dependent transport equation; Eigenvalue problems; Determination group constants; Reactor cell calculations; the adjoint function and its applications; Perturbation theory, Variational methods.

References:

Bell, G.L and S. Glass tone, Nuclear Reactor Theory, Van Nostrand, 1970.

Duderstadt, J.J., and W.R Martin, Transport Theory, John Wiley, 1979.

Case K1□ and P.E. Zweifel, Linear Transport Theory, Addison-Wesley, 1967.

Stamm'ler, RJ. and M.J. Abbate, Methods of Steady State Reactor Physics in Nuclear Design, Academic, 1983

NE-609 NUCLEAR REACTOR SAFETY

Compulsory	
Credits	3
Perquisite	NE-603
Course Format	Three hours of lectures per week

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

References:

Lewis, E.E., Nuclear Power Reactor Safety, John Wiley, 1977.

WASH-1400, Reactor Safety Study, U.S. Nuclear Regulatory Commission, 1975.

Thomas, T.J. and J.G. Berkeley (eds.), The Technology of Nuclear Reactor Safety Vol. 1, M.I.T. Press, 1964.

Jones, O.C., Nuclear Reactor Safety Heat Transfer, Hemisphere Pub., 1981.

McCormick, N.J., Reliability and Risk Analysis: Methods and Nuclear Power Applications, Academic, 1981.

NE-610 RELIABILITY AND RISK ANALYSIS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Reliability concepts; Probability distributions for describing failures; Failure data; Sampling, estimation and confidence limits; Reliability of simple systems; Synthesis of reliability for complex systems; Fault tree analysis; Event tree analysis Concepts of risks; Risk analysis for nuclear reactors; Risk analysis for the various stages of the nuclear fuel cycle Comparison of nuclear risks to risks from other energy sources; Risk benefit and cost-benefit analysis.

References:

McCormick, N.J., Reliability and Risk Analysis: Methods and Nuclear Power Applications, Academic, 1981.

Green, A.E., Safety Systems Reliability, John Wiley, 1983.

Lakner, A.A. and RT. Anderson, Reliability Engineering for Nuclear and other High Technology Systems, Elsevier 1985.

Billinton, R, and RN. Allan, Reliability Evaluation of Engineering Systems, Pitman, 1983.

WASH-1400, Reactor Safety Study, U.S. Nuclear Regulatory Commission, 1975.

NUREG-0492, Fault Tree Handbook, U.S. Nuclear Regulatory Commission, 1981.

NE-611 NUCLEAR REACTOR DESIGN

Compulsory	
Credits	3
Perquisite	NE-603
Course Format	Three hours of lectures per week

The course is intended to provide familiarity with the conceptual and practical problems associated with reactor design Group design efforts will involve integration of reactor physics, thermal hydraulics, materials science, shielding, safety and economics. Optimization procedure will be discussed. Students

will be required to use computer modules for analysis of various aspects of reactor design. Lectures, seminars and tutorials will be held to aid the students in their effort.

References:

Weisman, J. (ed.), Elements of Nuclear Reactor Design, Elsevier, 1983.

Stamm'ler, R J. and N. J. Abbate, Methods of Steady State Reactor Physics in Nuclear Design, Academic, 1983.

Sesonske, A., Nuclear Power Plant Design Analysis, Technical Information Centre, USAEC, 1973

Pederson, E.S., Nuclear Power Vol. I and II, Ann Arbor Science Pub. Inc., 1978.

Kuljian, HA, Nuclear Power Plant Design, A S. Barnes and Co., 1968.

NE-612 BOILING HEAT TRANSFER AND TWO PHASE FLOW

Compulsory	
Credits	3
Perquisite	NE-602
Course Format	Three hours of lectures per week

Analysis of boiling and condensation phenomena; Heat transfer rates in pool and flow boiling; Two phase flow: basic concepts, void-quality analysis, pressure losses; Flow instability, Critical flow; Instrumentation; Boiling water reactor core analysis.

