MS Physics Course Revision 2022

Department of Physics and Applied Mathematics
Pakistan Institute of Engineering and Applied Sciences

DPAM's MS Physics Courses and Fields of Specialization

Minimum Requirement: 46 credit hours (For Fellowship program) and 37 credits hours (For RFB Students) of course work including 12 credit hours of thesis research work

Sr. No.	Code	Course Title	Cr. Hrs	Status	Pre-requisites
1	PAM504	Radiation Detection and Protection	3	C	-
2	PAM507	Mathematical Physics	3	C	-
3	PAM508	Classical & Relativistic Mechanics	3	C	-
4	PAM510	Statistical Physics	3	C	-
5	PAM511	Modern Quantum Mechanics	3	C	-
6	PAM512	Electrodynamics	3	C	-
7	PAM516	Advanced Nuclear Physics	3	O	-
8	PAM523	Plasma Physics-I	3	O	-
9	PAM527	General Relativity and Cosmology-I	3	O	PAM508
10	PAM530	Mathematical Methods–I	3	O	PAM507
11	PAM533	Computational Physics	3	O	-
12	PAM534	Physics Simulation	3	O	-
13	PAM546	Graduate Physics Laboratory	3	C	-
14	PAM601	Fourier Optics	3	O	-
15	PAM602	Fiber Optics	3	O	-
16	PAM603	Particle Physics–I	3	O	PAM511
17	PAM604	Partial Differential Equations	3	O	PAM507
18	PAM606	Laser Physics	3	O	-
19	PAM607	Non–linear Dynamics in Physics	3	O	PAM533
20	PAM608	Advanced Fiber Optics	3	O	PAM512/Equivalent
21	PAM610	Simulations in Statistical Physics	3	O	PAM510
22	PAM612	Nonlinearities in Fiber Optics	3	O	PAM602
23	PAM614	Integrated Circuit Fabrication Processes	3	O	-
24	PAM615	Radiation Physics–I	2+1	O	-
25	PAM616	Mathematical Methods–II	3	O	PAM530
26	PAM617	Quantum Field Theory–I	3	O	PAM508
27	PAM618	Plasma Physics–II	3	O	PAM523
28	PAM619	Nanomaterial Physics	3	O	-
29	PAM620	Bio–Photonics	3	O	-
30	PAM621	Quantum Field Theory–II	3	O	PAM617
31	PAM622	Neutron Physics	2+1	O	PAM516
32	PAM623	Special Topics in Physics	3	O	-
33	PAM624	Accelerator Physics and Applications	3	O	-
34	PAM627	Particle Physics–II	3	O	PAM603
35	PAM631	Photodynamic Therapy	3	O	PAM606
36	PAM632	Superconducting Radio Frequency Technology	3	O	PAM512
37	PAM633	Polarization Imaging	3	O	PAM512
38	PAM634	Atomic and Molecular Physics	3	O	NIL
39	PAM635	Microwave Physics and Techniques	3	O	PAM512
40	PAM636	Semiconductor Physics	3	O	NIL
41	PAM637	General Relativity and Cosmology-II	3	O	PAM527
42	PAM638	Advanced Topics in Physics	3	O	PAM511
43	PAM640	Radiation Physics–II	2+1	O	PAM615
44	PAM641	Quantum Optics	3	O	-
45	PAM642	Statistical Methods for Data Analysis in Physics	3	O	PAM510
46	PAM643	Quantum Condensed Matter Physics	3	O	PAM511
47	PAM644	Particle Detectors and Electronics	3	O	PAM512
48	PAM645	Quantum Computation and Information	3	O	PAM641
49	PAM646	Beam Physics	3	O	-
50	PAM647	Non–linear Optics	3	O	-
51	PAM648	Experimental Techniques of Physics	3	O	-
52	PAM650	Computation in Accelerator Physics	3	O	PAM646
53	PAM658	Advanced Computational Condensed Matter Physics	3	O	PAM533
54	PAM690	Seminar Project	3	O	-
Fourth and Fifth Semesters					
55	PAM698	MS Thesis Research *	12	C	-

C stands for **C**ompulsory and **O** stands for **O**ptional

* Grade: Excellent, Very Good, Good, Fair, Satisfactory and Unsatisfactory will be awarded.

Specialization	Related Courses
Accelerator Physics	PAM624-Accelerator Physics and Applications, PAM646-Beam Physics, PAM627-Particle Physics–II, PAM650-Computation in Accelerator Physics, PAM632-Superconducting Radio Frequency Technology, PAM635-Microwave Physics and Techniques, PAM602-Fiber Optics, PAM644-Particle Detectors and Electronics
Condensed Matter Physics	PAM533- Computational Physics, PAM614- Integrated Circuit Fabrication Processes, PAM636- Semiconductor Physics, PAM619-Nanomaterial Physics, PAM648- Experimental Techniques of Physics, PAM642- Statistical Methods for Data Analysis in Physics, PAM643-Quantum Condensed Matter Physics, PAM658- Advanced Computational Condensed Matter Physics
Computational Physics	PAM534-Physics Simulation, PAM616- Mathematical Methods–II, PAM607- Non–linear Dynamics in Physics, PAM610- Simulations in Statistical Physics, PAM658- Advanced Computational Condensed Matter Physics
High Energy Physics	PAM527- General Relativity and Cosmology-I, PAM603- Particle Physics–I, PAM617- Quantum Field Theory–I, PAM621- Quantum Field Theory–II, PAM624- Accelerator Physics and Applications, PAM627-Particle Physics–II, PAM643- Quantum Condensed Matter Physics
Laser Physics	PAM601- Fourier Optics, PAM602- Fiber Optics, PAM641- Quantum Optics, PAM645- Quantum Computation and Information, PAM620-Bio–Photonics, PAM647- Non–linear Optics, PAM606- Laser Physics, PAM612- Nonlinearities in Fiber Optics, PAM 633- Polarization Imaging
Plasma Physics	PAM523- Plasma Physics-I, PAM534- Physics Simulation, PAM606-Laser Physics, PAM607- Non–linear Dynamics in Physics, PAM618-Plasma Physics–II
Radiation Physics	PAM504- Radiation Detection and Protection, PAM516- Advanced Nuclear Physics, PAM615- Radiation Physics–I, PAM640- Radiation Physics–II, PAM622- Neutron Physics

MS Physics
Semester wise Layout of Courses
(Revisions 2022)

Spring Semester (Semester 1)				
1	PAM507	Mathematical Physics	3	C
2	PAM508	Classical & Relativistic Mechanics	3	C
3	PAM512	Electrodynamics	3	C
4	PAM511	Modern Quantum Mechanics	3	C
5	NE501	Fundamental of Nuclear Engineering*	3	C
6	CMS501	Communication Skills	1	IR
7	CMS111	Grooming and Sprucing-1	NC	IR
Summer Session (Semester 2)				
8	PAM504	Radiation Detection and Protection*	3	C
9	PAM xxx	As per departmental Recommendations*	3	C
Fall Semester (Semester 3)				
11	PAM587	Statistical Physics	3	C
12	PAM546	Graduate Physics Laboratory	3	C
13	PAM xxx	Optional	3	O
14	PAM xxx	Optional	3	O
15	CMS512	Grooming and Sprucing-II	NC	IR
Spring Semester & Summer Semester (Semester 4 & 5)				
16	PAM698	MS Thesis Research-I	12	C

C stands for Compulsory Course, O stands for Optional, NC stands for none credit and IR for institute Requirement.
**These Courses are compulsory for all students on fellowship program.*

A minimum of 37 credit hours (25 CH of course work, 12 CH of Thesis Research) are required for the award of degree. For PAEC/other fellowships additional 9 CH course as mentioned above must be taken as well.

PAM504 Radiation Detection and Protection

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:

Interaction of radiation with matter, Basic principles of radiation detection; ionization chambers, Proportional and Geiger-Muller counters: Various types of Scintillation detectors; Radiation spectroscopy using Scintillation detectors: Semiconductor detectors; CdZnTe detectors, Neutron detection techniques. Basic electronic circuits and electronic equipment used in nuclear radiation detection systems; Probability distributions (discrete & continuous); Counting statistics. Radiation quantities & units, Safety standards for medical exposure, Principles & control of externa1 & internal exposure hazards, absorbed dose estimation from external exposure, Shielding design of neutron and gamma sources, Dose estimation from internally deposited radionuclides, IAEA Safety regulations for transport of radioactive materials, Radiation accident management & early medical treatment of radiation injury, Radioactive waste disposal methods, Calibration of survey meters

Book Recommendations:

1. Knoll G. F. Radiation Detection & Measurements, 4^{th} Ed., John Wiley and Sons, 2010.
2. Cember, H., Introduction to Health Physics, 4th Ed., Pergamon Press, 2008.
3. Martin, A. and Harbison, S., An Introduction to Radiation Protection, 7th Ed., RC Press, 2018.
4. Lamarsh, J. R. Introduction to Nuclear Engineering, 4th Ed., Addison-Wesley, 2017.

