Deccan Education Society's
FERGUSSON COLLEGE (AUTONOMOUS), PUNE

Syllabus

for

M. Sc.(Physics)
Part II
(Semester-III and Semester-IV)

[Pattern 2019]

from Academic Year

2020-21

Program Structure of M.Sc. (Physics) Part-II

Particulars	Paper	Paper code	Title of Paper	Type of Paper	No. of Credits
M.Sc. Semester-III	Paper- 1	PHY5301	Experimental Techniques in Physics	Special-2	4
	Paper - 2	PHY5302	Solid State Physics	CORE	4
	Paper - 3	*PHY5303	Physics of Semiconductor Devices	D Elective/ M**	4
	Paper -4	*PHY5304	Materials Synthesis, Processing and Applications	G Elective	4
	Paper– 5	*PHY5305	Astronomy and Astrophysics - I	D Elective/ M**	4
	Paper – 6	*PHY5306	Vacuum Science and Technology	D Elective/ M**	4
	Paper -7	PHY5307	Physics Practical Laboratory –III (Materials Science)	Special Lab-1	4
***Students should select any two courses for Semester III, from PHY5303, PHY5304, PHY5305 and PHY5306**					
M. Sc. Semester-IV	Paper- 1	PHY5401	Nuclear Physics	CORE	4
	Paper - 2	*PHY5402	Astronomy and Astrophysics – II	D Elective/ M**	4
	Paper - 3	*PHY5403	Physics of Nanomaterials	G Elective	4
	Paper -4	*PHY5404	Thin Film Physics and Technology	D Elective/ M**	4
	Paper– 5	*PHY5405	Atmospheric Science	D Elective/ M**	4
	Paper – 6	PHY5406	Physics Practical Laboratory –IV (Astrophysics + Atmospheric Science + MATLAB)	Special Lab-2	4
	Paper -7	PHY5407	Physics Practical Laboratory –V (Project)	CORE	4
***Students should select any two courses for Semester IV, from PHY5402, PHY5403, PHY5404 and PHY5405**					
*D = Departmental Elective					
M = MOOCs (Massive Open Online Course): **: Courses will be decided by the Chairman					

Extra Credit Courses for M. Sc.

Structure of Compulsory Add-on Credits for all PG courses					
Year	**Semester**	**Human Rights**	**Cyber Security**	**Skill Development**	**Total Credits**
First Year	I	2 Credits	--	--	2 Credits
	II	--	2 Credits	2 Credits	4 Credits
Second Year	III	--	2 Credits	2 Credits	4 Credits
	IV	--	--	--	--
		2 Credits	4 Credits	4 Credits	**10 Credits**

List of compulsory add on courses for PG:

	Course Codes	Title	Credits	Exam (Only Internal) Marks
1	XHR4100	Human Rights	2	50
2	XCS4200	Cyber Security -I	2	50
3	XSD4200	Skill Development -I	2	50
4	XCS5300	Cyber Security -II	2	50
5	XSD5300	Skill Development -II	2	50

Note: Only Course Grade must be printed for add-on courses and marks will not be counted for SGPA or CGPA calculations. Student must pass in all add-on courses to get the degree.

PHY5301 : EXPERIMENTAL TECHNIQUES IN PHYSICS [Credits – 4]

Course Outcomes After learning this course student will be able to CO1 To understand the basic block diagram of any instrument used for the purpose of characterization. CO2 To understand the basic concepts used for analyzing different physical, chemical, optical, structural, etc properties of materials. CO3 To get an idea regarding the interpretation and methods of analysis for the obtained data	
Unit I	**Sensors, Signals and Signal Analysis:** *Sensors*: Characteristics, classification, operating principles of sensors (electric, dielectric, acoustic, thermal, optical, mechanical, pressure, IR, UV gas and humidity). *Signals*: random signals and time series (basic), Signal analysis: Time and frequency domain analysis, spectral analysis, auto and cross correlation functions. Measurement errors and analysis.
Unit II	**Spectroscopic characterization**: (principle, instrumentation and working): Infra-Red (IR), Fourier Transform Infra-Red (FTIR), Ultraviolet-Visible (UV-VIS), Diffused Reflectance Spectroscopy (DRS), XPS, EDAX, Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR).
Unit III	**Structural and Morphological Characterization:** (principle, instrumentation and working): *X-ray Diffraction*: Production of X-rays, Types (continuous and characteristics), Bragg's diffraction condition, principle, instrumentation (with mass absorption filters) and working, Techniques used for XRD – Laue's method, Rotating crystal method, Powder (Debye-Scherrer) method, Derivation of Scherrer formula for size determination. *Neutron Diffraction*: Principle, Instrumentation and Working. *Optical Microscopy*: Principle, Instrumentation and Working of optical microscope. *Electron Microscopy*: Principle, Instrumentation and Working of Scanning Electron Microscope (SEM), Field Emission Scanning Electron Microscope (FESEM) –Advantages over SEM, Transmission Electron Microscope (TEM), Selected Area Electron Diffraction (SAED). *Probe Microscopy*: Scanning Tunnelling Microscope (STM) and Atomic Force Microscope (AFM).
Unit IV	**Thermal analysis**: Thermo-gravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC); Graphical analysis affecting various factors. *Magnetic Characterization*: Principle, Instrumentation and Working of Vibrating Sample Magnetometer (VSM), Analysis of Hysteresis loop, *SQUID Technique*: Principle, Instrumentation and Working.
Reference Books: 1. Instrumentation: Devices and Systems, C.S. Rangan, G.R. Sarma and V.S.V.	