References:

Lahey, RT., Jr. The Thermal-hydraulics of a Boiling Water Nuclear Reactor, ANS, 1977.

Rust, J.H, Nuclear Power Plant Engineering, Haralson, 1979.

El-Wakil, M.M., Nuclear Heat Transport, International Textbook, 1971.

Wallis, G.B., One Dimensional Two Phase Flow, McGraw-Hill, 1969.

NE-613 COMPUTATIONAL FLUID DYNAMICS

Compulsory	
Credits	3
Perquisite	NE-512
Course Format	Three hours of lectures per week

General differential equation; Numerical solution of energy and Navier Stokes equations; Numerical schemes and algorithms; Methods of obtaining convergence; Transient analysis; Finite difference and finite-element methods applied to fluid mechanics; Matrix solving techniques; Recent developments in CFD; Development of computer programs for CFD problems.

References:

Patanker, S.V., Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.

Anderson, D.A., J.C. Tannehill and RH. Pletcher, Computational Fluid Mechanics and Heat Transfer, Hemisphere 1984.

Holt, M., Numerical Methods in Fluid Dynamics, Springer-Verlag, 1984.

NE-614 RADIOACTIVE WASTE MANAGEMENT

Compulsory	
Credits	3
Perquisite	NE-605
Course Format	Three hours of lectures per week

Build-up and decay of radioactive nuclides; Major sources of nuclear waste; Gaseous, liquid and solid wastes; High level liquid waste, its characterization and projections for fuel cycle; Commercial high level liquid waste management; Solidification processes and products; Actinide partitioning of high level liquid waste; Low and medium level wastes and their treatment in gaseous, liquid & solid forms; Special wastes of tritium, krypton and iodine isotopes; Considerations of ultimate disposal of nuclear wastes; Assessment of long term safety; Design of a waste processing facility.

References:

Benedict. , T.H Pigford and HW. Levi, Nuclear Chemical Engineering, McGraw-Hill, 1981.

Mawsor, G.A., Management of Radioactive Wastes, Van Nostrand, 1965.

Proceedings of the Management of Radioactive Wastes from the Nuclear Fuel Cycle, IAEA, Vienna, 1976.

NE-615 NUCLEAR CHEMICAL PLANT DESIGN

Compulsory	
Credits	3
Perquisite	NE-513
Course Format	Three hours of lectures per week

Development of a chemical plant project; Process design: Evolution of physical and chemical operations of a process; Case- studies from conventional and nuclear chemical industry; Selection of process equipment and materials; Writing of order specifications; Student process design project; Design for the prevention of nuclear criticality in a radio-chemical plant; Fuel reprocessing plant first cycle hot cell design example; Shield design; Reprocessing hot cell shield design; Radio-chemical plant instrumentation, piping and pumping equipment layout planning; Maintenance philosophies; Plant siting; Project economic evaluation.

References:

Peters, M:S. and K.D. Tirmnerhaus, Plant Design and Economics for Chemical Engineers, McGraw-Hill, 1980.

Vilbrandt, F.C. and C.E. Dryden, Chemical Engineering Plant Designing, McGraw-Hill, 1959.

Stoller, S.M., Reactor Handbook Vol. II, Interscience, 1961.

Long, J.T., Engineering for Nuclear Fue! Reprocessing, Gordon and Breach, 1967.

Flagg, J.F. (ed.), Chemical Processing of Reactor Fuels, Academic, 1961.

NE-616 NUCLEAR REACTOR MATERIALS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Classification of plain carbon steels; Microstructures and their control in plain carbon steels; Effects of alloying elements on plain carbon steels; Classification of alloy steels; Manganese steels; Low alloy chromium steels; Chromium alloy molybdenum steels; Temper-embrittlement in low alloy steels; Iron chromium alloys; Iron-chromium-carbon alloys; Classification of wrought stainless steels; Ferritic stainless -steels; Martensitic stainless steels; Austenitic stainless steels; Precipitation hardening of stainless steels; Titanium alloys; Nickel base super alloys; Nickel-iron base super alloys; Metallurgy of zircaloy, Materials aspects of design and structural integrity of nuclear fuels, control rods, reactor pressure vessel, piping, heat exchanger, and turbines.

