

## MSc Course curriculum @ 2025-26

Semester	Course Code	Course Name (optional)	Course Credits (Optional)
1	PH5130	Quantum Mechanics-I	3
1	PH5110	Classical Mechanics	3
1	PH5120	Mathematical Physics-I	3
1	XXxxxx	English Communication	1
1	PH5210	Electrodynamics	3
1	PH5240	Statistical Mechanics	3
1	PH5101	Lab	2
			18
2	PH6708	Mathematical Physics-II	3
2	PH5230	Quantum Mechanics-II	3
2	PH5250	Optics & Photonics	3
2	PH5260	Atomic & Mol. Physics	3
2	PH6200	Solid State Physics	3
2	PH6170	Computational Physics	3
2	PH5201	Lab	2
			20
3	PH6270	Particle Physics	3
3	PH6278	Nuclear Physics	2
3	PH5140	Electronics	3
3	PHxxxx	Elective - I	3
3	PHxxxx	Elective - II	3
3	PH5315	Project	2
3	PH5311	Lab	2
			18
4	PHXXXX	Free Elective	3
4	PHXXXX	Elective - III	3
4	PHXXXX	Elective – IV	3
4	PH5315	Project – (Continued from Sem. III)	6
			18
<b>Total</b>			<b>71</b>

## Electives:

Course Code	Course Name	Course Credits
PH5340	Advanced Functional Materials and Applications	3
PH5380	Fundamentals of Semiconductors Physics and Devices	3
PH6730	Plasma Physics and MHD	3
PH5320	Concepts and Hands-On Observational Astrophysics	3
PH6450	Gravitation and Cosmology	3
PH5310	Introduction to Nanomagnetism with Lab	3
PH5460	Open quantum systems	3
PH6130	Data Science Analysis	3
PH6468	Advanced Particle Physics	3
PH6410	Quantum Field Theory	3
PH5420	Radiation Detection, Measurement and Instrumentation	3
PH5350	MEMS and Microsystems Technology	3
PH5430	Spintronics	3
PH5450	Energy harvesting: Sources, circuits, and applications	3
PH6300	Ultrafast Optics: Theory and experiments	3
PH5360	Optical Engineering and lab	3
PH5330	Fiber Optics, Technology, and Application	3

## COURSE CONTENT

PH5130	Quantum Mechanics-I	3-Credits
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Classical to quantum cross-over, basic principles of quantum mechanics, wave function and uncertainty principle, Schrodinger formalism, time-independent and time-dependent Schrodinger equations, Dirac formulation of quantum mechanics, completeness and orthonormalization of basis vectors, basis sets, eigenstate and eigenvalues, Schrodinger Equation in one dimension, probability current density, equation of continuity, Free particle solution of Schrodinger equation, box and delta function normalisation of free particle solution, potential step, potential barrier, particle in an infinite potential box, square well potential and tunnelling, linear harmonic oscillator. Orbital and spin angular momentum operators, angular momentum algebra, eigenstates and eigenvalues of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients, spin-orbit interaction and applications, central potential, solutions of schrodinger equation in a central potential, Hydrogen-like atom, 3 dimensional harmonic oscillator. Time independent perturbation theory for non-degenerate and degenerate energy levels, variational method, WKB

approximation and applications, time dependent perturbation theory, Fermi-golden rule, adiabatic approximation, sudden approximation.

**Reading Material:**

- Quantum Mechanics by Stephen Gasiorowicz
- Principles of Quantum Mechanics by R. Shankar
- Quantum Mechanics by Bransden and Joachain
- Quantum Mechanics I, II by JJ Sakurai

PH5110	Classical Mechanics	3 Credits
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Constraints, Generalized coordinates, D'Alembert principle, Lagrangian, Euler-Lagrange equations, Hamilton's principle, Galilean invariance, Symmetry and Conservation laws, Motion in one dimension, Two body problem, Kepler Problem, Scattering in central field, Small oscillations, Normal modes, Rigid body dynamics, Canonical equations, Canonical transformations, Action-angle variables, Hamilton-Jacobi equation.

