CURRICULUM & CREDIT FRAMEWORK

FOR

4-YEAR UG PROGRAMME

as per NEP, 2020 SYLLABUS

FOR

Bachelor of Science (B. Sc) in Physics

(w.e.f. Academic Session: 2023-2024)

Department of Physics

(Faculty of Science & Technology)

Aliah University IIA/27, Newtown, Kolkata 700160

West Bengal, India

1. Structure of the Undergraduate Program

Sl. No.	Broad Category of Course	Minimum Credit Requirement	
		3-Yr UG	4-Yr UG
1	Major (Core)	60	80
2	Minor Stream	24	32
3	Multidisciplinary	09	09
4	Ability Enhancement Courses (AEC)	08	08
5	Skill Enhancement Courses (SEC)	09	09
6	Value Added Courses common for all UG	06-08	06-08
7	Summer Internship	02-04	02-04
8	Research Projects/Dissertation	–	12
	Total	120	160
Note:* Honours students not undertaking research will study three courses for 12 credits in lieu of a research project/dissertation.			
A credit is a unit by which the coursework is measured; It determines the no. of hours of instruction required per week over the duration of a semester (minimum 15 weeks).			

2. Curricular components of the UG Program

a. **Disciplinary/interdisciplinary major:** In-depth study of a particular subject or discipline.
b. **Disciplinary/interdisciplinary minors:** Students who take a sufficient number of courses in a discipline or an interdisciplinary area of study other than the chosen major will qualify for a minor in that discipline or in the chosen interdisciplinary area of study.
c. **Vocational Education and Training:** A minimum of 12 credits will be allotted to the 'Minor' stream relating to job-oriented Vocational Education and Training and these can be related to the major or minor discipline or choice of the student.
d. **Courses from Other Disciplines (Multidisciplinary) (09 credits):** All UG students are required to undergo 3 introductory-level courses relating to Natural and Physical Sciences; Mathematics, Statistics, and Computer Applications; Library, Information, and Media Sciences; Commerce and Management; Humanities and Social Sciences: Students are not allowed to choose or repeat courses already undergone at the higher secondary level (12th class) in the proposed major and minor stream under this category.
e. **Ability Enhancement Courses (AEC) (08 credits):** Modern Indian Language (MIL) & English language focused on language and communication skills. List of MIL: Assamese,

Bangla, Bodo, Dogri, Gujarati, Hindi, Kashmiri, Kannada, Konkani, Maithili, Malayalam, Manipuri, Marathi, Nepali, Oriya, Punjabi, Tamil, Telugu, Santali, Sindhi and Urdu.

f. **Skills Enhancement Courses (SEC):** Objective: imparting practical skills, hands-on training, soft skills, etc., to enhance the employability of students.
   • 3 papers of 3 credits each, i.e., total 9 credits
   • To be offered in Ist, IInd & IIIrd semesters
g. **Summer Internship/Apprenticeship (02-04 credits):** Induction into actual work situations. Students who wish to exit after the first two semesters will undergo a 4-credit work-based learning/internship during the summer term in order to get a UG Certificate.
   • Community engagement and service and
   • Field-based learning/minor project can be part of summer term activity or part of a major or minor course depending upon the major discipline.
h. **Research Project/Dissertation:** only for 4-Year Bachelor’s degree (12 credits)
i. **Other Activities:** National Service Scheme (NCC), National Cadet Corps (NCC), adult education/literacy initiatives, mentoring school students, and other similar activities.
j. **Value-Added Courses (VAC):** Common to All UG Students (6-8 credits)
   1) Understanding India: knowledge and understanding of contemporary India with its historical perspective.
   2) Environmental science/education: to take appropriate actions for mitigating the effects of environmental degradation, climate change, and pollution, effective waste management, conservation of biological diversity, management of biological resources, forest and wildlife conservation, and sustainable development and living. The course will also deepen the knowledge and understanding of India’s environment in its totality, its interactive processes, and its effects on the future quality of people’s lives.
   3) Digital and technological solutions: Courses in Artificial Intelligence (AI), 3-D machining, big data analysis, machine learning, drone technologies, and Deep learning with important applications to health, environment, and sustainable living that will be woven into undergraduate education for enhancing the employability of the youth.
   4) Health & Wellness, Yoga education, sports, and fitness: physical and mental wellbeing.

3. Course Code Configuration

- Programme Code (eg., MBA/ HST/ CHM)
- Degree (UG)
- Paper Type
  - ☐ Major Core MCC
  - ☐ Major Discipline Specific Elective (DSE) MDS
  - ☐ Minor MIN
  - ☐ Multidisciplinary MDC
  - ☐ Ability Enhancement Courses AEC
  - ☐ Skill Enhancement Courses SEC

- ☐ Value Added Courses VAC
- ☐ Summer Internship SIP
- ☐ Research Projects/ Dissertation PRJ

- Paper No. : 3 digit; Year first; Semester 2nd, 2 digit Course No.
- Example:

P	H	Y	U	G	M	C	C	1	1	0	1
PROGRAMME CODE			DEGREE		PAPER TYPE (MAJOR CORE COURSE)			YEAR	SEM	RUNNING NUMBER FOR EACH PAPER TYPE	

4. Assessment scheme including Marks

- For 4 Credit Course: Theory + Practical/Tutorial (3+1)
- No full practical in Major (Core/DSE) and Minor
- Full practical only in SEC
- Teaching hours for 4 credit course (3L+1P/T) * 15 weeks
- Theory = 45 lecture hours
- Practical = 1 practical = 2 hours/week * 15 weeks = 30 practical hours
- Marks and the duration of end-semester examination of above mentioned courses are as follows:

Course type	**Credit**	**Full Marks**				**Time for end-sem written exam**	**Time for end-sem practical exam**
		Theory	**TA**	**Lab**	**Total**		
Major/Minor (no practical component)	4	80	20	–	100	3 hours	–
Major/Minor (with practical component)	3+1	60	15	25	100	2 hours 30 minutes	1 hour 30 minutes
SEC/MDC etc.	3	60	15	–	75	2 hours 30 minutes	–
AEC/CVAC etc.	4	80	20	–	100	3 hours	

5. Semester wise course distribution and course details

SEM	Course type	Course code	Course name	Credit	Total credit per semester
1	CC	PHYUGMCC1101	Mechanics	4	22
	CC	PHYUGMCC1102	Mathematical Physics I	4	
	SEC	PHYUGSEC1101	Basic Instrumentational Skill	3	
	AEC	UCCUGAEC1101	Urdu/Bengali	4	
	MDC	UCCUGMDC1101	Arabic	3	
	MIN	MATUGMIN1101	Offered by Mathematics Department	4	
	MIN(O)	PHYUGMIN1101	Mechanics	4	4
2	CC	PHYUGMCC1203	Electricity and Magnetism	4	22
	CC	PHYUGMCC1204	Wave and Optics	4	
	SEC	PHYUGSEC1202	Basic computational skill	3	
	CVAC	UCCUGVAC1201	EVS	4	
	MDC	UCCUGMDC1202	Bio Statistics	3	
	MIN	MATUGMIN1202	Offered by Mathematics Department	4	
	MDC(O)	UCCUGMDC1202	Frontiers in Physics	3	3
	MIN(O)	PHYUGMIN1202	Electricity and Magnetism	4	4
3	CC	PHYUGMCC2305	Thermal Physics	4	22
	CC	PHYUGMCC2306	Mathematical Physics II	4	
	SEC	PHYUGSEC2303	Data analysis and Scientific writing	3	
	AEC	UCCUGAEC2302	English	4	
	MDC	UCCUGMDC2303	Offered by other Department	3	
	MIN	MATUGMIN2303	Offered by Mathematics Department	4	
	MDC(O)	UCCUGMDC2303	Physics at different length scales	3	3
	MIN(O)	PHYUGMIN2303	Thermal Physics	4	4
4	CC	PHYUGMCC2407	Analog Electronics	4	20
	CC	PHYUGMCC2408	Elements of Modern Physics	4	
	CC	PHYUGMCC2409	Electromagnetic Theory	4	
	CVAC	UCCUGVAC2402	Understanding India	4	
	MIN	MATUGMIN2404	Offered by Mathematics Department	4	
	MIN(O)	PHYUGMIN2404	Elements of Modern Physics	4	4
5	CC	PHYUGMCC3510	Digital Electronics	4	20
	CC	PHYUGMCC3511	Quantum Mechanics and Applications	4	
	CC	PHYUGMCC3512	Statistical Mechanics	4	
	SIP	PHYUGSIP3501	Summer Internship Program	4	
	MIN	CHMUGMIN2301	Offered by Chemistry Department	4	
	MIN(O)	PHYUGMIN3505	Digital Electronics	4	4
6	CC	PHYUGMCC3613	Solid State Physics	4	20
	CC	PHYUGMCC3614	Nuclear and Particle Physics	4	
	CC	PHYUGMCC3615	Numerical Analysis and Computation	4	
	DSE	PHYUGMDS3601	Photonics/Biophysics	4	
	MIN	CHMUGMIN2302	Offered by Chemistry Department	4	
	MIN(O)	PHYUGMIN3606	Nuclear and Particle Physics	4	4

Physics Honours without research					
7	CC	PHYUGMCC4716	Advanced Mathematical Methods	4	24
	CC	PHYUGMCC4717	Advanced Statistical Mechanics	4	
	DSE	PHYUGMDS4702	Advanced Electrodynamics/ Atmospheric Physics	4	
	DSE	PHYUGMDS4703	Condensed Matter Physics/ General Theory of Relativity/ Laser Spectroscopy/ Medical Physics	4	
	DSE	PHYUGMDS4704	Electronics and Instrumentation	4	
	MIN	CHMUGMIN4703	Offered by other Department	4	
	MIN(O)	PHYUGMIN4707	Advanced Statistical Mechanics	4	4
8	CC	PHYUGMCC4818	Advanced Quantum Mechanics	4	24
	CC	PHYUGMCC4819	Advanced Classical Mechanics	4	
	DSE	PHYUGMDS4805	Nano Science and Technology/ Astrophysics and Cosmoloy/ Quantum Optics/ Geophysics	4	
	DSE	PHYUGMDS4806	Advanced Nuclear and Particle Physics	4	
	DSE	PHYUGMDS4807	Atomic and Molecular Physics	4	
	MIN	CHMUGMIN4804	Offered by other Department	4	
	MIN(O)	PHYUGMIN4808	Advanced Quantum Mechanics	4	4
Physics Honours with research					
7	CC	PHYUGMCC4716	Advanced Mathematical Methods	4	24
	CC	PHYUGMCC4717	Advanced Statistical Mechanics	4	
	DSE	PHYUGMDS4702	Advanced Electrodynamics/ Atmospheric Physics	4	
	DSE	PHYUGMDS4703	Condensed Matter Physics/ General Theory of Relativity/ Laser Spectroscopy/ Medical Physics	4	
	Dissertation	PHYUGPRJ4701	Literature review and Presentation	4	
	MIN	CHMUGMIN4703	Offered by other Department	4	
	MIN(O)	PHYUGMIN4707	Advanced Statistical Mechanics	4	4
8	CC	PHYUGMCC4818	Advanced Quantum Mechanics	4	24
	CC	PHYUGMCC4819	Advanced Classical Mechanics	4	
	DSE	PHYUGMDS4805	Nano Science and Technology/ Astrophysics and Cosmoloy/ Quantum Optics/ Geophysics	4	
	Dissertation	PHYUGPRJ4802	Project work and Presentation	8	
	MIN	CHMUGMIN4804	Offered by other Department	4	
	MIN(O)	PHYUGMIN4808	Advanced Quantum Mechanics	4	4

Note: MIN(O) and **MDC(O)** refers to the '**Minor'** and '**Multidisciplinary'** courses offered by the Department of Physics for other department's students

