Fergusson College (Autonomous)
Pune

Learning Outcomes-Based Curriculum

for

M. Sc. Physics

With effect from June 2024

Implementation of NEP-2020 for Two Year PG program

(As per GoM GE 16/05/2023)

Illustrative Credit distribution structure for Two Years PG (M.Sc.) and Ph. D. Programme

Year (2Yr PG)	**Level**	**Sem.** (2 Yr)	**Major**		**RM**	**OJT / FP**	**RP**	**Cum. Cr.**	**Degree**
			Mandatory	**Electives**					
I	**6.0**	**Sem I**	12-14 (2*4+2*2 Or 3*4+2)	4	4			20-22	**PG Diploma (after 3 Yr Degree)**
		Sem II	12-14 (2*4+2*2 Or 3*4+2)	4		4		20-22	
Cum. Cr. For PG Diploma			**24-28**	**8**	**4**	**4**	**-**	**40-44**	
Exit option: PG Diploma (40-44 Credits) after Three Year UG Degree									
II	**6.5**	**Sem III**	12-14 (2*4+2*2 Or 3*4+2)	4			4	20-22	**PG Degree After 3-Yr UG Or PG Degree after 4- Yr UG**
		Sem IV	10-12 (2*4 +2 or 3*4)	4			6	20-22	
Cum. Cr. for 1 Yr PG Degree			**22-26**	**8**			**10**	**40-44**	
Cum. Cr. for 2 Yr PG Degree			**46-54**	**16**	**4**	**4**	**10**	**80-88**	
2 Years-4 Sem. PG Degree (80-88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree (40-44 credits) after Four Year UG Degree									
	8.0		Course Work Min. 12 (3*4)		Training in Teaching / Education/ Pedagogy: 4			**16 + Ph.D. Work**	**Ph.D. in Subject**

Abbreviations: Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr.

Table-2: Department wise Courses Titles as per NEP guidelines
(Science faculty)

Semester	Paper Code	Paper Title	Credits
I	PHY-501	Classical Mechanics	4
	PHY-502	Mathematical Methods in Physics	4
	PHY-503 OR	(Elective –I Electronics)	4
	PHY-504	(Or Elective-II Electronic Instrumentation)	
	PHY-510	Research Methodology (Theory)	4
	PHY-520	Practical: Physics Practical Laboratory-I (General Lab-I)	2
	PHY-521	Practical: Physics Practical Laboratory–II (Computational Lab)	2
		Total Semester Credits	20
II	PHY-551	Quantum Mechanics	4
	PHY-552	Atoms, Molecules and Solids	4
	PHY-553 OR	(Elective–I Materials Science)	4
	PHY-554	(Or Elective-I Thin Film Physics)	
	PHY-560	OJT/FP	4
	PHY-570	Practical: Physics Practical Laboratory-III (General Lab-II)	2
	PHY-571	Practical: Physics Practical Laboratory-IV (Electronics Lab)	2
		Total Semester Credits	20
Total PG-I Credits			40

Semester	Paper Code	Paper Title	Credits
III	PHY-601	Electrodynamics	4
	PHY-602	Statistical Mechanics	4
	PHY-603 OR	(Elective-I Experimental Techniques in Physics)	4
	PHY-604	(Or Elective-II Atmospheric Science)	
	PHY-610	Research Project	4
	PHY-620	Practical: Physics Practical Laboratory-V (Special Lab-I) (Materials Science)	2
	PHY-621	Practical: Physics Practical Laboratory-VI (MATLAB)	2
		Total Semester Credits	20
IV	PHY-651	Solid State Physics	4
	PHY-652	Nuclear Physics	4
	PHY-653 OR	(Elective-I Astronomy and Astrophysics)	4
	PHY-654	(Or Elective-II Physics of Nanomaterials)	
	PHY-660	Research Project	6
	PHY-670	Practical: Physics Practical Laboratory-VII (Special Lab-II) (Atmospheric Science + Astronomy and Astrophysics)	2
		Total Semester Credits	20
Total PG-II Credits			40