References:

Smith, W.F., Structures and Properties of Engineering Alloys, McGraw-Hill, 1981

Roberts, J.T.A., Structural Materials in Nuclear Power Systems, Plenum, 1981

Ursu, I., Physics and Technology of Nuclear Materials, Pergamon, 1985

Ma, B.M., Nuclear Reactor Materials and Applications, Van-Nostrand Reinhold, 1983

Pickering, F.B., Physical Metallurgy and Design of Steels, Applied Science Publishers, 1978

NE-617 DEGRADATION AND FAILURE OF MATERIALS

Compulsory	
Credits	3
Perquisite	NE-515
Course Format	Three hours of lectures per week

Galvanic corrosion of metals and alloys; Crevice corrosion; Pitting; Intergranular corrosion; Erosion corrosion; Corrosion behavior of low alloy steels, stainless steels, nickel base alloys, and tin alloys; High temperature corrosion; Creep; High temperature materials and coatings; Fracture mechanics; Fatigue; Corrosion fatigue; Stress corrosion cracking; Hydrogen embrittlement; Pellet-clad interactions; Problems in PWR steam generators and steam turbines; Metal working defects; Casting defects; Heat treatment defects; Non-destructive testing; Fractography; Imperfections in materials induced by radiations; Effects of irradiation; Inspection of reactor components for structural integrity.

References:

Caddell, RK, Deformation and Fracture of Solids, Prentice-Hall, 1980

Fontana, M G., Corrosion Engineering, McGraw-Hill, 1987

Colangelo, V.J. and F.A Heiser, Analysis of Metallurgical Failures, john Wiley, 1974

Roberts, J.T., Structural Materials in Nuclear Power Systems, Plenum, 1981

Felbeck, D.K and AG. Atkins, Strength and Fracture of Engineering Solids, Prentice-Hall, 1984

NE-618 MECHANICAL BEHAVIOR OF MATERIALS

Compulsory	
Credits	3
Perquisite	NE-516
Course Format	Three hours of lectures per week

Three primary fatigue analysis methods: The stress life approach, the strain life approach, and the fracture mechanics approach; Relationship between fracture mechanics and Coffin-Manson law; Fatigue crack initiation phenomenology, Fracture crack initiation in notches; Fatigue crack propagation phenomenology; Time dependent fatigue behavior study; Effect of environment, frequency, etc.; Strain range partitioning methods; Frequency modified Coffin-Manson law, 10% rule; Damage modes: inter granular and trans granular, Methods of obtaining fatigue life using initial crack size; Importance of critical stress intensity factor.

References:

Bannantine, J.A, J.J. Comer, and J.L. Hand rock, Fundamentals of Metal Fatigue Analysis, Prentice-Hall, 1990.

Broek D., Elementary Engineering Fracture Mechanics, 4th Ed., Martinis Nijhoff, 1986.

Collins, J.A., Failure of Materials in Mechanical Design: Analysis, Prediction and Prevention, John Wiley, 1981.

Harvey, J.F., Theory and Design of Modern Pressure Vessels, 2nd Ed., Van Nostrand Reinhold Co., 1974.

NE-619 VACUUM METALLURGY

Compulsory	
Credits	3
Perquisite	NE-521
Course Format	Three hours of lectures per week

Vacuum pumps; Pressure measuring devices; Leak detection and proving; Metal refining in vacuum; Degassing in liquid state; Vacuum melting in resistance furnaces; Vacuum induction melting; Electron beam melting; Vacuum sintering; Vacuum heat treatments; Electron beam melting; Vacuum coating; Design of vacuum systems; Use of vacuum technology in production of Nuclear materials.

References:

Winkler, O. and R Bakish (eds.), Vacuum Metallurgy, Elsevier, 1971.

