MS Physics Program

REVISION
January 2015

Department of Physics & Applied Mathematics
Pakistan Institute of Engineering & Applied Sciences
Nilore, Islamabad 45650, Pakistan

PAKISTAN INSTITUTE OF ENGINEERING & APPLIED SCIENCES
Department of Physics and Applied Mathematics
Revision January 2015

MS Physics Course (Minimum Requirement: 34 credit hours of course work and 24 credit hours of thesis research)

MS Physics Courses					
S. No.	**Code**	**Course Title**	**Cr. Hrs.**	**Status**	**Pre-requisites**
1	PAM507	Mathematical Physics	3	C	NIL
2	PAM508	Classical & Relativistic Mechanics	3	C	NIL
3	PAM512	Electrodynamics	3	C	NIL
4	CMS501	Communication Skills	1	C	NIL
5	PAM516	Advanced Nuclear Physics	3	O	NIL
6	PAM523	Plasma Physics-I	3	O	NIL
7	NE526	Radioisotope Applications	2+1	O	NIL
8	PAM530	Mathematical Methods-I	3	O	PAM507
9	PAM533	Computational Physics	3	O	NIL
10	PAM534	Physics Simulation	3	O	NIL
11	PAM545	Fourier Optics	3	O	NIL
12	PAM546	Graduate Physics Laboratory	3	C	NILL
13	PAM551	Quantum Optics-I	3	O	NIL
14	PAM553	Fiber Optics	3	O	PAM545
15	PAM556	Radiation Physics-I	2+1	O	NIL
16	PAM566	Radiation Physics-II	2+1	O	PAM556
17	PAM569	Mathematical Methods-II	3	O	PAM507,PAM530
18	PAM572	Bio-Photonics	3	O	NIL
19	PAM578	Neutron Physics	2+1	O	PAM516
20	PAM579	Environmental Physics	2+1	O	NIL
21	PAM584	Non-linear Optics	3	O	PAM545
22	PAM587	Statistical Physics	3	C	NIL
23	PAM590	Atomic and Molecular Physics	3	O	NIL
24	PAM 604	Partial Differential Equations	3	O	PAM 507
25	PAM605	Quantum Optics-II	3	O	PAM551
26	PAM606	Laser Physics	3	O	NIL
27	PAM607	Non-linear Dynamics in Physics	3	O	PAM533
28	PAM608	Advanced Fiber Optics	3	O	PAM512/Equivalent
29	NE608	Neutron Transport Theory	3	O	PAM578
30	PAM609	Advanced Quantum Mechanics	3	C	NIL
31	PAM610	Simulations in Statistical Physics	3	O	PAM587
32	PAM612	Nonlinearities in Fibre Optics	3	O	PAM553
33	PAM618	Plasma Physics-II	3	O	PAM523
34	NE624	Thermonuclear Engineering	3	O	PAM523
35	PAM625	Special Topics in Physics-I	3	O	NIL
36	PAM626	Special Topics in Physics-II	3	O	NIL
37	PAM631	Photodynamic Therapy	3	O	PAM606
38	PAM633	Polarization Imaging	3	O	NIL
39	PAM658	Advanced Computational Condensed Matter Physics	3	O	PAM533
40	PAM690	Seminar Project	3	O	NIL
FOURTH AND FIFTH SEMESTERS					
41	PAM698	MS Thesis Research*	24	C	NIL

* Grade:, Excellent, Very Good, Good, Fair, Satisfactory and Unsatisfactory will be awarded;
Note: C Compulsory, O Optional;

Course-wise Fields of Specialization

Specialization	**Related Courses**
Computational Physics	PAM534, PAM569, PAM658,PAM610,PAM607
Laser Physics	PAM545, PAM551, ,PAM553,PAM572,PAM584, PAM605,PAM606,PAM 612,PAM 633
Plasma Physics	PAM523,PAM534,PAM606, PAM607, NE608, PAM618, NE624
Radiation Physics	NE526,PAM556, PAM566,PAM578,PAM579,NE608

List of Courses

Course Contents

PAM507 Mathematical Physics

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Vector and tensor calculus, Green's and Stoke's theorems, contra-, covariant- and metric tensors, diagonalization tensors for eigenvalue problems; Complex algebra, Infinite series, expansions, singularities, contour integration and Cauchy's theorem, residues; Convolution integrals, Integral transforms, periodic functions, Sturm-Liouville theory of orthogonal functions; Partial differential equations, solution techniques, Bessel's and Legendre's equations; Integral equations, transforms, generating functions.

Recommended Text:

1. G.B. Arfken and H. Weber, *Mathematical Methods for Physicists*, Academic Press, 2000.
2. R. V. Churchill, *Fourier Series and Boundary Value Problems*, 5th Ed., McGraw Hill, 1993
3. R. V. Churchill, *Complex Variables and Applications*, 6th Ed., McGraw Hill, 1996.
4. R. Courant and D. Hilbert, *Methods of Mathematical Physics, vol. 1*, Wiley, New York, 1989.
5. P. Dennery and A. Krzywicki, "*Mathematics for Physicists*," Harper and Row, 1996.

PAM508 Classical & Relativistic Mechanics

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Elementary principles, mechanics of a particle, constraints, D'Alembert's principle and Lagrange's equations; Variational principles, Hamiltonian principle; Two body central force problems, Kepler problem, scattering; Kinematics: orthogonal transformations, the Coriolis force; Rigid body equations: angular momenta, Small oscillations:, frequencies; Special Theory of relativity: Michelson-Morley experiments, Lorentz transformations, Covariant four vector formulations for velocity, momenta and acceleration, equivalence of mass and energy, relativistic conservation laws, relativistic Lagrangian and Hamiltonian; Canonical transformations: Poisson brackets, infinitesimal motions, angular momenta, symmetry groups.