**Reading Material:**

- Landau and Lifshitz, "Mechanics"
- Hand and Finch, "Analytical Mechanics"
- Goldstein, "Classical Mechanics"
- Pars, "A Treatise on Analytical Dynamics"
- Percival and Richards, "Introduction and Dynamics"
- Arnold, "Mathematical Methods of Classical Mechanics"

PH5120	Mathematical Physics-I	3 Credits
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Linear vector space, Metric space, Function space, Hilbert space, linear operators, N-dim. Vector space, Tensors, Transformation of basis, Invariant subspaces, Hermitian and Unitary matrices. Analytic functions, Cauchy theorem, Cauchy's integral representations, Taylor and Laurent series, Calculus of residues, Analytic continuation, conformal mapping, Fourier series, Fourier transforms, Convolution theorem, Laplace transforms, Applications of Fourier and laplace transforms, Series solution, separation of variables, SturmLiouville theory, Bessel equation and function, Legendre equation and function, Spherical harmonics, Green function and Nonhomogeneous differential equations, Special functions such as hermite, Laguerre, Chebyshev etc.

**Reading Material:**

- P. Dennery and A. Krzywicki; Mathematics for Physicists; Dover Publications
- Arfken and Weber; Mathematical methods for Physicists; Academic Press
- J. D. Jackson; Classical Electrodynamics

<b>PH5210</b>	<b>Electrodynamics</b>	<b>3 Credits</b>
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Electric field, Divergence and curl of electrostatic fields, electric potential, work and energy in electrostatics, conductors, Special techniques to solve Laplace's equations, separation of variables and Multiple expansion, Polarization, Field of a polarized object, Electric displacement and linear dielectrics, Lorentz force law, Biot-Savart Law, magnetic vector potential, magnetization, field of a magnetized object, linear and nonlinear media. Electromotive force, Electromagnetic induction, Maxwell's equations, conservation laws, Poynting theorem, Maxwell's stress tensor, conservation of momentum, Electromagnetic waves, Electromagnetic waves in vacuum and matter, Absorption and Dispersion, Wave Guides, Potentials and fields, Gauge transformations, Dipole radiation, Power radiated by point charge, Maxwell's equations in matter, Boundary conditions, Poynting's theorem, Newton's third law in Electrodynamics, Maxwell's stress tensor, Conservation of Momentum, Electromagnetic waves in vacuum, and matter, absorption and dispersion, Guided waves.

#### **Reading Material:**

- Introduction to Electrodynamics, 3rd Edition, by David J. Griffiths.
- Classical Electrodynamics : John David Jackson

<b>PH5240</b>	<b>Statistical Mechanics</b>	<b>3 Credits</b>
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Introduction to statistical methods; Statistical description of a physical system; Microcanonical ensemble; Canonical ensemble, Grand canonical and pressure ensemble, Quantum statistical mechanics, The ideal quantum gas, Thermodynamics of ideal Fermi and Bose gases, Bose-Einstein condensation, Phase transition and critical phenomena, Exact solution of 1D Ising model, Ising model (mean field, BraggWilliams, Bethe-Peierls approximation)

#### **Reading Material :**

- Statistical Physics of Particles by M. Kardar
- Statistical Mechanics by R. K. Pathria
- Statistical Physics - Landau and Lifshitz
- Statistical Mechanics by K. Huang

<b>PH5101</b>	<b>Lab</b>	<b>2 Credits</b>
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**List of experiments:**

1. Michelson Interferometer
2. Hall Effect
3. Ultrasonic Interferometer
4. Dielectric constant
5. Laser beam parameters
6. Optical Fiber
7. Applications of Diode
8. Applications of Transistor
9. Field Effect Transistor (FET)&MOSFET
10. Characteristics of sensors

PH6708	Mathematical Physics-II	3 Credits
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Special functions, Class, Cosets, Factor group, Character table, Reducible and Irreducible representations, Lie groups, Applications of group theory in Physics

**Reading Material:**

- J. F. Cornwell; Group theory in Physics; Academic Press

PH5230	Quantum Mechanics-II	3 Credits
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Scattering experiments and cross-sections, general features of scattering in presence of a potential, partial wave analysis, scattering by square well, scattering by hard sphere potential, born approximation, applications. Schrodinger and Heisenberg pictures, interaction picture, unitary transformations, symmetry principle and conservation laws, translation along spatial and temporal directions, spatial rotation and conservation of angular momentum, space reflection and parity conservation, time reversal invariance. Elements of relativistic quantum mechanics, the Klein-Gordon equation, the Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretations, non-relativistic limit of Klein Gordon and Dirac equations, equation of continuity and probability current density.