Mani,Tata Mc-Graw Hill Publishing Co. Ltd.
2. Instrumental Methods of Chemical Analysis, G. Chatwal and S. Anand, Himalaya Publishing House
3. Characterization of Materials, John B. Wachtman&Zwi. H. Kalman, Pub. Butterworth Heinemann (1992)
4. Instrumental Methods of Analysis by H.H. Willard, L.L. Merritt, J.A. Dean, CBS Publishers.
5. Elements of X-ray diffraction, Bernard Dennis Cullity, Stuart R. Stock, (Prentice Hall)
6. Methods of Experimental Physics, Vol. II (R. V. Coleman, Academic Press, NewYork and London, 1974)

PHY5302: SOLID STATE PHYSICS [Credits – 4]

Course Outcomes

After learning this course student will be able to

CO1 Student will be able to correlate the material properties based on the understanding of electron-lattice interaction.

CO2 This knowledge will enable the student to understand deeper aspects of materials science and engineering.

Unit I	**Band Theory of Solids:** Nearly free electron model, DC and AC electrical conductivity of metals. Bloch theorem (with proof), Kronig-Penney model, Motion of electron in 1-D according to band theory, Distinction between metals, insulators and intrinsic semiconductors, Reduced, periodic and extended zone schemes, Cyclotron resonance, Quantization of electronic orbit in a magnetic field. ***Reference*:** Kittel, Ch. 7 and 9
Unit II	**Diamagnetism and Paramagnetism:** Classical theory of diamagnetism, Langevin theory of Paramagnetism, Quantum theory of Paramagnetism, Paramagnetic susceptibility of conduction electron, Magnetic properties of rare earth ions & iron group ions with graphical representation, Crystal fieldsplitting, Quenching of orbital angular momentum. ***Reference*:** Kittel, Ch. 14
Unit III	**Ferromagnetism, Antiferromagnetism and Ferrimagnetism:** *Ferromagnetism*: Wiess theory, Curie point, Exchange integral, saturation magnetization and its temperature dependence, Saturation magnetization at absolute zero, ferromagnetic domains, Anisotropy energy, Bloch wall, *Antiferromagnetism*: Neel temperature, *Ferrimagnetism*: Curie temperature, susceptibility of ferrimagnets. ***Reference*:** Kittel, Ch. 15
Unit IV	**Superconductivity:** Occurrence of superconductivity, Meissner effect, Heat capacity, Energy gap, Microwave and IR properties, Isotope effect, Type I and II superconductors, Thermodynamics of superconductivity, London equation, London penetration depth, BCS theory, Quantization in a superconductivity ring, Qualitative discussion of Josephson superconductor tunnelling. ***Reference***: Kittel, Ch.12

Reference Books:

1. Introduction to solid states Physics - Charles, Kittle 7th Edition.
2. Solid States Physics - S. O. Pillai (Current edition).
3. Elementary Solid States Physics- M. Ali Omar.
4. Problem in Solid State Physics – S.O. Pillai.
5. Solid States Physics – A. J. Dekkar.
6. Solid States Physics – Wahab.
7. Solid State Physics: Neil W. Ashcroft, N. David Mermin.
8. Solid States Physics – C. M. Kacchawa

PHY 5303: PHYSICS OF SEMICONDUCTOR DEVICES [Credits-4]

Course Outcomes

After learning the course student will be able to

CO1 Apply knowledge of basic solid state physics for synthesis of semiconductor materials.

CO2 Apply the knowledge of semiconductors to illustrate the functioning of basic electronic devices.

CO3 Tailor the properties of materials for application in semiconductor devices.

CO4 Understand the fabrication methods of integrated circuits.