Pehlke, RD., Unit processes of Extractive Metallurgy, Elsevier, 1973.

Rosenquist, T., Principles of Extractive Metallurgy, McGraw-Hill, 1983.

Roth, A., Vacuum Technology, Elsevier, 1982.

Van Atta, C.M., Vacuum Science and Engineering, McGraw-Hill, 1965.

NE-620 CRYOGENIC AND VACUUM SYSTEM DESIGN

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Basic principles of cry pumping; Its advantages and disadvantages as compared to other pumps; Refrigeration and liquefaction cycles; Heat transfer; Insulation; Fluid dynamics; Materials of construction and technique of fabrication; Adsorption expanders and pumps safety; Thermo-physical data for cryogenic materials, their availability, production, storage, transfer and cost. Criteria for the selection of materials needed in ultra high vacuum systems; Cleaning techniques; Sealing techniques; Partial pressure analyzers; Leak detection using high frequency leak testers, halogen and helium leak detectors, mass spectrometer.

References:

White, G. K., Low Temperature Physics, Clarendon Press, 1979.

Haselden, G. G. (ed.), Cryogenic Fundamentals, Academic, 1971.

Roth; A., Vacuum Technology, North-Holland, 1976.

Van Atta, Vacuum Science and Engineering, McGraw-Hill, 1965.

Werner Espe, Materials for High Vacuum Technology Vol. I and II, Pergamon, 1968.

NE-621 THE BOUNDARY ELEMENT METHOD

Compulsory	
Credits	3
Perquisite	NE-522
Course Format	Three hours of lectures per week

Basic concepts and comparison with other methods; Solution of the Poisson equation: approximate solutions and weighted residual methods, Weak formulations: boundary and domain solutions; Potential problems and their solution by BEM; Combination of BEM and FEM; Singular elements for fracture mechanics.

References:

Brebbia, C.A, Thc Boundary Element Method for Engineers, Pentech, 1984.

Brebbia, C.A. and J. Dominguez, Boundary Element Method, McGraw-Hill, 1989.

NE-622 LASER PHYSICS

Compulsory	
Credits	3
Perquisite	NE-520
Course Format	Three hours of lectures per week

Stimulated emission; Einstein's A, B coefficients; Dipole radiation; Induced dipole moments; Maxwell's equations; Wave equation; Rotating wave approximation; Density matrix approach; Equations for-diagonal and off-diagonal matrix elements of density matrix for a two level system; Solution in rate equation approximation; Output power for single mode; Multimode operation; Doppler broadening; Saturation amplification; Spontaneous emission; Coherent states; Coherence properties; Introduction to stochastic processes; Autocorrelation functions; Spatial temporal coherence; Photon statistics in thermal and laser sources. Geometrical optics approach for periodic focusing systems; Resonator g parameter, Stability diagrams; Methods of wave optics (diffraction approach); Huygen's principle; Gaussian waves; Propagation and focusing of Gaussian waves; Concept of waist, spot size, Rayleigh range etc.; Field patterns of commonly used resonators; Higher order (non-Gaussian) modes; Unstable resonators.

References:

Sargent M., M D. Scully. and W.E. Lamb, Laser Physics, Addison-Wesley, 1974.

Siegman, A. E., Introduction to Lasers and Masers. McGraw-Hill, 1971.

Smith, W.V. and P.P. Sorokin, The Laser, McGraw-Hill. 1966.

