LIST OF B. TECH. ELECTIVES

PH 451: Plasma Physics 3-0-0-6

General definition and properties of plasma, Motion of the charged particles in space and time varying electromagnetic field, Kinetic theory and thermodynamics of Plasma, Debye shielding, Boltzman and Fokker-Planck equation, Transport and collision in plasma, plasma fluid theory, hydrodynamics and magneto hydrodynamics, magnetic mirror, waves in plasma, plasma instabilities, plasma radiation and Plasma spectroscopy, Boltzman –Saha equation, neutral and non neutral plasma, Generation and diagnostics of plasma, plasma processing and other industrial applications industrial, Tokamak, nuclear fusion.

Texts and References:

1. J A Bittencourt, *Fundamentals of Plasma Physics(3rd Edition),* Springer (2008)
2. Chen, Francis F, *Introduction to plasma Physics and controlled fusion*, Plenum Press NY (1984).
3. Robert J. Goldston and Paul H. Rutherford, *Introduction to plasma physics*, IOP, Bristol (1995).
4. Griem, Hans R., *Principles of plasma spectroscopy,* University Press, Cambridge (1997)
5. I H Hutchinson, *Principles of Plasma Diagnostics*, Cambridge (1994)

PH 452: Magnetic Recording 3-0-0-6

(Pre-requisite: PH415 or equivalent)

History and overview of magnetic recording, Physics of Magnetism, Various forms of magnetic energies, Hard and Soft magnetic materials, Fundamental recording theory, Media magnetization, Erasure and Overwrite, Recording Zone and losses, Play Back Theory, Magnetic head circuits, Magnetoresistance, Anisotropic Magnetoresistance (AMR), Giant Magnetoresistance (GMR) Heads, Tunneling Magnetoresistance (TMR) heads, Spin Valves, Field from Magnetic Heads, Perpendicular head fields, Flux linkage and leakage, Particulate media, Thin magnetic films, Flexible media and Rigid disk substrates, Magnetic Properties of the media, Effects of Time and Temperature; Storage stability; measurement of spin polarization, Recording of a single transition, Narrow-track and short-gap recording, Perpendicular recording, Ultrahigh density recording, Future projection on recording and devices based on magnetoelectronics.

Texts and References:

1. Michael Ziese and Martin J Thornton (Eds).,*Spin Electronics* ,Springer (2001).
2. Martin L. Plumer, Johannes Van Ek and D. Weller, *The Physics of Ultra-high Density Magnetic Recording*, Springer (2001).
3. Finn Jorgensen, *The Complete Handbook of Magnetic Recording,* TAB Books(1995).
4. M. Johnson, *Magnetoelectronics,* Academic Press (2004).
5. C.D. Mee and E.D. Daniel, *Magnetic Recording Technology*, McGraw-Hill Professional(1996).

PH 453: Robotics Fundamentals 3-0-0-6

Prerequisite: PH-211 Classical Mechanics (or equivalent)

Types of robots and manipulators. Kinematics and dynamics of manipulators. Geometric model of manipulators. Velocity and acceleration analysis of manipulators. Positioning and orientation of manipulators. Pick and place operations. Forward and inverse dynamics, Euler-Lagrange equations and constrained dynamics of manipulators. Analyses of serial and parallel robotic manipulators**.** Incorporation of gravity and friction. Some applications of SE(3) group.

Texts and References :

1. J. Angeles, *Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithm* (*3rd Edition)*, Springer(2007).
2. D. D. Ardayfio, *Fundamentals of Robotics*, CRC Press(1987).
3. J. J. Craig, *Introduction to Robotics: Mechanics and Control (2nd Edition)*, Addison-Wesley Longman(1986).
4. H. Goldstein, *Classical Mechanics*(3rd Edition), Pearson Education(1995).
5. Y. Koren, *Robotics for Engineers*, McGraw-Hill(1985).
6. J. M. Selig, *Geometric Fundamentals of Robotics* (2nd Edition), Springer(2005).