6. Overview of Curriculum and Credit Framework for 4 year UG Honours offered by Aliah University

4 YR CURRICULUM & CREDIT FRAMEWORK: UG HONOURS WITH RESEARCH Annexure -1

		Major				Minor		Multi-disciplinary		AEC		SEC		VAC		SIP		Dissertation		Total	
Minimum Credit Requirement		80				32		9		8		9		6-8		2-4		12		158-162	
		Core		DSE																	
Year	Semes-ter	No. of Paper	Credit @ 4	No. of Paper	Credit @4	No. of Paper	Credit @4	No. of Paper	Credit @3	No. of Paper	Credit @4	No. of Paper	Credit @ 3	No. of Paper	Credit @ 4	No. of Paper	Credit @ 4	No. of Paper	Credit @ 4+8=12	No. of Paper	Credit
1	I	2	8	0	0	1	4	1	3	1	4	1	3	0	0	0	0	0	0	6	22
	II	2	8	0	0	1	4	1	3	0	0	1	3	1	4	0	0	0	0	6	22
2	III	2	8	0	0	1	4	1	3	1	4	1	3	0	0	0	0	0	0	6	22
	IV	3	12	0	0	1	4	0	0	0	0	0	0	1	4	0	0	0	0	5	20
3	V	3	12	0	0	1	4	0	0	0	0	0	0	0	0	1	4	0	0	5	20
	VI	3	12	1	4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	5	20
4	VII	2	8	2	8	1	4	0	0	0	0	0	0	0	0	0	0	0	4	5	24
	VIII	2	8	1	4	1	4	0	0	0	0	0	0	0	0	0	0	0	8	4	24
	TOTAL	19	76	4	16	8	32	3	9	2	8	3	9	2	8	1	4	0	12	42	174
		23 (Core + DSE) = 92 credits																			

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AEC -	Ability Enhancement Course	SEC -	Skill Enhancement Course	VAC -	Value Added Course

4 YR CURRICULUM & CREDIT FRAMEWORK: UG HONOURS WITHOUT RESEARCH Annexure -2

		Major				Minor		Multi-disciplinary		AEC		SEC		VAC		SIP		Dissertation		Total	
Minimum Credit Requirement		80				32		9		8		9		6-8		2-4		12		158-162	
		Core		DSE																	
Year	Semes-ter	No. of Paper	Credit @ 4	No. of Paper	Credit @4	No. of Paper	Credit @4	No. of Paper	Credit @3	No. of Paper	Credit @4	No. of Paper	Credit @ 3	No. of Paper	Credit @ 4	No. of Paper	Credit @ 4	No. of Paper	Credit @ 4+8=12	No. of Paper	Credit
1	I	2	8	0	0	1	4	1	3	1	4	1	3	0	0	0	0	0	0	6	22
	II	2	8	0	0	1	4	1	3	0	0	1	3	1	4	0	0	0	0	6	22
2	III	2	8	0	0	1	4	1	3	1	4	1	3	0	0	0	0	0	0	6	22
	IV	3	12	0	0	1	4	0	0	0	0	0	0	1	4	0	0	0	0	5	20
3	V	3	12	0	0	1	4	0	0	0	0	0	0	0	0	1	4	0	0	5	20
	VI	3	12	1	4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	5	20
4	VII	2	8	3	12	1	4	0	0	0	0	0	0	0	0	0	0	0	0	6	24
	VIII	2	8	3	12	1	4	0	0	0	0	0	0	0	0	0	0	0	0	6	24
	TOTAL	19	76	7	28	8	32	3	9	2	8	3	9	2	8	1	4	0	0	45	174
		26 (Core + DSE) = 104 credits																			

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AEC -	Ability Enhancement Course	SEC -	Skill Enhancement Course	VAC -	Value Added Course

7. Semester wise credit distribution of the courses offered by the Department of Physics

SEM	Course type	Course code	Credit distribution			
			Theory	Tutorial	Lab	Total
1	CC	PHYUGMCC1101	3	0	1	4
	CC	PHYUGMCC1102	3	1	0	4
	SEC	PHYUGSEC1101	3	0	0	3
	MIN(O)	PHYUGMIN1101	3	0	1	4
2	CC	PHYUGMCC1203	3	0	1	4
	CC	PHYUGMCC1204	3	0	1	4
	SEC	PHYUGSEC1202	3	0	0	3
	MDC(O)	UCCUGMDC1202	3	0	0	3
	MIN(O)	PHYUGMIN1202	3	0	1	4
3	CC	PHYUGMCC2305	3	0	1	4
	CC	PHYUGMCC2306	3	0	1	4
	SEC	PHYUGSEC2303	3	0	0	3
	MDC(O)	UCCUGMDC2303	3	0	0	3
	MIN(O)	PHYUGMIN2303	3	0	1	4
4	CC	PHYUGMCC2407	3	0	1	4
	CC	PHYUGMCC2408	3	0	1	4
	CC	PHYUGMCC2409	3	0	1	4
	MIN(O)	PHYUGMIN2404	3	0	1	4
5	CC	PHYUGMCC3510	3	0	1	4
	CC	PHYUGMCC3511	3	1	0	4
	CC	PHYUGMCC3512	3	1	0	4
	SIP	PHYUGSIP3501	–	–	–	4
	MIN(O)	PHYUGMIN3505	3	0	1	4
6	CC	PHYUGMCC3613	3	0	1	4
	CC	PHYUGMCC3614	3	1	0	4
	CC	PHYUGMCC3615	3	0	1	4
	DSE	PHYUGMDS3601	3	1	0	4
	MIN(O)	PHYUGMIN3606	3	1	0	4
Physics Honours without research						
7	CC	PHYUGMCC4716	3	1	0	4
	CC	PHYUGMCC4717	3	1	0	4
	DSE	PHYUGMDS4702	3	1	0	4
	DSE	PHYUGMDS4703	3	1	0	4
	DSE	PHYUGMDS4704	3	1	0	4
	MIN(O)	PHYUGMIN4707	3	1	0	4
8	CC	PHYUGMCC4818	3	1	0	4
	CC	PHYUGMCC4819	3	1	0	4
	DSE	PHYUGMDS4805	3	1	0	4
	DSE	PHYUGMDS4806	3	1	0	4
	DSE	PHYUGMDS4807	3	1	0	4
	MIN(O)	PHYUGMIN4808	3	1	0	4
Physics Honours with research						
7	CC	PHYUGMCC4716	3	1	0	4
	CC	PHYUGMCC4717	3	1	0	4
	DSE	PHYUGMDS4702	3	1	0	4
	DSE	PHYUGMDS4703	3	1	0	4
	Dissertation	PHYUGPRJ4701	–	–	–	4
	MIN(O)	PHYUGMIN4707	3	1	0	4
8	CC	PHYUGMCC4818	3	1	0	4
	CC	PHYUGMCC4819	3	1	0	4
	DSE	PHYUGMDS4805	3	1	0	4
	Dissertation	PHYUGPRJ4802	–	–	–	8
	MIN(O)	PHYUGMIN4808	3	1	0	4

Semester: I	
Course Name: Mechanics **Course Code: PHYUGMCC1101** **Credit: 4 [3 (Theory) + 1 (Practical)]** **Course type: Major/Core** **Lectures: 45** **Course Name: Mechanics** **Course Code: PHYUGMIN1101** **Credit: 4 [3(Theory)+1(Practical)]** **Course type: Minor (Offered by the Physics department for the students of other departments)**	
Course Objectives: Mechanics is a branch of the physical sciences that is concerned with the state of rest or motion of bodies that are subjected to the action of forces. It's a fundamental subject which describes the behavior of physical bodies and provides the basic concepts related to the motion of all the objects around us in our daily life. The course builds a foundation of various applied fields in science and technology; especially in the field of mechanical engineering. The course comprises the study of vectors, laws of motion, momentum, energy, rotational motion, gravitation, fluids, elasticity and special relativity.	
Fundamentals of Dynamics	**8 Lectures**
Review of Newton's Laws: Mechanistic view of the Universe. Concepts of Inertial frames, force, and mass. Solution of the equations of motion (E.O.M.) in simple force fields in one, two- and three-dimensions using Cartesian, Cylindrical polar, and Spherical polar coordinate systems. *Dynamics of systems of particles*: Difficulty of solving the E.O.M. for systems of particles. Newton's third Law. External and Internal forces. Momentum and Angular Momentum of a system. Torque acting on a system. Conservation of Linear and Angular Momentum. Centre of mass and its properties. Two-body problem. *Variable-mass system*: motion of the rocket.	
Work and Energy	**6 Lectures**
Work and Kinetic energy Theorem. Conservative and non-conservative forces. Potential energy. Elastic potential energy. Force as the gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of energy; Qualitative study of one-dimensional motion from potential energy curves. Stable and unstable equilibrium; Energy of a system of particles.	
Collisions	**2 Lectures**
Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.	
Gravitation and Central Force Motion	**6 Lectures**
Central Force. Reduction of the two-body central force problem to a one-body problem. Setting up the E.O.M. in plane polar coordinates; Differential equation for the path. Motion under an Inverse-square force. Newton's Law of Gravitation. Inertial and gravitational mass. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS); Gravitational potential energy. Potential and Field due to spherical shell and solid sphere.	
Non-Inertial Systems	**8 Lectures**

Galilean transformations and Galilean invariance; Non-inertial frames and the idea of fictitious forces. E.O.M. with respect to a uniformly accelerating frame. E.O.M. with respect to a uniformly rotating frame - Centrifugal and Coriolis forces. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems. Laws of Physics in a laboratory on the surface of the earth.	
Rotational Dynamics	**6 Lectures**
Constraints defining the rigid body. Degrees of freedom for a rigid body; Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Parallel and perpendicular axes theorem; Calculation of moment of inertia for rectangular, cylindrical, and spherical bodies. The kinetic energy of rotation. Motion involving both translation and rotation.	
Elasticity	**4 Lectures**
Relation between elastic constants. Twisting torque on a Cylinder or Wire. Bending of a beam-internal bending moment.	
Fluid Motion	**5 Lectures**
Kinematics of Moving Fluids: equation of continuity. The idea of compressible and incompressible fluids, Idea of streamlined and turbulent flow, Reynold's number. Euler's Equation. The special case of fluid statics $F = \nabla p$: Simple applications (e.g.: Pascal's Law and Archimedes principle).	

Reference Books

- An introduction to mechanics, D. Kleppner, R. J. Kolenkow
- Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et. al.
- Analytical Mechanics, G. R. Fowles and G. L. Cassiday
- Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton, M. Sands
- University Physics, Ronald Lane Reese
- Mechanics, D. S. Mathur
- University Physics. F. W. Sears, M.W Zemansky, H.D. Young
- Theoretical Mechanics, M. R. Spiegel
- Mechanics, Keith R Simon
- Fluid mechanics, Landau, Lifshitz
- Properties of Matter, F. C. Champion and N. Davy

General Topic

Discussion on random errors in observations. Measurement principles of length (or diameter) using vernier caliper, screw gauge and traveling microscope. Discussion on the parts of Sextant.

List of Practical

- To study the random error in observations of the time period of some oscillation using a chronometer.
- To determine the Moment of Inertia of a regular body using another auxiliary body and a cradle suspended by a metallic wire.
- To determine the Moment of Inertia of a Flywheel.
- To determine g and velocity for a freely falling body using Digital Timing Technique
- To determine the Coefficient of Viscosity of water by the Capillary Flow Method (Poiseuille's method).
- To determine Young's Modulus by flexure method.
- To determine the Modulus of Rigidity of a Wire by a torsional pendulum.
- To determine the height of a building using a Sextant.
- To determine the elastic Constants of a wire by Searle's method.
- To determine the value of g using Bar Pendulum.
- To determine the value of g using Kater's Pendulum.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Engineering Practical Physics, S. Panigrahi & B. Mallick
- Practical Physics, G. L. Squires

Course Outcomes:
On completion of this course, the students are expected to,
CO1: Understand the fundamentals of classical mechanics in inertial frame of reference, such as, Newton's laws of motion, Dynamics of the system of particle, Conservation of Linear and Angular momentum,Work energy theorem and Collision
CO2: Understand the fundamentals of classical mechanics in inertial frame of reference, such as, Newton's laws of motion, Dynamics of the system of particle, Conservation of Linear and Angular momentum,Work energy theorem and Collision
CO3: Realize the general properties of matter, such as, gravitation and motion of central force, elasticity and fluid dynamics
CO4: Gain the substantial experience to realize the dynamics of a classical body by understanding various experimental procedures

Course Name: Mathematical Physics I
Course Code: PHYUGMCC1102
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15

Course Objectives:
The main objective of this course is to familiarize students with a range of primary mathematical methods that are essential for solving advanced problems in theoretical physics. This Course Enables the Student to understand the linear equations, vector spaces, matrices, linear transformations, determinants, eigenvalue, eigenvectors, differential equations, orthogonal curvilinear coordinates, Dirac delta function etc. This course will help to construct a concrete mathematical basis, necessary for student pursuing major in graduate-level physics

Calculus	**15 Lectures**

Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). Convergence condition of Taylor series and corresponding tests;
*First Order and Second Order Differential equation*s: First Order Differential equations and Integrating Factor. Homogeneous and Inhomogeneous equations with constant immune deficient, particular integral. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral;
Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factors with a simple illustration. Constrained Maximization using Lagrange Multipliers.