**Reading Material:**

- Quantum Mechanic by Stephen Gasiorowicz
- Principles of Quantum Mechanics by R. Shankar
- Advanced Quantum Mechanics by J.J. Sakurai
- Quantum Mechanics by Bransden and Joachain

PH5250	Optics & Photonics	3 Credits
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Propagation of Light, Fermat's Principle, Lens and Aberration, Interference, Coherence of Light, Diffraction Theory, Polarization, Fourier Optics, Linear Interaction between Light and Matter, Non-linear Interaction between Light and Matter and basics of nonlinear optics, LASERs basics, Gaussian Optics, Fundamentals of Optical Engineering

Reading Material:

- Principles of Optics, Max Born and Emil Wolf
- Optics by Hecht and Ganesan
- Fourier Optics by Goodman

<b>PH5260</b>	<b>Atomic &amp; Mol. Physics</b>	<b>3 Credits</b>
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Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectral lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Experimental techniques in atomic and molecular physics: Absorption, Fluorescence, Raman, Two-photon, Doppler-limited and Doppler-free spectroscopy, X-ray and photoelectron spectroscopy, Cooling and trapping of atoms/ions.

Reading Material:

- Physics of atoms and molecules by Brensden and Joachain
- Atomic and molecular spectroscopy by Svanberg
- Fundamentals of Molecular Spectroscopy by C.N. Banwell and E.M. McCash

<b>PH6200</b>	<b>Solid State Physics</b>	<b>3-credits</b>
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Crystal structure, Wave diffraction and Reciprocal lattice, Free electron Fermi gas, Band theory of solids, Lattice Vibrations and phonons, Thermal properties, Semiclassical theory of transport, Magnetism and magnetic systems, Dielectrics and Ferroelectrics, Semiconductors, Optical processes and excitons, Superconductivity, Nanostructures

Reading Material:

- C. Kittel, Introduction to Solid State Physics, 8th Edition,
- Solid state Physics by N. W. Ascroft and N. D. Marmin
- Condensed Matter Physics by M. P. Marder

<b>PH5170</b>	<b>Computational Physics</b>	<b>3-credits</b>
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Introduction to programming (Python/MATLAB/C++/C/Fortran95), Numerical differentiation and integration, Monte carlo methods, Curve fitting, Linear and nonlinear regression, Roots and optimization of multivariable functions, Solution of nonlinear equations, Numerical matrix computing, Numerical Fourier analysis, Numerical solutions of ordinary and partial differential equations, Numerical solution of Physics problems (Wave equation, Poisson equation, heat equation, Laplace equation, Schrodinger equation, Nonlinear dynamics, Ising model, Statistical mechanics, molecular dynamics etc.)

#### Reading Material:

- Computational Physics by Tao Pang
- Computational Physics by R. H. Landau, M. J. Paez and C. C. Bordeianu

PH5201	Lab	2-Credit
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#### List of experiments:

1. Millikan Oil drop experiment
2. Fabry – Perot interferometer
3. e/m Ratio
4. Laser Emission and Absorption
5. Multiplexer and Demultiplexer
6. Faraday Effect
7. Klystron Characteristics
8. Amplitude Modulation and Demodulation
9. Op – amp applications
10. Arduino programing experiment

PH6270	Particle Physics	3 Credits
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Basic constituents of matter, Fundamental forces in nature, Accelerators:Cosmic and Manmade, Detectors. Classification of particles, Quark contents of Hadrons, Particle quantum numbers, Gell-Mann Nishijima formula, Relativistic kinematics, scattering amplitudes, Cross sections,decay rate and life-time. Breit-Wigner formula, continuous symmetries and conservation laws. Discrete symmetries. CPT theorem, Weak processes, pion decay, GIM mechanism, Parity violation, Quark mixing,CKM matrix, Neutrino Physics, Elements of Quantum Chromodynamics,Electroweak interaction, Symmetry breaking and Higgs mechanism,Standard Model of Particle Physics and Physics beyond the standard model

#### Reading Material:

1. Introduction to Elementary Particles, D. J. Griffiths;
2. Quarks and Leptons, F. Halzen and A. Martin;
3. Collider Physics, R. Phillips and V Barger

4. Gauge theory of elementary Particles, Cheng and Li;

5. Introduction to High Energy Physics, D. H. Perkins.

<b>PH6278</b>	<b>Nuclear Physics</b>	<b>2 Credits</b>
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Discovery of Nuclei, Rutherford scattering, Nuclear radii and charge distributions, nuclear binding energy, semi-empirical mass formula; nuclear models; radioactivity, nuclear reactions, Elementary ideas of alpha, beta, and gamma decays.