Program Outcomes (POs) for M. Sc. Programme	
PO1	**Disciplinary Knowledge:** Demonstrate comprehensive knowledge of the discipline that form a part of an postgraduate programme. Execute strong theoretical and practical understanding generated from the specific programme in the area of work.
PO2	**Critical Thinking and Problem solving:** Exhibit the skill of critical thinking and understand scientific texts and place scientific statements and themes in contexts and also evaluate them in terms of generic conventions. Identify the problem by observing the situation closely, take actions and apply lateral thinking and analytical skills to design the solutions.
PO3	**Social competence:** Exhibit thoughts and ideas effectively in writing and orally; communicate with others using appropriate media, build effective interactive and presenting skills to meet global competencies. Elicit views of others, present complex information in a clear and concise and help reach conclusion in group settings.
PO4	**Research-related skills and Scientific temper:** Infer scientific literature, build sense of enquiry and able to formulate, test, analyse, interpret and establish hypothesis and research questions; and to identify and consult relevant sources to find answers. Plan and write a research paper/project while emphasizing on academics and research ethics, scientific conduct and creating awareness about intellectual property rights and issues of plagiarism.
PO5	**Trans-disciplinary knowledge**: Create new conceptual, theoretical and methodological understanding that integrates and transcends beyond discipline-specific approaches to address a common problem.
PO6	**Personal and professional competence**: Perform independently and also collaboratively as a part of team to meet defined objectives and carry out work across interdisciplinary fields. Execute interpersonal relationships, self-motivation and adaptability skills and commit to professional ethics.
PO7	**Effective Citizenship and Ethics** : Demonstrate empathetic social concern and equity centred national development, and ability to act with an informed awareness of moral and ethical issues and commit to professional ethics and responsibility.
PO8	**Environment and Sustainability**: Understand the impact of the scientific solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.
PO9	**Self-directed and Life-long learning:** Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

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Fergusson College (Autonomous), Pune

Program Specific Outcomes (PSOs) and Course Outcomes (COs) 2023-24

Department of Physics

Programme: M.Sc. Physics

Program Specific Outcomes (PSOs) for M. Sc. Physics	
PSO No.	**Program Specific Outcomes(PSOs) Upon completion of this programme the student will be able to**
PSO1	**Academic competence**: (i) **Associate** the universal applications of physics in all disciplines. **Articulate** fundamental and advance concepts, principles and processes underlying physical phenomena in different branches ranging from classical mechanics to quantum mechanics and extended to electrodynamics, statistical mechanics, atomic, molecular and solid state physics, nanomaterials and electronic science. (ii) **Demonstrate** mathematical, statistical and computational ability in problem solving. **Demonstrate** and **explain** various mathematical techniques, numerical methods, experimental techniques to broaden independent thinking and scientific temper.
PSO2	**Personal and Professional Competence:** (i) Execute experimental and project work independently. (ii) Carry out laboratory oriented numerical calculations and experimental data interpretation. Analyse self-generated data through experiments as well as archival data (iii) Formulation of physics concepts, effective presentation and communication skills through seminars and group discussions. Develop skills of technical report writing along with precise presentation with effective communication. Apply appropriate concepts and various methods to solve wide range of problems. Incorporate the hands-on training of soldering to connect electronic components for designing circuits for device applications.
PSO3	**Research Competence:** (i) Use of in-house laboratory setup for building instrumentation. Integrate and interpret data. Evaluate the research findings in materials sciences and astrophysics. Apply experimental skills for interdisciplinary research work. Review of research papers, books for publications in journals. Apply experimental skills for projects / research and need for interdisciplinary research Carry out projects in basic, applied and interdisciplinary science to develop conceptual understanding and an orientation towards research. Interpret and analyse the results of the research project. Integrate mathematical / statistical and computational data to analyse and formulate theories. Implement Projects and research paper writing and book reviews.
PSO4	**Entrepreneurial and Social competence:** Enhance analytical skills and research aptitude in specific areas related to physics including materials science, thin film technology, solar energy, radiation dosimetry, astrophysics, atmospheric science, energy generation and storage for academic research and industrial applications. Develop job oriented analytical skills on an advanced level needed in industry, consultancy, education, research or public administration. **(i)** Employ and develop skills in specific areas related to physics and engineering for industrial application, production and technology development and transfer. **(ii)** Develop social awareness through internships and science popularization