Vector Calculus	**25 Lectures**

Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product, and their interpretation in terms of area and volume, respectively. Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivatives. The gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities using Kronecker delta and Levi-Civita symbols. *Vector Integration*: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. The notion of infinitesimal line, surface and volume elements. Line, surface, and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes's Theorems and their applications (no rigorous proofs).	
Orthogonal Curvilinear Coordinates	**5 Lectures**
Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl, and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.	
Matrices	**10 Lectures**
Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar, and Unit Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace of a Matrix. Inner Product; Eigen-values and Eigenvectors. Cayley-Hamiliton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.	
Dirac Delta function and its properties	**2 Lectures**
Definition of Dirac delta function. Representation as the limit of a Gaussian function and rectangular function. Properties of Dirac delta function	
Theory of Errors	**3 Lectures**
Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error. Least-squares fit. Error on the slope and intercept of a fitted line.	
Reference *Books* ● Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. Harris ● Mathematics of Classical and Quantum Physics, Frederick W. Byron and Robert W. Fuller ● An introduction to ordinary differential equations, E. A. Coddington ● Differential equations, G. F. Simmons ● Mathematical Tools for Physics, J. Nearing ● Mathematical methods for Scientists and Engineers, D. A. McQuarrie ● Mathematical Physics, Goswami ● Essential Mathematical Methods, K. F. Riley & M. P. Hobson ● Mathematical methods in the Physical Sciences, M. L. Boas ● Advanced Engineering Mathematics, D. G. Zill and W. S. Wright ● Engineering Mathematics, S. Pal, and S. C. Bhunia ● Advanced Engineering Mathematics, E. Kreyszig ● Matrices and Tensors in Physics, A. W. Joshi	
Course Outcomes: On completion of this course, the students are expected to, **CO1:** Understand basic concepts of 3D vectors, vector calculus and its physical interpretation and curvilinear coordinate	

CO2: Demonstrate competence with the basic ideas of linear algebra including concepts of linear systems, theory of matrices, linear transformations, bases and dimension, eigenvalues, eigenvectors and Diagonalization.
CO3: Solve second order linear differential equations
CO4: Calculation of errors in different experiments.

Course Name: Basic instrumentation skill
Course Code: PHYUGSEC1101
Credit: 3 (Theory)
Course type: Skill Enhancement Courses
Lectures: 45

Course Objectives:

The main objective of this course is to familiarize students with different types of instrumentation necessary to construct an experiment in physics. This Course helps the students to understand and comprehend the use of various instruments, such as, voltmeter, ammeter, digital multimeter and CRO etc.

Basic of Measurement	**4 lectures**

Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Multimeter: Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance.

Electronic Voltmeter	**4 lectures**

The advantage over conventional multimeter for voltage measurement with respect to input impedance and sensitivity. Principles of voltage measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. AC millivoltmeter: Type of AC millivoltmeters: Amplifier-rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter, specifications and their significance.

Cathode Ray Oscilloscope	**8 lectures**

Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. Use of CRO for the measurement of voltage (dc and ac frequency, period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working.

Signal Generators and Analysis Instruments	**4 lectures**

Block diagram, explanation and specifications of low-frequency signal generators. Pulse generator and function generator. The brief idea for testing and specifications. Distortion factor meter, wave analysis.

Digital Instruments	**4 lectures**

Principle and working of digital meters. Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.

Digital Multimeter	**4 lectures**

Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time-base stability, accuracy, and resolution.	
Production of Vacuum	**8 lectures**
Classification, types, and ranges of vacuum, Mechanical pumps (Rotary, Lobe and Turbo molecular pumps), Diffusion pump, Getter and Ion pumps, Cryopumps, Titanium sublimation Pump, Pump Fluids; Materials in Vacuum: Vaporisation, out-gassing, glasses and Ceramics. Joints, Seals and Components, Gaskets and Motion feed through.	
Measurement of Pressure	**9 lectures**
Classification, types and ranges of vacuum gauges, Low-pressure measurement gauge; Mcleod gauge, Thermal conductivity gauge (thermocouple vacuum gauge and Pirani gauge), Ionization gauge- Cold Cathode - Penning Gauge - Inverted Magnetron Gauge. High-pressure measurement gauge; manometer, electrical resistance pressure gauge (Resistance type, photoelectric type, piezoelectric type, variable capacitor type), elastic pressure gauge (bourdon tube, diaphragm gauge) Measurement of Partial pressure, Flow measurement, Leak Testing.	
The test of lab skills will be of the following test items ● Use of an oscilloscope. ● CRO as a versatile measuring device. ● Circuit tracing of Laboratory electronic equipment, ● Use of Digital multimeter/VTVM for measuring voltages ● Circuit tracing of Laboratory electronic equipment, ● Winding a coil/transformer. ● Study the layout of the receiver circuit. ● Troubleshooting a circuit ● Balancing of bridges	
Reference Books ● A textbook in Electrical Technology - B L Theraja ● Performance and design of AC machines - M G Say ● Digital Circuits and systems, Venugopal ● Digital Electronics, Subrata Ghoshal ● Devices and circuits, S. Salivahanan & N. S.Kumar ● Electronic circuits: Handbook of design and applications, U.Tietze, Ch.Schenk ● Electronic Devices, 7/e Thomas L. Floyd	
Course Outcomes: On completion of this course, the students are expected to, **CO1:** Understand the usage of various basics electronics devices requires for any physics experiments, such as voltmeter, ammeter and digital multimeter **CO2:** Gain a substantial understanding of various signal generator and their usages **CO3:** Realize the use of Cathode Ray Oscilloscope **CO4:** Understand the production of vacuum and the measurement of pressure.	

Semester: II	
Course Name: Electricity and Magnetism **Course Code: PHYUGMCC1203** **Credit: 4 [3 (Theory) + 1 (Practical)]** **Course type: Major/Core** **Lectures: 45** **Course Name: Electricity and Magnetism** **Course Code: PHYUGMIN1202** **Credit: 4 [3(Theory)+1(Practical)]** **Course type: Minor (Offered by the Physics department for the students of other departments)**	
Course Objectives: This subject includes electricity, electric currents, magnetism and Electrodynamics and its applications which have the key role in the development of the modern technological world. The course in electricity and electrodynamics is an essential component of a physics programme at graduate level. Students will learn the historical advance of electricity and magnetism, the concept of electric field and magnetic field and the concept of electric current and its subsequent properties.	
Electric Field	**13 Lectures**
Coulomb's Law and Principle of superposition leading to the definition of Electrostatic Field. Field lines; Divergence of the Electrostatic Field. Flux, Gauss's theorem of electrostatics. Applications of Gauss theorem to find Electric fields due to charge configurations with spherical, cylindrical, and planar symmetry; Curl of the Electrostatic Field and its conservative nature. Electric potential. Potential for a uniformly charged spherical shell and solid sphere. Calculation of electric Field from potential; Laplace's and Poisson's equations. Uniqueness Theorems. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere; Conductors: Electric Field and charge density inside and on the surface of a conductor. Conductors in an electrostatic field. Force per unit area on the surface. The capacitance of a conductor. The capacitance of an isolated spherical conductor. Parallel plate condenser; Electrostatic energy of a system of charges. Electrostatic energy of a charged sphere; Energy per unit volume in electrostatic Field.	
Dielectric Properties of Matter	**6 Lectures**
Electric potential and field due to an electric dipole. Electric dipole moment. Force and torque on a dipole; Electric Fields inside matter: Electric Polarization. Bound charges. Displacement vector. Relations between E, P and D. Gauss's theorem in dielectrics. Linear Dielectric medium. Electric Susceptibility and Permittivity. Capacitor (parallel plate, spherical, cylindrical) filed with dielectric.	
Magnetostatic Field	**8 Lectures**
Biot-Savart's Law. Force on a moving point charge due to a magnetic field: Lorentz force law. Application of Biot-Savart's Law to determine the magnetic field of a straight conductor, circular coil. The force between two straight current-carrying wires; Divergence of the magnetic Field - its solenoidal nature. Magnetic vector potential; Curl of the Magnetic Field. Ampere's Circuital Law. Its application to (1) Infinite straight wire, (2) Infinite planar surface current, and (3) Solenoid.	
Magnetic Properties of Matter	**3 Lectures**

Potential and field due to a magnetic dipole. Magnetic dipole moment. Force and torque on a magnetic dipole in a uniform magnetic field; Magnetization. Bound currents. The magnetic intensity - H. Relation between B, H and M. Linear media. Magnetic Susceptibility and Permeability. Brief introduction of dia-, para- and ferro-magnetic materials. B-H curve and hysteresis.	
Electromagnetic Induction	**4 Lectures**
Ohm's law and definition of E.M.F. Faraday's laws of electromagnetic induction, Lenz's Law. Self-Inductance and Mutual Inductance. Reciprocity Theorem. Introduction to Maxwell's Equations. Charge conservation. Displacement current and resurrection of Equation of Continuity; Energy stored in a magnetic Field.	
Electrical Circuits	**7 Lectures**
Charge Conservation-equation of continuity. Transients in D.C.: Growth and decay of current, charging and discharging of capacitors in CR, LR & LCR circuits; oscillatory discharge; time constant; time variation of total energy in LCR circuit; AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Phasor diagram. Series LCR Circuit: (1) Resonance, (2) Power Dissipation (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit	
Network theorems	**4 Lectures**
Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits	

Reference Books

- Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury
- Electricity and Magnetism, Edward M. Purcell
- Introduction to electrodynamics, D. J. Griffiths.
- Feynman Lectures Vol.2, R. P. Feynman, R. B. Leighton, M. Sands
- Elements of electromagnetic, M. N. O. Sadiku
- Electricity and Magnetism, D. Chattopadhyay and P. C. Rakshit
- Electricity and Magnetism, J. H. Fewkes & J. Yarwood.

General topic

Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances (e) Checking electrical fuses, and (f) circuit continuity check. Demonstration on Carey Foster's bridge, potentiometer, resistance box, inductor coil, moving coil galvanometer (in dead beat and ballistic mode), etc.

List of Practical

- To determine an unknown Low Resistance using Carey Foster's Bridge.
- To verify the Thevenin and Norton theorems.
- To verify the Superposition and Maximum power transfer theorems.
- To determine self-inductance of a coil by Anderson's bridge.
- To study the response circuit of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
- To study the response circuit of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
- To study the characteristics of a series RC Circuit.
- To determine an unknown Low Resistance using a Potentiometer.
- To determine the resistance of a galvanometer using Thomson's method.
- Measurement of field strength B and its variation in a solenoid (determine dB/dx)
- Determination of the horizontal component of the earth’s magnetic field.

Reference Books

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Advanced level Physics Practical, Michael Nelson and Jon M. Ogborn
- Engineering Practical Physics, S. Panigrahi and B. Mallick
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal

Course Outcomes:

On completion of this course, the students are expected to,

CO1: Gain a substantial knowledge and understanding of the electric field and the dielectric properties of matter along with the necessary mathematical formulation to realize the concept itself, such as Gauss's law, Poisson and Laplace equation.