PAM507 Mathematical Physics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:

Vector and tensor calculus, Green's and Stoke's theorems, contra-, covariant- and metric tensors, diagonalization tensors for eigenvalue problems, Special Functions: Bessel's and Legendre's Functions, generating functions. Green's functions, Gamma Function, Hypergeometric functions, Elliptic functions, periodic functions, Sturm-Liouville theory of orthogonal functions, Integral Transforms, Fourier series, (separable partial differential equations, classical partial differential equations, Heat equation, Wave equation, Laplace's equation, Boundary value problems, Complex algebra, Infinite series, expansions, singularities, contour integration and Cauchy's theorem, residues; Convolution integrals.

Book Recommendations:

1. G. B. Arfken, H. J. Weber and F. E. Harris, Mathematical Methods for Physicists, 7th Ed, Academic Press, 2012.
2. D. G. Zill, Advanced Engineering Mathematics, 6th Ed, Jones and Bartlett, 2018.
3. P. Dennery and A. Krzywicki, Mathematics for Physicists, Dover, 2012.

4. R. V. Churchill, Complex Variables and Applications, 7th Ed., McGraw Hill, 2003.
5. R. Courant and D. Hilbert, Methods of Mathematical Physics, vol. 1, Wiley, NewYork, 1989.
6. P. Dennery and A. Krzywicki, “Mathematics for Physicists,” Harper and Row, 1996.
7. K. F. Riley, M. P. Hobson, and S. J. Bence, Mathematical Methods for Physics and Engineering, Cambridge, 1999.

PAM508 Classical and Relativistic Mechanics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

1. Herbert Goldstein, Charles P. Poole and John Safko, Classical Mechanics, 3rd Edition, Pearson Education, 2011
2. Sadri Hassani, Special Relativity: A Heuristic Approach, Elsevier Science, 2017
3. L.D. Landau and E. M. Lifschitz, Mechanics, 3rd Edition, Elsevier, Reprinted 2005
4. J. B. Marion, Classical Dynamics of Particles and Systems, Academic Press, 2013

PAM510 Statistical Physics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Thermodynamic variables, thermodynamic limit, thermodynamic transformations. Classical ideal gas, first law of thermodynamics, application to magnetic systems, heat and entropy, Carnot cycle. Second law of thermodynamics, absolute temperature, temperature as integrating factor, entropy of ideal gas. Conditions for equilibrium, Helmholtz free energy, Gibbs potential, Maxwell relations, chemical potential. First-order phase transition, condition for phase coexistence. The statistical approach: phase space, distribution function, microcanonical ensemble, the most probable distribution, Lagrange multipliers. Maxwell-Boltzmann distribution, Transport phenomena. Quantum statistics: thermal wavelength, identical particles, Fermi and Bose statistics, pressure,

entropy, free energy, equation of state, Fermi gas at low temperatures, application to electrons in solids and white dwarfs. The Bose gas: photons, phonons, Debye specific heat, Bose-Einstein condensation, equation of state, liquid helium. Canonical and grand canonical ensembles, partition function, connection with thermodynamics, fluctuations minimization of free energy, photon fluctuations, pair creation.

Book Recommendations:

1. Swendsen, Robert (2012).,An Introduction to Statistical Mechanics and Thermodynamics. Oxford University Press.
2. Gould, Harvey and Tobochnik, Jan (2010) Statistical and Thermal Physics. Princeton University Press.
3. Introduction to Statistical Physics, Kerson Huang, (Taylor and Francis, 2001).
4. Statistical Mechanics, Raj Kumar Pathria, second edition (India, 1996).

PAM511 Modern Quantum Mechanics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Stern-Gerlach Experiment, bra-ket and matrix representation, The Schrodinger, Heisenberg, and Interaction pictures, Concept of classical paths, principle of least action, introduction to path integral, propagators and Feynman Path Integrals, Time independent perturbation theory, Time dependent perturbation theory, Scattering theory: The S-Matrix, The Optical theorem, partial wave approximation, scattering resonance, Quantum Interference Phenomena, adiabatic approximation, Aharonov-Bohm effect, Berry Phase in atomic and condensed matter systems, Quantum Hall effect, topological insulators, Relativistic quantum mechanics, Dirac equation, Fine structure and Zeeman effect, spin-orbit interaction and relativistic correction.

Book Recommendations:

1. J. J. Sakurai, Jim Napolitano, Modern Quantum Mechanics, Cambridge University Press, 2017
2. P. A. M. Dirac, The Principles of Quantum Mechanics, Lulu Press, Inc, 2019
3. J. J. Sakurai, Advanced Quantum Mechanics, Addison-Wesley, 1985
4. R. Shanker, Principles of Quantum Mechanics, 2nd Edition, Springer Science & Business Media, 2012
5. Riazuddin, Fayyazuddin, Quantum Mechanics, 2nd Edition, World Scientific Publishing Company, 2012
6. A Guide To Feynman Diagrams In The Many-body Problem, Richard D. Mattuck, (Dover, 1992)

PAM512 Electrodynamics

Course Status: Compulsory

Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:

Electric field; Dirac delta-functions; Gauss' Law; potential; field energy; Poisson and Laplace equations; Green's functions approach for electrostatic problems; Method of Images; Electrostatic potential with and without azimuthal symmetry; Multipoles, polarization, susceptibility, and dielectrics; Boundary value problems; Molecular polarizability; Dielectric electrostatic energy; Magneto statics: Biot-Savart Law, Ampere's Law, Magnetic Vector Potential, magnetic moment; Forces on current distributions; magneto statics problems. Faraday's Law; Maxwell's displacement current; Vector and scalar potentials; Gauge transformation; wave equation; Magnetic field energy; EM field energy and momentum conservation, Harmonic EM fields; energy conservation; Plane electromagnetic wave propagation, energy, polarization, Reflection, refraction, total internal refraction at an interface; Propagation with dispersion, absorption, conductivity; Plane waves in conductors and dielectrics

Book Recommendations:

1. J. D. Jackson, Classical Electrodynamics, 3rd Edition, John-Wiley and Sons, 1998
2. Anupam Garg, Classical Electromagnetism in a Nutshell, Princeton University Press, 2012
3. James B. Westgard, Electrodynamics: A Concise Introduction, Springer, 1997 Edition, Reprinted 2011
4. Landau and Lifshitz, The Classical Theory of Fields, Butterworth-Heinemann; 4th Edition, 1980
5. D.J.Griffiths, Introduction to Electrodynamics, 5th Edition, Pearson, 2017
6. Jonathan W. Keohane and Joseph P. Foy, An Introduction to Classical Electrodynamics, Maricourt Academic Press, 2018
7. Kurt Lechner, Classical Electrodynamics: A Modern Perspective, 1st Edition, Springer, 2018

PAM516 Advance Nuclear Physics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:

Atomic Nucleus; nuclear properties, symmetries of the nuclear Hamiltonian, deuteron, 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.

Book Recommendations:

1. Kenneth S. Krane, Introductory Nuclear Physics, Wiley India, 2008
2. Jose M. Arieas, M. Lozano eds., An Advanced Course in Modern Nuclear Physics,

Springer-Verlag Berlin Heidelberg, 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

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:

Introduction to Plasmas, Characteristic Scales in a Plasma, Single Particle Motion in Constant Uniform Fields, Multiple Timescale Methods, Particle Motion in Constant, Nonuniform Magnetic Fields, Magnetic Moment and the Mirror Force, Particle Motion in Temporally Varying Magnetic Fields and Adiabatic Invariance, Computational Methods for Plasma Physics, Particle Motion in Slowly Varying Electric Fields and Polarization Drift, The Ponderomotive Force, Collisions and Resistivity, Kinetic Description of a Plasma, Moment Equations, The Two Fluid Equations, The Magneto hydrodynamic (MHD) Equations, The Frozen-in Flux Theorem, Magnetic Diffusion and Intro to MHD Waves, MHD Waves: Alfven, Fast, and Slow Waves; Validity of MHD approximation, Conservation of energy in ideal MHD, MHD Wave Observations and MHD Equilibria, Force-Balanced MHD Equilibria, Waves in a Cold, Un-magnetized Plasma, Properties of Waves in Cold, Un-magnetized Plasmas, Cold vs. Warm Un-magnetized Plasma Waves, Controlled Thermonuclear Fusion.