Recommended Text:

1. H. Goldstein, *Classical Mechanics*, 2nd Ed., Addison-Wesley, 1994.
2. A. P. French, *Special Relativity*, Van Nostrand, (1982).
3. L.D. Landau and E. M. Lifschitz, *Mechanics*, Addison-Wesley, 1960.
4. J. B. Marion, *Classical Dynamics of Particles and Systems*, 4th Ed., Academic Press, 1995.

PAM512 Electrodynamics

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Maxwell's equations, Gauge transformation. Poynting Vector, Conservation laws, Plane electromagnetic waves in non-conducting and conducting medium. Polarization. Propagation in a dispersive medium. Reflection and refraction. Total internal reflection. Radiation by moving charges. Lienard-Wiechert potentials and fields. General angular and frequency distributions of radiation of localized oscillating sources. Electric dipole fields and radiation. Magnetic dipole and electric quadropole fields. Multipole radiations. Multipole expansion of electromagnetic fields. Angular distributions. Sources of multipole radiation. Spherical wave expansion of vector plane waves. Scattering of electromagnetic wave by a conducting sphere.

Recommended Text:

1. J. D. Jackson, *Classical Electrodynamics*, John-Wiley and Sons, 1975.
2. D. J. Griffiths, *Introduction to Electrodynamics*, 2nd ed., Prentice Hall, 1989.
3. A. O. Barut, *Electrodynamics and Classical Theory of Fields and Particles*, Dover, New York, 1980.

PAM516 Advanced Nuclear Physics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Atomic Nucleus; nuclear properties, symmetries of the nuclear Hamiltonian, deutron, binding energies, sizes and nuclear shapes, spin, parity and isomers; nuclear decay modes; nuclear reactions; Mossbauer spectroscopy; nuclear structure, quarks & gluons, nuclear force, nuclear models; unstable nuclei, quark-gluon plasma; Nucleo-synthesis, supernovae, neutron stars; symmetries

Recommended Texts:

1. Kenneth S. Krane, *Introductory Nuclear Physics,* John Wiley & Sons, 1987.
2. Jose M. Arieas, M. Lozano eds., *An Advanced Course in Modern Nuclear Physics,* Springer Verlag, 2001.
3. S. Kuyucak ed., *Frontiers in Nuclear Physics,* World Scientific, 1999.
4. S. Samuel, M. Wong, *Introductory Nuclear Physics*, Wiley-Interscience, 1999.

PAM523 Plasma Physics-I

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Confinement schemes; magnetic confinement and stability. Description of Tokomaks, mirror machines, and pinch devices. Supplementary Heating. Diffusion in Weakly ionized gases. Diffusion across a magnetic field. Diffusion in fully ionized plasmas. Bohm diffusion and neoclassical diffusion. Hydro-magnetic equilibrium. The concept of Diffusion of a magnetic field into plasma. Certification of instabilities. Two stream instability. The gravitational instability. Resistive drift waves. Solution of linearlized Vlasov equation. Time asymptotic solution. Vlasov theory of small amplitude waves in field free uniform/non-uniform magnetized cold/hot plasmas. The Vlasov theory of Plasma Stability

Recommended Texts:

1. N. A. Kran and A. W. Travelpiece, *Principles of Plasma Physics*, McGraw Hill, 1973.
2. S. Glasstone and R. H. Loveberg, *Controlled Thermonuclear Reactions*, D. Van Nustrand, 1960.
3. M. O. Hagler & M. Kristanson, *An Introduction to Controlled Thermonuclear Fusion*, Lexington, 1977.
4. F. F. Chen, *Introduction to Plasma Physics*, Plenum, 1973.

NE526 Radioisotope Applications

Status	Optional
Credits	2+1
Pre-requisite	Nil
Course Format	two hours of lectures + one credit hour of lab. work 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.

Recommended Texts:

1. G.G. Eichholz, (ed), *Radioisotope Engineering*, Marcel Dekker Co., New York, 1972.
2. R. L. Ely, and R.P. Gardner, *Nuclear Measurement Methods in Engineering*.
3. J. Kehl,, D. Zentuer, and R.R. Lukens, *Radioisotopes Applications in Engineering*, Van Nostrand, 1961
4. J. C. Domanus, *Practical Neutron Radiography*; Kluwer Academic, 1992.

PAM530 Mathematical Methods-I

Status	Optional
Credits	3
Pre-requisite	PAM507
Course Format	Three hours of lectures per week

Linear differential equations and special functions. Separation of coordinates. Series solution. The Wronskian. The hyper-geometric series. Asymptotic series, one regular and one irregular singular point. Integral representation. Green's functions. Types of boundary conditions. Difference equations and Green's functions. Source points and boundary points. Green's function for steady waves. Wave equation. Diffusion equation.

Recommended Text:

1. G.B. Arfken and H. Weber, *Mathematical Methods for Physicists* ,Academic Press, 2000.
2. R. Courant and D. Hilbert, *Methods of Mathematical Physics, vol. 1*, Wiley, New York, 1989.
3. P. M. Morse and H. Feshbach, *Methods of Mathematical Physics*, McGraw-Hill. 1953.
4. P. Dennery and A. Krzywicki, *"Mathematics for Physicists," Harper and Row*, 1996.