CO2: Understand the basic of electric current and its properties according to Ohm's law and Kirchhoff's law and realize the concept of networks and the necessary theorems to understand it, such as Thevenin theorem and Norton theorem

CO3: Realize the concept of magnetic field and magnetic flux along with the magnetic properties of matter, such as susceptibility, auxiliary magnetic field, magnetization etc.

CO4: Study the concept of electromagnetic induction, Faraday's law and its thermodynamic implication, Inductance and concept of induced and displacement current

Course Name: Waves and Optics
Course Code: PHYUGMCC1204
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Objectives:

This course provides a comprehensive understanding of oscillatory and wave motion, focusing on simple harmonic motion, damped and forced oscillations, and resonance. It explores wave properties, including longitudinal and transverse waves, wave equations, and energy transport. The course also covers the principles of superposition, standing waves, and the mathematical formulation of wave interactions. Additionally, students will study the fundamentals of optics, including interference, diffraction, and the special theory of relativity. Practical applications and experimental procedures are integrated to reinforce theoretical knowledge and develop hands-on skills in analyzing wave and oscillatory phenomena.

Simple Harmonic Motion	**4 Lectures**

SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor.

Superposition of Harmonic Oscillations	**4 Lectures**

Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences; Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

Wave Motions	**7 Lectures**

Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Traveling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. The pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave; Water Waves: Ripple and Gravity Waves	
Velocity of Waves	**2 Lectures**
Velocity of Transverse Vibrations of Stretched Strings; Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction.	
Superposition of Harmonic Waves	**4 Lectures**
Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment; Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes; Superposition of N Harmonic Waves. Phase and Group Velocities.	
Wave Optics	**3 Lectures**
Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence.	
Interference	**8 Lectures**
Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fiaeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.	
Interferometer	**3 Lectures**
Michelson Interferometer- (1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes; Fabry-Perot interferometer.	
Diffraction	**10 Lectures**
Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating; Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit, and a wire.	

Reference Books

- Waves: Berkeley Physics Course, Vol. 3, Francis Crawford
- Fundamentals of Optics, F.A. Jenkins and H. . White
- Principles of Optics, Max Born and Emil Wolf
- Optics, Ajoy Ghatak
- The Physics of Vibrations and Waves, H. J. Pain
- The Physics of Waves and Oscillations, N. K. Bajaj
- Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna
- Optics, 4th Edn., Eugene Hecht
- A textbook of Optics; N Subramanyam, B. Lal and M.N.Avadhanulu

General Topic

In the practical classes, students should be thoroughly familiarized with Schuster's focusing for their general proficiency with spectrometers; Sodium and mercury vapor lamps; Demonstrations on adjustments of spectrometers etc.

List of Practical

- To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda 2 - T$ law.
- To determine the refractive index of the Material of a prism using sodium source.
- To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
- To determine wavelength of sodium light using Fresnel Biprism.
- To determine wavelength of sodium light using Newton's Rings.
- To study Lissajous Figures to determine the phase difference between two harmonic oscillations.
- To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
- To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
- To investigate the motion of coupled oscillators.

Reference Books

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal

Course Outcomes

On completion of this course, the students are expected to:

CO1: Understand the fundamentals of oscillatory motion, including SHM, damped and forced oscillations, resonance, and superposition of harmonic oscillations. Solve differential equations for these motions and analyze the associated energies.

CO2: Comprehend wave motion principles, including the properties of plane and spherical waves, longitudinal and transverse waves, and wave equations. Analyze wave propagation, energy transport, intensity, and particle and wave velocities.

CO3: Analyze wave velocities in various contexts, including transverse vibrations of strings and longitudinal waves in fluids, and understand Newton's and Laplace's formulas for sound velocity.

CO4: Understand the superposition of harmonic waves, including standing waves, normal modes, and wave interactions. Analyze energy transfer in vibrating strings and the formation of standing waves in various systems.

CO5: Gain practical experience with waves and oscillations, including using spectrometers, analyzing interference patterns, and determining properties like refractive index, wavelength, and phase difference in optical and mechanical systems.

Course Name: Basic Computational Skill
Course Code: PHYUGSEC1202
Credit: 3 (Theory)
Course type: Skill Enhancement Courses
Lectures: 45

Course Objectives:

This course aims not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- Highlights the use of computational methods to solve physical problems
- Use of computer language as a tool in solving physics problems (applications)
- Course will consist of hands-on training on Problem solving on Computers.

Introduction	**4 Lectures**
Importance of computers in Physics, paradigm for solving physics problems for solution. Usage of Linux as an Editor. Algorithms and Flowcharts: Algorithm: Definition, properties and development. Flowchart: Concept of flowchart, symbols, guidelines, types. Examples: Cartesian to Spherical Polar Coordinates, Roots of Quadratic Equation, Sum of two matrices, Sum and Product of a finite series, calculation of sin(x) as a series, algorithm for plotting (1) Lissajous figures and (2) trajectory of a projectile thrown at an angle with the horizontal.	
Scientific Programming	**10 Lectures**
Some fundamental Linux Commands (Internal and External commands). Development of FORTRAN, Basic elements of FORTRAN: Character Set, Constants and their types, Variables and their types, Keywords, Variable Declaration and concept of instruction and program. Operators: Arithmetic, Relational, Logical and Assignment Operators; Expressions: Arithmetic, Relational, Logical, Character and Assignment Expressions. Fortran Statements: I/O Statements (unformatted/formatted), Executable and Non-Executable Statements, Layout of Fortran Program, Format of writing Program and concept of coding, Initialization and Replacement Logic. Examples from physics problems.	
Control Statements	**10 Lectures**
Types of Logic (Sequential, Selection, Repetition), Branching Statements (Logical IF, Arithmetic IF, Block IF, Nested Block IF, SELECT CASE and ELSE IF Ladder statements), Looping Statements (DO-CONTINUE, DO-ENDDO, DO-WHILE, Implied and Nested DO Loops), Jumping Statements (Unconditional GOTO, Computed GOTO, Assigned GOTO) Subscripted Variables (Arrays: Types of Arrays, DIMENSION Statement, Reading and Writing Arrays), Functions and Subroutines (Arithmetic Statement Function, Function Subprogram and Subroutine), RETURN, CALL, COMMON and EQUIVALENCE Statements), Structure, Disk I/O Statements, open a file, writing in a file, reading from a file. Examples from physics problems.	
Programming	**10 Lectures**
1. Exercises on syntax on the usage of FORTRAN 2. Usage of GUI Windows, Linux Commands, familiarity with DOS commands and working in an editor to write source codes in FORTRAN. 3. To print out all natural even/ odd numbers between given limits. 4. To find maximum, minimum and range of a given set of numbers. 5. Calculating Euler number using exp(x) series evaluated at x=1	
Visualization	**3 Lectures**
Introduction to graphical analysis and its limitations. Introduction to Gnuplot. importance of visualization of computational and computational data, basic Gnuplot commands: simple plots, plotting data from a file, saving and exporting, multiple data sets per file, physics with Gnuplot (equations, building functions, user-defined variables and functions), Understanding data with Gnuplot	
Hands-on exercises	**8 Lectures**
● To compile a frequency distribution and evaluate mean, standard deviation etc. ● To evaluate the sum of finite series and the area under a curve. ● To find the product of two matrices	

- To find a set of prime numbers and Fibonacci series.
- To write a program to open a file and generate data for plotting using Gnuplot.
- Plotting the trajectory of a projectile projected horizontally.
- Plotting the trajectory of a projectile projected making an angle with the horizontally.
- Creating an input Gnuplot file for plotting data and saving the output for seeing on the screen. Saving it as an EPS file and as a PDF file.
- To find the roots of a quadratic equation.
- Motion of a projectile using simulation and plot the output for visualization.
- Numerical solution of the equation of motion of simple harmonic oscillator and plot the outputs for visualization.
- Motion of a particle in a central force field and plot the output for visualization.

Reference Books

- Introduction to Numerical Analysis, S.S. Sastry
- Computer Programming in Fortran 77". V. Rajaraman
- LaTeX–A Document Preparation System", Leslie Lamport
- Gnuplot in action: understanding data with graphs, Philip K Janert
- Schaum's Outline of Theory and Problems of Programming with Fortran, S Lipsdutz and A Poe
- Computational Physics: An Introduction, R. C. Verma, et al.
- A first course in Numerical Methods, U.M. Ascher and C. Greif
- Elementary Numerical Analysis, K.E. Atkinson

Course Outcomes:

On completion of this course, the students are expected to:

CO1: Understand the role of computers in solving physics problems and develop skills in using Linux as a programming environment. Gain proficiency in creating algorithms and flowcharts for problem-solving.
CO2: Develop and execute scientific programs using FORTRAN, including the usage of fundamental elements, operators, expressions, and control statements. Apply these skills to solve physics problems.
CO3: Utilize Gnuplot for graphical analysis and visualization of computational data, including plotting functions, trajectories, and physics-based data sets.
CO4: Perform practical exercises to compile and analyze data, evaluate mathematical series, solve matrix problems, and simulate physical systems. Develop programs to visualize the motion of projectiles, harmonic oscillators, and particles in central force fields.

Course Name: Frontiers in Physics
Course Code: UCCUGMDC1202
Credit: 3 (Theory)
Course type: Multidisciplinary Courses
Lectures: 45

Course Objective:
The objective of this course is to provide students with a foundational understanding of the nature of science, the universe, matter, and fundamental forces. The course aims to develop critical thinking through proper reasoning and experimental evidence, exploring key scientific concepts and their impact on our understanding of the natural world.

Nature of Science	**10 Lectures**

Role of proper reasoning and experiments, with examples. Inductive and deductive logic. The character of physical laws, including universality. Difference between science and pseudoscience.

Universe	**12 Lectures**

The Copernican revolution, Kepler's laws and the Solar system, Galileo and the birth of Telescopic Astronomy, Modern observations: Stars and galaxies, the Life cycle of stars. Birth of the Universe, Big Bang and Hubble expansion, Dark matter and dark energy. Origin of life & exoplanets.	
Matter	**13 Lectures**
Atoms and molecules: The physical basis of the Periodic table. Heat and Thermodynamics: A basic idea about the kinetic theory of gases; Distinction between ideal and real gases; The three laws of thermodynamics. Concept of Entropy. Radioactivity: Alpha, beta & gamma decay; X-Rays – Properties. Structure of the atom: Electron, Nucleus: proton and neutron. Mention of the Standard Model of particles & interactions.	
Forces	**10 Lectures**
Laws of falling bodies, Inertia, Gravitation, Electricity and Magnetism, Light and its dual property. The microscopic world of Quantum Mechanics. Special and General Theory of Relativity (brief and qualitative ideas only) [*No Mathematical derivation beyond simple algebra should be used*]	

Reference Books

- Six Easy Pieces – Richard P. Feynman
- The first three minutes – Steven Weinberg
- The character of physical laws – Richard P. Feynman
- Introduction to Astronomy: From Darkness to Blazing Glory
- Perspectives of Modern Physics- Arthur Beiser
- Concepts of Modern Physics- Arthur Beiser
- Universe in a Nutshell– Stephen Hawkins
- Evolution of Physics – Einstein and Leopold Infeld.
- আধুনিক বিজ্ঞানের ক্রমবিকাশ, সম্পাদনা -সুশান্তমজুমদার, ভূপতি চক্রবর্তী, অনুষ্টুপ প্রকাশনী।

Course Outcomes:
Upon completing this course, students will be able to:
CO1: Comprehend the role of reasoning and experiments in science, differentiating between inductive and deductive logic, and distinguishing science from pseudoscience.
CO2: Gain knowledge of the universe's structure, including the Copernican revolution, Kepler's laws, the life cycle of stars, the Big Bang theory, Hubble expansion, dark matter, and dark energy.
CO3: Understand atomic and molecular structure, thermodynamics, radioactivity, and the Standard Model of particle physics.
CO4: Explore fundamental forces, including gravitation, electromagnetism, and the basics of quantum mechanics and relativity, with an emphasis on conceptual understanding.
CO5: Develop the ability to analyze scientific phenomena and articulate the character of physical laws and their universality.