PH 454: Antenna Theory and Applications 3-0-0-6

Prerequisite: PH-301 Electromagnetics (or equivalent)

Definition of basic antenna concepts. Point sources and polar plots. Analyses of arrays of point sources. Electric dipole and thin linear antennas. Loop antenna, far field pattern. Helical antenna, axial modes. Biconical antenna and its impedance. Cylindrical antenna, integral equations and the moment method. Self and mutual impedances. Arrays of dipoles and apertures. Reflector antennas.

Texts and References*:*

1. J. D. Kraus, *Antennas (2nd Edition)*, TMH (2001).
2. C. A. Balanis, *Antenna Theory: Analysis and Design (3rd Edition)*, Wiley Interscience(2005).
3. J. D. Jackson, *Classical Electrodynamics (3rd Edition)*, John Wiley(2005).
4. R. E. Collin, *Antennas and Radio Wave Propagation*, McGraw-Hill(1985)**.**

PH 455: Microwave Theory and Applications 3-0-0-6

Prerequisite: PH-301 Electromagnetics (or equivalent)

Transmission Lines: Circuit models, lossless and lossy lines, Field analysis, Smith chart. Waveguides, Striplines, and Microstrips. Microwave circuits: Impedance and admittance matrices, scattering matrix, transmission matrix, signal flow graph, modal extiction. Impedance matching, stub tuning, matching transformers, tapered lines. Microwave cavities and resonators, cavity perturbations. Power dividers, directional couplers, and microwave filters. Microwave amplifiers, oscillators, and mixers. Wireless communication systems.

Texts and References*:*

1. D. M. Pozar, *Microwave Engineering (3rd Edition)*, John Wiley (2005).
2. R. E. Collin, *Foundations for Microwave Engineering (2nd Edition)*, Wiley Interscience (2001).
3. S. Y. Liao, *Microwave Devices and Circuits (3rd Edition)*, Prentice Hall (1995).
4. J. D. Jackson, *Classical Electrodynamics (3rd Edition)*, John Wiley (2005).
5. G. D. Vendelin, A. M. Pavio, and U. L. Rohde, *Microwave Circuit Design*, John Wiley (1990).

PH 456: Physics of Carbon-Based Materials 3-0-0-6

(8th semester)

Prerequisites : PH 415/Equivalent

Historical background on allotropes of carbon - graphite and diamond. Brief overview of structure, electronic and mechanical properties. Newly discovered allotropes of carbon - fullerenes, carbon nanotubes, graphene.

Fullerenes: Production, intercalation compounds, synthesis, characterization, physical properties and technological applications of fullerenes.

Carbon Nanotubes : Formation of carbon allotropes, nanoscale numerical simulation techniques, interatomic potentials and forces in nanotubes, continuum and atomistic theories of mechanical properties, thermal transport in nanotubes, fluid flow in nanotubes and technological applications of carbon nanotubes.

Graphene: Atomic structure of graphene, band description, quasiparticles and the Dirac cone, relativistic dispersion and anomalous Hall effect, Klein paradox and proposed technological applications.

Texts and References :

1. A. Paoletti and A. Tucciarone (Eds.), *The Physics of Diamond, vol. 135, International School of Physics Enrico Fermi*, IOS Press, Amsterdam, The Netherlands (1997).
2. Pierre Delhaes (Ed.), *Graphite and Precursors (World of Carbon)*, Gordon and Breach Science Publishers (2001).
3. Wanda Andreoni (Ed.), *The Physics of Fullerene based and Fullerene related Materials, Series on Physics and Chemistry of Materials with Low Dimensional Structures*, Kluwer Academic Publishers (2000).
4. Hashem Rafii-Tabar, *Computational Physics of Carbon Nanotubes(1st Edition)*, Cambridge University Press (2007).
5. N.M.R. Peres, F. Guinea, and A.H. Castro Neto, *Electronic properties of two-dimensional carbon*, Annals of Physics, vol. 321, pp. 1559 (2006).
6. Mikhail I. Katsnelson, *Graphene: carbon in two dimensions*, Materials Today, vol.10, Issues 1-2, pp. 20 (review article) January-February (2007).