Book Recommendations:

1. F. Chen, Plasma Physics and Controlled Fusion, 3rd Edition, Springer International Publishing Switzerland, 2018
2. D. Gurnett and A. Bhattacharjee, Introduction to Plasma Physics with Space and Laboratory Applications, Cambridge University Press, 1st Edition, 2005
3. T.J.M. Boyd and J.J. Sanderson, The Physics of Plasmas, Cambridge University Press, 2003
4. R.D. Hazeltine and F.L. Waelbroeck, The Framework of Plasma Physics, CRC Press, 2004
5. N.A. Krall and A.W. Trivelpiece, Principles of Plasma Physics, McGraw-Hill, 1973
6. D.R. Nicholson, Introduction to Plasma Theory, Wiley, 1983

PAM527 General Relativity and Cosmology

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM508
Course Format: 03 hours of lectures per week

Course Contents:

Introduction to pre-Einstein relativity, Einstein's Principle of Relativity and a new Concept of Space time (Minkowski), space time diagrams, Relativistic Kinematics including Relativistic

Momentum and Energy, Four Vectors and Lorentz Transformation with its properties, Electromagnetism, 4-current density, EM field equations and Lorentz gauge, Electric and magnetic fields in inertial frames, Electromagnetism in arbitrary coordinates, Equation of motion for a charged particle. Elements of differential geometry (including manifolds and coordinates, curvature, differential forms etc.), General Relativity: Einstein's Theory of Gravity, Einstein's field equations (basic), Schwarzschild black holes (basic idea of spherically symmetric solution), Concept of Gravitational waves and its detection.

Book Recommendations::

1. Spacetime and Geometry by Sean Carroll, Pearson Education Limited (2014)
2. General Relativity: An Introduction for Physicists" by M. P. Hobson, George Efstathiou, Anthony N. Lasen by, Cambridge (2006).
3. Gravity: An Introduction To Einstein'S General Relativity" by James Hartle, Pearson (2003)
4. Theory of Relativity" by Fayyazuddin, Riazuddin and M. Jamil Aslam, World Scientific (2015)
5. Gravitation: Foundations and Frontiers by T. Padmanabhan, Cambridge (2010)

PAM530 Mathematical Methods-I

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM507
Course Format: 03 hours of lectures per week

Course Contents:
Vector and Tensor Analysis: Vectors in 3D spaces, Coordinate Transformations, Differential Vectors Operators, Vectors Integration, Potential Theory, Tensors in General coordinates, Differential forms, Integrating forms, Vector Spaces: Vectors in function Spaces, Operators and their transformations, Invariants. Eigenvalue Problems, Ordinary Differential Equations: First and Second Order Ordinary Differential Equations, Series Solutions- Frobenius Method, Strum Liouville Theory, Special Functions: Bessel Functions, Legendre Function, Chebyshev Polynomials, Hermite Functions, Lagueree function, Hypergeometric Functions, and Elliptic Integrals.

Book Recommendations:

1. George B. Arfken, Hans J. Weber, Frank E. Harris, Mathematical Methods for Physicists: A Comprehensive Guide, 7th Edition, Academic Press, 2013
2. R. Courant and D. Hilbert, Methods of Mathematical Physics, Volume 1, Wiley-VCH, 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

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil

Course Format: 03 hours of lectures per week

Course Contents:
Linear algebra: Exact methods, iterative methods, eigen-values and eigenvectors; Initial and Boundary value problems; Partial differential equations. Stochastic Methods: deterministic randomness, tests for randomness, random walks, equi-distribution, transformation of probability densities, rejection methods, multivariate distributions; random sequences, Markov chains, Gaussian Markov sequence, Wiener-Levy process, Deterministic and Stochastic Optimization, Simulated annealing, Genetic Algorithms.

Book Recommendations:

1. M. Newman, Computational Physics, 2nd Edition, CreateSpace Independent Publishing Platform, 2012
2. L. Garcia, Numerical Methods for Physics, 2nd Edition, CreateSpace Independent Publishing Platform; 2015
3. R. H. Landau, M. J. Paez and C. C. Bordeianu, Computational Physics: Problem Solving with Python, 3rd edition, Wiley-VCH 2015
4. G. Bohm and G. Zech, Introduction to Statistics and Data Analysis for Physicists, 3rd Revised Edition, Verlag Deutsches Elektronen-Synchrotron, 2017
5. T. Pang, An Introduction to Computational Physics, 2nd Edition, Cambridge University Press, 2006
6. W. L. Dunn and J. K. Shultis, Exploring Monte Carlo Methods, Elsevier, USA, 2012
7. Franz J. Vesley, Computational Physics-An Introduction, Kluwer Academic Publishers, N. Y. 2001
8. N. J. Giordano, Computational Physics, Prentices Hall, 2001

PAM534 Physics Simulations

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

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, 3rd Edition, John Wiley, 2016

3. S. M. Ross, Simulation, 5th Edition, Elsevier Academic Press, 2013
4. R. L. Zimmerman, F. I. Olness, Mathematica for Physics, 2nd Edition, Addison Wesley, 2002.

PAM546 Graduate Physics Laboratory

Course Status: Optional
Credits hours: 0+3
Pre-requisite: Nil
Course Format: 09 contact hours per week

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

1. Determination the wavelength of diode laser.
2. Determination of coherence length of He-Ne Laser using Michelson Interferometer.
3. Determination of Refractive index gradient and diffusion coefficient of salt solution from laser deflection measurement.
4. Magnetic permeability of water.
5. Investigation of the profile of the rotating liquid's surface and the determination of the acceleration due to gravity.
6. Study of the birefringence of mica
7. Experiment for studying the optical anisotropy.
8. Experiment to investigate the electrical and thermal properties of LEDs.
9. Experiment to investigate the properties of capacitors.
10. Determination of the range of alpha-particles in air using SSNTDs
11. Study of etching parameters and critical angle for etching for SSNTDs
12. Determination of Alpha-to-fission ratio of Cf-252 source using SSNTDs
13. Absolute alpha-source strength measurements using SSNTDs.
14. Determination of neutron fluence and personal dosimetry using SSNTDs
15. Use of SSNTDs for environmental radon level measurements
16. Nuclear lifetime measurements using TPHC technique.
17. Study of isotopic composition using neutron activation analysis.
18. Neutron cross section measurements using transmission method
19. Study of decay scheme and angular correlation of Co-60.
20. Study of Rutherford scattering of alpha-particles from thin foils.
21. Charged particle spectrometry and decay ratios of Am-241 using surface barrier detectors.
22. Study of Compton scattering and determination of scattering cross section
23. Neutron diffusion parameter studies using BF3 detector.
24. Absolute activity measurement using coincidence technique.
25. Measurement of radioactive half lives using counting technique.
26. Interferometry Measurement of Resonant Absorption and Refractive Index in Rubidium

27. Measuring the Hyperfine Levels of Rubidium Using Saturated Absorption Spectroscopy
28. Determination of activation energy of semiconducting materials using current-voltage characteristics at different temperature

Book Recommendations:

1. Lab Manuals

PAM601 Fourier Optics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

1. Joseph W. Goodman, Introduction to Fourier Optics, 4th Edition, McGraw-Hill, New York, 2017
2. Keigo Eizuka, Engineering Optics, Springer-Verlag, 4th Edition, Berlin, 2019
3. Xiangang Luo, Engineering Optics 2.0: A Revolution in Optical Theories, Materials, Devices and System, Springer, 2019

PAM602 Fiber Optics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Optical fibers, optical fiber as communication channels, fibers transmission characteristics, signal degradation in optical fibers, attenuation and dispersion, chromatic, material and waveguide dispersions, multimode versus single mode fibers, Maxwell’s equations and propagation of light in planer waveguides, electro-optic components, semiconductor lasers, pn, p-i-n, and avalanche photodiodes.