Unit I	**Properties of Semiconductors:** Band structure of semiconductors, carrier concentration at thermal equilibrium forintrinsic and doped semiconductors, carrier energy distribution, application ofFermi factor to semiconductors, Density of available states, Excess carriers, Carriertransport phenomena (Mobility,Resistivity, Hall effect), Recombination process, Basicequation for semiconductor device operation.
Unit II	**PN Junction:** Basic device technology, Depletion region and depletion capacitance, CurrentVoltage characteristics (Ideal case, Shockley Equation), Generation-recombinationprocess, High injection condition, Diffusion capacitance, Narrow base diode, Junctionbreakdown.
Unit III	**Junction Transistor & Field Effect Devices:** Formation of transistor, Basic Current-Voltage relationship, Current gain in transistor, Injection efficiency, Base transport factor, Depletion layer and surface recombination. Static characteristics (common base & common emitter configurations). Power transistor: General consideration, Second breakdown switching transistor, Uni-junction transistor Schottky diode, Semiconductor Controlled Rectifier, Junction Field Effect Transistor Basic characteristics: static characteristics, Dynamic characteristics, current limiter.
Unit IV	**Metal Semiconductor & Metal Insulator Semiconductor Devices:** Schottky effect, Energy Band relation at metal semiconductor contact, Ideal condition and surface states depletion layer, General expression for barrier height, Current transport theory in Schottky barrier, Thermionic emission theory, Diffusiontheory. Measurements of Schottky barrier height, current voltage measurement, forward characteristics, reverse characteristics. Metal semiconductor IMPATT Diode. Ideal MIS diode, surface states, surface charges and space charges, effects of metal work function.

Reference Books:

1. Physics Solid State Devices – B.B.Streetman.
2. Physics of Semiconductor Devices – S.M. Sze
3. Fundamentals of Semiconductor Devices – J. Lindmayer and C.Y. Wrigley
4. Introduction to Semiconductor devices – K.J.M. Rao
5. Physics of Semiconductor Devices – Michael Shur
6. Semiconductor Physics – Smith

PHY 5304 : MATERIALS SYNTHESIS,PROCESSING AND APPLICATIONS [Credits – 4]

Course Outcomes

After learning this course student will be able to

CO1 Students will be able to synthesis different materials by different synthesizing techniques.

CO2 Students can modify the properties of materials according to the requirement by choosing proper substitution, materials processing technique etc.

CO3 Student will be able to use knowledge to explore the different applications in the field of magnetic and piezoelectric materials.

Unit I	**Diffusion in Solids:** Mechanism of Diffusion, Fick's first law of diffusion, Fick's second law of diffusion, solution to Fick's second law (error function), Atomic model of diffusion, Applications based on the second law, experimental determination of D, corrosion resistance of duralumin, decarburization of steel.
Unit II	**Materials Synthesis:** Materials Synthesis: Concept of equilibrium and nonequilibrium processing and their importance in materials science. Synthesis of Bulk materials: Metallic and non metallic materials, Ceramics and other materials. Basic concepts of powder technologies, compaction, sintering, calcination, phenomenon of particle coalescence, porosity, vitrification reactions.
Unit III	**Materials Processing:** Quenching: concept, glass formation, splat quenching. Processing of surface layers of solids: Ion beam processing, features of ion induced phenomenon, low induced phenomenon in materials, Laser processing: Laser types: CW and pulsed laser, various types of laser processing, concepts of laser annealing, alloying cladding and laser deposition with examples. Other methods: Sputtering and chemical CVD processing.
Unit IV	**Applications of Materials** Ferromagnetic materials, magnetic domains, hysteresis. Hard magnets and soft magnets. Origin of interaction in ferromagnetic material, rare earth garnets orthoferrites and Haemitite, Hexagonal ferrites. High Tc materials (Refractory materials), Giant magnetoresistance (GMR) materials (with brief discussion on magnetoresistance). Quasi crystals, optical materials, piezoelectric and ferroelectric material, nanoparticles.

Reference Books:

1. Elements of Materials Science and Engineering (5th edition), Lawrence H. Van Vlack,Addison-Wesley Publishing Co. ISBN: 0-201-08089-3
2. Materials Science and Engineering – A First Course (5th edition), V.Raghvan, PHI Learning Pvt. Ltd., New Delhi, ISBN: 978-81-203-2455-8
3. Materials Science and Metallurgy for Engineers, V. D. Kodgire and S. V. Kodgire, Everest Publishing House, ISBN: 81-86314-008
4. Materials Science, G. K. Narula, K. S. Narula and V. K. Gupta, Tata McGraw Hill Publishing Co. Ltd, New Delhi, ISNN: 0-07-451796-1

5. Physical Metallurgy (Part I) R.W.Cahn and P. Hassen, North Holland Physics Publishing, New York.
6. Introduction to Materials science for engineers (6^{th} edition)-J. F.Shaekelford and M. K. Murlidhara- Pearson Education.
7. Experiments in Materials Science – Prof. E.C. Subbarao et.al.
8. Experiments in Materials Science – V. Raghavan

PHY5305: ASTRONOMY AND ASTROPHYSICS – I [Credit-4]

Course Outcomes

After learning this course student will be able to

CO1 Apart from developing liking and inquisitiveness in this subject, students can take it up as a career in astronomy and astrophysics and provide the much needed man power for research in this field and contribute in major upcoming projects in Astronomy and Astrophysics.