PH 457: Nuclear Science and Technology 3-0-0-6

Review of nuclear physics: general nuclear properties, models of nuclear structure, nuclear reactions, nuclear decays and fundamental interactions.

Nuclear radiation: radioactivity, radiation dosimetry, dosimetry units and measurement; radiation protection and control; applications of radiation: medical applications, industrial radiography, neutron activation analysis, instrument sterilization, nuclear dating.

Nuclear fission: nuclear energy, fission products, fissile materials, chain reactions, moderators, neutron thermalization, reactor physics, criticality & design; nuclear power engineering; energy transport and conversion in reactor systems, nuclear reactor safety; nuclear fusion: controlled fusion, nuclear fusion reactions, fusion reactor concepts, magnetic confinement, tokamak, inertial confinement by lasers.

Nuclear waste management: components and material flow sheets for nuclear fuel cycle, waste characteristics, sources of radioactive wastes, compositions, radioactivity and heat generation; waste treatment and disposal technologies; safety assessment of waste disposal.
Particle accelerators and detectors: interactions of charged particles, gamma rays and neutrons with matter, electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators, gas-filler counters, scintillation detectors, and semiconductor based particle detectors.

Texts and References:

1. K. S. Krane, *Introductory Nuclear Physics*, John Wiley (1987).
2. R. J. Blin-Stoyle, *Nuclear and Particle Physics*, Springer (1991).
3. J. K. Shultis and R. E. Faw, *Fundamentals of Nuclear Science and Engineering*, Marcel Dekker (2007)
4. James E. Turner, *Atoms, Radiation, and Radiation Protection*, Wiley-VCH (2007)
5. R. L. Murray, *Nuclear Energy 6th Ed*., Butterworth-Heinemann (2008).
6. James J. Duderstadt and Louis J. Hamilton, *Nuclear Reactor Analysis*, Wiley (1976)
7. Perkins, Donald H., *Introduction to High Energy Physics*, Cambridge University Press (2000).
8. John R. Lamarsh and Anthony J. Baratta, *Introduction to Nuclear Engineering*, Prentice Hall (2001)
9. A. G. Chmielewski, C. M. Kang, C. S. Kang, and J. L. Vujic, *Radiation Technology: Introduction to Industrial and Environmental Applications*, Seoul National University Press (2006)

PH 458: Applied Superconductivity 3-0-0-6
(7th/8th semester)

Basics of superconductivity, superconducting materials, Electrodynamics of superconductors, London's model, flux quantization, type II superconductors, critical magnetic fields, pinning, the critical state model, electrodynamic behaviour at high (microwave) frequencies both at weak and strong applied fields for both isotropic and anisotropic superconductors, Josephson Junctions, Dc and rf superconducting quantum devices (SQUID), equivalent circuits, Josephson logic circuits, high-speed superconducting electronics, and quantized circuits for quantum computing. Architecture of superconducting magnets, Elements of Superconducting levitation, Levitation forces and schemes, superconducting bearings, dynamics of levitated systems, magnetic levitation transportation.

Texts and References:

1. M. Tinkham, *Introduction to Superconductivity (2^{nd} edition),* Courier Dover Publications (2004).
2. Charles P. Poole, Jr., Horacio A. Farach, Richard J. Creswick and Ruslan Prozorov, *Superconductivity*, Academic Press(1995).
3. Werner Buckel , Reinhold Kleiner , *Superconductivity Fundamentals and applications (2^{nd} edition),* John Wiley-VCH(2003).
4. Shu-Ang Zhou , *Electrodynamics of solids and microwave superconductivity,* John Wiley and Sons (1999).
5. F. C. Moon and Pei-Zen chang, *Superconducting levitation*, Wiley-VCH (1995).
6. J. C Gallop, *SQUIDS, the Josephson Effects and Superconducting Electronics*, Taylor and Francis (1991).

PH 459: Nonlinear Fiber Optics and applications 3-0-0-6

Basic characteristics of an optical fiber: Fiber losses, Chromatic dispersion, Polarization mode dispersion, Fiber nonlinearities, fiber modes, single-mode fiber.