PAM533 Computational Physics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Linear algebra: Exact methods, iterative methods, eigen-values and eigenvectors; Stochastic Methods: equi-distribution, transformation of probability densities, rejection methods, multivariate distributions; random sequences, Markov chains, Gaussian Markov sequence, Winer-Levy process, Quantum mechanical simulations; Deterministic and Stochastic Optimization, Simulated annealing, Genetic Algorithms; Initial and Boundary value problems; Partial differential equations.

Recommended Texts:

1. R. H. Landau, M. J. Páez, C. C. Bordeiano, *Computational Physics*, Problem Solving with Computers, 2nd Edition, Wiley, 2007.
2. N. J. Giordano, H. Nakanishi, *Computational Physics*, 2nd edition, Prentics Hall, 2006.
3. Franz J. Vesley, *Computational Physics-An Introduction*, Kluwer Acad. Pub., 2001.
4. T. Pang, *An Introduction to Computational Physics*, 2nd Edition, Cambridge University Press, 2006.

PAM534 Physics Simulations

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Classification: discrete and continuous models; Mathematical modeling: equation ordered models, deterministic and stochastic models, ODE & PDE based models, Applications to various systems; Simulation Techniques: Digital Simulations; GUIs, Languages, Mathematica and Matlab, simulation process; Deterministic simulation; grids and discretization, numerical approximations; Stochastic Simulation; random processes and random number generators, Monte Carlo methods, discrete events, Metroplis and Gibbs sampling, sensitivity analysis, applications.

Recommended Texts:

1. H. Gould, J. Tobochnik, W. Christian, *An Introduction to Computer Simulation Methods*: Applications to Physical Systems, 3rd Edition, 2007.
2. R. Y. Rubinstein, D. P. Kroese, *Simulation and the Monte Carlo Method*, 2nd Edition, John Wiley, 2008.
3. S. M. Ross, *Simulation*, 4th Edition, Elsevier Academic Press, 2006.
4. R. L. Zimmerman, F. I. Olness, *Mathematica for Physics*, 2nd Edition, Addison Wesley, 2002.

PAM545 Fourier Optics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Analysis of two-dimensional signals and systems: Fourier analysis in two dimensions, local spatial frequency localization, linear systems, two-dimensional sampling theory. Diffraction theory: Kirchhoff formulation, Rayleigh-Sommerfeld formulation, generalization to non-monochromatic waves, diffraction at boundaries. Fresnel and Fraunhofer diffraction, frequency analysis of optical imaging systems. in-coherent and coherent optical information processing systems, VanderLugt filter; application to character recognition, holography; applications to interferometry, optical elements, data storage and others.

Recommended Texts:

1. Joseph W. Goodman, *Introduction to Fourier Optics*, McGraw-Hill, New York, 1996.
2. K. Eizuka, *Engineering Optics*, Springer-Verlag, Berlin, 1983.

PAM546 Graduate Physics Laboratory

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three credit hours of practical lab. work per week

From the following list of experiments, a minimum of 8 experiments have to be performed by the students.

1. Laser parametric studies
2. Line-of-sight communication using Lasers
3. Optical Computations using Lasers
4. Determination of the range of alpha-particles in air using SSNTDs
5. Study of etching parameters and critical angle for etching for SSNTDs
6. Determination of Alpha-to-fission ratio of Cf-252 source using SSNTDs
7. Absolute alpha-source strength measurements using SSNTDs.
8. Determination of neutron fluence and personal dosimetry using SSNTDs
9. Use of SSNTDs for environmental radon level measurements
10. Nuclear lifetime measurements using TPHC technique.
11. Study of isotopic composition using neutron activation analysis.
12. Neutron cross section measurements using transmission method
13. Study of decay scheme and angular correlation of Co-60.
14. Study of Rutherford scattering of alpha-particles from thin foils.
15. Charged particle spectrometry and decay ratios of Am-241 using surface barrier detectors.
16. Study of Compton scattering and determination of scattering cross section
17. Neutron diffusion parameter studies using BF_3 detector.
18. Absolute activity measurement using coincidence technique.
19. Measurement of radioactive half lives using counting technique.
20. Positron lifetime measurements

PAM551 Quantum Optics-I

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Atom-field interaction, Rabi oscillations, inclusion of atomic decay, optical Bloch equations, Maxwell-Schrödinger equations, semi-classical laser theory, coherence atomic effects, coherent population trapping, electromagnetically induced transparency, lasing without inversion, atom optics, laser cooling

Recommended Texts:

1. M. O. Scully and M. Suhail Zubairy, *Quantum Optics*, Cambridge Press, 1995.
2. M. Sargent III, M. O. Scully, and W. E. Lamb, Jr., *Laser Physics*, Addison-Wesley, Reading, 1974.
3. P. Meystre and M. Sargent, *Elements of Quantum Optics*, 3rd ed., Springer Verlag, 1999.

PAM553 Fibre Optics

Status	Optional
Credits	3
Pre-requisite	PAM545l
Course Format	Three hours of lectures per week

Optical fibres; attenuation and dispersion performance characteristics, optical fibre as communication channels; Maxwell's equations and propagation of light in planer waveguides, model waveguide and material dispersion, fibres transmission characteristics; Electro-optic components, PIN and avalanche photodiodes, semiconductor lasers.

Recommended Texts:

1. J. M. Senior, *Optical Fibre Communications: Principles and Practice*, Prentice Hall, 1992.
2. G. Keiser, *Optical Fibre Communications*, McGraw Hill, NY, 1991.
3. L. Kazovsky, S. Benedetto, A. Willner, *Optical Fibre Communication Systems*, Artech House, Bosten, 1998.