**Reading Material:**

1. Nuclear Physics: Principles and Applications (Manchester Physics Series Book 44);  
John Lilley 1st Edition Wiley
2. KS Krane; Introductory Nuclear Physics 3rd John Wiley & Sons Inc
3. John R. Lamarsh, Anthony J. Baratta Introduction to Nuclear Engineering 3rd Pearson
4. Frank Close NUCLEAR PHYSICS: A VERY SHORT INTRODUCTION Illustrated Oxford University Press

<b>PH5140</b>	<b>Electronics</b>	<b>3 Credits</b>
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Introduction, Thevenin's Theorem, Norton's Theorem, Diode Theory, Rectifiers, Optoelectronics devices (LED, Photodiode, Laser Diode), Transistors and their frequency response (BJT, JFET, MOSFET), Voltage and Power amplifiers, Differential Amplifiers, Operational amplifiers, Binary digits, logic operations, number systems, logic gates, Boolean algebra, K-maps, combinational logic gates, functions of logic gates (adder, comparator etc), Flip flops and its applications (counters, shift registers, memory and storage)

**Reading Material:**

- Albert Paul Malvino, Electronic Principles – latest Edition, Tata McGraw Hill
- L.Floyd, Electronic Devices, "Pearson Education" New York
- Ben.G. Streetman, Solid state electronic devices, Prentice Hall, Englewood cliffs, NJ
- Thomas L.Floyd, Digital Fundamentals – latest edition, Prentice Hall,
- Albert Paul Malvino Donald P. Leach, Digital Principles and Applications , TataMcGrawHill

<b>PH5311</b>	<b>Lab</b>	<b>2 Credits</b>
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**List of experiments:**



1. Zeeman effect
2. Constant deviation Spectrometer
3. XRD-I
4. XRD-II
5. Magnetostriction
6. Microwaves
7. Electron diffraction
8. Four Probe method
9. ESR and NMR
10. Solar cell characterization

## Electives:

PH5340	Advanced Functional Materials and Applications	3 Credits
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PH5380	Fundamentals of Semiconductors Physics and Devices	3 Credits
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PH6730	Plasma Physics and MHD	3 Credits
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Plasma and its occurrence in nature • Concept of Temperature • Debye Shielding • Plasma Parameter • Criteria for Plasmas • Applications of Plasma Physics • Motion of charged particles in fields • Waves in plasmas Methods of plasma production • Ionization and equilibrium models in a plasma • Radiation from plasmas and diagnostics • Absorption processes and instabilities in plasmas • Laser Plasma Interaction Modes of description of a plasma • Collisional plasma • The one-fluid description • The two-fluid description. Collisionless plasma • The guiding center limit of the Vlasov equation • The double adiabatic theory • Consequences of the MHD description. Conservation relations • Flux frozen in plasma

### Reading Material:

- Chen, F. F. *Introduction to Plasma Physics*. 2nd ed. Plenum Press, 1995. ISBN: 9780306307553.
- Tanenbaum, B. S. *Plasma Physics*. New York, NY: McGraw-Hill, 1967. ISBN: 9780070628120.
- Dendy, R., ed. *Plasma Physics*. Cambridge, UK: Cambridge University Press, 1994. ISBN: 9780521433099. (Recommended for specific chapters on space and plasmas and on industrial plasmas)

- Hutchinson, I. H. *Principles of Plasma Diagnostics*. 2nd ed. Cambridge, UK: Cambridge University Press, 1987. ISBN: 9780521326223.
- W. L. Kruer, "The Physics of Laser Plasma Interaction" Addison-Wesley Publishing Co. 1987
- Shalom Eliezer, "The Interaction of High-Power Lasers with Plasmas" Institute of Physics Publishing Ltd. 2002
- Paul Gibbon, "Short Pulse Laser Interactions with Matter-An Introduction" Imperial College Press 2007