Nonlinear pulse propagation**:** Derivation of The Nonlinear-Schrödinger equation (NLSE), variational and numerical methods to solve NLSE.

Optical solitons: Modulation instability, physics of optical soliton formation in optical fiber, bright and dark solitons, soliton-soliton interactions, effect of higher order perturbations.

Highly nonlinear fibers: Fibers with silica cladding, tapered fibers with air cladding, non-silica fibers, microstructured fibers.

Applications: Nonlinear fiber gratings, slow light, nonlinear fiber coupler, fiber-lasers, pulse compression, super continuum generation, soliton communication system.

Texts and references:

1. G.P.Agrawal,*Nonlinear Fiber Optics*, 4th ed. Academic Press,2007
2. G.P.Agrawal,*Applications of Nonlinear Fiber Optics*, Academic Press,2001
3. R.W.Boyd,*Nonlinear Optics*,3^{rd} ed. Academic press,2007

PH 460: Electroceramics 3-0-0-6

Introduction: A historical account of the discovery and development of ceramic materials for electrical and electronic applications. Physical principles of electrical and electronic properties of ceramics. Ionic structure, defects, spontaneous polarization, phase transitions, electrical conduction and charge displacement processes.

Fabrication of ceramics: General methods and new developments in ceramic processing. Sintering and microstructure development: Solid state sintering, densification vs. coarsening processes, grain boundary mobility mechanisms, porosity evolution, viscous densification, liquid phase sintering, constrained sintering.

Dielectrics and insulators: Capacitive and ferroelectric applications. Dielectric properties for low-, medium- and high-permittivity ceramics.

Measurement techniques: Basic principles and techniques for dielectric, ferroelectric and piezoelectric property measurements. Structure and property correlations.

Piezoelectric ceramics: General characteristics and commercial applications of typical piezoceramics.

Pyroelectric materials: Properties and measurements of pyroelectric coefficients of ceramics, thermal and infrared detection.

Electro-optic ceramics and Magnetic ceramics: Basic concepts, properties and applications of model ferrites.

Texts:

1. A. J. Moulson, J. M. Herbert, Electroceramics, 2nd Ed., John Wiley & Sons Ltd, 2003.
2. M.N.Rahaman, Ceramic processing and sintering, 2nd Ed., 2nd Ed., Marcel Dekker, Inc, New York, 1995.

References:

1. S. Somiya,F. Aldinger, N. Claussen, R. M. Spriggs, K. Uchino, K. Koumoto, M. Kaneno, Handbook of Advanced Ceramics, Volume II Processing and their Applications, Elsevier Inc, 2003.
2. M. W Barsoum, Fundamentals of ceramics, IOP Publishing Ltd, 2003
3. R.C. Buchanan, Ceramic Materials for Electronics: Processing, Properties, and Applications. Electrical Engineering and Electronics, 2nd Ed., Marcel Dekker, Inc, New York, 1991.

PH 461: Electron transport in Nanostructures 3-0-0-6

Pre-requisite: PH 302/PH 405 for B. Tech/M. Sc

Basics of electron transport: Two dimensional electron gas, characteristic length scales, ballistic and diffusive transport, confinement and quantization of electronic states in quantum wires and quantum dots, Magnetic field and Hall effect, Quantum Hall effect, screening and collective excitations in low dimensional systems; Drude model: coherent and incoherent transport, Kubo formula, Fluctuation-dissipation theorem, generalization to spin-dependent transport, Boltzmann equation, approaches to local equilibrium; Transport in semiconductor nanostructures: Landauer formalism, Greens functions, S-Matrix, Self energy, Landauer-Buttiker formula, generalization to the multi-channel case, transport in quantum waveguide structures, Coulomb blockade effects in two terminal devices and single electron transistors; Transport through metal-superconductor interfaces: Proximity effect, basic theory of Andreev reflection, point contact and crossed Andreev reflection, Andreev interferometer.