NE-623 LASER SYSTEM TECHNOLOGY AND APPLICATIONS

Compulsory	
Credits	3
Perquisite	NE-520
Course Format	Three hours of lectures per week

Classification of laser systems; Spectroscopy of specific systems; Design of solid state laser techniques; Pumping geometries; Pump sources; Technological details; Amplification; Mode selection; Q-switching; Pulse narrowing; Design techniques of gas lasers; Mode locking; Mode selection; Stabilization; Amplification; Optical elements including mirrors, lenses/beam-splitters and optical coatings; Mechanical stability of laser systems; Electronics necessary for laser system. Properties of laser beams; Harmonic generation; Spectroscopy; Multiphoton processes; Distance measurements by conventional methods, interferometry, optical radar and range finder; Types, techniques, and applications of holography; Processing of industrial and semiconductor materials; Vapor deposition for thin films; Communications methods including conventional methods, lasers and fibers, step index fibers, graded index; Loss mechanisms; Transmitters/Receivers; Satellite communication by lasers; Military applications including range finders, guiding systems, pistols, defense systems; Other applications such as computer/integrated optics, fusion, medicine, high speed photography, laser gyroscope.

References:

Arechhi, F. T. and E.O. Schulz-Dubois (eds.), Laser Handbook Vol. I and II, North-Holland, 1972.

Schafer, F. P., Dye Lasers, Springer-Verlag.

Hrad, Principles/Practices of Laser Technology.

Elion, H. A., Laser Systems and Applications, Pergamon, 1967.

Ross, M. (ed.), Laser Applications Vol. I, II and III, Academic, 1977.

NE-624 THERMONUCLEAR ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

The fusion reactions and their cross sections; Thermonuclear reaction power density; Radiation losses; The Lawson criterion; Transport and electromagnetic theory applicable to confined plasmas; Survey of methods of magnetic confinement; Achievement of a thermonuclear plasma by inertial confinement; Cold fusion. A general fusion reactor design; The first wall; Heat Transfer systems; Tritium breeding and confinement; Superconducting magnets; High powered lasers; Other reactor components. Conceptual fusion reactor systems; The tokamak reactor; The magnetic mirror reactor, The laser driven reactor; Economics of fusion and future prospects.

References:

Reader, J. et. al., Controlled Nuclear Fusion: Fundamentals of its Utilization for Energy Supply, John Wiley, 1986.

Teller, E., (ed.), Fusion, Academic, 1981.

Stacey, W.M., Jr., Fusion and Technology: An Introduction to the Physics and Technology of Magnetic Confinement Fusion, John Wiley, 1984.

Kamas T., Fusion Reactor Physics, Ann Arbor, 1977.

NE–625 REACTOR CONTROL AND INSTRUMENTATION

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Reactor kinetics; Transfer function; Overview of reactor systems; Out core sensors; In core sensors; Process instrumentation; Signal conditioning; Transfer function measurement systems; Control rod drives and indicating systems; Power supplies; Installation of instrumentation systems; Quality assurance and reliability; Protection systems; Instrumentation systems of nuclear power plants.

References:

Schultz, M.A., Control of Nuclear Reactors and Power Plants, McGraw-Hill, 1961.

Horror, J.M., and J.G. Berkeley, Nuclear Reactor Instrumentation Handbook Vol. I and II, USAEC.

McCormick, N.J., Reliability and Risk Analysis: Methods and Nuclear Power Applications, Academic, 1981.

NE-626 OPTIMAL CONTROL ENGINEERING

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

State-space representation of physical systems; Selection of a performance measure; The optimal control law; The principle of optimality applied to the optimal control problem; The calculus of variations; Necessary conditions or optimal control; Linear regulator problems; Pontryagin's minimum principle and state inequality constraints; Minimum time and minimum control effect problems; Numerical determination of optimal control by the method of steepest-decent and by the method of variation of extremals.

References:

Kirk, D.E., Optimal Control Theory, Prentice-Hall, 1972.

Sage, A.P. and C.C. White, Optimum Systems Control, Prentice-Hall, 1977.

Lewis, F.L., Optimal Control, John Wiley & Sons, 1986.

Whittle, P., Risk-Sensitive Optimal Control, John Wiley & Sons, 1990.

NE-627 COMPUTER SYSTEM MANAGEMENT

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

Data structures; Linear lists; Stacks; Queues; Dequeues; Linked lists; Circular lists; Doubly linked lists; Arrays; Trees; Sorting, searching and organization of files; Operating systems; Types of operating systems; Parallel processing and synchronization; Memory management techniques; system deadlocks and their prevention; Sample operating system design; Analog, Digital and Hybrid computations; Implementation of models of EAI-Minihybrid.