Book Recommendations:

1. G. Keiser, Optical Fibre Communications, McGraw-Hill, 2013
2. J. M. Senior, Optical Fiber Communications: Principle and Practice, 3rd Edition, Prentice Hall, Reprint 2011

3. P. Kumbhakar, M. K. Mandal, Photonics and Fiber Optics: Foundations and Applications, CRC Press, 2019

PAM603 Particle Physics-I

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM511
Course Format: 03 hours of lectures per week

Course Contents:

Qualitative description of the Standard Model of particle physics; Interactions of particles with matter; Underlying concepts: special relativity and non-relativistic quantum mechanics; Decay rates and cross sections: Fermi's golden rule, phase-space and wave function normalization, particle decays, interaction cross sections, differential cross sections; Klein-Gordon and Dirac equations: derivation, probability density and probability current, Dirac spinors, covariant form of the Dirac equation, solutions to the Dirac equation, antiparticles, spin and helicity states, intrinsic parity of Dirac fermions; Interaction by particle exchange: Feynman diagrams and virtual particles, quantum electrodynamics and Feynman rules; $e^- e^+$ annihilation: calculations in perturbation theory, Spin, Chirality and Trace techniques; $e^- p^+$ elastic scattering; Deep inelastic scattering: $e^- p^+$ and eq scattering, quark-parton model and parton distribution function.

Book Recommendations:

1. Thomson, M. Modern Particle Physics. Cambridge: Cambridge University Press, 2013.
2. David J. Griffiths, Introduction to Elementary Particles, Wiley-VCH, Second Revised Edition, 2008.

PAM604 Partial Differential Equation

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM507
Course Format: 03 hours of lectures per week

Course Contents:

Classification of equations and characteristics, Derivations of different types of partial differential quations, First and Second order partial differential equations (Heat Equation, Wave Equation, Laplace Equation), Initial and boundary value problems in bounded regions, Integral transforms for solving initial and boundary value problems. Integral Relations, Mathieu differential equation. Green's functions for bounded regions. Numerical Solutions of Partial Differential Equations.

Book Recommendations:

1. Erich Zauderer, Partial Differential Equations of Applied Mathematics, 3rd Edition, John Wiley & Sons, 2011
2. R. C. McOwen, Partial Differential Equations: Methods & Applications, Prentice Hall, 2002
3. J. Vaillant, Partial Differential Equations and Mathematical Physics, Springer Verlag, 2003
4. O.A. Ladyzhenskaya and J. Lohwater, The Boundary Value Problems of Mathematical

Physics, Springer Science & Business Media, 2013

PAM615 Radiation Physics-I

Course Status: Optional
Credits hours: 2+1
Pre-requisite: Nil
Course Format: 02 hours of lectures and 03 hour lab work per week.

Course Contents:
Artificial and Natural radiation sources, interaction of charge particles, photons and neutrons with matter, modes of radioactive decay, kinetics or radioactivity, radionuclide production, 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 origin and transport of radon; radon monitoring devices based on SSNTDs; neutron and radon dosimetry using SSNTDs; methods of track image enhancement; spark counters; electrical breakdown devices; scintillator-filled etch pit counting; automatic and semi-automatic image analysis; fission track dating. Experiments related to radiation physics.

Book Recommendations:

1. G. F. Knoll, Radiation Detection and Measurement, 4th Edition, Wiley, 2010
2. M. F. L'Annunziata, Handbook of Radioactivity Analysis, 3rd Edition, Academic Press, 2012.
3. S. A. Durrani and R. K. Bull, Solid State Nuclear Track Detection Principles, Methods and Applications, Pergamon, 1987.
4. R. L. Fleischer, P. B. Price and R. M. Walker, Nuclear Tracks in Solids, Univ. California Press, 1975

PAM606 Laser Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Light in Cavities, Einstein Theory of Light- Matter Interactions, Absorption, Emission, and dispersion of Light, Collision and Doppler Broadening, Absorption and Gain Coefficients, population inversion, Photon and population Rate Equations in steady-state and transient systems, Pumping Three- and Four-Level Lasers, Small-Signal Gain and Saturation gain analysis, Spatial and Spectral Hole Burning and Lamb dip, Large Output Coupling, Frequency Pulling, Polarization and Modulation, Frequency Stabilization, Multimode and Pulsed Lasing, methods of Q-switching, Multimode Laser Oscillation, Phase-Locked Oscillators, Mode locking and methods of Mode-locking, Amplification of Short Pulses, Amplified Spontaneous Emission, Ultra-short Light Pulses, Optical resonators, resonator g-parameters, stability diagram, unstable and stable systems, laser modes, single mode operation, amplification of short optical pulses, ultra-short light pulses. Optical Amplifiers, Properties of Lasing Material, Gas, chemical, free electron and x-ray Lasers, Liquid

Lasers, Solid-state lasers, Fiber Lasers, and their Applications.

Book Recommendations:

1. O. Svelto, Principles of Lasers, Springer; 5th edition, 2010
2. P. E. Milonni and J. H. Eberly, Laser Physics, John-Wiley & amp; Sons Inc. New Jersey, 5th edition, 2010.
3. C. Rulliere, Femtosecond laser pulses, Springer Science, New York, Springer; 2ndedition, 2007.
4. E. Seigman, Lasers, University Science Books, California, 1986.
5. W. T. Silfvast, Laser Fundamentals, Cambridge University Press, Cambridge, 2000 Edition, Springer Science, New York, 1998.

PAM607 Non-Linear Dynamics in Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM533
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

1. Gregory L Baker, Gregory L. Baker, Jerry P. Gollub, Chaotic Dynamics: An Introduction, Cambridge University Press, 1996
2. Steven H. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, 2nd Edition, Avalon Publishing, 2014
3. V. B. Sheorey, Nonlinear Dynamics and Computational Physics, Alpha Science Int'lLtd., 1999
4. Stan Wagon, Mathematica in Action: Problem Solving Through Visualization and Computation, 3rd Edition, Springer Science & Business Media, 2010

PAM608 Advanced Fiber Optics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM512 or Equivalent
Course Format: 03 hours of lectures per week

Course Contents:
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, optical NRZ and RZ modulation formats, 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.

Book Recommendations:

1. J. M. Senior, Optical Fiber Communications: Principle and Practice, 3rd ed., Prentice Hall, reprinted in 2011.
2. G. Keiser, Optical Fibre Communications, McGraw-Hill, 2013.
3. G. P. Agrawal, Nonlinear Fiber Optics, 6th ed., Academic Press, New York, 2019.
4. Y. S. Kivshar and G. P. Agrawal, Optical Solitons: From Fibers to Photonic Crystals, Academic Press, New York, 2003.

PAM641 Quantum Optics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Atom field interaction semi classical theory, Rabi oscillations, inclusion of atomic decay, optical Bloch equations, Maxwell-Schrodinger equations, semi-classical laser theory, Density Matrix, coherence atomic effects, coherent population trapping, electromagnetically induced transparency, lasing without inversion, atom optics, laser cooling. Quantization of electrostatic field. Fock Number states, Coherent states, Squeezed states, quantum theory of atom field interaction.

Book Recommendations:

1. M. O. Scully and M. Suhail Zubairy, Quantum Optics, Cambridge Press, 1997.
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, 4 th ed., Springer Verlag, 2007.
4. D.F. Walls and Gerard J. Milburn, Quantum Optics, 2nd ed., Springer-Verlag Berlin Heidelberg, 2008

PAM610 Simulations in Statistical Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM510
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

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.

PAM644 Particle Detectors and Electronics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM512
Course Format: 03 hours of lectures per week

Course Contents:
Basic architectural elements, Typical tasks for electronics, Racks, Crates, Protocols, Pulse bouncing, grounding, basic bits and pieces, boards, design methods, Trigger Systems, LabVIEW, Optoelectronics; Data transmission, fiber optics, Techniques for low T, Calorimetry; Shower Theory B, Homogeneous & Sampling Methods, Radiation lengths, Interaction lengths, Compensation low energy detectors, Calorimeters: em calorimetry, resolutions etc., Photons electron separation, Statistical pi zero separation, Liquid Ar/Kr, gas sampling, scintillator detectors, scintillator sampling, Crystal detectors, Hadronic Calorimeters, resolutions, steel scintillator, compensating hadron & muon, Wire Chambers: radiation damage, Modes, proportional, streamer, Geiger, Straws, MWPCs, Drift chambers, Jet chambers, TPCs, photon detectors, TEA, TAME, Silicon: Silicon Signals, Lorenz angle, Shaping and speed, Radiation effects, CCDs, silicon drift detectors xray detectors, PID; Time of flight, dEdx, gamma/e/pizero, muon detectors, neutrino detection, PID 2 Threshold Cherenkov detectors, RICH Cherenkov, Transition Radiation, non-accelerator/dark matter detector design, Collider Detector Design, Neutrino detector design.