Texts/References:

1. Electrical Transport in Nanoscale Systems - M. Di Ventra, Cambridge University Press (2009)
2. Electronic Transport in Mesoscopic systems – S. Datta, Cambridge University Press (1999)
3. Electron transport in Nanostructures and Mesosocopic devices – T. Ouisse, John Wiley and Sons (2008)
4. Nanostructures and Mesoscopic systems- W.P. Kirk and MA. Reed, Academic Press (1992)
5. Transport in Nanostructures – D.K. Ferry, S.M. Goodnick and J. Bird, Cambridge Press, 2nd Ed. (2009)
6. Quantum Transport Theory – J. Rammer, Perseus Books (1998)

PH 462: Quantum Technology and Phenomena in Macroscopic systems

Pre-requisite: Quantum Mechanics (PH 204) **3-0-0-6**

Review of the harmonic oscillator and two-level atomic systems, Ladder operators, Coherent states, Bloch vector, Rabi-oscillations, Basic idea about quantization of electromagnetic fields, Cooper pair box and its approximation as a two-level system, Microwave transmission line, Quantization of the transmission line and resonator, Jaynes-Cummings model in circuit QED, Dissipation in quantum systems, Lindblad Markoff master equations, Application to relaxation in a two-level system and harmonic oscillator, Bloch equations for a dissipative two-level system, Multi-qubit architectures, multi-qubit entanglement, strongly-driven artificial atoms, Cavity optomechanics, Quantum description of optomechanics, Mechanical cooling and squeezing.

Texts and References:

1. M. Devoret, B. Huard,R. Schoelkopf and L. F. Cugliandolo, *Quantum Machines: Measurement and Control of Engineered Quantum Systems*, Oxford University Press, (2014).
2. G. S. Agarwal, *Quantum Optics*, Cambridge University Press, (2013).
3. W. P. Bowen and G.J. Milburn, Quantum Optomechanics, CRC Press (Taylor and Francis Group), (2016).
4. N. K. Langford, *Circuit QED* -Lecture Notes, arXiv:1310.1897v1 7 Oct (2013).

PH 463: Theory of relativity 3-0-0-6

Pre-requisite: Classical Mechanics (PH 201), Electromagnetics (PH 202)

Review of basic concepts of special theory of relativity; Relativistic mechanics: Four dimensional formulation, Action function for a free particle, energy and momentum, Lagrangian and Hamiltonian formulation, decay of particles, elastic collision of particles, mechanics of continuous media; Relativistic electrodynamics: Invariance of electric charge and covariance of Maxwell's equations, Four vector potential, Field tensors, Gauge invariance, Lorentz transformation of the electromagnetic (EM) field, dual of the EM field tensors, Lorentz force and EM energy momentum tensor, action function for the EM field; Basics of General Relativity: mathematical preliminaries, distance and time intervals, covariant differentiation, metric tensor and Christoffel symbols, the curvature tensor, properties of the curvature tensor, action function for the gravitational field, the energy momentum tensor, the Einstein's equation, solution of Einstein's equation in spherically symmetric background.

Text/References:

1. Introduction to Special Relativity – Robert Resnick, Publisher: Wiley India Pvt. Ltd., 1st edition (2010).
2. The Special Theory of Relativity – S. Banerjee and A. Banerjee, Publisher: PHI learning Pvt. Ltd., 2nd Edition (2012).
3. The Classical Theory of Fields – L. D. Landau and E. M. Lifshitz, Publisher: CBS publisher and distributor, New Delhi, 4th Edition (2008).
4. A first course in General Relativity – Bernard Schutz, Publisher: Cambridge University Press, 2nd Edition (2012).
5. Spacetime Physics: Introduction to Special Relativity, E. F. Taylor and J. A. Wheeler, Publisher: W. H. Freeman, 2nd Edition (1992).
6. Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity-Steven Weinberg, Publisher: Wiley, 1st Edition (2008).
7. Gravity: An Introduction to Einstein's General Relativity – James B. Hartle, Publisher: Pearson Education, 1st Edition (2014).