Unit I	**Overview of the universe:** Qualitative description of interesting astronomical objects, (from planets to large scale structures), Length, Mass and Timescales, Physical conditions in different objects, Evolution of structures in the universe, red-shift. Radiation in different bands, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities, Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature, Celestial Sphere, Astronomical Coordinate Systems, Measurement of Time.
Unit II	**The sun and stellar structure and evolution:** Solar Photosphere Solar Atmosphere, Chromosphere, Corona, Solar Activity, Basic Composition of Interstellar Medium, Formation of Protostar, Jeans Criterion Fragmentation of Collapsing Clouds from Protostar to Pre-Main Sequence Hayashi Line, Cosmic Abundances, Stellar Nucleosynthesis, Evolution of Stars, Supernovae. Basic Familiarity with Compact Stars, Equation of State and Degenerate Gas of Fermions. Theory of White Dwarf, Chandrasekhar Limit, Neutron Star, Gravitational Red-shift of Neutron Star. Stellar Spectra and classification: Spectral Types and their Temperature Dependence, Black Body Approximation, H-R Diagram, Luminosity Classification.
Unit III	**Galaxies:** Galaxy Morphology, Milky Way Galaxy, Spiral and Elliptical galaxies, Galaxies as self-gravitating systems; spiral structure, Supermassive black holes, AGN's and their types, Quasars and Radio Galaxies Seyferts, BL Lac Objects and Optically Violent Variables, The Nature of the Central Engine, Unified Model of the Various Active Galaxies. Nature of Rotation of the Milky Way, Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms, Stars and Star Clusters of the Milky Way, Properties of and Around the Galactic Nucleus,
Unit IV	**Observational Astronomy & Astronomical instruments**: Concept of time, Magnitudes: apparent and absolute, constellations. Observation of Sun, Eclipses, Moon, planets, meteor showers, transits, occultation's. Optical telescopes, mounts, light gathering power, magnification, and resolution. Spectroscopes, CCD camera, photometer, filters, photometry, Radio telescopes, interferometry UV, IR, X-ray and Gamma ray telescopes. Orbiting space based telescopes: HST, Chandra.
Reference Books:	

1. Modern Astrophysics, B. W. Carroo and D. A. Ostlie, (Addison-Weseley).
2. The physical universe, F. Shu, (University Science books).
3. The Physics of Astrophysics, Volume I and II, F. Shu, (University Science books).
4. Theoretical Astrophysics, Volumes I, II and III,
5. T. Padmanabhan, (Cambridge University Press)
6. Astrophysics for Physicists, Arnab Rai Choudhari, (Cambridge University Press).
7. Astronomy and Astrophysics, A.B. Bhattacharya, S. Joardar, R. Bhattacharya (Overseas press)
8. Astrophysical Techniques, C.R. Kitchin, 6th Edition (CRC press)

PHY5306: VACUUM SCIENCE AND TECHNOLOGY [Credit-4]

Course Outcomes

After learning this course student will be able to

CO1 Students get knowledge of various pumps and gauges.

CO2 Physics behind different techniques of creating and measurement of vacuum is understood.

CO3 Skills regarding vacuum trouble shooting and leak detection, isolation and removal are acquired.

CO4 Applications of ideas and theories in kinetic theory of gases, collisions, mean free path, molecular flow etc. in production and measurement of vacuum are learnt.

Unit I	**Vacuum Science:** *Kinetic theory of gases*: Atomistic concept of gas pressure and temperature, Molecular distribution functions, Impingement rate of molecules on a surface, Free path of gas molecules, Gas viscosity and flow, gas conductance of a vacuum line, gas impedance of a vacuum line, flow of gases through apertures, elbows, tubes etc. for viscous and molecular flow regimes.
Unit II	**Production of Vacuum:** Meaning of vacuum and vacuum measuring units, vacuum ranges, pumping speed and pump down time. **Vacuum Pumps:** Mechanical pumps (Oil sealed rotary pump, Roots Pump, Molecular drag pump), Diffusion pump (Operating principles, back streaming, traps and baffles, performance ranges), Cryosorption pumps, Getter pumps (Chemical cleanup and sublimation pumps, Electrical cleanup and ion pumps, Evapor ion pumps, Sputter ion pumps, Titanium sublimation pump)
Unit III	**Vacuum Measurements:** Measurement of low pressure, Pressure gauges for low to high vacuum, Mc Leod manometer, Thermal conductivity gauges, Pressure gauges for high to ultrahigh vacuum, Hot cathode ionization gauges, Cold cathode ionization gauges, Operation of High-vacuum gauges.
Unit IV	**Vacuum Applications:** Applications in science, technology, research, space science, medical science, day to day life. Use of vacuum in particle accelerators.