	programs. Execute awareness of ethical issues: emphasis on academic and research ethics, need and value of lifelong learning, international perspective, importance of academic and research ethics, human rights, scientific misconduct, intellectual property rights and issues related to cyber laws and plagiarism.

SEMESTER III

M. Sc. II Semester III		
PHY-601	**Electrodynamics**	**Credits:04** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the mathematical description of electromagnetic phenomena based on basic physical quantities.	1
CO2	Apply Maxwell's equations in analyzing the nature of electromagnetic field due to time varying charge and current distribution.	2
CO3	Illustrate vector potential and electric field of a localized current distribution using multipole expansion problems.	3
CO4	Analyze the nature of electromagnetic waves and its propagation through different media and interfaces.	4
CO5	Determine charged particle dynamics and radiation from localized time varying electromagnetic sources.	5
CO6	Compose relative problems in electrodynamics and resolve them through the fundamental equations.	6

Unit No.	Title of Unit and Contents	No. of Lectures
I	**Electrostatics and Dielectrics:** **Electrostatics:** Coulomb's law, Gauss's law and its applications, Laplace equations in two and three dimensions, multipole expansions for a localized charge distribution in free space, linear quadrupole potential and field, energy in electrostatic fields. **Dielectrics:** linear dielectrics, polarisation, electric displacement, Gauss's law in dielectric materials, boundary conditions at the interface of two dielectrics. ***Reference*:**1,2,4,5,6,7,8,9,10	**12**
II	**Magnetostatics and Electrodynamics:** **Magnetostatics**: Magnetic forces, The Biot-Savart's law and Ampere's law and its applications, magnetic vector potential, magnetostatics boundary conditions, magnetic fields inside matter. **Electrodynamics:** Electromotive force, Faraday's law of electromagnetic induction, energy in Magnetic fields, Maxwell's correction to Amperes law, differential and integral forms of Maxwell's equations. ***Reference*:**1,2,4,5,6,7,8,9,10	**12**
III	**Electromagnetic Waves and its Propagation:** Poynting's theorem, Electromagnetic wave equations, Electromagnetic plane waves in free space, non-conducting and conducting media, Polarisation on reflection and refraction of electromagnetic waves, Fresnel's equations, Brewster's law, skin effect and skin depth. ***Reference*:**1,3,4,5,6,7,8	**12**
IV	**Electromagnetic Potentials and Fields:** Scalar and vector potentials, Coulomb gauge and Lorentz gauge, Gauge transformations, Wave equations in terms of electromagnetic potentials, the d'Alembertian operator, Hertz potential and its use in computation of radiation fields, Lienard-Wiechert potentials, Fields of moving point charge. ***Reference*:**1,2,3,4,5,6,8	**12**

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

1. Introduction to Electrodynamics, D. J. Griffiths (Prentice Hall, India)
2. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat, (Narosa Publishing House).
3. Classical Electricity & Magnetism, W. K. H. Panofsky and Phillips, (Addison-Wesley).
4. Foundations of Electromagnetic Theory, J. R. Reitz, F. J. Milford and R. W. Christy, (Pearson).
5. Classical Electrodynamics, by J. D. Jackson, (John Wiley).
6. Electromagnetic Theory and Electrodynamics, Satya Prakash, Kedar Nath Ram Nath, (Meerut).
7. Electromagnetics, B. B. Laud, (Willey Eastern).
8. Classical Theory of Fields, L. D. Landau and E. M. Lifshitz, (Addison-Wesley).
9. Feynmann Lectures, Volume II, R. P. Feynman, Leighton and Sands, (Narosa Publishing House).
10. Berkley Series, Volume II, E. M. Purcell (Mc-GrawHill).