PH5320	Concepts and Hands-On Observational Astrophysics	3 Credits
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The course is divided into 3 parts: We begin with an introduction to the foundational concepts of astronomy and astrophysics. This includes celestial mechanics, the operating principles of modern telescopes, and theories of planet and Moon formation, culminating in an in-depth exploration of planetary atmospheres. The first part concludes with an introduction to the exciting field of exoplanet science. In the accompanying hands-on session, you'll learn how to detect exoplanets using radial velocity profiles, working with real data from NASA's Kepler and TESS missions. In the second part of the course, we delve into stellar structure, properties, and evolution, leading to the formation of compact objects such as neutron stars, black holes, and X-ray binaries. The corresponding hands-on session will teach you how to estimate stellar brightness through photometric measurements, using observational data from the Keck telescope, USA and the Indian Telescope. The final part of the course focuses on extragalactic astrophysics, covering topics such as galaxy morphology, active galactic nuclei (AGN), and the properties of quasars. In the concluding hands-on session, you will perform X-ray time series analysis using X-ray data from pulsars and black holes, obtained from the Indian space mission AstroSat.

### Reading Material:

Introduction to Modern Astrophysics: Ostile and Caroll

PH6450	Gravitation and Cosmology	3 Credits
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- Review of Newton's non-relativistic theory of gravitation: Inverse square law, the notion of gravitation field intensity vector, Newton's scalar potential, the Poisson equation for Newton's gravity, Uniqueness, mean value, Earnshaw's theorems, and Multipole expansion of the Scalar potential. Principles of Equivalence of Galileo and Newton, Tidal Forces on extended objects due to gravity.
- Review of Special Relativity: Inertial frames, Lorentz/Poincaré transformations, Invariant space-time interval (Minkowski metric), Minkowski spacetime, timelike, spacelike, and lightlike separated events, lightcones, Lorentz group & its generators.

- Review of Special Relativity (Continued): Relativistic index notation (4-vector notation), Scalars, Vectors, Tensors, etc., Invariant tensors, Differential Forms and Exterior Calculus.
- Special relativistic formulations of point particles (free) and Newton's laws of motion, Covariant equations for fluid mechanics.
- Fluid mechanics (Continued): Stress-Energy-Momentum Tensor, fluid mechanics, Maxwell theory, Alternative derivation of Maxwell's equations (in terms of potentials) purely from Lorentz symmetry and conservation of charge.
- Lorentz covariant equations for gravity ala Maxwell's equations: Fierz-Pauli field (symmetric tensor potential) and Fierz-Pauli equation, Gauge symmetry of Fierz-Pauli field. Coupling to matter: From Minkowski metric to curved metric, gauge invariance as general coordinate transformation symmetry.
- Mathematical Preliminaries I: Elements of point set topology: topological spaces, homeomorphisms, Topological manifolds, Differentiable manifolds, Differential geometry: Charts & Atlases, Tangent space, cotangent space, functions (tensor fields), Pseudotensors and curves on manifolds, smooth maps, pushforward and pullbacks, flows, Lie derivatives.
- Mathematical Preliminaries II: Riemannian manifolds: metric and geodesic equation, Parallel transport and affine connections, Levi-Civita connection (Christoffel symbols), Covariant derivatives, Killing vector and Conservation laws, Geodesic deviation equation & the Riemann Curvature tensor, Ricci tensor, Ricci scalar and the Einstein field equation, Properties of the Riemann tensor,  
Newtonian limit.
- Linear approximation of Einstein field equations: Recovering Fierz-Pauli equation, Lorenz gauge, gravitational waves: polarization and detection, and gravitational radiation.
- Non-linear vacuum solution: Deriving the Schwarzschild Solution for metric outside a spherical mass distribution, Uniqueness theorem, Thin shell, and Newton's theorem. Coordinate and curvature singularities.
- Timelike and lightlike geodesics in the Schwarzschild spacetime: ISCO, Photon Sphere, Precession of the perihelion of planets, Deflection of light, Gravitational redshifting and time-dilation, Shapiro's radar-echo delay.
- Optional topics: Homogeneous & Isotropic Cosmological Models: FLRW universes, Friedmann and Acceleration Equation, Cosmological constant, De Sitter universe, Hubble expansion and galactic redshifts. The Hot Big-Bang: From Planck era to Baryogenesis, The Cosmic microwave background, Dark Matter and Dark energy, Origin of Structure.