Book Recommendations:

1. Helmuth Spieler, Semiconductor Detector Systems, Oxford University Press, 2005
2. G. F. Knoll, Radiation Detection & Measurements, 3rd Edition, John Wiley, 2005
3. Konrad Kleinknecht, Detectors for Particle Radiation, 2nd Edition, Cambridge University Press, 2003
4. Claus Grupen, Boris Shwartz, Particle Detectors, 2nd Edition, Cambridge University Press, 2011

PAM612 Nonlinearities in Fiber Optics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM602
Course Format: 03 hours of lectures per week

Course Contents:
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, cross phase modulation, solitons, stimulated Raman scattering, stimulated Brillouin scattering, other nonlinear effects, computer simulations for pulse evolution behavior.

Book Recommendations:

1. G. P. Agrawal, Nonlinear Fiber Optics, 6th ed., Academic Press, New York, 2019.
2. G. P. Agrawal, Fiber-Optic Communication Systems, 4th ed., John Wiley & Sons, 2010.
3. M. F. Ferreira, Nonlinear Effects in Optical Fibers, John Wiley & Sons, 2011

PAM645 Quantum Computation and Information

Course Status: Compulsory
Credits hours: 03
Pre-requisite: PAM641
Course Format: 03 hours of lectures per week

Course Contents:
Quantum superposition, qubits, single qubit transformation, Physical examples of qubits, review of density matrix and tensor product. Quantum theory of measurement, entanglement and quantum indistinguishability, EPR argument and Bell's inequality, single qubit, two qubit, and multiqubit quantum gates:, quantum circuits, quantum fourier transform, phase estimation, order finding, quantum algorithms based on quantum Fourier transform, quantum algorithms based on amplitude amplifications, quantum teleportation and super dense coding, No cloning theorem, quantum key distribution protocols with physical implementation, Experiments leading towards quantum computation and cryptography in atomic, optical and condensed matter physics.

Book Recommendations:

1. M. A. Nielsen and I. L. Chung, Quantum Computing and Quantum Information, 2nded., Cambridge Univ. Press, Cambridge, 2010.
2. R. K. Brylinski and G. Chen, Mathematics of Quantum Computation, Chapman & Hall, London, 2002.
3. Jack D. Hidary, Quantum Computing: An Applied Approach, Springer International Publishing Cham, Switzerland, 2019.

PAM614 Integrated Circuit Fabrication Processes

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Invention of the Transistor, Emergence of Silicon Valley, Moore's Law, Clean Room, Modern CMOS Technology, Crystal Growth and Wafer Engineering, Semiconductor Manufacturing, Gettering and

Wafer Cleaning, Lithography and Pattern Transfer: photolithography, electron beam lithography and next generation lithographic technique, Thermal Oxidation and the Si/SiO2 Interface, Dopant Diffusion and Ion Implantation, Thin Film Deposition and Epitaxy, Etching, Process integration, CMOS and other transistor technologies, Back-end Technology, packaging and yield, Scaling laws and their influences on process and design selection.

Book Recommendations:

1. Jose Pineda de Gyvez and Dhiraj K, Integrated Circuit Manufacturability – The Art of Process and Design Integration (IEEE Press) 1998
2. James D. Plummer, Michael D. Deal and Peter B, Silicon VLSI Technology: Fundamentals, Practice and Modeling, Griffin (Prentice Hall Electronics and VLSI Series) 2000
3. Stephen A. Campbel, Fabrication Engineering at the Micro and Nanoscale, 4th edition(Oxford University Press) 2012
4. Gary S. May and Costas J. Spanos, Semiconductor Manufacturing and Process Control (IEEE, Wiley-Interscience) 2006
5. Hans H. Gatzen, Volker Saile, Jürg Leuthold, Micro and Nano Fabrication: Tools and Processes, Springer, 2015.

PAM640 Radiation Physics-II

Course Status: Optional
Credits hours: 2+1
Pre-requisite: PAM615
Course Format: 02 hours of lectures and 03 hour lab work per week.

Course Contents:
Radiation hazard; basic principles of protection; time distance and shielding; internal radiation protection; medical surveillance; external radiation protection; shielding in radiation installations, health physics instrumentation; evaluation of protective measures; disposal of solid liquid and airborne radioactive waste. Radiation dosimetry; exposure; absorbed dose; exposure measurement; absorbed dose measurement, charge particle equilibrium; Bragg-Gray principle, Spencer-Attix cavity theory; Kerma; Film badge dosimeter; luminescent dosimeters; chemical/Fricke dosimetry; dose calculations; dose from surface contamination; internally deposited radioisotopes; total dose; dose commitment; micro-dosimetry, Industrial Radiography, non-destructive testing systems; Radiographic equivalence; exposure factors; x-ray safety. Experiments related to radiation physics.

Book Recommendations:

1. Denise Orth, Essentials of Radiologic Science, Second Edition, Wolter Kluwer, 2017
2. T. Johnson, Introduction to Health Physics, 5th Edition, McGraw-Hill Inc, 2017.
3. J. E. Martin, Physics for Radiation Protection: A Handbook, 3rd Edition, Wiley, 2013.
4. J. E. Turner, Atoms, Radiation, and Radiation Protection, 3rd Edition, Wiley VCH, 2007

PAM616 Mathematical Methods-II

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM530
Course Format: 03 hours of lectures per week

Course Contents:
Orthogonal functions and Fourier series, Partial differential equations: Classification of PDEs, Initial and Boundary Value Problems in Rectangular and Polar Coordinates (Heat Equation, Wave Equation, Laplace Equation), Green's functions. Integral transforms method, Complex variable theory: Complex variables and functions, Cauchy Residue Theorem, Cauchy Integral Formula and Cauchy Integral Theorem, Zeros and Singularities, Series and Residues, Evaluation of Integrals in Complex Plane. Conformal Mapping, Gamma Function, Group Theory: Introduction to group theory, Symmetry and Physics, Discrete Groups, Direct Groups, Symmetric Group, Lorentz Group, Space Groups.

Book Recommendations:

1. Erich Zauderer, Partial Differential Equations of Applied Mathematics, 3rd Edition, John Wiley & Sons, 2011
2. J. Vaillant, Partial Differential Equations and Mathematical Physics, Springer Verlag, 2003
3. George B. Arfken, Hans J. Weber, Frank E. Harris, Mathematical Methods for Physicists: A Comprehensive Guide, 7th Edition, Academic Press, 2013
4. R. C. McOwen, Partial Differential Equations: Methods & Applications, Prentice Hall, 2002

PAM617 Quantum Field Theory-I

Course Status: Compulsory Optional
Credits hours: 03
Pre-requisite: PAM508
Course Format: 03 hours of lectures per week

Course Contents:
Review of Classical Mechanics, Moving from classical particle mechanics to mechanics of continuous systems (Euler Lagrange equations), the concept of field, classical Lagrangians and Hamiltonians for fields, field equations, canonical formalism and Poisson brackets for fields, variational methods for field theory. Introduction of special relativity and formulation of relativistic classical field theory, four dimensional formulation of fields and the stress-energy momentum tensor, scalar Field. Linear fields and the Klein-Gordon equation, variational method and field equations, Symmetries and conservation laws, Noether theorem, Linear massless scalar fields and the Maxwell field equations, the electromagnetic energy-momentum tensor. Gauge invariance, the Lorenz gauge, charge conservation, four-currents, Canonical stress tensor; conserved, traceless & symmetric stress tensor, Particle and field energy momentum & angular momentum conservation. The massive vector (Proca) Field, the tensor field, the massless tensor field.

Book Recommendations:

1. Horatiu Nastase, Classical Field Theory, Cambridge 2019.
2. J. Franklin, Classical Field Theory, Cambridge 2017.
3. Quantum Field Theory for the Gifted Amateur, by T. Lancaster, S. J. Blundell, Oxford, (2014).
4. D. E. Soper, Dover, Classical Field Theory, 2008.
5. An Introduction to Quantum Field Theory, M.E.Peskin and D.V.Schroeder, 1995.
6. Laudau, L.D. and Lifshitz, M, Pergamon, The Classical of Theory of Fields 1980.