Semester: III

Course Name: Thermal Physics
Course Code: PHYUGMCC2305
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Name: Thermal Physics

Course Code: PHYUGMIN2303 Credit: 4 [3(Theory)+1(Practical)] Course type: Minor (Offered by the Physics department for the students of other departments)	
Course Objectives: This course aims to provide a comprehensive understanding of thermodynamics, focusing on fundamental concepts and their applications in physics and engineering. Students will learn the principles of thermodynamics laws, including the zeroth, first, second, and third laws, and their significance in describing the behavior of thermodynamic systems. Additionally, the course covers thermodynamic potentials, kinetic theory of gases, molecular collisions, real gases, and conduction of heat, providing a solid foundation for further studies in thermal physics.	
Introduction to Thermodynamics	**20 Lectures**
Zeroth and First Law of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature. Concept of Work & Heat, State Functions, Internal Energy and First Law of Thermodynamics. Its differential form, First Law & various processes. Applications of First Law: General Relation between Cp and Cv, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. *Second Law of Thermodynamics*: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence; Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale; Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature-Entropy diagrams for Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero	
Thermodynamic Potentials	**8 Lectures**
Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations; Maxwell's Thermodynamic Relations; Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) T-dS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.	
Kinetic Theory of Gases	**15 Lectures**
Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. *Molecular Collisions*: Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.	

Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling

Conduction of Heat	**2 Lectures**

Thermal conductivity, diffusivity. Fourier's equation for heat conduction its solution for rectilinear flow of heat.

Reference Books

- Heat and Thermodynamics, M.W. Zemansky, Richard Dittman
- Thermal Physics, S. Garg, R. Bansal and Ghosh
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich
- Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger
- Concepts in Thermal Physics, S. J. Blundell and K. M. Blundell, 2nd edn.
- Thermodynamics and an introduction to thermostatistics, H. B. Callen
- Thermal Physics, A. Kumar and S. P. Taneja
- Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition

General Topics

Discussion on logscale plot to study power law dependence, decay constant etc. Discussion on the properties of PRT, thermocouple, diode sensor etc.

List of Practical

- Verification of Stefan's law using a torch bulb.
- To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
- To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using constant current source.
- To calibrate a thermocouple [one end in ice and another end at water bath which to be heated.] to measure temperature in a specified Range by Null Method using a potentiometer.
- To calibrate a thermocouple to measure temperature in a specified Range by direct measurement using Op-Amp differential amplifier and to determine Neutral Temperature [One end in ice and another end at water bath which to be heated.]
- Calibration of thermocouple [one end at room temperature other end in the oil bath] and determination of boiling point of water.
- Measuring unknown temperature using a diode sensor.
- To determine Mechanical equivalent of Heat, J, by Callender and Barne's constant flow method.
- To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
- To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal

Course Outcomes:

On completion of this course, the students are expected to,

CO1: Understand the fundamental principles of thermodynamics, including the zeroth and first laws, thermodynamic equilibrium, state functions, internal energy, and the application of first law to various processes.

CO2: Gain knowledge of the second law of thermodynamics, reversible and irreversible processes, heat engines, Carnot cycle, refrigerators, entropy, and its applications in determining the efficiency of thermodynamic processes.
CO3: Acquire an understanding of thermodynamic potentials, including internal energy, enthalpy, Helmholtz free energy, and Gibbs free energy, and their applications in describing thermodynamic systems.
CO4: Analyze the behavior of gasses using kinetic theory, including the Maxwell-Boltzmann distribution, mean free path, collisions, and transport phenomena. Understand the deviations of real gasses from ideal behavior and the application of equations of state.
CO5: Develop skills in conducting experiments to verify thermodynamic principles, including Stefan's law, determination of thermal conductivity, temperature coefficient of resistance, and calibration of temperature sensors. Gain practical experience in measuring unknown temperatures and determining the mechanical equivalent of heat.

Course Name: Mathematical Physics II
Course Code: PHYUGMCC2306
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Objective:
This course is one of the fundamental courses necessary for the physics students and it is a continuation of the Mathematical Physics I. This course aims to provide a comprehensive understanding of probability theory, covering independent and dependent random variables, various probability distribution functions, and their mean and variance. It will also help to equip students with the knowledge of Fourier series, including the representation of periodic functions, determination of Fourier coefficients, and applications in summing infinite series and solving differential equations.

Introduction to probability	**5 lectures**

Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance.
Dependent events: Conditional Probability. Bayes' Theorem and the idea of hypothesis testing.

Fourier Series	**8 Lectures**

Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Euler relation Complex representation of Fourier series. expansion of functions with arbitrary period. expansion of non-periodic functions over an interval. even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

Frobenius Method and Special Functions	**15 Lectures**

Singular Points of Second Order Linear Differential equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. expansion of function in a series of Legendre Polynomials. Multipole expansion in electrostatics. Orthonormality of Hermite and Laguerre polynomials (statements only). Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions [$J_0(x)\ and\ J_1(x)$] and Orthogonality.	
Some Special Integrals	**4 Lectures**
Beta and Gamma Functions and Relation between them. expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).	
Partial Differential Equations	**6 Lectures**
Solutions to partial differential equations, using separation of variables: Laplace's equation in problems of rectangular symmetry. Wave equation and its solution for vibrational modes of a stretched string. rectangular and circular membranes. Diffusion Equation.	
Variational calculus in Physics	**7 Lectures**
Basic ideas of functionals. Extremization of action as a basic principle in mechanics. Lagrangian formulation. Euler's equations of motion for simple systems: harmonics oscillators, simple pendulum, spherical pendulum, coupled oscillators. Cyclic coordinates. Symmetries and conservation laws. Legendre transformations and the Hamiltonian formulation of mechanics. Canonical equations of motion. Applications to simple systems.	

Reference Books

- Mathematical Methods for Physicists: Arfken, Weber
- Fourier Analysis, M. R. Spiegel
- Mathematics for Physicists, Susan M. Lea
- Differential equations, George F. Simmons
- Partial Differential equations for Scientists & engineers, S. J. Farlow
- Engineering Mathematics, S. Pal and S. C. Bhunia
- Mathematical methods for Scientists & engineers, D. A. McQuarrie
- Mathematical Physics, P. K. Chattopadhyay
- Mathematical Methods for Physics and engineers, K. F. Riley, M. P. Hobson and S. J. Bence
- Mathematics for Physicists, P. Dennery and A.Kraywicki
- Mathematics of Classical and Quantum Physics (Vol 1 &2), Frederick W. Byron, Robert W. Fuller
- Mathematical Methods of Physics, J. Mathews, R. L. Walker

General Topics:
Computer architecture and organization, memory and Input/output devices; Basics of scientific computing: Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods; Errors and error Analysis: Truncation and round off errors, Absolute and relative errors, Floating point computations.

Introduction to plotting graphs with GNUPlot/QtiPlot/Labplot (or equivalent):
Basic 2D and 3D graph plotting: Plotting functions and data files, fitting data using Qtiplot's fit function, polar and parametric plots, modifying the appearance of graphs, Surface and contour plots, exporting plots.

Programming in Python:

Introduction to programming: constants, variables and data types, dynamical typing, operators and expressions, modules, I/O statements, file handling, iterables, compound statements, indentation in python, the if-elseif-else block, for and while loops, nested compound statements.
Sample problems: Elementary calculations with different type of data e.g., area and volume of regular shapes using formulae. Creation and handling one dimensional array. Sum and average of a list of numbers stored in an array, finding the largest and lowest number from a list, swapping two data in a list, sorting of numbers in an array using bubble sort, insertion sort method. Calculation of term value in a series and finding the other terms with a seed (value of particular term) and calculation of different quantities with series. Convergence and accuracy of series. Introduction of a three-dimensional array. Simple calculations of matrices e.g., addition, subtraction, multiplication. Curve fitting, least square fit, Goodness of fit, standard deviation
Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Introduction to online graph plotting using matplotlib. Use scipy to generate Legendre Polynomials and Bessel function and then plot those using matplotlib.
Note: A list of suggestive numerical problems will be circulated from time to time.

Reference Books

- Introduction to Numerical Analysis, S. S. Sastry
- Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey
- Introduction to computation and programming using Python, J. Guttag
- Effective Computation in Physics: Field guide to research with Python, A. Scopata and K.D. Huff
- A first course in Numerical Methods, U.M. Ascher & C. Greif
- Elementary Numerical Analysis, K. Atkinson
- Numerical Methods for Scientists & Engineers, R. W. Hamming
- An Introduction to computational Physics, T. Pang
- Computational Physics, Darren Walker
- Mathematical Methods for Physics and engineers, K. F. Riley, M. P. Hobson and S. J. Bence
- Complex Variables, A. S. Fokas & M. J. Ablowitz
- Numpy beginners guide, Idris Alba
- Computational Physics, D. Walker
- Simulation of OD /PD Models with MATLAB, OCTAV and SCILAB: Scientifc and Engineering Applications: V. Wouwer, P. Saucez, C.V. Fernandez.

Course Outcomes:
On completion of this course, students are expected to,
CO1: Develop a solid grasp of probability theory, enabling students to analyze and interpret the behavior of random variables and probability distribution functions.
CO2: Master the concepts of Fourier series, enabling students to expand periodic and non-periodic functions and solve differential equations using Fourier analysis.
CO3: Acquire proficiency in solving differential equations using the Frobenius method and special functions such as Legendre, Bessel, Hermite, and Laguerre polynomials.
CO4: Understand the application of variational calculus in physics, including extremization of action, Lagrangian formulation, and solving Euler's equations of motion for simple systems.
CO5: Gain practical skills in scientific computing and numerical analysis using Python, including curve fitting, solving partial differential equations, and plotting graphs using libraries such as NumPy, SciPy, and Matplotlib.

Course Name: Data analysis and Scientific writing
Course Code: PHYUGSEC2303
Credit: 3 (Theory)
Course type: Skill Enhancement Courses
Lectures: 45

Course Objective: This course aims to provide students with a comprehensive understanding of data analysis techniques and the principles of scientific writing. Students will learn how to collect, prepare, analyse, and visualise data using tools such as XMGRACE and LibreOffice Calc. Additionally, the course will cover the fundamentals of scientific writing, including structure, types, and ethics. Practical sessions will involve hands-on experience in analysing datasets and preparing scientific manuscripts using LaTeX.	
Introduction to Data Analysis	**5 Lectures**
Definition, Importance and applications of data analysis in various fields; Types of Data: Qualitative vs. Quantitative, Structured vs. Unstructured	
Data Collection and Preparation	**5 Lectures**
Methods of Data Collection, Surveys, Experiments, Observational Studies, Mathematical simulations, Numerical calculations, Data Sources, Primary vs. Secondary Data, Public Data Sources and Databases, Data Cleaning	
Statistical Measures of Data Analysis	**5 Lectures**
Mean, Median, Mode, Variance, Standard Deviation, Introduction to Curve fitting, Least Square fitting, Empirical Formula using Curve Fitting: Example of the Work of Henrietta Swan Leavitt and Edwin Hubble	
Data Visualization with XMGRACE and LibreOffice Calc	**10 Lectures**
Introduction to Data Visualization, Importance of Visualization in Data Analysis, Creating Charts and Graphs, Bar, Pie, Histogram, Line, and Scatter Plots, Visualisation with XMGRACE and LibreOffice Calc	
Introduction to Scientific Writing	**5 Lectures**
Basics of Scientific Writing, Importance and Purpose, Types of Scientific Writing, Research Papers, Review Articles, Technical Reports, Ethics in Scientific Writing, Plagiarism, Data Fabrication, and Falsification	
Comprehensive Study of a Scientific Article	**5 Lectures**
Structure of a Scientific Article:, How to write: Abstract, Introduction, Methodology, Results and Discussion, Conclusion, Bibliography	
Introduction to LaTeX	**10 Lectures**
What is LaTeX: Benefits and Applications, Basic LaTeX Commands and Structure, Advanced LaTeX Features: Tables, Figures, Citations, and References, Managing Bibliography with LaTex: Use of Natbib, Bibliography Styles, How to make .bib file	

Recommended Resources:

- Textbooks:
  - "Introduction to Statistical Learning" by Gareth James, et al.
  - "Practical Statistics for Data Scientists" by Peter Bruce and Andrew Bruce
- Online Resources:
  - MOOCs on platforms like Coursera, edX
  - Online tutorials and forums (e.g., Stack Overflow, DataCamp)
- Software Tools:
  - XMGRACE, LibreOffice Calc, LaTeX (Overleaf or local installation)

Course Outcome:
On completion of this course, students are expected to,
CO1. Understand and differentiate between various types of data and their importance in different fields.
CO2: Gain substantial knowledge to develop the understanding of data processing, cleaning and its interpretation using various statistical measures
CO3: Learn the basics of scientific articles and their types, the scientific ethics and code of conduct
CO4: Develop an understanding to utilise various types of softwares such as XMGRACE, LibreOffice Calc and LaTex.