Reference Books:

1. Hand book of Thin Film Technology, L. I. Maissel and R. Glang, Mc-Graw Hill Book Co. 1970, 07-039742-2
2. Vacuum Physics and Techniques, T. A. Delchar, Chapman and Hall.
3. Vacuum Technology, A. Roth, (North Holland, Elsevier Science B.V. 1990)
4. High Vacuum Techniques, J. Yarwood, (Chapman and Hall, London, 1967
5. Online resources can be used for reference.

PHY5307: PHYSICS PRACTICAL LABORATORY – III (Special Lab -1) (Material Science) [Credit-4]

Course Outcomes

After learning this course student will be able to

CO1 Study, test and measure the properties of materials.

CO2 Understand the special phenomena in materials science.

CO3 Make the applications of characterisation techniques for the determination of structural parameters.

CO4 Acquire design skills for developing methods to study and measure material parameters and constants.

Sr. No.	Title of the Experiment
1	Study of X-ray diffractogram of different samples.
2	To analyse FTIR spectra and to identify the functional groups of unknown materials.
3	To measure resistivity and activation energy of thin film using ‘Two Probe Method’
4	Ionic conductivity of NaCl
5	Measurements of ‘Creep’
6	Study of phase diagram using Pb- Sn alloy as a binary mixture
7	Pumping speed of rotary pump and conductance of long tube
8	Determination of Solar constant
9	Determination of thickness of thin film using Tolansky’s technique
10	To analyse UV-Visiblespectra of different materials
11	To study the Meissner effect and to determine the transition temperature of high temperature superconductor (YBCO)
12	Stress measurements of thin films
13	Beam divergence of LASER beam
14	Measurements of magnetic properties using Hysteresis loop tracer.
15	Transition temperature and Curie constant of ferroelectric material
16	Variation of conductivity of ferrite with temperature
17	Measurements of Thermoe. m. f.
18	Dielectric to ferroelectric transition in modified $BaTiO_3$
19	Study of properties of PZTs

PHY5401 : NUCLEAR PHYSICS [Credits – 4]

Course Outcomes After learning this course student will be able to CO1 Students will be able to understand the general properties and concepts of nuclei. CO2 Students can understand different radiation detectors and nuclear models. CO3 Student will be able to learn and explain nuclear reaction dynamics, nuclear reactors and accelerators. CO4 Student will understand nuclear interactions.	
Unit I	**General Properties and Concepts of Nuclei:** Nuclear Mass & Binding Energy, Measurement of Charge, Radius- Electron Scattering Experiment, Concept of Mass Spectrograph. Nuclear spin, Magnetic Dipole Moments & Electric Quadrupole Moments of Nuclei, Radioactivity, Unit of Radioactivity, Alpha Decay: Velocity of Alpha Particles, Disintegration Energy, Range-Energy Relationship, Geiger-Nuttall Law, Beta Decay: Conditions for Spontaneous Emission of β^-&β^+Particles, Selection Rules, Origin of Beta Spectrum-Neutrino Hypothesis, Gamma Decay: Gamma decay selection rules, Decay Scheme of ^{137}Cs &^{60}Co Nuclei, Internal Conversion, Internal Pair Creation.
Unit II	**Radiation Detectors and Nuclear Models:** Interaction of nuclear radiation (electron, neutron, gamma rays and ions) with matter, **Radiation Detectors**: NaI (Tl) Scintillation Detector, Si (Li) and Ge (Li) Detectors, High Purity Germanium Detector. **Nuclear Models**: Shell Model- Square Well Potential, Harmonic Oscillator Potential, Spin-Orbit Coupling, Predictions of the Shell Model, Achievements and Failures of Shell Model, Fermi Gas Model, Collective Model.
Unit III	**Reaction Dynamics, Nuclear Reactors and Accelerators:** **Reaction Dynamics**: Types of Nuclear Reactions, Conservation Laws in Nuclear Reactions, Q of Nuclear Reaction, Compound Nucleus Hypothesis, **Nuclear Reactors**: Fission Chain Reaction, Four Factor Formula, Multiplication Factor, General Properties and Concepts of Nuclear Reactors, Reactor Materials, Types of Reactors, List of different types of Reactors developed in India. **Accelerators**: Van de Graff, Microtron, Cyclotron, Electron and Proton Synchrotron, Pelletron.
Unit IV	**Nuclear Interactions and Particle Physics:** **Nuclear Interactions**: Low Energy Neutron-Proton Scattering, Scattering Length, Spin Dependence of neutron-proton Interaction, proton-proton and neutron-neutron Scattering at Low Energies. **Particle Physics**: Classification of Elementary Particles, Mass Spectra and Decays of Elementary Particles- Leptons and Hadrons, Quantum Numbers, Conservation Laws, Quarks.