7. Mark Burgess, Classical Covariant Fields, Cambridge 2002.

PAM618 Plasma Physics-II

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM523
Course Format: 03 hours of lectures per week

Course Contents:
Review of Coulomb collisions and relaxation time scales; Development of Kinetic Theory using Klimontovich equation, Liouville equation and BBGKY Hierarchy; Truncation of BBGKY Hierarchy; Derivation of fluid theory from the plasma kinetic equation; Derivation of the MHD model; Collisional terms in fluid theory; Basic properties of the Vlasov equation and Vlasov equilibria; Analytic continuation Landau contours; Landau damping; Physical origin and validity of Landau damping; Maxwellian plasmas ion acoustic waves; Kinetic stability Newcomb-Gardner Theorem Nyquist Method; Ion acoustic instability Bump-on-tail distributions; Method of characteristics; Vlasov theory of electrostatic waves in a magnetized plasma; Electrostatic dispersion relation for magnetized plasma with Maxwellian distributions; Bernstein waves Electrostatic ion-cyclotron waves; Electromagnetic waves in a magnetized plasma; Parallel propagating electromagnetic waves with Maxwellian distributions; BGK Modes; Drift Waves; Quasi-linear Theory-Particle Transport; Quasi-linear Theory–Velocity space diffusion; Introduction to Kinetic simulation using Particle-in-cell Approach.

Book Recommendations:

1. N.A. Krall and A.W. Trivelpiece, Principles of Plasma Physics, McGraw-Hill, 1973
2. T.J.M. Boyd and J.J. Sanderson, The Physics of Plasmas, Cambridge University Press, 2003
3. D.R. Nicholson, Introduction to Plasma Theory, Wiley, 1983
4. D. Gurnett and A. Bhattacharjee, Introduction to Plasma Physics with Space and Laboratory Applications, Cambridge University Press; 1st Edition 2005
5. F. Chen, Plasma Physics and Controlled Fusion, 3rd Edition, Springer International Publishing Switzerland, 2018
6. T. Stix, Waves in Plasmas, Springer Science & Business Media, 1992
7. Birdsall and Langdon, Plasma Physics via Computer Simulation, CRC Press, 1991

PAM619 Nanomaterial Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Method of preparation of 0D, 1D, and 2D nano-materials, Top down & Bottom up approaches, fabrication of nano-materials using lithography, deposition, molecular beam epitaxy, chemical vapour deposition, and other chemical techniques. Quantum confinement & energy levels, Band structure, Density of states in 0D, 1D, 2D & 3D materials, Quantum dots, wires & wells, Parabolic, triangular, cylindrical & spherical wells, Band gap engineering, Hetero-structures & super-lattices, 2D electron

gas, Effective mass in hetero-structures.

Book Recommendations:

1. G. Cao, Y. Wang, Nanostructures and Nano-Materials: Synthesis, properties and applications, World Scientific Series in Nano-science and Nanotechnology, World Scientific Pub. Co., 2011, 2nd Edition.
2. T. Tsurumi, H. Hirayama, M. Vacha, T. Taniyama, Nanoscale Physics for Materials Science, Taylor and Francis Group, CRC Press, 2009.
3. S. Thomas, N. Kalarikkal, A. M. Stephan, B. Raneesh and A. K. Haghi, Advanced Nanomaterials: Synthesis, Properties, and Applications, Taylor & Francis Group, CRC Press, 2014.
4. M. Kuno, Introductory Nanoscience: Physical and Chemical Concepts, Garland Science, 2011.
5. Low-Dimensional Semiconductor Structures: Fundamentals and Device Applications by Keith Barnham and Dimitri Vvedensky; ISBN 9780511624247; Cambridge University Press
6. The Physics of Low-dimensional Semiconductors: An Introduction by John H. Davies, ISBN 9780511819070; Cambridge University Press

PAM620 Biophotonics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Interaction of light with biological material, radiative transport theory. Optical properties of tissues with strong multiple scattering, Light scattering methods and instruments for medical diagnosis. principles and applications of bioimaging: quantitative different optical imaging techniques and diffuse optical tomography, Interferometric and speckle-interferometric methods, qualitative: Time and frequency domain spectroscopy and tomography of tissues. Optical coherence tomography, polarization-sensitive optical coherence tomography. biosensors and bio-nanophotonics.

Book Recommendations:

1. G. Keiser, Biophotonics: Concepts to Applications, Springer 2016.
2. B. Di Bartolo and J. Collins, Biophotonics: Spectroscopy, imaging, sensing, and Manipulation, Springer 2009.
3. L. Wang, Hsin-I Wu, Biomedical Optics, Wiley Interscience 2007.
4. R. Splinter, Brett A. Hooper, An introduction to Biomedical Optics, Taylor & Francis group, 2006.
5. M. Niemz, Laser-Tissue Interaction, Springer-Verlag, Berlin, 2003.
6. V. Tuchin, Tissue Optics, SPIE, Washington, 1999.

PAM621 Quantum Field Theory-II

Course Status: Optional

Credits hours: 03
Pre-requisite: PAM617
Course Format: 03 hours of lectures per week

Course Contents:

Non-abelian gauge theories: Yang-Mills Lagrangian, local and global gauge transformation. Multiple vacua. Brief review of group theory, quantization of non-abelian gauge theories, ghost field (BRS transformations). Unitarity: ghost field and unitarity, optical theorem and Cutkosky rules, examples: e + e → hadrons (evidence of color). Radiative corrections in QCD: one loop divergences (gauge boson self-energy, fermion self-energy), fermion gluon vertices, beta function and asymptotic freedom. Callan-Symanzik equation: renormalization scale, methods of characteristics, examples in $\phi 4$ theory and QCD. Weak interactions and Fermi theory: spontaneous symmetry breaking, massive gauge bosons (Higgs mechanism), Goldstone theorem with application to pi-sigma lagrangian, Goldstone bosons. Electroweak unification: Gauge theory with spontaneous symmetry breaking, neutral and charged currents, radiative corrections from fermionic loops, Higgs couplings, Higgs contribution to vector boson self-energy, calculation: top quark decay into (i) W + b (ii) ϕ+ b, Higgs decay into: (i) W+W (ii) ϕ + W (iii) $\phi + \phi$, Yang Mills character of W-bosons (triple tri-linear coupling), triangle anomaly. Multiple vacua in QCD and the strong CP problem.

Book Recommendations:

1. Quantum Field Theory for the Gifted Amateur, by T. Lancaster, S. J. Blundell, Oxford, (2014).
2. Quantum Field Theory in a Nutshell, A. Zee, (Princeton University Press, 2003)
3. Quantum Field theory by M. A. Srednicki, Cambridge (2007)
4. Quantum Field Theory, by F. Mandl and G. Shaw, 2nd Edition, John Wiley, (2010).
5. Quantum Field Theory by L. H. Ryder, (2nd edition), Cambridge, (2013)
6. An Introduction to Quantum Field Theory, M.E.Peskin and D.V.Schroeder, 1995.

PAM622 Neutron Physics

Course Status: Optional
Credits hours: 2+1
Pre-requisite: PAM516
Course Format: 02 hours of lectures and 03 hour lab work per week.

Course Contents:

Neutron cross sections, experimental measurements, data libraries; Neutron sources, nuclear reactions, energetics, (a,n) and (g, 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. Experiments related to Neutron Physics.

Book Recommendations:

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

PAM623 Special Topics in Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

1.
2.
3.

PAM624 Accelerator Physics and Applications

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Overview of history of accelerators, the invention of the synchrotron leading to the modern circular and linear colliders, particle sources, Magnet configurations, design of dipoles, quadrupoles and multipole magnets, Transverse optics; strong and weak focusing, magnets and field expansions, transvers and longitudinal beam dynamics; phase stability, principles and design of microwave cavities, Synchrotron radiation effects, energy loss, damping of both transverse and longitudinal oscillation, Basic concepts in plasmas, Coherent and incoherent tune shifts, Non Linear Dynamics, Beam Transport, Accelerator application in medical, industry and research.

Book Recommendations:

1. Wiedemann, Helmut, Particle Accelerator Physics, 4th Edition, Springer, 2015.ISBN-10: 3319183168
2. Alexander Wu Chao, Herbert O Moser, Zhentang Zhao, Accelerator Physics,Technology and Applications, World Scientific Publishing, 2004. ISBN: 981-238-794-3
3. W. Chao, K. H. Mess, Accelerator Physics and Engineering, Second Edition, World Scientific, 2013, ISBN: 978-981-4415-84-2.
4. Mario Conte and William M. MacKay, An Introduction to the Physics of Particle Accelerators, Second Edition, World Scientific Press, 2008, ISBN: 978981277961.
5. S.Y. Lee, Accelerator Physics, Third Edition, World Scientific, 2012, ISBN: 9814374946.