Course Name: Physics at different length scales
Course Code: UCCUGMDC2303
Credit: 3 (Theory)
Course type: Multidisciplinary Courses
Lectures: 45

Course Objective:
This course aims to provide students with a comprehensive understanding of key concepts in modern physics, including subatomic particles, material physics, and astronomy. It will also aim to develop the critical thinking and analytical skills of the students through the study of the nature of science, the universe, matter, forces, and the discovery of subatomic particles. Students will explore fundamental principles, experimental techniques, and applications in various fields, preparing them for advanced studies and research in physics and related disciplines.

Discovery of Subatomic particles	5 Lectures

A historical perspective The Discovery of the Electron: Cathode Rays, Thomson’s Experiment, Measurement of electric charge. The Nucleus: Radioactivity, Rutherford’s experiment and the discovery of the nucleus, the Neutron. More particles: Neutrinos, Positrons, Other antiparticles, Muons and Pions, Strange particles, Quarks

Material physics in a nutshell	20 Lectures

Fundamentals of materials science; Structure: Introduction to microstructure, and nanostructure; Introduction, importance and examples for nanomaterials, biomaterials, electronic, optical, and magnetic materials, ceramic and glass materials, composite materials, polymeric materials, metals and alloys; Introduction and applications of modern engineering materials: shape memory materials, chromic materials (thermo, photo, and electro chromic), rheological fluids, metallic glasses, advanced ceramics;
Introduction to complex fluids, liquid crystals, macromolecules. Liquid Crystals: Structure and classification of mesophases; introduction to molecular theories of liquid crystals; symmetry and order parameter. Macromolecules: Random walk and polymers; DNA denaturation process. Introduction and

applications of Ferroelectricity and ferroelectric materials, Piezoelectricity and piezoelectric materials, pyro-electric materials.

Astronomy	**20 Lectures**

Introduction of stars, galaxies, clusters, black holes, dark matter, dark energy;Different type of galaxies including Milky Way galaxy, Super massive black holes in galaxies, Active galactic nuclei; Mass, length, time and magnitude scales in astronomy; Measurement of stellar parameters: distance parallax, Cepheid variables, nova and supernovae, red shift, stellar spectra, spectral lines; Thermal radiation and thermodynamic equilibrium, Boltzmann and Saha equation, black body radiation. Observational tools: telescope as a camera, optical telescopes (refracting and reflecting telescopes), radio telescopes, astronomical instruments and detectors, observations at other wavelengths (infrared, ultraviolet, X-ray and Gamma ray astronomy).

Reference Books

- The Physics of Low-dimensional Semiconductors: An Introduction, John H. Davies
- Superconductivity Of Metals And Alloys, P. G. De Gennes
- Concepts of modern physics, A. Beiser
- Introductory Astronomy and Astrophysics, Zeilik and Gregory

Course Outcomes:

Upon completing this course, students will be able to:

CO1: Understand the role of proper reasoning and experiments in science, distinguishing between science and pseudoscience.

CO2: Explain the principles of the universe, including the Copernican revolution, Kepler's laws, the life cycle of stars, and the Big Bang theory.

CO3: Describe the structure of matter, including atoms, molecules, and the periodic table, as well as the laws of thermodynamics and the concept of entropy.

CO4: Comprehend the fundamental forces of nature, including gravitation, electromagnetism, quantum mechanics, and relativity.

CO5: Analyze the historical discovery of subatomic particles and the development of material physics, including nanomaterials, biomaterials, and modern engineering materials.

Semester: IV

Course Name: Analog Electronics
Course Code: PHYUGMCC2407
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

This course aims to provide students with a comprehensive understanding of electronics, from its historical development to modern applications, covering semiconductor devices, amplifiers, oscillators, and operational amplifiers. Analog electronics and the comprehensive understanding of the subject are extremely necessary for any students with an inclination towards a research career, especially in experimental physics.

Semiconductor Diodes	**6 Lectures**

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diodes. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diodes.	
Two-terminal Devices and their Applications	**6 Lectures**
Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter; Zener Diode and its application as Voltage Regulation (Load regulation and line regulation).	
Bipolar Junction transistors	**12 Lectures**
n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Physical Mechanism of Current Flow (unbiased). Current gains α and β Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Active, Cut off and Saturation Regions.Transistor Biasing and Stabilization Circuits. Fixed Bias, collector to base bias, and Voltage Divider Bias.	
Hybrid parameters	**6 Lectures**
Two port analysis of a transistor, definition of h-parameters, equivalent circuit, emitter follower, stability factor, low frequency model. Comparison of CB, CC and CE amplifiers.	
Feedback Amplifiers and Oscillators	**15 Lectures**
Feedback in Amplifiers: Principle of feedback, negative and positive feedback, Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise; Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators, Weinbridge and crystal oscillators	

Reference Books

- Integrated electronics, J. Millman and C.C. Halkias
- Electronics: Fundamentals and Applications, J. D. Ryder
- Solid State electronic Devices, B. G. Streetman & S. K. Banerjee
- Electronic Devices & circuits, S. Salivahanan & N. S. Kumar
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad
- Microelectronic circuits, A. S. Sedra, K. C. Smith, A. N. Chandorkar
- Electronic circuits: Handbook of design & applications, U.Tietze, C. Schenk
- Semiconductor Devices: Physics and Technology, S. M. Sae
- Microelectronic Circuits, M. H. Rashid
- Electronic Devices, 7/e Thomas L. Floyd

General Topics

Discussion on the operational principles of the relevant circuits used in the experiments.

List of Practical

- To study V-I characteristics of PN junction diode and Light emitting diode (LED) (using both current and voltage source).
- To study the reverse characteristics of Zener diode and study the load and line regulation.
- To study the characteristics of a BJT in CE configuration.
- To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
- To study the frequency response of voltage, gain of a RC-coupled transistor amplifier.

- To study the static characteristics of FET
- To study OPAMP-inverting amplifier, non-inverting amplifier, adder, substractar, comparator, integrator, differentiator.
- To design a Wien bridge oscillator for given frequency using an Op-Amp.
- To design a Phase Shift Oscillator of given specification using Op-Amp.
- To study the Colpitts's Oscillator.
- Study of V-I & power curves of Solar Cells and find maximum power point and efficiency.
- Using Schmitt trigger and associated circuit (with OPAMP) generate different waveforms.

Reference Books

- Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad
- Electronic Principle, Albert Malvino
- Electronic Devices & circuit Theory, R. L. Boylestad & L. D. Nashelsky

Course Outcomes:

On completion of this course, students are expected to,

CO1: Grasp the foundational concepts of electronics, tracing its historical development from valve circuits to semiconductor devices.

CO2: Comprehend semiconductor diodes, including fabrication, characteristics, and their applications in rectifiers and voltage regulation.

CO3: Analyze bipolar junction transistors and field-effect transistors, understanding their configurations, characteristics, and practical applications.

CO4: Master amplifier circuits, including biasing techniques, frequency response, and feedback mechanisms, for various applications in electronics.

CO5: Apply theoretical knowledge to practical experiments, demonstrating proficiency in operational amplifiers and other electronic components, including waveform generation and circuit analysis.

Course Name: Elements of Modern Physics
Course Code: PHYUGMCC2408
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Name: Elements of Modern Physics
Course Code: PHYUGMIN2404
Credit: 4 [3(Theory)+1(Practical)]
Course type: Minor (Offered by the Physics department for the students of other departments)

Course Objective:

This course provides a comprehensive understanding of the emergence of quantum theory, covering topics such as blackbody radiation, Planck's quantum hypothesis, the photoelectric effect, and the Bohr-Sommerfeld theory of atomic structure. It also introduce students to the elements of quantum mechanics, including the postulates of quantum mechanics, time evolution, simultaneous measurements, and nuclear physics

Emergence of Quantum Theory	**10 Lectures**

Blackbody Radiation, Planck's quantum hypothesis, Planck's constant. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law; Photoelectric effect and Compton scattering-light as a collection of photons. Davisson-Germer experiment. de-Broglie wavelength and matter waves. Wave-particle duality. Wave

description of particles by wave packets. Group and Phase velocities and relation between them. Probability interpretation: Normalized wave functions as probability amplitudes. Two-Slit experiment with photons and electrons. Linear superposition principle as a consequence. Position measurement- gamma ray microscope thought experiment. Heisenberg uncertainty principle (Statement with illustrations). Impossibility of a particle following a trajectory.	
Introduction to Quantum Mechanics	**15 Lectures**
Postulates of Quantum Mechanics: States as normalized vectors (normalized wave functions). Dynamical variables as linear Hermitian operators. Predictions of quantum mechanics from solving the eigenvalue equation for the observables. Expectation values of observables. Ehrenfest theorem. *Time evolution*: Schrödinger equation for non-relativistic particles. Stationary states. Solution of Schrodinger's equation using expansion in stationary states. Time evolution of expectation values. *Simultaneous measurements*: Compatible and incompatible observables and their relation to commutativity. Heisenberg's uncertainty relation for a pair of incompatible observables. Symmetry and degeneracy. Idea of the Angular momentum operators.	
One dimensional systems	**10 Lectures**
Particle moving in one dimension: Position, Momentum and Energy operators. Probability and probability current densities in one dimension. Boundary conditions on wave functions. Particle in a one dimensional infinitely rigid box: energy eigenvalues and eigenfunctions, normalization. Quantum mechanical scattering and tunneling in one dimension across a step potential & rectangular potential barrier. Continuity of wave function, boundary condition and emergence of discrete energy levels. Square well potential.	
Special Theory of Relativity	**10 Lectures**
Constancy of speed of light. Postulates of Special Theory of Relativity. Lorentz transformation. Causality and simultaneity in different frames. Length contraction. Time dilation. Light cone. Relativistic addition of velocities. Relativistic energy-momentum and mass-energy relation. Minkowski space-time. The metric tensor (flat space-time only). Raising and lowering of indices with metric tensors. Four vectors: (time-like, space-like and light-like),four-velocity and acceleration; four-momentum and force. Relativistic in variants and kinematics: Decay, elastic collision and reaction. Lagrangian formulation of relativistic mechanics. Covariant Lagrangian formulation.	
Reference Books ● Concepts of Modern Physics, Arthur Beiser ● Introduction to Modern Physics, Rich Meyer, Kennard, Coop ● Introduction to Quantum Mechanics, David J. Griffth ● Physics for scientists and engineers with Modern Physics, Jewett and Serway ● Modern Physics, G. Kaur and G. R. Pickrell ● Quantum Mechanics: Theory & Applications, A. K. Ghatak & S. Lokanathan ● Primer of Quantum Mechanics, M. Chester ● Nuclear Physics, S. N. Ghosal ● Laser Physics and Spectroscopy, P. N. Ghosh ● Modern Physics, J. R. Taylor, C. D. Zafratos, M. A. Dubson ● Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin ● Quantum Physics, Berkeley Physics, Vol.4. E. H. Wichman ● Basic ideas and concepts in Nuclear Physics, K. Heyde ● Six Ideas that Shaped Physics: Particle Behave like Waves, T. A. Moore ● Perspectives of Modern Physics- Arthur Beiser	

- Modern Physics, K. S. Krane
- Introduction to Special Relativity – Robert Resnick
- The Classical Theory of Fields, L.D Landau, E.M Lifshitz

General Topics
Discussion on working principles of tunnel diode, vacuum diode, discharge tube.
List of Practical
- To determine the wavelength of H-alpha emission line of Hydrogen atom.
- To determine the value of e/m by Bar magnet.
- To show the tunneling effect in tunnel diode using I-V characteristics.
- Measurement of Planck’s constant using black body radiation and photodetector.
- Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
- To determine the Planck’s constant using LEDs of at least 4 different colours.
- To determine the ionization potential of mercury.
- To setup the Millikan oil drop apparatus and determine the charge of an electron.