Reference Books:

1. The Atomic Nucleus, R. D. Evans, Tata McGraw Hill.
2. Nuclear Physics, 2nd Edition, I. Kaplan, 1989, Narosa, New Delhi.
3. Concepts of Nuclear Physics, B. L. Cohen, Tata McGraw Hill.
4. Nuclear Physics, D. C. Tayal, Himalaya Publishing House.
5. Nuclear Physics an Introduction, 2nd edition, S. B. Patel, New Age International Publishers.
6. Atomic and Nuclear Physics, S. N. Ghoshal, S. Chand.
7. Nuclei and Particles, Emilio Segre, W.A. Benjamin Inc.
8. Introductory Nuclear Physics, K. S. Krane, 1988, Wiley, India.
9. Nuclear Radiation Detectors, S. S. Kapoor and V. S. Ramamurthy, Wiley eastern Limited.

PHY5402: ASTRONOMY AND ASTROPHYSICS - II [Credits – 4]

Course Outcomes

After learning this course student will be able to

CO1 Apart from developing liking and inquisitiveness in this subject, students can take it up as a career in astronomy and astrophysics and provide the much needed man power for research in this field and contribute in major upcoming projects in Astronomy and Astrophysics in India and Aboard.

CO2 Students will learn the applications of fundamental subjects like mathematics, electrodynamics in astrophysics.

Unit I	**Astrophysics** **A. Gravity:** Newtonian gravity and basic potential theory, Simple orbits – Kepler's laws and precession, flat rotation curve of galaxies and implications for dark matter, virial theorem and simple applications, role of gravity in different astrophysical systems. **B. Radiative Processes:** Overview of radiation theory and Larmor formula, Different radiative processes: Thomson and Compton scattering, Bremsstrahlung, Synchrotron [detailed derivations are not expected] Radiative equilibrium, Planck spectrum and properties; line widths and transition rates in QT of radiation, qualitative description of which radiative processes contribute in which waveband/ astrophysical system, distribution function for photons and its moments, elementary notion of radiation transport through a slab, concept of opacities. **C. Gas Dynamics:** Equations of fluid dynamics; equation of state in different regimes [including degenerate systems]; Models for different systems in equilibrium, Application to White dwarfs / Neutron stars, Simple fluid flows including supersonic flow, example of SN explosions and its different phases.
Unit II	**Large scale structures & the expanding universe:** Cosmic Distance Ladder. An Example from Terrestrial Physics Distance Measurement using Cepheid Variables Hubble's Law, Distance-Velocity Relation, Clusters of Galaxies, The Virial Theorem and Dark Matter, Friedmann Equation and its Solutions, Cosmology, Cosmological models, Early Universe and Nucleosynthesis, Cosmic Background Radiation, Evolving vs. Steady State Universe
Unit III	**Principles of relativity:** Overview of Special Relativity, space-time diagrams, Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of space-time. Geometrical Framework of General Relativity: Curved spaces, tensor algebra, Metric, affine connection, covariant derivatives, Physics in curved space-time, Curvature-Riemann tensor, Bianchi identities, Action Principle,

	Einstein's field equations, Energy momentum tensors, energy-momentum tensor for a perfect fluid, connection with Newton's theory. Solutions to Einstein's Equations and their Properties: Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles. The three classical tests of GR, black holes, event horizon-one way membranes, Gravitational Waves.
Unit IV	**Cosmological models:** Cosmological Principles, Robertson-Walker metric, cosmological redshift, Hubble's law, Observable quantities-luminosity and angular diameter distances. Dynamics of Friedmann-Robertson-Walker models. Solutions of Einstein's equations for closed, open and flat Universes. Physical Cosmology and the Early Universe: Thermal History of the Universe: Temperature - redshift relation, distribution functions in the early Universe-relativistic and non-relativistic limits. Decoupling of neutrinos and the relic neutrino background-Nucleosynthesis. Decoupling of matter and radiation; Cosmic microwave background radiation. Inflation-Origin and growth of Density Perturbations.

Reference Books:

1. General Relativity and Cosmology, J. V. Narlikar, (Macmillan company of India Ltd., Delhi).
2. Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, (Pergamon Press, Oxford).
3. First course in general relativity, B. F. Schutz, (Cambridge University Press).
4. Introduction to Cosmology, J. V. Narlikar, (Cambridge University Press).
5. Astrophysics for Physicists, Arnab Rai Choudhari, (Cambridge University Press).
6. Astronomy and Astrophysics, A.B. Bhattacharya, S. Joardar, R Bhattacharya (Overseas press)
7. Astrophysical Techniques, C.R. Kitchin, 6^{th} Edition (CRC press)

PHY 5403: PHYSICS OF NANO MATERIALS [Credits-4]

Course Outcomes

After learning the course student will be able to

CO1 Learn about the basic Physics behind the Nanomaterials.

CO2 Use different techniques for synthesis and characterization of Nanomaterials.