M. Sc. II Semester III		
PHY-602	**Statistical Mechanics**	**Credits: 4** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define and describe the concepts of probability, macrostates and microstates and phase space.	1
CO2	Compare and distinguish between different types of particles, statistics and distribute bosons, fermions and classical particles among energy levels.	2
CO3	Apply the principles of probability in distribution of particles in different systems and calculate thermodynamic probability.	3
CO4	Analyze the different types of statistical distribution of particles.	4
CO5	Determine and interpret the probability of any type of events.	5
CO6	Formulate and apply the distribution functions to Fermi-Dirac system and Bose-Einstein system.	6

Unit No.	Title of Unit and Contents	No. of Lectures
I	**Statistical Description and Thermodynamics of Particles:** Specification of the state of the system, Macroscopic and Microscopic states, Phase space, Statistical ensemble, Postulate of equal a priori probability, Behaviour of density of states, Lowville's theorem (Classical). Equilibrium conditions and constraints, Distribution of energy between systems in equilibrium, Approach to thermal equilibrium, Sharpness of the probability distribution, Dependence of the density of states on the external parameters, Equilibrium between interacting systems.	**12**
II	**Classical Statistical Mechanics:** Micro-canonical ensemble, System in contact with heat reservoir, Canonical ensemble, Applications of canonical ensembles (Paramagnetism, Molecule in an ideal gas, Law of atmosphere), System with specified mean energy, Calculation of mean values and fluctuations in a canonical ensemble, Connection with thermodynamics, Grand-canonical ensemble, Physical interpretation of α, Chemical potential in the equilibrium state, Mean values and fluctuations in grand canonical ensemble, Thermodynamic functions in terms of the Grand partition function.	**12**
III	**Applications of Statistical Mechanics and Quantum Distribution Functions:** Classical partition functions and their properties, Calculations of thermodynamic quantities, Ideal monatomic gas, Gibbs paradox, Equipartition theorem and its Simple applications. i) Mean kinetic energy of a molecule in a gas ii) Brownian motion iii) Harmonic Oscillator iv) Specific heat of solid, Maxwell velocity distribution, Related distributions and mean values. Symmetry of wave functions, Quantum distribution functions, Boltzmann limit of Boson and Fermion gases, Evaluation of the partition function, Partition function for diatomic molecules, Equation of state for	**12**

	an ideal gas, quantum mechanical paramagnetic susceptibility.	
IV	**Ideal Bose and Fermi Systems:** Photon gas – i) Radiation pressure, ii) Radiation density, iii) Emissivity, iv) Equilibrium number of photons in the cavity. Einstein derivation of Planck's law, Bose- Einstein Condensation, Specific heat, Photon gas – Einstein and Debye's model of solids Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature, Electronic specific heat, White – Dwarfs (without derivation).	**12**

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

1. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill International Edition (1985).
2. Fundamentals of Statistical Mechanics, B. B. Laud, New Age International Publication (2003).
3. Statistical Mechanics, R. K. Pathria, Butterworth Heinemann (2nd Edition).
4. Statistical Mechanics, K. Huang, John Willey and Sons (2nd Edition).
5. Statistical Mechanics, Satya Prakash and Kedar Nath, Ram Nath Publication (2008).
6. Statistical Mechanics by Loknathan and Gambhir.

M. Sc. II Semester III		
PHY-603	**Experimental Techniques in Physics**	**Credits: 4** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define the working principles of the different characterization techniques.	1
CO2	Apply knowledge about the time domain representation and classification of discrete time signals and systems.	2
CO3	Explain the strengths and limitations of each characterization technique.	3
CO4	Analyze the data obtained by the different characterization techniques.	4
CO5	Judge experimental tools for different characterizations of samples.	5
CO6	Generate the breadth of knowledge in the application and design of engineering instruments.	6

Unit No.	Title of Unit and Contents	No. of Lectures
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.	**12**
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).	**12**
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).	**12**
IV	**Thermal analysis**: Thermo-gravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC);	**12**

	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.	