Reference Books
- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th edition, reprinted 1985, Heinemann educational Publishers.
- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th edn, 2011, Kitab Mahal.

Course Outcome:
On the completion of this course, students are expected to,
CO1: Develop a deep understanding of the fundamental concepts of quantum theory, including the wave-particle duality, wave description of particles, and the Bohr-Sommerfeld model of atomic structure.
CO2: Acquire proficiency in solving the Schrödinger equation for non-relativistic particles, analyzing quantum mechanical systems using eigenvalue equations, and understanding the time evolution of quantum states.
CO3: Master the principles of simultaneous measurements in quantum mechanics, including the Heisenberg uncertainty principle and the relationship between compatible and incompatible observables.
CO4: Gain insight into nuclear physics, including the structure of atomic nuclei, the nature of nuclear forces, radioactivity, fission, fusion, and the operation of nuclear reactors.
CO5: Develop practical skills through laboratory experiments, such as determining the wavelength of hydrogen emission lines, measuring Planck's constant using blackbody radiation, and demonstrating the tunneling effect in tunnel diodes.

Course Name: Electromagnetic Theory
Course Code: PHYUGMCC2409
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Objective:
This course aims to provide a thorough understanding of Maxwell's equations, including vector and scalar potentials, gauge transformations, and boundary conditions at interfaces between different media. It delves deep into the theory of electromagnetism to explore the propagation of electromagnetic waves in various media, including unbounded media, conducting media, and bounded media, covering topics such as wave impedance, reflection, and refraction. It will also introduce the electromagnetic origin of wave optics, including Kirchhoff's integral theorem, polarization phenomena, and the propagation of electromagnetic waves in anisotropic media.

Maxwell Equations	10 Lectures
Review of Maxwell's equations. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.	
EM Wave Propagation in Unbounded Media	**10 Lectures**
Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gasses, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.	
EM Wave in Bounded Media	**8 Lectures**
Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence)	
Electromagnetic origin of Wave Optics	**7 Lectures**
Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only); Description of Linear, Circular and Elliptical Polarization. Origin of Double-Refraction: Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula.	
Polarization in uniaxial crystals	**6 Lectures**
Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Production & analysis of polarized light. Babinet Compensator and its Uses.	
Rotatory polarization	**4 Lectures**
Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade and biquartz polarimeters.	

Reference Books

Introduction to electrodynamics, D. J. Griffiths

- Optics, E. Hecht
- Elements of electromagnetism, M. N. O. Sadiku
- Introduction to electromagnetic Theory, T. L. Chow
- Fundamentals of electromagnetism, M. A. W. Miah
- Electromagnetic field Theory, R.S. Kshetrimayun
- Engineering electromagnetic, Willian H. Hayt
- Electromagnetic Field Theory for engineers & Physicists, G. Lehner
- Electromagnetic Fields & Waves, P. Lorrain & D. Corson
- Electromagnetics, J. A. Edminster, Schaum Series

- Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu

General Topics
Discussion on the working principles of polaroids, polarimeter, photometers etc.

List of Practical
- To determine the specific rotation of sugar solution using Polarimeter.
- To study the polarization of light by refection and determine the polarizing angle for air-glass interface.
- To determine the refractive Index of (1) glass and (2) a liquid by total internal refection using a Gaussian eyepiece.
- To study dependence of radiation on angle for a simple Dipole antenna.
- To determine Brewster's angle for air-glass interface using a prism.
- To study Fresnel's law by the reflection on the surface of a prism.
- To verify the Malus law using a pair of polaroids.
- To analyze elliptically polarized light by using babinet compensator.

Reference Books
- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Electromagnetic Field Theory for Engineers & Physicists, G. Lehner

Course Outcome:
On completion of this course, students are expected to,
CO1: Demonstrate a deep comprehension of Maxwell's equations and their applications, including the calculation of vector and scalar potentials and the analysis of wave equations.
CO2: Gain proficiency in analyzing electromagnetic wave propagation in different media, understanding concepts such as wave impedance, reflection, and refraction at interfaces.
CO3: Acquire the ability to explain the electromagnetic origin of wave optics phenomena, including polarization, double refraction, and optical rotation, and their experimental verification.
CO4: Develop practical skills through laboratory experiments, such as determining the specific rotation of sugar solutions, studying the polarization of light by reflection, and analyzing elliptically polarized light using a Babinet compensator.
CO5: Apply theoretical knowledge to practical situations, including the determination of refractive indices, Brewster's angle, and the verification of Malus' law, fostering a deeper understanding of electromagnetic field theory concepts.

Semester: V

Course Name: Digital Electronics
Course Code: PHYUGMCC3510
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Name: Digital Electronics
Course Code: PHYUGMIN3505
Credit: 4 [3(Theory)+1(Practical)]
Course type: Minor (Offered by the Physics department for the students of other departments)

Course Objective:

This course will provide students with a comprehensive understanding of integrated circuits (ICs), including their types, components, and scale of integration. It also helps them to familiarize with digital circuits, covering binary numbers, logic gates, Boolean algebra, and data processing circuits etc.	
Digital Circuits	**6 Lectures**
Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.	
Boolean algebra	**8 Lecture**
De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.	
Data Processing Circuits	**5 Lectures**
Basic idea of Multiplexers, De-multiplexers, Decoders, Encoder	
Circuits	**10 Lectures**
Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor; Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.	
Shift registers	**4 Lectures**
Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).	
Counters (4 bits)	**4 Lectures**
Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter.	
Operational amplifier	**8 Lectures**
Characteristics of an Ideal and Practical OP-AMP. (IC 741), Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground; Inverting and non-inverting amplifiers Applications of OP-AMPs: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier	

Reference Books
- Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha
- Fundamentals of Digital Circuits, Anand Kumar
- Digital Circuits and systems, Venugopal
- Digital electronics, G. K. Kharate
- Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer
- Logic circuit design, Shimon P. Vingron
- Digital electronics, Subrata Ghoshal
- Digital electronics, S. K. Mandal
- Microprocessor Architecture Programming & applications with 8085

General Topics
In the Beginning of practical course, a brief history of development of electronics should be introduced.
List of Practical
To design OR & AND logic with diode and resistor. Basic logic gates with Transistors. To verify the logics by any type of universal gate NAND/NOR.
- Formation of different combinatorial problems by construction of Truth Table and implementation using basic logic gates.
- For a given truth table and logic equation, minimize and design the circuit using logic gate ICs.
- Half Adder, Full Adder and 4-bit binary Adder.
- Construction of half subtractor, full subtractor, adder-subtractor using full adder IC.
- To build Flip-Flop (RS, D-type and JK) circuits using NAND gates.
- To design an astable multivibrator of given specifications using 555 Timer.
- To design a monostable multivibrator of given specifications using 555 Timer.
- To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
- To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.

Reference Books
- Modern Digital electronics, R.P. Jain
- Basic electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller

Course Outcome:
On completion of the course, students are expected to,
CO1: Develop a solid understanding of integrated circuits, including their advantages, drawbacks, and classifications, enabling students to analyze and select appropriate ICs for different applications.
CO2: Acquire proficiency in designing and analyzing digital circuits, including the conversion of decimal to binary and vice versa, implementation of logic gates, and simplification of logic circuits using Boolean algebra.
CO3: Demonstrate the ability to design and construct various types of sequential circuits, such as flip-flops, timers, shift registers, and counters, and analyze their behavior using timing diagrams.
CO4: Gain practical skills through laboratory experiments, including the design and implementation of basic logic gates, construction of adders, subtractors, flip-flops, and multivibrators, and analysis of sequential circuits.
CO5: Apply theoretical knowledge to practical scenarios in computer organization, including understanding the functioning of input/output devices, data storage mechanisms, memory organization, and memory interfacing, fostering a deeper comprehension of digital systems.

Course Name: Quantum Mechanics and Applications
Course Code: PHYUGMCC3511
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15

Course Objective: This course helps students to develop a comprehensive understanding of quantum mechanics, emphasizing the Schrödinger equation and its applications across various physical systems, like Harmonic oscillator, Particle in a box etc. This course will also help them to familiarize with advanced topics including angular momentum, spin, and perturbation theory to analyze complex quantum mechanical systems. Lastly, the application of quantum mechanics is extended to understand many-electron systems and atomic spectra etc.	
Two and Three dimensional systems	**6 Lectures**
Particle moving in two-and three-dimensional rigid boxes, Idea of symmetry and degeneracy	
Simple harmonic oscillator	**6 Lectures**
Setting up the eigenvalue equation for the Hamiltonian. Energy levels and energy eigenfunctions in terms of Hermite polynomials (Solution to Hermite differential equation may be assumed). Ground state, zero-point energy & uncertainty principle.	
Hydrogen-like atoms	**13 Lectures**
Reduction of a two body problem to a one body problem. The time independent Schrodinger equation for a particle moving under a central force - the Schrodinger equation in spherical polar coordinates. Separation of variables. Angular equation and orbital angular momentum. Spherical Harmonics (Solution to Legendre differential equation may be assumed). Radial equation for attractive coulomb interaction - Hydrogen atom. Solution for the radial wavefunctions (Solution to Laguerre differential equation may be assumed). Shapes of the probability densities for ground & first excited states. Orbital angular momentum quantum numbers *l* and *m*; *s*, *p*, *d* shells.	
Generalized Angular Momenta and Spin	**8 Lectures**
Generalized angular momentum. Electron's magnetic Moment and Spin Angular Momentum. Gyromagnetic Ratio and Bohr Magneton and the g - factor. Energy associated with a magnetic dipole placed in a magnetic field. Larmor's Theorem. Stern-Gerlach Experiment; Addition of angular momenta - statement only. Restriction of eigenvalues from $\left\|j_1 \sim j_2\right\|$ to $j_1 + j_2$	
Spectra of Hydrogen atom and its fine structure	**8 Lectures**
Bohr model for hydrogen like ions, Bohr-Sommerfeld model, Fine structure of H atom, spectra of alkali atoms. Formula for first order non degenerate perturbative correction to the eigenvalue - statement only; Spin-orbit interaction and relativistic correction to the kinetic energy and Darwin term; fine structure of the hydrogen atom	
Atoms in Electric & Magnetic Fields	**5 Lectures**
Zeeman Effect: Normal and Anomalous Zeeman Effect (Formula for first order perturbative correction to the eigenvalue to be assumed); Paschen Back effect & Stark effects (Qualitative Discussion only)	
Many electron atoms	**6 Lectures**

Identical particles. Symmetric & Antisymmetric Wave Functions. Pauli's Exclusion Principle. Hund's Rule. Periodic table; Fine structure splitting. L-S and J-J coupling scheme. Spectral Notations for Atomic States and Term symbols. Spectra of Alkali Atoms.	
Molecular Spectra	**8 Lectures**
Concept of molecular potential, Born-Oppenheimer approximation, Separation of nuclear and electronic wavefunctions, Types of molecular spectra; Electronic, vibrational and rotational spectra, idea of Raman effect	

Reference Books

- A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan
- Quantum Mechanics, Robert Eisberg and Robert Resnick
- Quantum Mechanics, Leonard I. Schiff
- Quantum Mechanics, G. Aruldhas
- Quantum Mechanics, Bruce Cameron Reed
- Quantum Mechanics: Foundations & Applications, Arno Bohm
- Quantum Mechanics for Scientists & Engineers, D. A. B. Miller
- Quantum Mechanics, Eugen Merzbacher
- Introduction to Quantum Mechanics, D. J. Griffth
- Quantum Mechanics, Walter Greiner
- Fundamentals of molecular spectroscopy/ by Colin N. Banwell and Elaine M. McCash
- Quantum Mechanics, Volume 1 &2, C. Cohen-Tannoudji, B. Diu, F. Laloë
- Quantum Physics, S. Gasiorowicz
- Lectures on Quantum Mechanics, S. Weinberg

Course Outcome:

On completion of this course, students are expected,

CO1: Understand the principles of the Schrödinger equation and its application in describing the behavior of quantum systems.