### **Reading Material:**

- Schutz, Bernard F. "A first course in General Relativity", Cambridge University Press; 2nd edition (14 May 2009) (Advanced Undergraduate/ Postgraduate level)

- Carroll, Sean M.. "Spacetime and Geometry: An Introduction to General Relativity", Cambridge University Press, 2019. (Advanced Undergraduate/Postgraduate level)
- Ohanian, Hans C., Ruffini, Remo. "Gravitation and Spacetime", Cambridge University Press, 2013.(Advanced Undergraduate/ Postgraduate level)
- Hartle, James: "Gravity: An Introduction to Einstein's General Relativity", Cambridge Univ. Pr (2 September 2021) (Advanced Undergraduate/Postgraduate level)
- Weinberg, Steven. "Gravitation and cosmology: principles and applications of the general theory of relativity", Wiley, 1972. (Postgraduate/ PhD level)
- Stephani, Hans. "Relativity: An Introduction to Special and General Relativity", Cambridge University Press, 2004. (Postgraduate/ PhD level)
- D'Inverno, Ray. "Introducing Einstein's Relativity", Oxford University Press, Oxford University Press, U.S.A. (9 Aug. 1990) (Advanced Undergraduate/ Postgraduate level)
- Misner, Charles W., Thorne, Kip S., Wheeler, John Archibald. "Gravitation", United Kingdom: Princeton University Press, 2017. (Postgraduate/ PhD level)
- Nakahara, Mikio. "Geometry, Topology, and Physics", United Kingdom: Taylor & Francis, 2003.

(Postgraduate/PhD level)

#### **Prerequisites:**

- Analytical Mechanics
- Electrodynamics
- Special Relativity
- Mathematical Methods (Vector calculus, Linear Algebra, ODEs, PDEs)

<b>PH5310</b>	<b>Introduction to Nanomagnetism with Lab</b>	<b>3 Credits</b>
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Basics of magnetism, Magnetism at nanoscale (thin films and nanostructures), Magnetic interactions, Magnetic anisotropies, Magnetic domains, Spin textures at nanoscale (nanodisk, nanorings, nanowires), Interfacial physics in thin film multilayers, Techniques in nanomagnetism and applications (magnetic recording). Experimental (SEM, MOKE, MFM, VSM, Lithography etc.) and virtual (micromagnetic simulations) Lab for nanomagnetism.

#### **Reading Material:**

1. Principles of nanomagnetism: Alberto P. Guimaraes
2. Introduction to magnetic materials: B.D. Cullity

3. Magnetic materials: Fundamentals and Applications: Nicola A. Spaldin
4. Magnetic domains: Alex Hubert and Rudolf Schafer

PH5460	Open quantum systems	3 Credits
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#### Part 1: Irreversibility in quantum systems from noise and dissipation

##### i) General concepts and techniques:

- a) Concepts of density matrix, mixed state, von-Neumann entropy and quantum master equation,
- b) Born-Markov approximation and Redfield quantum master equation,
- c) Nakajima-Zwanzig projection operator method, general quantum master equation, and quantum regression.
- d) Quantum and classical noises in a quantum system, and description via Redfield quantum master equation.

##### ii) Examples:

- a) Qubit under noises, the concept of T1 and T2 times.
- b) Modeling an ideal photon detector and finding the spectrum of light detected from a qubit driven by classical noise.
- c) A two-level molecular junction, coupled to two baths at different temperatures.

#### Part 2: Irreversibility in quantum systems from quantum measurements

##### i) General concepts and techniques:

- a) Completely positive trace preserving (CPTP) maps, Kraus operators
- b) CPTP maps as a generalized measurement, and concept of positive-operator valued measure (POVM).
- c) Collisional or repeated interaction model, and continuous measurement.
- d) Lindblad quantum master equation as a limit of repeated interaction model.
- e) Stochastic unraveling of Lindblad equation, and concept of quantum trajectory.

##### ii) Examples:

- a) Modeling an ideal photon counter at a quantum trajectory level as a single probe qubit.

#### Prerequisite:

At least one previous course on Quantum Mechanics.

**Reading Material:**

Theory of open quantum systems: Breuer and Petruccione

Quantum computation and quantum information: Nielsen and Chuang

Statistical methods in quantum optics: Carmichael

PH6130	Data Science Analysis	3 Credits
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Measurement, analysis; Probability distributions; Parameter Estimation; Hypothesis testing; Model Comparison; Confidence Intervals; Bootstrap and Jackknife analysis. Bayesian Analysis; Markov Chain Monte Carlo techniques; Dimensionality Reduction; Time-series analysis. Periodogram analysis.