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

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, New York and London, 1974).

M. Sc. Semester III		
PHY-604	**Atmospheric Science**	**Credits: 4 Hours:60**
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Define the moisture parameters, cloud condensation nuclei.	1
CO2	Represent thermodynamic diagrams and locate, interpret the parameters.	2
CO3	Calculate potential and virtual temperatures.	3
CO4	Explain concepts of atmospheric thermodynamics.	4
CO5	Compare different types of scattering processes in the atmosphere.	5
CO6	Write a report on the different mechanisms of precipitation.	6

Unit. No.	Title of Unit and Contents	No. of Lectures
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, Moisture parameters, Thermodynamic diagrams - general considerations, Emagram, Tephigram, Hydrostatic equilibrium, Concept of geopotential height and thickness of layer,	**12**
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.	**12**
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.	**12**
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.	**12**

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

1. Introduction to Theoretical Meteorology, Hess S. L., 1959, Holt; New York
2. Climatology, D. S. Lal, 2003, Sharda Pustak Bhawan

3. An Introduction to Weather and Climate, Trewartha G. T., 1943, Mc Graw-Hill Book Company, 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

M. Sc. II Semester III		
PHY-620	**Physics Practical Laboratory-V (Special Lab-I) (Materials Science)**	**Credits: 4 Hours: 60**
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Tabulate the appropriate experimental data accurately and maintain systematic record of day to day laboratory activities.	1
CO2	Discuss the results using the appropriate physical scientific framework and required tools.	2
CO3	Interpret professional quality in textual and graphical presentations of laboratory data and computational results.	3
CO4	Analyse different experimental results by developing analytical abilities to address real world problems.	4
CO5	Determinepossible causes of discrepancy in practical experimental observations, results in comparison to theoretical results.	5
CO6	Develop the skills related to betterment in research, education, industry-academia progress.	6

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-Visible spectra 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 Thermoemf.
18.	Dielectric to ferroelectric transition in modified $BaTiO_3$
19.	Study of properties of PZTs
Any 12 experiments need to be performed	

M. Sc. II Semester III		
PHY-621	**Practical: Physics Practical Laboratory-VI (Computational Physics using MATLAB)**	**Credits: 4** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Identify the objectives of a given data computation-based experiments.	1
CO2	Interpret the proper numerical method of data computation.	2
CO3	Implement proper use of data to solve given problem.	3
CO4	Analyse the data for a given numerical method and the obtained results.	4
CO5	Evaluate the accuracy of common numerical methods.	5
CO6	Compile their computational skill to solve common and scientific problems.	6

Sr. No.	Title of the Experiment
1.	Using of Least Square Method (Linear and Exponential) to fit the Given Data
2.	Bisection Method
3.	Regula Falsi Method
4.	Newton-Raphson Method
5.	Secant Method
6.	Successive Approximation
7.	Gauss Elimination Method, Gauss Seidel Iterative Method
8.	Use of Lagrange Interpolation & Spline Interpolation Method
9.	Trapezoidal and Simpson's Rule
10.	Gaussian Quadrature Formulae
11.	Euler's Method
12.	Runge-Kutta 2^{nd} order Method
13.	Runge-Kutta 4^{th} order Method
Any 12 experiments need to be performed	

SEMESTER IV

M. Sc. II Semester IV		
PHY-651	**Solid State Physics**	**Credits: 4** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the advances in band theory of solids.	1
CO2	Explain the origin of magnetism and magnetic interactions leading to different types of magnetic materials and associate the interplay between the electrical and magnetic behaviour of superconductors.	2
CO3	Calculate quantities associated with conduction mechanism in materials, magnetic properties and superconductivity.	3
CO4	Analyse the role of electron-lattice interaction in determining the properties of materials.	4
CO5	Review types of materials based on their electrical and magnetic properties.	5
CO6	Specify the types and properties of magnetic materials. Develop an understanding of classification of materials based on band theory.	6