PAM556 Radiation Physics-I

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Two hours of lectures + one credit hour lab. work per week

Radiation Sources, interaction of radiations with matter, introduction to nuclear track detectors, track formation mechanisms; radiation damage in solids; track formation models; bulk track and electrochemical etching; track etching geometry; thermal fading of latent damage trails; use of track detectors in particle identification; an overview of properties, origin and transport of radon; radon monitoring devices based on SSNTDs; neutron and radon dosimeter with track detectors; methods of track image enhancement; spark counters; electrical breakdown devices; scintillator-filled etch pit counting; automatic and semi-automatic image analysis; fission track dating.

Recommended Texts:

1. S. A. Durrani and R. K. Bull, *Solid State Nuclear Track Detection Principles, Methods and Applications*, Pergamon, 1987.
2. R. L. Fleischer et al., *Nuclear Tracks in Solids*, Univ. California Press, 1974.

PAM566 Radiation Physics-II

Status	Optional
Credits	3
Pre-requisite	PAM556
Course Format	Three hours of lectures per week

Production of X-rays, Industrial Radiography, non-destructive testing systems; Radiographic equivalence; exposure factors; x-ray safety, radiation hazard; shielding in radiation installations, basic principles of protection; medical surveillance; radiation dosimetry; exposure; absorbed dose; exposure measurement; absorbed dose measurement; Bragg-Gray principle; Kerma; Film badge dosimeter; thermoluminiscent dosimeter; chemical dosimetry; dose calculations; dose from surface contamination; internally deposited radioisotopes; total dose; dose commitment; external radiation protection; time distance and shielding; internal radiation protection; health physics instrumentation; evaluation of protective measures; disposal of solid liquid and airborne radioactive waste.

Recommended Texts:

1. C.A. Jacobi and D.Q. Paris *Textbook of Radiologic Technology*, 6^{th} ed., Mosby Co., St. Louis Missouri, 1997.
2. S. C. Bushong, *Radiologic Science for Technologists: Physics, Biology and Protection*, Mosby Co., St. Louis Missouri, 2004.
3. H. Cember, *Introduction to Health Physics*, 3^{rd} ed., McGraw-Hill Inc, 1996.

PAM569 Mathematical Methods-II

Status	Optional
Credits	3
Pre-requisite	PAM507,PAM530
Course Format	Three hours of lectures per week

Random walks and partial differential equations; First order partial differential equations; Classification of PDEs, characteristics; Initial and Boundary Value problems in bounded regions; Integral transforms, Integral relations; Green's functions; Variational and other methods; Perturbation techniques; Asymptotic methods.

Recommended Texts:

1. E. Zauderer, *Partial Differential Equations of Applied Mathematics*, John Wiley & Sons, 1998.
2. J. Vaillant, *Partial Differential Equations and Mathematical Physics*, Springer Verlag, 2003.
3. G.B. Arfken and H. Weber, *Mathematical Methods for Physicists* ,Academic Press, 2000.
4. R. C. McOwen, *Partial Differential Equations: Methods & Applications*, Prentice Hall, 2002.

PAM572 Bio-Photonics

Status	Optional
Credits	3
Pre-requisite	PAM528
Course Format	Three hours of lectures per week

Optical properties of tissues with strong multiple scattering, propagation of polarized light in tissue. Light scattering methods and instruments for medical diagnosis. Time and frequency domain spectroscopy and tomography of tissues. Interferometric and speckle-interferometric methods. Optical coherence tomography, polarization-sensitive optical coherence tomography.

Recommended Texts:
1. V. Tuchin, *Tissue Optics*, SPIE, Washington, 1999.
2. M. Niemz, *Laser-Tissue Interaction*, Springer-Verlag, Berlin, 2003.

PAM578 Neutron Physics

Status	Optional
Credits	3
Pre-requisite	PAM516
Course Format	Two hours of lectures+ one credit hour lab. work per week

Neutron cross sections, experimental measurements, data libraries; Neutron sources, nuclear reactions, energetics, (α,n) and (γ, n) sources, research reactors, experimental facilities; Neutron detection, boron, lithium and helium counters; Neutron fields, neutron transport and diffusion equations, solution for standard geometries; Neutron slowing down, Nuclear resonances, spatial distributions of thermal and fast neutrons; time dependent neutron diffusion, multiplying systems, flux and spectra; slowing down parameters.

Recommended Text:
1. K. H. Beckurtz and K. Wirtz, *Neutron Physics*, Springer, 1964.
2. J. N. Marion and J. L. Fowler, *Fast Neutron Physics*, Interscience, 1963.
3. G. C. Phillips, J. B. Marrion and J. R. Risser, *Progress in Fast Neutron Physics,* Chicago University Press,1963.

PAM579 Environmental Physics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Two hours of lectures+ one credit hour lab. work per week

Structure an composition of the Atmosphere: layers, ideal gas model, temperature structure; the hydrosphere: properties, hydrologic cycle, humidity, cloud formation and rain; Winds: the Beaufort Scale, origin of winds, forces, cyclones, gradients and patterns; the Ground: soil and its properties, water flow, temperature profiles; Energy & the Environment: resources, energy production, nuclear power, renewable energy resources, energy conservation; Sound and Noise: the decibel, noise and its measurement, design of partitions; Solar Radiation and Atmosphere: the Sun, Solar energy, cycles, solar spectra, radiative energy transport, radiation balance, the Ozone layer, role of CO_2, H_2O and the Greenhouse Effect; Nuclear Pollution: biological effects, radiation protection standards, and regulatory practices, environmental radioactivity; Other Pollutants: sources, acid rains, toxic elements, agricultural chemicals, chlorofluorocarbons (CFCs), toxic gases, marine pollutants, transport of pollutants.