PH 464: Fundamentals of Cosmology 3-0-0-6

Pre-requisite: Classical Mechanics (PH 201)

A brief review of General Relativity; The Observed Universe and its Dynamics, Friedmann-Lemaitre-Robertson-Walker (FLRW) metric, Friedmann equation and its solutions; Thermal history of the Universe, Matter-Radiation equality, Formation of cosmic microwave background (CMB), Recombination, Neutrino decoupling and Cosmic neutrino background; Calculation of relic abundance, Boltzmann equation; Composition of the Universe, Origin of matter, Big Bang Nucleosynthesis, abundance of light elements, dark matter and dark energy, Cosmological constant as dark energy, Origin of matter-antimatter asymmetry, Baryogenesis; Structure formation in the Universe, perturbations, gravitational instability, Newtonian and relativistic theory of evolution of density perturbations, evolution of structure, Power spectrum, CMB anisotropies; Beyond the standard model of cosmology, Horizon, flatness and monopole problems in the standard model of cosmology, Cosmic Inflation as a solution to these problems, Models of inflation, Origin of primordial perturbations.

Text/References:

1. S. Dodelson, Modern Cosmology, Academic Press (2003).
2. E. W. Kolb and M. S. Turner, The Early Universe, Levant Books (2007).
3. V. Mukhanov, Physical Foundations of Cosmology, Cambridge University Press (2005).
4. P. Schneider, Extragalactic Astronomy and Cosmology, Springer (2015).
5. M. Roos, Introduction to Cosmology, Wiley-Blackwell (2015).
6. S. Serjeant, Observational Cosmology, Cambridge University Press (2010).

PH 466: Advanced Statistical Mechanics 3-0-0-6

(subject to Senate approval)

Introduction to Phase transitions: Thermodynamics of phase transition, Features of first and second order transitions, Phase diagrams, critical phenomena, oder parameter, critical phenomena in different systems, response, correlation and fluctuation, critical opalescence. Critical point exponents: identifying critical exponents, determining the exponent inequalities, Homogeneity of free energy and scaling of critical exponents, data collapse and universality. Overview of statistical mechanics: Ensembles, ensemble averages, partition functions, free energy, response functions, fluctuations. Models and their ground states: Spin-l/2 and Spin-l Ising Models, q-state Potts model, X-Y and Heisenberg models. Ground state configurations, classical and quantum critical phenomena, applications of models, Universality among different models. Mean Field Theory: Mean Field Theories for Ising model, Weiss mean field, Bogoliubov inequality, Bragg-Williams mean field, solution of mean field equation, determination of critical exponents, correlation length and correlation functions, upper critical dimension, Bethe approximation in one and two dimensional Ising models. Landau theory: Landau potential, continuous transition, critical exponents, discontinuous transition, asymmetric potential and first order transition, Ginzburg -Landau theory. Transfer matrix: Methodology, setting up the transfer matrix for one dimensional Ising model, eigenvalues and eigenvectors of transfer matrix, calculation of free energy, magnetization, susceptibility, specific heat and correlation function, transfer matrix for spin- 1 Ising and q-states Potts' models. Transfer matrix formalism for two dimensional Ising model, free energy function, critical point and exponents. Series Expansion: High and low temperature series, application in 1-d and 2-d Ising models, Duality transformation and critical point, analysis of different series. Renormalization Group: Prescription of RG transformation and RG operation, flow in parameter space, rescaling of free energy density and correlation length, critical exponent, fixed point, universality, application of RG in 1-d and 2-d Ising models.

Text/Referencs:

1. R. K. Pathria, Statistical Mechanics, Butterworth-Heinemenn, Oxford (2011).
2. J. M. Yeomans, Statistical Mechanics of Phase transitions, Oxford University Press, Oxford (1992).
3. H. E. Stanley, Introduction to Phase transitions and Critical Phenomena, Oxford University Press, Oxford (1971).
4. J.J. Binney, N.J. Dowrick, A.J. Fisher, and M.E.J. Newman, The Theory of Critical Phenomena, Clarendon Press, Oxford (2002).