Unit No.	Title of Unit and Contents	No. of Lectures
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	**12**
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 field splitting, Quenching of orbital angular momentum. ***Reference*:** Kittel, Ch. 14	**12**
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	**12**
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	**12**

	superconductivity ring, Qualitative discussion of Josephson superconductor tunnelling. ***Reference***: Kittel, Ch.12	

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

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

M. Sc. Semester IV		
PHY-652	**Nuclear Physics**	**Credits: 4 Hours:60**
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Recall the general properties and concepts of nuclei.	1
CO2	Explain types of nuclear interactions, working of different types of nuclear detectors and accelerators.	2
CO3	Illustrate different types of nuclear reactions and understand the working of nuclear reactors.	3
CO4	Differentiate models of nucleus for better understanding of nuclear interaction and review the reaction dynamics.	4
CO5	Determine the type of nuclear reactions and outline the processes of different scattering mechanisms.	5
CO6	Design a table of elementary particles, classify mass spectra, elementary particles and their decay mechanisms.	6

Unit No.	Title of Unit and Contents	No. of Lectures
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.	**12**
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	**12**
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.	**12**
IV	**Nuclear Interactions and Particle Physics:** **Nuclear Interactions:** Low Energy Neutron-Proton Scattering, Scattering Length, Spin Dependence of neutron-proton Interaction,	**12**

	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.	

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

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.

M. Sc. II Semester IV		
PHY-653	**Fundamentals of Astronomy & Astrophysics**	**Credits: 4 Hours:60**
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Identify the astrophysical system and classify them	1
CO2	To understand astrophysical processes and systems, ranging from our own sun to stars, galaxies and the whole universe.	2
CO3	To use of physics, mathematics and statistics to get a new understanding of the universe.	3
CO4	Explain the different Astrophysical system problems.	4
CO5	Establish competence in focused areas of astrophysical theory and experiment.	5
CO6	To formulate scientific problems in mathematical terms and apply analytical and numerical methods towards its solution.	6

Unit No.	Title of Unit and Contents	No. of Lectures
I	**Overview of the universe:** Celestial Sphere, Co-ordinate system and Timescales, Length, Mass and, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities, Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature, Measurement of Time. Black body radiation, Specific intensity and flux density, stellar parallax, magnitude and color index **The solar system:** Celestial mechanics, Elliptical orbits, Kepler's law, Virial theorem, Earth-Moon System, Tidal forces, Precession of Earth's axis, interiors, atmospheres, planets, terrestrial planets, Jovian planets	**15**
II	**Star:** Classification, Formation of Spectral Lines, Hertzsprung-Russell diagram, Atmosphere, Description of radiation field, opacity, radiative transfer, spectral lines **Sun:** Interior, Atmosphere, Solar Activity and Helioseismology **Stellar Interior:** Hydrostatic equilibrium, Pressure equation of state, Energy sources, Energy transport and convection, Model building, Main sequence **Binary stars:** Classification, White Dwarfs, Neutron Stars, Black hole in binaries. Star formation: Pre and Post Main sequence, Degenerate remnants of stars, Chandrasekhar limit, dwarf's, pulsar.	**15**
III	**Radiative processes:** Synchrotron emission a) a single particle b) an ensemble of electrons, Energy loss and electron spectrum, Compton scattering, Multiple Compton scattering, Bremsstrahlung, Thermal bremsstrahlung **The Milky Way Galaxy:** Distribution of stars, Morphology, Kinematics, Interstellar medium,	**15**