Recommended Texts:
1. N. Mason, and P. Hughes, *Introduction to Environmental Physics: Planet Earth, Life and Climate*, Taylor and Francis, 2001.
2. E. Boeker, and R. v. Groundelle, *Environmental Physics,* 2nd ed., Wiley, 1999.
3. J. Blunden and A. Reddish, *Energy Resources and Environment*, Hodder and Soughton, 1996.
4. L. E. Kinsler, A. R. Frey, A. B. Coppens and J. V. Sanders, *Fundamentals of Acoustics*, 3rd edition, Wiley, 2000.
5. M. Eisenbud, *Environmental Radioactivity,* McGraw-Hill, 1987.

PAM584 Non-Linear Optics

Status	Optional
Credits	3
Pre-requisite	PAM545, PAM528
Course Format	Three hours of lectures per week

Electric field and polarization, wave propagation in non-linear anisotropic media, Pockels effect and related phenomenon, second harmonic generation, parametric effects, Raman and Brillouin effect, optical Kerr effect, four wave mixing, propagation of light pulses, Solitons, non-linear effects in glass fibres.

Recommended Texts:
1. E. G. Sauter, *Nonlinear Optics*, John Wiley & Sons, NY, 1996.

2. Y. R. Shen, *The Principles of Non-linear Optics*, Wiley NY, 1984.
3. N. Blooembergen, *Nonlinear Optics*, Addison Wesley, Reading, MA, 1996.
4. R. W. Boyed, *Nonlinear Optics*, Academic Press, CA, 2000.

PAM587 Statistical Physics

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Review of thermodynamics and Statistical Mechanics. Empirical equation of state. Ideal gas laws. Van der Waal's equation. Critical Phenomenon. Hugoniot equation. Mie-Gruneisen equation. Semi-empirical theory of Gruneisen ratio. Theoretical calculations of equation of state. Exactly soluble models. Classical ideal gas. Non-interacting Fermi gas. Non-interacting Bose gas. Paramagnets. Ising model. Approximate methods. Thomson-Fermi model. Debye-Huckle theory. Statistical mechanics of Plasmas. Cluster expansions. Computer based calculations of equation of state. Methods of molecular dynamics. Monte Carlo Techniques.

Recommended Texts:

1. H. Eyring, D. Henderson, N. J. Stover and E. M. Eyring, *Statistical Mechanics and Dynamics*, John- Wiley and Sons, 1982.
2. K. Huang, *Statistical Mechanics*, John-Wiley and Sons, 1987.
3. L. D. Landau and F. M. Lifshitz, *Statistical Physics*, 3rd ed., Pergmon, 1980.

PAM590 Atomic and Molecular Physics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Hydrogen atom review: degeneracy, spin-orbit coupling and fine structure, hyperfine interactions, spectral consequences of fine structure. Electron-electron interactions: coupled angular momentum, Pauli Exclusion Principle, exchange interaction, helium energy levels, coulomb/exchange integrals, degeneracy, alkali metal energy levels. Atom - field Interactions: dipole transitions, normal and anomalous Zeeman Effect, Lande g-factor, spectral consequences of applied fields, Stark effect. Atom - atom Interactions: Van der Waals bonding, covalency, new degrees of freedom rotations and vibrations, molecular electronic spectra, experimental probes Raman and infrared spectroscopy, selection rules.

Recommended Text:

1. W. Demtroder, *Atoms, Molecules and Photons*, Springer Berlin, 2010
2. D. Budker, D. Kimball, D. DeMille, *Atomic Physics: An exploration through problems and solutions*, Oxford University Press, Oxford, 2008
3. G.W.F. Drake, *Handbook of Atomic, Molecular and Optical Physics*, Springer, Berlin, 2006
4. M. Born, *Atomic Physics*, 8th Edition, Dover Publications, New York, 1989.

PAM 604 Partial Differential Equations

Status	Optional
Credits	3
Pre-requisite	PAM 507
Course Format	Three hours of lectures per week

Derivations of different types of partial differential equations, First order partial differential equations, Classification of equations and characteristic, Initial and boundary value problem in bounded regions, Integral transforms for solving initial and boundary value problems. Mathieu differential equation. Green's functions for bounded regions.

Recommended Text:

1. E. Zauderer, *Partial Differential Equations of Applied Mathematics*, John Wiley & sons, New York, 1998.
2. R. McOwen, *Partial Differential Equations: Methods & Applications*, Prentice Hall, New Jersey 2002.
3. J. Vaillant, *Partial Differential Equations and Mathematical Physics*, Springer- Verlag, New York, 2003.
4. O. A. Ladyzhenskaya, *The Boundary Value Problem of Mathematical Physics*, Springer-Verlag, New York, 1985

PAM605 Quantum Optics-II

Status	Optional
Credits	3
Pre-requisite	PAM551
Course Format	Three hours of lectures per week

Quantum superposition, qbits, single-qbit transformation, entanglement and quantum indistinguishability, EPR argument and Bell's inequality, models for computation, Turing machines, circuits, universal quantum gates, quantum algorithms, quantum teleportation, quantum cryptography, experiments leading towards quantum computation.

Recommended Texts:

1. M. A. Nielsen and I. L. Chung, *Quantum Computing and Quantum Information*, Cambridge Univ. Press, Cambridge, 2000.
2. R. K. Brylinski and G. Chen, *Mathematics of Quantum Computation*, Chapman & Hall, London, 2002.