Unit I	**Quantum Size Effects:** Effect of reduction of dimensions, Quantum size effect. Particle in a box, density of states for a zero, one, two, and three dimensional box, Surface and interface effects, surface energy and surface curvature. Sintering, Ostwald ripening and Agglomeration. Electrostatic and Steric Stabilization. Introduction to nano-sized materials and structures.
Unit II	**Synthesis of Nanomaterials:** High energy Ball Milling, Melt mixing, Physical Vapour Deposition, Cluster Beam Deposition, Sputter Deposition, Chemical Vapour Deposition. Homogeneous and Heterogeneous nucleation, Growth of nuclei controlled by diffusion and surface process. Synthesis of nanoparticles: Wet chemical method (colloidal route), Electrochemical Method, Langmuir-Blodgett method, Sol-gel method and Hydro thermal method, Radiation route.
Unit III	**Special Nanomaterials:** Fullerene, Graphene, Types and Structures of Carbon nanotubes, Porous Silicon, Aerogels, Passivation of quantum dots by core-shell structures, Nano- composites.
Unit IV	**Properties and Applications and (Future) of Nanomaterials:** Mechanical, Thermal, Electrical, Optical and Magnetic Properties. Surface Plasmon Resonance and Super-paramagnetism. Application to Nanoelectronics, Super capacitors, Quantum Dots and Quantum well devices, (QD sensitized solar cells and dye-sensitized Solar cells), Optical Devices, Medical, Biological, Automobiles (Engineering), Space, Defence, Sports and Cosmetics. Social and Ethical issues involved in applications of nanomaterials.

Reference Books:

1. Nanotechnology: Principles and Practices.Sulabha K. Kulkarni, Capital Pub.
2. Nanostructures and Nanomaterials Synthesis, Properties & Applications. GuozhongCao, Imperials college Press London.
3. Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein &R.C. Commorata. Institute of Physics Publishing, Bristol & Philadelphia.
4. Introduction to Nanotechnology. C.P. Poole Jr.& F. J.Owens, Wiley Student Ed.
5. Nano: The Essentials. T.Pradeep, McGraw Hill Education.
6. Nanotechnology: Fundamentals and applications by ManasiKarkare, I.K. International Pvt. Ltd., New Delhi (2008).
7. Properties of Semiconductor Nanocrystals by S. V. Gaporenko (Cambridge Press), 1997.

PHY 5404 THIN FILM PHYSICS AND TECHNOLOGY [Credits – 4]

Course Outcomes

After learning this course student will be able to

CO1 Apply the knowledge of basic principles of material science in thin film technology.

CO2 Use various techniques to synthesize thin films of desired characteristics.

CO3 Make applications of thin films for devices fabrication.

CO4 Acquire skills required for entrepreneurship or jobs in the field of thin films.

Unit I	**Thin Film Deposition Techniques and Thickness Measurement:** Introduction: brief discussion of the bulk and the thin film properties, Physical Vapour Deposition Methods: Evaporation – thermal, e-beam; Sputter Deposition - DC, RF, Microwave; Pulsed Laser, Plasma assisted deposition, Molecular Beam Epitaxy, Chemical Vapour Deposition Methods: CVD, MOCVD, Spray pyrolysis, coating, Other Techniques: Langmuir Blodgett, Self-Arrangement Monolayer, Dip coating and Spin Coating Thickness Measurement Techniques: Tolansky technique, Talystep (stylus) method, Quartz crystal microbalance, Stress measurement by optical method, Gravimetric method.
Unit II	**Theories and models of thin film growth:** Theories of thin film nucleation**:** Impingement, Adsorption and Thermal Accommodation, The CapillarityModel,The Atomistic Models, Structural Consequences of Thin Film Nucleation, The Four stages of film Growth, The Incorporation of Defects During Growth.
Unit III	**Properties of thin films:** Electrical Properties: Source of Resistivity in Metallic conductors, Influence of thickness on the resistivity of thin films, Hall Effect & Magnetoresistance in thin films, Fuch-Sondhemir theory, TCR and its effects. Mechanical properties: Adhesion & its measurement with mechanical and nucleation methods, stress measurement by using optical method. Optical properties: Properties of Optical Film Materials, Thin Film Optics, Multilayer Optical Film Applications. Antireflection Coatings, Multilayer Films, Interference Filters, Polarizers.
Unit IV	**Emerging Thin Film Materials and Applications:** Patterning techniques (Photolithography), Diamond Films, Thin film resistors, capacitors, Junction devices (Diodes, Transistors, Solar cells), ICs, Thin film sensors (gas and humidity), Thin films for information storage (Magnetic and optical recording), Metallurgical applications, Photo thermal converters, Optical coatings.