**Reading Material:**

- Statistics, Data Mining and Machine Learning in Astronomy by Z. Ivezić, A. Connolly, J. VanderPlas and Alexander Gray
- Data Reduction and Error Analysis for the Physical Sciences. P.R. Bevington
- Data Analysis. A Bayesian tutorial by D.S. Sivia

PH6468	Advanced Particle Physics	3 Credits
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Standard Model as Gauge theory, Electroweak Lagrangian, Two-Three-body decays, muon decay, Scattering amplitude calculation, Symmetry breaking and Higgs mechanism, Yukawa interactions, CKM and CP-violation, Pion decay, flavour symmetries, Neutrino Oscillation, Neutrino matter effect, neutrino interactions, Neutrino mass, Dark Matter phenomenology, Young Tableau, Physics beyond the standard model.

**Reading Material:**

- F. Halzen and A. Martin, Quarks and Leptons, John Wiley
- Quantum Field theory by Peskin and Schroeder
- Gauge theory of elementary Particles Cheng and Li
- Particle Physics by Kerson and Huang
- Massive Neutrinos in Physics and Astrophysics by Mohapatra and Pal

PH6410	Quantum Field Theory	3 Credits
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This is an introductory course on Quantum Field Theory. It covers quantization of scalar fields in detail and towards the very end of the course also introduces elements of Quantum

Electrodynamics. The topics covered are: Free real and complex scalar fields, Canonical quantization, Interacting scalar fields. Feynman propagator, n-point correlation functions and their perturbative expansion, the S-Matrix and its expansion in Feynman diagrams, Kallen-Lehmann spectral representation, LSZ reduction. Cross-section and its connection to the S-Matrix. Renormalization, Dimensional regularization,  $\Phi^4$  theory at one-loop. Dirac Equation, Quantization of Electromagnetic fields, Gauge invariance, Elements of quantum Electrodynamics. Feynman rules and Feynman diagram for spinor electrodynamics.

**Reading Material:**

- M. Peskin & D. Schroeder, "An Introduction To Quantum Field Theory"
- M. Schwartz, "Quantum Field Theory and the Standard Model"
- M. Srednicki "Quantum Field Theory"
- S. Weinberg, "The Quantum theory of fields: Foundations", Volume 1

PH5420	Radiation Detection, Measurement and Instrumentation	3 Credits
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PH5350	MEMS and Microsystems Technology	3 Credits
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PH5430	Spintronics	3 Credits
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PH6168/EP4068:

Spintronics

Credits: 2

Energetics of magnetic system, Domain and Domain wall, Magnetoresistance and spin dependent transport, Magnetic Recording, Materials for spintronics, Opportunity and challenges in spintronics, Length and time correlation in magnetic system, Spin transfer torque, Spin orbit interaction, Skyrmions, Spin injection, Ultrafast Spin dynamics, Spin relaxation, Spin waves, Micromagnetic methods.

**Reading Material:**

- Magnetic waves and oscillations by Gurevich and Melkov
- Micromagnetic methods using OOMMF by Donahue and Porter

- Magnetic domains by Hubert and Schäfer
- Introduction to Magnetism by Cullity

PH5450	Energy harvesting: Sources, circuits, and applications	3 Credits
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PH6300	Ultrafast Optics: Theory and experiments	3 Credits
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Laser basics; Pulsed Optics; Principle of Mode-locking-Active and Passive; Femtosecond laser pulses; Ultrafast-pulse measurement methods; dispersion and dispersion compensation; ultrafast nonlinear optics; manipulation of ultrashort pulses; application of ultrashort pulses: time resolved and THz spectroscopy, coherent control; attosecond pulses. Matlab/Python/R Simulation

#### Reading Material:

- Ultrafast Optics by Andrew M. Weiner, Wiley.
- Femtosecond laser pulses: principles and experiments ed. Claude Rullière, Springer.

PH5360	Optical Engineering and lab	3 Credits
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PH7400/EP4400:

Optical Engineering and lab

Credits: 3

Basics of Geometrical Optics and Diffraction Theory, Optical Components: Mirrors, Lens, Prisms, Thin lens theory, Aberrations, Basic Optical Instruments, Lens Design and evaluation, Introduction to Optical Instrument design. 1 credit Lab/Simulation Matlab/Python/R

#### Reading Material:

- Optical Engineering Fundamentals, Second Edition, Bruce H Walker, SPIE Press
- Basic Optical Engineering for Engineers and Scientists, Haiyin Sun, SPIE Press
- Modern Optical Engineering, W.J. Smith, McGraw-Hill

PH5330	Fiber Optics, Technology, and Application	3 Credits
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