PAM606 Laser Physics

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Principles of lasers; population inversion, pumping processes, steady-state laser pumping, rate equations in steady-state and transient systems, laser gain saturation analysis. Optical resonators, resonator g-parameters, stability diagram, unstable and stable systems, laser modes, single mode operation. Broadening mechanisms, Q-switching, methods of Q-switching, laser beam properties. Mode locking, amplitude and frequency modulation mode locking, spatial hole burning, spectral hole burning and Lamb dip, amplification of short optical pulses, ultrashort light pulses. Some laser systems and their applications.

Recommended Texts:

1. C. Rulliere, *Femtosecond laser pulses*, Springer Science, New York, 2005
2. O. Svelto, *Principles of Lasers*, 4th Edition, Springer Science, New York, 1998
3. W. T. Silfvast, *Laser Fundamentals*, Cambridge University Press, Cambridge, 2000
4. P. E. Milonni and J. H. Eberly, *Lasers*, John-Wiley, New York, 1988.
5. J. T. Verdeyen, *Laser Electronics*, Printice Hall,
6. A. E. Seigman, *Lasers*, University Science Books, California, 1986.

PAM607 Non-Linear Dynamics in Physics

Status	Optional
Credits	3
Pre-requisite	PAM533
Course Format	Three hours of lectures per week

Dynamical systems, phase space, Poincare section, spectral analysis, Basin of attraction, bifurcation diagrams; the Logistic map, period doubling, Lyapunov exponents, entropy; Characterization of chaotic attractors; prediction of chaotic states, method of analogues, linear approximation method, modification of chaotic states; spatio-temporal chaos, intermittency; Quantum maps, chaos in non-equilibrium statistical mechanics, driven systems; inter-mode traces in the propagator for particle in the box.

Recommended Texts:

1. G. L. Baker and J. P. Gollub, *Chaotic Dynamics: An Introduction*, Cambridge Univ. Press, 1996.
2. S. Strogatz, *Nonlinear Dynamics & Chaos: With Applications to Physics, Biology, Chemistry, & Engineering*, Perseus Books Group, 2001.
3. V. B. Sheorey, *Nonlinear Dynamics and Computational Physics*, Narosa Pub. House, London, 1999.
4. S. Wagon, *Mathematica in Action*, Freeman & Co., NY, 1999.

PAM608 Advanced Fiber Optics

Status	Optional
Credits	3
Pre-requisite	PAM512/Equivalent
Course Format	Three hours of lectures per week

Fiber modes analysis using Maxwell equations and Bessel functions, single mode fibers, performance limiting factors, fiber attenuation, fiber dispersion, polarization mode dispersion, pulse compression, optical connections, optical time domain reflectometer (OTDR), fiber transmitters, erbium-doped fiber amplifiers, Raman amplifiers, optical detection techniques, and their performance, quantum limit of photo-detection, coherent detection, modern techniques for optical modulation, nonlinear Schrödinger equation, pulse propagation using Gaussian pulse, chirped-Gaussian pulse and super-Gaussian pulse, hyperbolic-secant based optical pulse solitons, bright and dark solitons.

Recommended Texts:

1. J. M. Senior, *Optical Fiber Communications:* Principle and Practice, 3rd ed., Prentice Hall, New Jersey, 2009.
2. G. Keiser, *Optical Fiber Communications*, 5th ed. McGraw Hill, New York,, 2013.
3. G. P. Agrawal, *Nonlinear Fiber Optics*, 5th ed., Academic Press, New York, 2012.
4. Y. S. Kivshar and G. P. Agrawal, *Optical Solitons: From Fibers to Photonic Crystals*, Academic Press, New York, 2003.

NE608 Neutron Transport Theory

Status	Optional
Credits	3
Pre-requisite	PAM578
Course Format	Three hours of lectures per week

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

Recommended Texts:

1. J. J. Duderstadt and W. R. Martin, *Transport Theory*, John Wiley, 1979.
2. G. I. Bell and W. R. Martin, *Nuclear Reactor Theory*, Van Nostrand, 1970.
3. K. M. Case and P. E. Zweifel, *Linear Transport Theory*, Addison-Wesley, 1967.
4. R. J. Stamm'ler and M. J. Abbate, *Methods of Steady State Reactor Physics in Nuclear Design,* Academic, 1983.

PAM609 Advanced Quantum Mechanics

Status	Compulsory
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

The Schrodinger, Heisenberg, and Interaction pictures, propagators and Feynman Path Integrals, Lipmann-Schwinger equation, The S-Matrix, The Optical theorem, Quantum Interference Phenomena: Aharonov-Bohm effect, Relativistic quantum mechanics, Dirac equation, Relativistic hydrogen atom, Spin and its magnetic moment, Spin-orbit coupling revisited.

Recommended Texts:

1. J. J. Sakurai, *Modern Quantum Mechanics*, Revised Edition, Pearson, Publication, 2004.
2. P. M. Dirac, *Quantum Mechanics*, 4th Edition Oxford Science Publication, 1982.
3. J. J. Sakurai, *Advanced Quantum Mechanics*, Addison-Wesley, 1985.
4. R. Shanker, *Principles of Quantum Mechanics*, 2nd edition, Springer-Verlag, 1994.
5. Fayyazuddin and Riazuddin, *Quantum Mechanics*, World Scientific Publishing, 1990.