References:

Yourdan, E., Techniques of Program Structure and Design, Prentice-Hall, 1975.

Berztiss, A.T., Data Structures: Theory and Practice, Academic, 1975.

Genuys, F., Programming Languages, Academic.

Madnik, S.E., and J.J. Donovan, Operating Systems, McGraw-Hill, 1974.

Mane, M.M., Computer System Architecture, Prentice-Hall, 1976.

NE-628 SPECIAL TOPICS IN NUCLEAR ENGINEERING-III

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week

This is a course on advanced topics not already included in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The topic and contents of the course must be approved by the Board of faculty.

NE-629 REACTOR OPERATION AND EXPERIMENTS

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Three hours of lectures per week Nine hours of laboratory work per week for Experiments

Introduction to research reactors and their ancillary equipment; Manpower requirements and duties; Reactor design; Reactor description; Reactor instrumentation; Fuel handling and storage; Reactor Operating procedures.

Reactor Experiments: A minimum of four experiments must be performed from the following list:

Investigation of reactivity effects of the thermal column and beam tubes.

Study of Xenon poisoning build-up and decay.

Reactivity importance function for neutron absorbers.

Measurement of absorption cross-section by comparison method

Effect of delayed neutrons and measurement of power coefficient of reactivity.

Statistical weight distribution curve; danger-coefficient and absorption cross-section.

References:

A Brief Functional Description of the Pakistan Research Reactor, PINSTECH Report No. RO-5.

PARR Neutron Flux Scan and Absolute Power Measurement, PINSTECH Report No. NED-6.

A Manual of Reactor Laboratory Experiments, (ANL-6990), TLD, 4500.

Glower, D.D., Experimental Reactor Analysis and Radiation Measurement, McGraw-Hill.

Hoag, J.B., Nuclear Reactor Experiments, Van Nostrand, 1958.

NE-630 CONTROL AND SIMULATION LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of eight experiments must be performed from the following list:

Determination of time constant, damping ratio, and natural frequencies from the transient response and measurement of frequency response of open and closed loop dc servo system.

Close loop behavior of ac servo system.

Open and closed loop speed and position control using advance d.c. servomechanism.

Comparison and study of PID control actions and tuning rules.

Time and frequency response analysis of first, second and third order systems using a pneumatic servo system..

Study of effects of non-linearities such as saturation, dead-zone, hysterisis, etc. on the performance of feedback systems.

Study of a thermal system with time lag.

Familiarization with digital storage oscilloscope, operation of 555 timer as pulser and square wave generator.

Simulation of linear systems on digital computer.

Simulation of non-linear systems on digital computer.

Simulation of process control on digital computer.

Speed and position control of a stepper motor.

Solution of non-linear state equations on analogue computer.

References:

Almas Arshad, Experiments in Control Systems and Computer Simulation, CNS-13, 1984.

Instructional Manuals of ES-130, DC Modular Servo, Chemical Process Trainer, Jack & Nozzle Flapper, Published by Feedback.

Kuo, B.C., Automatic Control Systems, Prentice-Hall, 1985.

Ogata, K., Modern Control Engineering, Prentice-Hall, 1990.

NE-631 RADIATION PHYSICS LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of six experiments will be performed from the following list:

Study of scattering of gamma rays from flat surfaces.

Experimental study of the shielding properties of concrete for fission product gamma-rays.

Positron life time studies in different materials.

X-ray fluorescence with proportional and HPGe or Si (Li) detector.

Study of the shielding characteristics of single and laminated materials for gamma-rays.

Shielding characteristics of different materials for fast neutrons.

Determination of resonance integrals using activation foils.

Thermal and fast neutron activation.

Alpha- X-Ray Coincidence and study of decay scheme of Cm-244.

Decay scheme study and determination of angular correlation of emitted radiations.