Reference Books:

1. Hand book of Thin Film Technology: L. I. Maissel and R. Glang, Mc Graw Hill Book Co. 1970, 07-039742-2
2. Thin Film Phenomena: K. L. Chopra, Mc Graw Hill Book Co. 1969
3. Material Science of Thin Films: M. Ohring, Academic Press, 1992, ISBN: 0-12-524990-X
4. Thin Film Process: J. L. Vossen and Kern, Academic Press, 1978

PHY5405: ATMOSPHERIC SCIENCE [Credit-4]

Course Outcomes

After learning this course student will be able to

CO1 Graduates can demonstrate skills for interpreting and applying atmospheric observations.

CO2 Graduates can demonstrate knowledge of the atmosphere and its evolution.

CO3 Graduates can demonstrate knowledge of the role of water in the atmosphere.

CO4 Graduates can demonstrate skills for communicating their technical knowledge.

Unit I	**Introduction to Earth's Atmosphere**: Origin of atmosphere, Atmospheric composition, Layers (Troposphere, Stratosphere, Mesosphere, Ionosphere, D, E, F-I, F-II),Thermal structure of earth's atmosphere, Thermodynamic laws, Equation of state (Case of dry and moist air), Adiabatic, pseudo adiabatic and isothermal processes, Entropy, Potential temperature, Virtual temperature, Humidity parameters,Clausius-Clapeyron equation, Thermodynamic diagrams - general considerations, Emagram, Tephigram, Hydrostatic equilibrium, Concept of geopotential height and thickness of layer,
Unit II	**Interaction of Radiation with Atmosphere**: Black body radiation law(Planck's law), Wein's displacement law, Kirchhoff'slaw, Solar and terrestrial radiation, Implications of solar radiations to the earth & atmosphere, Polar lights(Aurora), Scattering (Rayleigh and Mie), Radiation balance of earth & atmosphere(Heat budget), Greenhouse effect.
Unit III	**Upper Atmosphere:** Thermal structure of troposphere, Radio wave propagation, Strato-sphere circulation and stratospheric warming, Quasi-Biennial oscillation, Spatiotemporal variation of Ozone, Umkehr effect, Ozone depletion.
Unit IV	**Cloud Physics:** Atmospheric aerosol, Condensed nuclei, Curvature and solute effect, Condensation, Growth of cloud droplets by diffusion, by collision and by coalescence, Collection efficiency, Freezing nuclei, Mechanism of growth of ice particles in cloud, Artificial rain, Thunderstorm and hail, Observational studies of cloud structure.

Reference Books:

1. Introduction to Theoretical Meteorology, Hess S. L., 1959, Holt; New York
2. Climatology, D.S.Lal, 2003, ShardaPustakBhawan
3. An Introduction to Weather and Climate, Trewartha G. T., 1943, Mc Graw-Hill BookCompany, Inc.; New York; London
4. Atmospheric Science: An Introductory Survey, Vol. 92, Wallace J. M., Hobbs P. V., 2006,Academic Press
5. A Short Course in Cloud Physics, Yau M. K., Rogers R., 1996, Elsevier
6. Basics of Atmospheric science by A. Chandrashekhar,PHI Learning
7. The Atmosphere:An introduction to Meteorology, F.K.Lutgens, E.J.Tarbuck, Dennis Tasa, Pearson Publications

PHY5406: PHYSICS PRACTICAL LABORATORY-IV: (Special Lab-2)
(Astrophysics + Atmospheric Science+ MATLAB) [Credit-4]

Course Outcomes
After learning this course student will be able to
CO1 Make use of appliances like Antenna kits, photometers etc.
CO2 Plot T-φ grams and apply them to study atmospheric parameters.
CO3 Apply the techniques in Python and MATLAB in developing simulations.

Sr. No.	Title of Experiment
1.	Measurement of solar limb darkening effect using photometer
2.	Determination of different radiation patterns using different antenna
3.	To verify Wien's displacement law and to find the temperature of the source.
4.	Identification of Elements using Fraunhauffer Spectrum
5.	Study of T-Φ gram
6.	Determination of Thickness of the Layer of air using T-Φ gram
7.	Introduction to MATLAB
8.	Shift of Fermi level of semiconductor
9.	To study diffraction using N number of Slits
10.	Simulating 1D Simple Harmonic Oscillator and simple pendulum
11.	Simple interfacing experiment using PLC
12.	Design and built P-I controller (dc motor speed controller with tachometer feedbackconcept)
13.	Design build and test 4-20 mA current transmitter for an input of 0-10V using singleended power supply.
14.	To design and built P-I-D controller

PHY5407: PHYSICS PRACTICAL LABORATORY – V (Project) [Credit-4]

Course Outcomes

After learning this course student will be able to

CO1 Do the literature survey.

CO2 Prepare a research project with detailed plan.

CO3 Acquire necessary experimental skills.

CO4 Make use of sophisticated instruments and softwares.

CO5 Understand the international standards in measurement techniques.

CO6 Analyse the acquired data and make use of bibliography to justify the results.

CO7 Draw conclusions with correct logical and scientific reasoning.