PAM646 Beam Physics

Course Status: Optional
Credits hours: 03

Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Physics of intense charged particle beams, the role of space charge, particle equations of motion, the paraxial ray equation, and the Vlasov equation, 4-D and 2-D equilibrium distribution functions, reduced moment and envelope equation formulations of beam evolution, transport limits and focusing methods, the concept of emittance and the calculation of its growth from mismatches in beam envelope and from space-charge non-uniformities using system conservation constraints, the role of space-charge in producing beam halos, longitudinal space-charge effects, stable and unstable oscillation modes of beams, the role of space charge in the injector, intense beam applications; beam sources and low energy beam transport and acceleration, beam driven high-energy-density physics and heavy-ion fusion, spallation neutron sources, accelerator driven systems for nuclear waste transmutation.

Book Recommendations:

1. Martin Reiser, The Theory and Design of Charged Particle Beams, 2nd Edition, Wiley-VCH, 2008
2. James Rosenzweig, Fundamentals of Beam Physics, Oxford University Press, 2003
3. K.Y. Ng, Physics of Intensity Dependent Beam Instabilities, World Scientific, 2006

PAM647 Non-Linear Optics

Course Status: Compulsory
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Nonlinear Optical susceptibility of materials, origin of optical nonlinearities, Wave-Equation Description of Nonlinear Optical Interactions, symmetry properties of nonlinear susceptibility tensors coupled-wave equations. Second harmonic, sum-, and difference frequency generation. Phase matching conditions and techniques to achieve phase matching, parametric amplification. Electro-optic effect, multi-photon absorption, Intensity dependent refractive index and resulting self-processes, stimulated Raman scattering, acousto-optics, Ultrafast and Intense-Field Nonlinear Optics

Book Recommendations:

1. R. W. Boyed, Nonlinear Optics, Academic Press, MA, 4 th Edition 2020
2. Georg A. Reider Photonics: An Introduction, Springer, 2016.
3. E. G. Sauter, Nonlinear Optics, John Wiley & amp; Sons, NY, 1996.
4. Y. R. Shen, The Principles of Non-linear Optics, Wiley NY, 1984.
5. N. Blooembergen, Nonlinear Optics, Addison Wesley, Reading, MA, 1996.

PAM627 Particle Physics-II

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM603

Course Format: 03 hours of lectures per week

Course Contents:
Symmetries and the quark model: symmetries in quantum mechanics, flavor symmetry, combining quarks into baryons, ground state baryon wavefunctions, Isospin representation of antiquarks, SU(3) flavour symmetry; Quantum Chromodynamics: local gauge principle, color and QCD, gluons, color confinement, running alphs$_S$ and asymptotic freedom, QCD in $e^- e^+$ annihilation, hadron-hadron collisions; Weak interaction: weak charged-current interaction, parity, V-A structure, chiral structure, W-boson propagator, helicity; Weak interactions of leptons: lepton universality and neutrino scattering, structure functions in neutrino interactions, charged-current ep scattering; Neutrino Oscillations: neutrino flavors, mass and weak eigenstates, neutrino oscillations of two and three flavors; CP violation and weak hadronic interactions: weak interactions of quarks, the CKM matrix, CP violation in the Standard Model; Electroweak Unification; The Higgs boson; Physics beyond Standard Model.

Book Recommendations:

1. Thomson, M. Modern Particle Physics. Cambridge: Cambridge University Press, 2013.
2. David J. Griffiths, Introduction to Elementary Particles, Wiley-VCH, Second Revised Edition, 2008.

PAM650 Computation in Accelerator Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM646
Course Format: 03 hours of lectures per week

Course Contents:
Matrix inversion, Eigenvalues, Eigen-functions, Taylor, Fourier, equation solvers, scattering of particles, Beam design and dynamics analysis, R.F. cavities and magnet design, calculation of beam instabilities and polarization effects, particle tracking with higher order multipole fields, Biot-Savert for a Current Loop simulation, Helmholtz Coil, Cyclotron simulation, Quadrupole lens simulation, Hamiltonian Matrix, Beam transport using Monte Carlo methods.

Book Recommendations:

1. Volker Ziemann, Hands-on Accelerator Physics Using MATLAB, CRC Press, 2019 ISBN 9781138589940
2. Dan Green, Beams and Accelerators with MATLAB, World Scientific Publisher, 2018 ISBN 978-981-3237-46-9
3. Martin Berz, Modern Map Method in Particle Beam Physics, Academic Press, 1999
4. Cleave B. Moler, Numerical Computing with MATLAB, Society for Industrial and Applied Mathematics, 2004
5. Stanley B. Lippman and Josee Lajoie, C++ Primer, 3rd Edition, Addison-Wesley, 1998

PAM648 Experimental Techniques of Physics

Course Status: Optional
Credits hours: 03

Pre-requisite: Instructor's Consent
Course Format: 03 hours of lectures per week

Course Contents:
Vacuum technology and cryogenic techniques, Electrical measurement techniques: IV and CV measurements, resistivity measurement and Hall measurements, Optical measurement techniques: Ellipsometry, Photoluminescence and Raman spectroscopy, X-ray diffraction techniques, scanning electron and transmission electron microscope working principle, contrast mechanism in electron microscopy. Electron diffraction. energy and wavelength dispersive spectroscopy. Scanning probe microscopy (Scanning Tunneling microscope, Atomic force microscope), Rutherford backscattering, Thermal Properties Measurement Techniques

Book Recommendations:

1. Dieter K. Schroder, Semiconductor Material and Device Characterization, 3rd Edition, Wiley-IEEE Press, 2015
2. Y. Leng, Materials Characterization, 2nd Edition, Wiley, 2013
3. Bert Voigtländer, Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy, Springer, 2016
4. Milton Ohring, Materials Science of Thin Films, 2nd Edition, Academic Press, 2001
5. Thermal Properties Measurement of Materials by Yves Jannot and Alain Degiovanni; Online ISBN:9781119475057, 2018

PAM631 Photodynamic Therapy

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM606
Course Format: 03 hours of lectures per week

Course Contents:
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, cyto protective mechanisms in PDT, molecular mechanisms regulating proto-porphyrin 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.

Book Recommendations:

1. M. P. Goldman, Photodynamic Therapy, Saunders, Elsevier, 2nd Edition, 2008.
2. 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.

PAM632 Superconducting Radio Frequency Technology

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM512
Course Format: 03 hours of lectures per week

Course Contents:
Introduction, advantages and limitations of SRF technology, Fundamentals of RF & microwave engineering, Basic concepts of RF superconductivity, RF losses and related figures of merits, Q vs. E, Related phenomena, field emission, multipacting, ponderomotive effects, SRF systems: requirements and challenges, Beam-cavity interaction: fundamental mode beam loading, wake fileds and higher-order modes, instabilities and cures, Systems engineering approach to SRF system design: interconnectedness, cost optimization, Cavity design and optimization, Cryomodule design, Fundamental power couplers, HOM dampers, Frequency tuners, Cavity fabrication techniques, preparation and testing, High-power RF systems.

Book Recommendations:
1. H. Padamsee, J. Knobloch, and T. Hays, RF Superconductivity for Accelerators, John Wiley & Sons, 2nd Edition, 2008
2. H. Padamsee, RF Superconductivity: Science, Technology and Applications, Wiley-VCH, 2009
3. A. W. Chao and M. Tigner, Handbook of Accelerator Physics and Engineering, World Scientific, 3rd Edition, 2006

PAM633 Polarization Imaging

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM512
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:
1. Dennis H. Goldstein, Polarized Light, 3rd Revised Edition, CRC Press, 2017
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

PAM634 Atomic and Molecular Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Central forces and Angular Momentum, 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, Complex Atoms, energy levels, coulomb/exchange integrals, degeneracy, equivalent electrons, alkali-metal energy levels. Atom-field Interactions: dipole transitions, normal and anomalous Zeeman Effect, Lande g-factor, spectral consequences of applied fields, Stark effect. Transition Probabilities: Time dependent perturbation theory, Spontaneous Emission, Transition moments for complex Atoms, Life time, selection rules and oscillator strength, 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.