Low level alpha-beta counting system study and environmental monitoring.

Beta particle detection using liquid scintillators.

References:

Nasir Ahmad and Tahir Mahmood, Experiments in Reactor Physics and Radiation Shielding, CNS-12, 1982.

Profio, A.E., Experimental Reactor Physics, John Wiley, 1976.

NE-632 ENGINEERING AND MATERIALS LABORATORY

Compulsory	
Credits	3
Perquisite	Nil
Course Format	Nine hours of laboratory work per week

A minimum of eight experiments will be performed from the following list:

Materials Science:

Tensile, hardness, and impact testing of metals and alloys.

Metallography of various metals and alloys and study of phase distributions.

Comparison of corrosion rates of various metals and alloys by weight loss technique.

Study of electrochemical behavior of metals and alloys in corrosive media.

Effects of annealing, normalizing, quenching and tempering on hardness and microstructure.

Effects of cold working, recovery, and recrystallization on microstructure and mechanical properties of metals and alloys.

Study of powder compaction and sintering.

Sensitization and solution heat treatment of stainless steel.

Separation Processes:

Analytical estimation of uranium in aqueous and organic solutions.

Analytical estimation of free acidity in the presence of uranium.

Partition studies of the distribution of uranium (aqueous/organic) in TBP solvent as a function of nitric acid concentration.

Batch stepwise countercurrent extraction of uranium to construct X-Y diagrams for process Flow-sheet development.

Studies of continuous current and differential solvent extraction in a spray column pilot plant.

Studies of batch distillation with rectification in a packed column pilot plant.

Studies of resin column preparation, backwashing, adsorption and elution in a double column pilot plant.

Thermal Hydraulics:

Investigation of the effect of pressure on critical heat flux.

Determination of friction factors for water flow in various components.

Study of characteristics of various types of pumps.

Study of film wise and drop wise condensation.

Study of shell and tube type heat exchangers.

Investigation on heat and mass transfer unit.

Oil hydraulic control circuits study.

Study of pneumatic control circuits. Stress Analysis:

Use of electrical strain gauges in structural mechanics.

Determination of stress at different points in mechanical structures using model analysis.

Determination of stress direction in different mechanical structures.

Determination of stress concentration factors in various geometries.

Determination of stress at different points in mechanical structures using coating analysis.

Preparation, application and calibration of brittle coatings and moire fringe analysis.

References:

Perry, RH and D.W. Green, Perry's Chemical Engineers Handbook, McGraw-Hill, 1984.

Holman, J.P., Experimental Methods for Engineers, McGraw-Hill, 1984.

Dally, J.W. and W.F. Riley, Experimental Stress Analysis, McGraw-Hill, 1978.

Sheikh, P.A., A Manual of Experiments in Materials Laboratory, CNS/M-I9, 1988.

NE-697 MS Thesis Project

Compulsory	
Credits	3+9
Perquisite	Nil
Course Format	Three hours of lectures per week

The thesis will start during the fourth semester with 3 credit hours and will continue in fifth semester with nine credit hours. The student will undertake an in-depth study of some Nuclear Engineering related problem. This will be done either by joining an on-going research programme, or by initiating a new programme under the guidance of a PIEAS faculty member. The nature of the project may be research, development or design and may involve experimental, theoretical, or computational work or a combination of these. Each student will be assigned a 'Project Supervisor' from the PIEAS faculty. 'Co-supervisors' may also be assigned, depending on the nature of the work. The supervisor and co-supervisor/s will guide, instruct and supervise the student in this study. They will also be responsible for reporting the grade of the student based on their evaluation. In this evaluation they may be aided by committee of experts to be appointed by Rector PIEAS. The student shall write a comprehensive report and shall deliver at least one seminar before the end of the semester. The report and the seminar shall also be used in the overall evaluation of the student. Normally, this project is to be completed by the end of the fifth semester. However, if the supervisors feel that more time is needed for the satisfactory completion of the project, the duration may be extended beyond the end of the semester.