	Galactic Centre **Nature of galaxies:** Hubble sequence, Spirals and irregular galaxies, Spiral structure, Elliptical galaxies **Structure of the universe:** Extragalactic distance scale, Expansion of the universe Clusters of galaxies **Cosmology:** Models of the universe, Relics of the big bang, Formation of large-scale structure, Observations of the cosmological significance	
IV	**Observational Astronomy & Instrumentation**: Different types of telescopes, mounts, light gathering power, magnification, and resolution. Spectroscopes, CCD: history, working and application, photometer, filters, photometry, Radio telescopes, interferometry UV, IR, X-ray and Gamma ray telescopes. Orbiting space-based telescopes: HST, Chandra Observational Techniques: Earth's Atmosphere – Airmass, Astronomical Seeing, Atmospheric Refraction, Scintillation, Atmospheric Observing Windows, Active & Adaptive Optics	**15**

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

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)

M. Sc. II Semester IV		
PHY-654	**Physics of Nanomaterials**	**Credits: 04** **Hours: 60**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	List different types and forms of Nanomaterials.	1
CO2	Discuss the quantum size effect on the properties of materials.	2
CO3	Examine the different techniques to synthesize the Nanomaterials.	3
CO4	Explain the properties of nanomaterials with the help of theoretical models.	4
CO5	Measure the particle size and determine structure parameters using different characterization techniques.	5
CO6	Write a report on development of the systems and devices for applications of Nanomaterials in different fields.	6

Unit No.	Title of Unit and Contents	No. of Lectures
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.	**12**
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 Hydrothermal method, Radiation route.	**12**
III	**Special Nanomaterials:** Fullerene, Graphene, Types and Structures of Carbon nanotubes, Porous Silicon, Aerogels, Passivation of quantum dots by core-shell structures, Nano- composites.	**12**
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.	**12**

*12 hours will be utilized for other curricular activities like assignments and evaluation.

References:

1. Nanotechnology: Principles and Practices. Sulabha K. Kulkarni, Capital Pub.

2. Nanostructures and Nanomaterials Synthesis, Properties & Applications. Guozhong Cao, 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 Manasi Karkare, I.K. International Pvt. Ltd., New Delhi (2008).
7. Properties of Semiconductor Nanocrystals by S. V. Gaporenko (Cambridge Press), 1997.

M. Sc. II Semester IV		
PHY-670	**Physics Practical Laboratory-VII (Special Lab-II) (Atmospheric Science + Astronomy and Astrophysics)**	**Credits: 04 Hours:**
Course Outcomes (COs) On completion of the course, the students will be able to:		**Bloom's cognitive level**
CO1	Tabulate the appropriate experimental data accurately and maintain systematic record of performed experiments laboratory	1
CO2	Discuss the results using scientific tools in experiments related to astrophysics.	2
CO3	Interpret professional quality in textual and graphical presentations of experimental data using MATLAB tools.	3
CO4	Analyze theoretical and experimental results and by developing analytical abilities for research.	4
CO5	Determine possible causes of discrepancy in practical experimental observations, results in the subjects of atmospheric sciences and astrophysics.	5
CO6	Develop the skills related to betterment in research, education, industry-academia progress.	6

Sr. No.	Title of the Experiment
1.	Study of Tephigram
2.	Determination of Thickness of the Layer of air using Tephigram
3.	Determination of Solar constant
4.	Analysis of Upper air data using; radiosondes, ozonesondes
5.	Analysis of surface meteorological data from IMD; temperature, pressure, wind speed, rainfall
6.	Measurement of Aerosol Properties using Radiometer
7.	Measurement of total Ozone using Ozonometer.
8.	Illustration of H-R diagram
9.	Resolving power of Telescope
10.	Light Curve of Binary Star using Virtual Observatory Data
11.	To verify Wien's displacement law and to find the temperature of the source.
12.	Identification of Elements using Fraunhoffer Spectrum
13.	Measurement of solar limb darkening effect using photometer
14.	Determination of different radiation patterns using different antenna
Any 12 experiments need to be performed	