PAM610 Simulations in Statistical Physics

Status	Optional
Credits	3
Pre-requisite	PAM587
Course Format	Three hours of lectures per week

Introduction, basic notations, phase transition, ergodicity and broken symmetry, fluctuations, Ising model, probability, non-equilibrium and dynamics; Sampling and Monte Carlo methods, percolations, random walks; Importance sampling Monte Carlo, spin-flip sampling, discrete variable models, spin-exchange sampling, micro-canonical methods, ensambles, statics and dynamics of polymer models; Lattice systems, cluster flipping methods, specialized techniques, classical spin models, systems with quenched randomness, free energy and entropy sampling, Off-lattice models, fluids, short- and long-range forces, adsorbed monolayers, complex fluids, polymers, configurational bias and smart Monte Carlo methods.

Recommended Texts:

1. D. P. Landau, Kurt Binder, *A Guide to Monte Carlo Simulations in Statistical Physics*, Cambridge, 2000.
2. M. E. J. Newman, G. T. Barkema, *Monte Carlo Methods in Statistical Physics*, Oxford Univ. Press, 1999.

PAM612 Nonlinearities in Fibre Optics

Status	Optional
Credits	3
Pre-requisite	PAM553
Course Format	Three hours of lectures per week

In-depth analysis of chromatic dispersion using Taylor's series, Sellmeier equation, normal and anomalous dispersion regimes, pulse propagation equation for single mode fiber, split-step Fourier method, in-depth analysis of group velocity dispersion using Gaussian pulses, chirped Gaussian pulses, hyperbolic-secant pulses, and super-Gaussian pulses, exponential pulse etc., dispersion management, optical amplifiers, fiber nonlinearities, self-phase modulation, interaction of self-phase modulation and group velocity dispersion, self steepening effect, modulation instability, solitons, stimulated Raman scattering, stimulated Brillouin scattering, other nonlinear effects, computer simulations for pulse evolution behavior.

Recommended Texts:
1. G. P. Agrawal, *Nonlinear Fiber Optics*, Academic Press, 2006
2. G.P. Agrawal, *Fiber-Optic Communication Systems,* John Wiley & Sons, 2005
3. Y. S. Kivshar, *Optical Solitons* Academic Press, 2003

PAM618 Plasma Physics-II

Status	Optional
Credits	3
Pre-requisite	PAM523
Course Format	Three hours of lectures per week

Basic requirements of ICF. Laser plasma interaction. Ablation physics. Hydrodynamic compression. Energy transport. Introduction to non-linear plasma theory. Quasi-linear theory. Conservation of particles, momentum and energy. Coherent three waves interaction. Three wave interaction with random phase. Non-linear Landau damping. Shielding of a moving test charge. Electric field fluctuations in Maxwellian and non-Maxwellian plasmas. Emission of electrostatic waves. Electromagnetic fluctuations and radiations. Scattering of incoherent radiation from plasma density fluctuations. Emission of radiation from a plasma. Black-body radiation. Cyclotron radiation. The source theory of radiation from a plasma.

Recommended Texts:
1. J. J. Duderstadt and G. A. Mosses, *Inertial Confinement Fusion*, John-Wiley and Sons, 1982.
2. M. O. Hagler and M. Kristiansen, *An Introduction to Controlled Thermonuclear Fusion*, Lexington, 1977.
3. A. Hasegawa, *Plasma Instabilities and Non-linear Effects*, Springer-Verlag, 1975.
4. N. A. Krall and A. W. Travelpiece, *Principles of Plasma Physics*, McGraw Hill, 1986.

NE624 Thermonuclear Engineering

Status	Optional
Credits	3
Pre-requisite	PAM523
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; Achievements 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 design of reactor systems; the Tokamak reactor; the magnetic mirror reactor; the laser driven reactor; economics of fusion and future prospects.

Recommended Texts:
1. T. Reader et al., *Controlled Nuclear Fusion: Fundamentals of its Utilization for Energy Supply*, John Wiley, 1986.
2. W. M. Stacey Jr, *Fusion and Technology: An Introduction to the Physics and Technology of Magnetic Confinement Fusion*, John Wiley, 1984.
3. T. Kammash, *Fusion Reactor Physics*, Ann Arbor, 1977

PAM625 Special Topics in Physics-I

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

This is a course on advances in Physics not already covered in the syllabus. This special paper may be conducted as a lecture course or as an independent study course. The topic and contents of this paper must be approved by the BOS, PIEAS.

PAM626 Special Topics in Physics-II

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

This is a course on advances in Physics not already covered in the syllabus. This special paper may be conducted as a lecture course or as an independent study course. The topic and contents of this paper must be approved by the BOS, PIEAS.

PAM631 Photodynamic Therapy

Status	Optional
Credits	3
Pre-requisite	PAM 606
Course Format	Three hours of lectures per week

Principles of PDT, Mechanisms of PDT, Cell structure and functions: Transport across the membrane, Cell signaling, molecular pathways in cell death, Cellular and molecular biology of cancer, cytoprotective mechanisms in PDT, molecular mechanisms regulating protoporphyrin synthesis and PDT efficacy, Molecular and cellular mechanisms of the immune response induced by the PDT, cellular and molecular mechanisms of photodynamic injury of nerve cells, sensitizers for PDT and imaging, photophysics and photochemistry in PDT, combining PDT with antiangiogenic therapy, technologies and biophysical techniques for PDT, nano particles in PDT and factors in the establishment and spread of PDT.