Book Recommendations:

1. W. Demtroder, Atoms, Molecules and Photons, Springer Berlin, 3 rd ed. 2018
2. Robert L. Brooks, The Fundamentals of Atomic and Molecular Physics, Springer New York, 2013
3. D. Budker, D. Kimball, D. DeMille, Atomic Physics: An exploration through problems and solutions, Oxford University Press, Oxford, 2008
4. G.W.F. Drake, Handbook of Atomic, Molecular and Optical Physics, Springer, Berlin, 2006
5. M. Born, Atomic Physics, 8th Edition, Dover Publications, New York, 1989.

PAM635 Microwave Physics and Techniques

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM512
Course Format: 03 hours of lectures per week

Course Contents:
Maxwell’s equations, Green’s functions, boundary conditions, wave propagation and plane waves, plane wave reflection from a media interface, dielectric interface. Transmission line theory including wave propagation, field analysis, generator and load mismatches, Smith chart, rectangular and circular waveguides, coaxial lines, microwave network analysis, impedance matching, microwave resonators, physics of the microwave tubes, dielectric and other lossy materials, time harmonic analysis, perturbation and variational techniques, microwave antennas, and microwave measurements; attenuation, SWR, impedance, phase-shift, noise factor. Millimetre waves and applications. Acceleration by RF systems for the linear accelerator and storage rings including beam and cavity interaction, beam-loading, higher-order mode (HOM) effects and mode damping.

Book Recommendations:

1. R.E. Collin, Foundation of Microwave Engineering, New York, McGraw-Hill, 2001
2. David M. Pozar, Microwave Engineering, 4th Edition, Wiley, 2011
3. Alexander S. Gilmour, Klystrons, Traveling Wave Tubes, Magnetrons, Cross-Field

Amplifiers, and Gyrotrons, Artech House, 2011

PAM636 Semiconductor Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
Semiconductors, charge carriers in semiconductors, dopants and Fermi level in semiconductors, charge neutrality, tunneling effect, the triangular potential well, carrier drift and diffusion, graded impurity distribution, the hall effect, carrier generation and recombination, characteristics of excess carriers, ambipolar transport, quasi-Fermi energy levels, excess-carrier life time, surface effects, pn junction and its biasing, pn junction current, small signal model of pn junction, generation recombination currents, junction breakdown, charge storage and diode transients, tunnel diode, The Schottky barrier diode, metal-semiconductor ohmic contacts, hetrojunctions, The bipolar junction and related physics, metal oxide field effect transistor and related physics, optical devices, modern semiconductor devices.

Book Recommendations:

1. Donald A. Neaman, Dhrubes Biswas, Semiconductor Physics and Devices, Tata McGraw-Hill, 4th edition, 2012.
2. S. M. Sze, Kwok K Nge, Physics of semiconductor devices, Wiley-Interscience; 3rd edition, 2006.
3. J.Singh, Semiconductor Devices - Basic Principles, Wiley, 2001.
4. Taur and Ning, Fundamentals of Modern VLSI Devices, Cambridge Press, 1999.
5. Richard S. Muller, Theodore I. Kamins, Device electronics for Integrated circuits, Wiley, 3rd edition, 2002.

PAM637 General Relativity and Cosmology-II

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM527
Course Format: 03 hours of lectures per week

Course Contents:
Review of Special Relativity, The equivalence principle and space-time curvature, Vector calculus on manifolds, Vector calculus on manifolds, The gravitational (Einstein's) field equations, The Schwarzschild geometry, Schwarzschild Black holes (detailed), Experimental tests of general relativity, The Friedmann–Robertson–Walker geometry. Introduction to Cosmology, Cosmological principle (Maximally symmetrical universe), Cosmological models, Cosmological Inflation, gravitational waves and its detection, Quantum mechanical emission of radiation by black holes, Black hole evaporation, Robertson-Walker metrics, The Friedmann equation.

Book Recommendations:

1. Space-time and Geometry by Sean Carroll, Pearson Education Limited (2014)

2. General Relativity: An Introduction for Physicists" by M. P. Hobson, George Efstathiou, Anthony N. Lasenby, Cambridge (2006)
3. Gravity: An Introduction To Einstein'S General Relativity" by James Hartle, Pearson (2003)
4. Theory of Relativity" by Fayyazuddin, Riazuddin and M. Jamil Aslam, World Scientific (2015)
5. Gravitation: Foundations and Frontiers" by T. Padmanabhan, Cambridge (2010)
6. A First Course in General Relativity", 2nd Edition (Cambridge U., 2009) by Schutz

PAM638 Advanced Topics in Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil
Course Format: 03 hours of lectures per week

Course Contents:
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.

Book Recommendations:

1. 1.
2. 2.
3. 3

PAM642 Statistical Methods for Data Analysis in Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM510
Course Format: 03 hours of lectures per week

Course Contents:
Probability: first principles, probability density function and cumulative distribution function, Bayes' theorem, frequentist vs Bayesian approach; Special distributions; Convolution; Central Limit theorem; Monte Carlo: random number generators, Monte Carlo integration, weighted events, rejection method, inverse transformation method, composite method, Gaussian generator; Parameter estimation: properties of estimators, substitution methods, maximum likelihood method, least squares method, esimators for binned data; Confidence intervals; and Hypothesis testing.

Book Recommendations:

1. Olaf Behnke, Kevin Kröninger, Grégory Schott and Thomas Schörner-Sadenius, Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods, Wiley-VCH, 2013.
2. Luca Lista, Statistical Methods for Data Analysis in Particle Physics, 2nd Edition, Springer International Publishing, 2017.

PAM643 Quantum Condensed Matter Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM511
Course Format: 03 hours of lectures per week

Course Contents:

The free electron gas: Tight Binding Model, Electron-Electron Interactions, Fermi Liquid Theory, Second Quantization, Linear Response Theory, Hartree-Fock theory, Screening, Random Phase Approximation, Instabilities. Quantum magnetism: Theory of quantum magnetism, Ising and Heisenberg magnets, Mean field Theory, Landau Theory, Critical Phenomenon, Magnetism in the Hubbard Model, Anderson model of local moments, Kondo effect, and Poor Man's scaling, Quantum spin chains. Transport phenomena, Boltzmann equation, electrical and thermal conductivities, thermo-electric effects. Superconductivity: Macroscopic properties, Cooper problem, BCS Theory and important predictions, Ginzburg-Landau theory, Josephson Effect and SQUIDs.

Book Recommendations:

1. Condensed matter in a nutshell' by G. D. Mahan. 2011.
2. Advanced Condensed Matter Physics 1st Edition, Leonard M. Sander, Cambridge University Press, 2009.
3. Condensed Matter Physics by M. P. Marder. (John Wiley & Sons, 2010)
4. Principles of condensed matter physic, P.M. Chaikin and T.C. Lubensky, Principles of Condensed Matter Physics, Cambridge University press, 2000.
5. Superconductivity: M. Tinkham, "Introduction to Superconductivity" (Dover Publications, 2004)

PAM658 Advanced Computational Condensed Matter Physics

Course Status: Optional
Credits hours: 03
Pre-requisite: PAM533
Course Format: 03 hours of lectures per week

Course Contents:

Many electron systems: Crystal Hamiltonian, Born Oppenheimer approximation, Variational principle, Hartree-Fock theory, Density Functional Theory: Fundamental theorems, Kohn-Sham formalism, practical aspects - basis sets, pseudo-potential, Brillouin zone sampling, approximate exchange-correlation functionals. Strongly correlated materials and the DFT+U approach. Molecular dynamics simulations, molecular systems, Langevin dynamics, ensembles and symplectic integrators, quantum molecular dynamics; Quantum Monte Carlo method, Interatomic potentials, the cohesive energy, pair potentials, interatomic potentials to model ionic materials.

Book Recommendations:

1. R. Martin, Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004
2. D. Scholl, Density Functional Theory, Wiley, 2009
3. D.C. Rapaport, The art of molecular dynamics simulation, Cambridge University Press, 2004

4. Richard Lisar, Introduction to computational materials science, Cambridge University Press, 2013
5. David P. Landau, Kurt Binder, A Guide to Monte Carlo Simulations in Statistical Physics, Cambridge University Press, 4th Edition, 2014
6. J. M. Thijssen, Computational Physics, 2nd Edition, Cambridge, 2007

PAM690 Seminar Project

Course Status: Optional
Credits hours: 03
Pre-requisite: Nil

Course Contents:
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

Course Status: Compulsory
Credits hours: (6+6) 4^{th} and 5^{th} semeter
Pre-requisite: Nil

Course Contents:
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 Excellent, Very Good, Good, Fair, Satisfactory and Unsatisfactory.