Recommended Text:

1. M. P. Goldman, *Photodynamic Therapy*, Saunders, Elsevier, 2nd Edition, 2008.
2. A. B. Uzdensky, *Photodynamic therapy at the cellular level*, Research Signpost, 2007.
3. H. Masuhara, S. Kawata and F. Tokunaga, *Nano biophotonics Science and Technology*, Elsevier, Amsterdam, 2007.
4. R. D Bookers, E. Boysen, *Nanotechnology*, Wiley Publishing, Indiana, 2005.
5. D. M. Terrian, *Cancer cell signaling Methods and Protocols*, Humana Press. New York, 2003.
6. W. M. Saltzman, *Drug Delivery*: *Engineering Principal for drug therapy*. Oxford University Press, Oxford, 2001.

PAM633 Polarization Imaging

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Polarization Ellipse, Stokes polarization parameters, Mueller matrices for polarization components, Methods of measuring stokes parameters, Measurement of characteristics of polarization, Elements, Mathematics of Mueller matrices, Jones matrices, Poincare sphere, Fresnel Arago interference laws, optical activity and Faraday rotation, Stokes Polarimeter, Mueller Matrix Polarimeter, Ellipsometry, General Imaging Systems, Polarisation based imaging systems, Scope and application of polarization imaging techniques.

Recommended Text:

1. D. Goldstein, *Polarized Light*, Crc Pr I Llc; 3rd edition 2010.
2. E. Wolf, *Introduction to the theory of coherence and polarization of Light*, Cambridge University Press, 2007
3. V. V. Tuchin, L. Wang and D. A. Zimnyakoy, *Optical Polarization in Biomedical Applications*, Springer, New York, 2006.
4. R.M.A. Azzam and N.M. Bashara, *Ellipsometry and Polarized Light*, North Holland, 1988.

PAM658 Advanced Computational Condensed Matter Physics

Status	Optional
Credits	3
Pre-requisite	PAM533
Course Format	Three hours of lectures per week

Scattering theory, quantum scattering, calculation of cross-sections; Variational techniques, solution of generalized eigen-value problem; Hartree-Fock method, the helium atom, many electron system, Slater determinants; Density functional theory, local approximation, exchange and correlation, applications; Molecular dynamics simulations, molecular systems, Langevin dynamics, ensembles and symplectic integrators, quantum molecular dynamics; Stochastic techniques; quantum Monte Carlo: variational, diffusion, path-integral, Lattice; The Finite Element Method and partial differential equations; Applications.

Recommended Texts:

1. J. M. Thijssen, *Computational Physics*, 2nd Edition, Cambridge, 2007.
2. M. H. Kalos, P.A. Whitlock, *Monte Carlo Methods*, 2nd Edition, Wiley-VCH Verlag, 2008.
3. N.J. Giordano, H. Nakanishi, *Computational Physics*, 2nd Edition, Prentice Hall, 2006.
4. R. H. Landau, M. J. Páez, C. C. Bordeiano, *Computational Physics, Problem Solving with Computers*, 2nd Edition, Wiley, 2007.
5. W. R. Gibbs, *Computations in Modern Physics*, 3rd Edition, World Scientific, NY, 2006.

PAM690 Seminar Project

Status	Optional
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

This course is intended for a study of some physics problem. The student may join some on-going research program or initiate a new program in close cooperation with a faculty member. The faculty member will instruct, supervise and guide the conduct of this study with the student. He is charged with the primary responsibility of reporting the grade based on the evaluation of the performance of the fellow. He may be aided in the process of evaluation by a panel of examiners to be appointed by the head of the department. A project report and seminar are to be given by the student before the end of the semester.

PAM698 MS Thesis Research

Status	Compulsory
Credits	24
Pre-requisite	Nil
Course Format	Full time research for two semester

Two semesters are reserved for MS Thesis Research on full time basis. The student will undertake an in-depth study of a research problem in the fourth semester which will be continued in the fifth semester. This nature of Research can be theoretical and/or experimental. Each student shall complete the Thesis Research under the guidance of a Thesis Supervisor. A co-supervisor may also be assigned depending on the nature of the work involved. The work carried out by the student will be evaluated by the Project Supervisor (and Co-Supervisor, if any). Their evaluation will be aided by a panel of examiners, preferably from outside, appointed by the Head of the department in consultation with the Project Supervisor and Co-Supervisor. The student shall submit a comprehensive report and shall deliver at least one seminar before the completion of the Thesis Research and defend the thesis before the panel of examiners and the Thesis Supervisor, Co-Supervisor. At the end of the Thesis Research, the overall grade for research work performed will be given as A, B, C or D.

MS (Physics)

Semester-wise Layout of Courses
(Revision January 2015)

SPRING SEMESTER				
1	PAM507	Mathematical Physics	3	C
2	PAM508	Classical & Relativistic Mechanics	3	C
3	PAM512	Electrodynamics	3	C
4	PAM609	Advanced Quantum Mechanics	3	C
5	NE-501	Fundamental of Nuclear Engineering*	3	O
SUMMER SESSION				
6	NE-605	Radiation Shielding*	3	O
7	PAMxxx	Optional-1	3	O
FALL SEMESTER				
8	PAM587	Statistical Physics	3	C
9	PAM546	Graduate Physics Laboratory	3	C
10	PAMxxx	Optional-2	3	O
11	NE510 OR NE507	Nuclear Power Plant System* OR Radiological Engineering*	3	O
12	CMS501	Communication Skills	1	C
SPRING SEMESTER				
15	PAM698	MS Thesis Research	12	C
SUMMER SEMESTER				
16	PAM698	MS Thesis Research	12	C

Student has to take two optional courses from the fields of Computational Physics, Laser Physics, Plasma Physics or Radiation Physics.

* The contents of these courses are provided in the course contents of MS DNE Program.