CO2: Gain proficiency in solving eigenvalue problems and analyzing the quantum mechanics of simple systems such as the harmonic oscillator and hydrogen-like atoms.

CO3: Develop a comprehensive understanding of advanced quantum mechanics topics including angular momentum, spin, and perturbation theory, enabling the analysis of complex quantum systems.

CO4: Acquire knowledge of the behavior of atoms in external electric and magnetic fields, many-electron atoms, and the fine structure of atomic spectra, with an emphasis on practical applications and theoretical foundations.

Course Name: Statistical Mechanics
Course Code: PHYUGMCC3512
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15

Course Objective:

This course will equip students with a foundational understanding of statistical mechanics, covering basic probability concepts, macrostates, microstates, and ensembles, alongside classical and quantum theories of radiation, and statistical distributions for systems of identical particles such as classical particle, boson and fermion. It will also develop their ability to analyze thermodynamic functions, such as entropy and specific heat, and apply statistical methods to describe the behavior of various physical systems.

Basics of Statistical Mechanics	6 Lectures
Basic probability concepts and relations among probabilities, Binomial distribution, Calculation of mean values, Probability density, Specification of state of a system, Equilibrium and irreversibility, Interactions between two systems: thermal, mechanical and diffusive, Statistical definition of temperature, pressure and entropy	
Classical Statistical Mechanics	**20 Lectures**
(a) Macrostate & Microstate, Phase space, density of states and Liouville's theorem; Concept of ensemble, ensemble average and Ergodic hypothesis; Fluctuation in a physical quantity. (b) Microcanonical ensemble, postulate of equal priori probability. Boltzmann hypothesis, entropy and thermodynamic probability; Entropy calculation of ideal gas in microcanonical ensemble; Gibbs paradox; Sackur-Tetrode equation, Nernst's theorem. (c) Canonical ensemble, partition Function, thermodynamic functions of an ideal gas in terms of partition function. (d) Grand canonical ensemble and chemical potential.	
System of identical particles	**7 Lectures**
Collection of non-interacting identical particles, classical approach and quantum approach: distinguishability and indistinguishability. Exchange symmetry of wave functions, symmetric and antisymmetric wave functions. Average value in quantum statistics. Maxwell-Boltzmann distribution, emergence of Boltzmann factor, partition function. Law of Equipartition of Energy (with proof). Bosons and Fermions. Spin statistics theorem (statement only). Pauli exclusion principle for Fermions.	
Classical Theory of Radiation	**7 Lectures**
Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's ionization formula. Rayleigh-Jeans Law. Ultraviolet Catastrophe.	
Bose-Einstein Statistics	**10 Lectures**
B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.. Phonon gas. Debye theory of specific heat of solids. T^3 law.	
Fermi-Dirac Statistics	**10 Lectures**
Fermi-Dirac Distribution Law, Thermodynamic functions of a completely and strongly Degenerate Fermi Gas, Fermi energy, Fermi temperature, Fermi momentum, Sommerfeld correction to free electron theory in a Metal. Specific Heat of Metals, Relativistic Fermi gas, White dwarf stars, Chandrasekhar mass limit, Wiedemann-Franz law	

Reference Books

- Statistical Mechanics, R. K. Pathria
- Fundamentals of Statistical and Thermal Physics, F. Reif
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F W Sears and G L Salinger
- An Introduction to Statistical Mechanics & Thermodynamics, R. H. Swendsen
- Statistical and Thermal Physics, S. Lokanathan and R. S. Gambhir
- Statistical Mechanics, B. B. Laud
- Thermodynamics & Statistical Mechanics, P. V. Panat
- Thermal and Statistical Physics, R.B. Singh
- Statistical Mechanics, Gupta & Kumar
- Statistical Mechanics, K. Huang
- Statistical Physics of Particles, M. Kardar

Course Outcome:

On completion of this course, students are expected to,

CO1: Understand the fundamental concepts of statistical mechanics, including probability distributions, ensembles, and equilibrium.

CO2: Analyze classical and quantum theories of radiation, including blackbody radiation and Planck's quantum postulates.

CO3: Explain the statistical behavior of systems of identical particles, distinguishing between bosons and fermions, and apply Bose-Einstein and Fermi-Dirac statistics to describe their properties.

CO4: Calculate and interpret thermodynamic functions for strongly degenerate gases, including Bose-Einstein condensation and Fermi energy, and analyze their applications in real-world phenomena such as specific heat in metals and the Chandrasekhar mass limit for white dwarf stars.

Course Name: Summer Internship Program
Course Code: PHYUGSIP3501
Credit: 4

Course Objectives: Summer internship is an added prospect offered to the students to obtain experience in research or industry. Students may choose to pursue summer internship in one of the research institutes, CSIR laboratories, Universities or manufacturing industries. Students shall submit a work done report endorsed by the mentor/institute or industry authority. The internship program may include community engagement and services.

Course Outcome: Students are expected to get exposure to diversified work culture and domain knowledge by going to other institutes or industry. After successful completion of this course, the student will be able to demonstrate lifelong learning processes through critical reflection of internship experiences.

Semester: VI

Course Name: Solid States Physics
Course Code: PHYUGMCC3613
Credit: 4 [3(Theory)+1(Practical)]
Course type: Major/Core
Lectures: 45

Course Objective: This course will provide students with a comprehensive understanding of the fundamental principles underlying the behavior of materials, focusing on crystal structure, lattice dynamics, magnetic properties, dielectric properties, ferroelectricity, elementary band theory, and superconductivity.	
Crystal Structure	**12 Lectures**
Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with Basis Central and Noncentral Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor.	
Elementary Lattice Dynamics	**10 Lectures**
Lattice Vibrations and Phonons: Linear Monatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law	
Magnetic Properties of Matter	**8 Lectures**
Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of Dia- and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.	
Elementary band theory of Solid	**8 Lectures**
Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (4 probe method) & Hall coefficient.	
Elementary Superconductivity	**7 Lectures**
Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)	
Reference Books ● Introduction to Solid State Physics, Charles Kittel ● Elements of Solid-State Physics, J. P. Srivastava ● Introduction to Solids, Leonid V. Azaroff ● Solid State Physics, N. W. Ashcroft and N. D. Mermin ● Solid State Physics, H. Ibach and H. Luth ● Solid State Physics, Rita John ● Elementary Solid-State Physics, 1/e M. Ali Omar ● Solid State Physics, M.A. Wahab ● Solid State Physics and Electronics, A. B. Gupta and N. Islam	
General Topics Discussion on the operation of the relevant circuits used for the different studies in the following experiments. **List of Practical** ● To determine the Coupling Coefficient of a Piezoelectric crystal. ● Determination of variation of the Dielectric Constant of a dielectric Materials with frequency. ● To study PE hysteresis of a Ferroelectric Crystal. ● To study BH hysteresis of ferromagnetic material.	

- To determine the Hall coefficient of a semiconductor sample by four probe method.
- Measurement of susceptibility of paramagnetic solution (Quincke's Tube Method)
- To measure the Magnetic susceptibility of Solids.
- To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
- To study the temperature coefficient of a semiconductor (NTC thermistor).

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn
- A Text Book of Practical Physics, I. Prakash & Ramakrishna
- Elements of Solid-State Physics, J. P. Srivastava

Course Outcome:

Upon completion of this course, students are expected to,

CO1: Understand the concepts of crystal structure, including lattice translation vectors, Miller indices, reciprocal lattice, and types of lattices, and analyze diffraction of X-rays by crystals using Bragg's law.

CO2: Explain the fundamental aspects of lattice dynamics and phonons, including Dulong and Petit's Law, Einstein and Debye theories of specific heat, and the temperature dependence of phonon spectra in solids.

CO3: Describe the magnetic properties of matter, distinguishing between dia-, para-, ferri-, and ferromagnetic materials, and analyze the classical and quantum mechanical theories underlying paramagnetism and ferromagnetism.

CO4: Analyze dielectric properties of materials, including polarization, electric susceptibility, and dielectric constant, and explain phenomena such as normal and anomalous dispersion, as well as the ferroelectric properties of materials like structural phase transition and piezoelectricity.

Course Name: Nuclear and Particle Physics
Course Code: PHYUGMCC3614
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15

Course Name: Nuclear and Particle Physics
Course Code: PHYUGMIN3606
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Minor (Offered by the Physics department for the students of other departments)

Course Objective:

The course aims to provide students with a comprehensive understanding of the fundamental principles of nuclear physics, covering the structure of nuclei, nuclear models, radioactivity decay processes, nuclear reactions, interaction of nuclear radiation with matter, detectors for nuclear radiations, particle accelerators, particle physics, and nuclear astrophysics.

General Properties of Nuclei	10 Lectures

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curie, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excited states.

Nuclear Models	**10 Lectures**
Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, Nature of nuclear force.	
Radioactivity decay	**5 Lectures**
Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law. Beta decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. Gamma decay: Gamma ray emission & kinematics, internal conversion.	
Nuclear Reactions	**5 Lectures**
Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).	
Interaction of Nuclear Radiation with matter	**5 Lectures**
Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.	
Detector for Nuclear Radiations	**5 Lectures**
Ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT).	
Particle Accelerators	**5 Lectures**
Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons.	
Elementary Particle Physics	**5 Lectures**
Types of particles and their families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons, Quark structure of hadrons.	
Nuclear Astrophysics	**10 Lectures**
Early universe, primordial nucleosynthesis (particle nuclear interactions), stellar nucleosynthesis, concept of Gamow window, Nuclear reactions of astrophysical importance and nucleosynthesis, heavy element production: r- and s- process path.	
Reference Books ● Introductory nuclear Physics by Kenneth S. Krane ● Concepts of nuclear physics by Bernard L. Cohen. ● Introduction to the physics of nuclei & particles, R.A. Dunlap. ● Introduction to High energy Physics, D.H. Perkins ● Introduction to elementary Particles, D. Griffith ● Quarks and Leptons, F. Halzen and A. D. Martin	

- Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde
- Radiation detection and measurement, G. F. Knoll
- Physics and engineering of Radiation Detection, Syed Naeem Ahmed
- Theoretical Nuclear Physics, J. M. Blatt & V. F. Weisskopf
- Nuclear Astrophysics- A course of Lectures, Md. A. Khan

Course Outcome:

On completion of this course students are expected to,

CO1: Understand the constituents of the nucleus, their intrinsic properties, and quantitative facts about mass, radii, charge density, binding energy, and average binding energy, as well as the main features of binding energy versus mass number.

CO2: Explain the liquid drop model approach, the semi-empirical mass formula, the condition of nuclear stability, evidence for nuclear shell structure, and the basic assumption of the shell model.

CO3: Describe the processes and theories of alpha, beta, and gamma decay, including energy kinematics, emission processes, and relevant laws.

CO4: Analyze different types of nuclear reactions, conservation laws, kinematics, Q-value, reaction cross-section, and the concepts of compound and direct reactions, as well as their astrophysical importance and nucleosynthesis.

Course Name: Numerical Analysis and Computation
Course Code: PHYUGMCC3615
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15

Course Objective:

This course aims to provide the students with adequate knowledge of numerical computations, which is a necessary attribute for any students, pursuing higher education in Physics. Numerical computation, such as, the numerical root searching techniques, numerical calculus, curve fitting etc. is the backbone for any data related analysis in theoretical, applied and experimental physics. Students will also be provided a comprehensive understanding of the applicability of numerical computation via a list of important practicals as well.

Root Searching of Algebraic Equations	**5 Lectures**
Bisection method, Newton-Raphson method, Regula Falsi method	
Finite Difference Calculus	**5 Lectures**
Numerical differentiation using a continuous function and using a discrete data points, Newton forward, backward and centre divided difference methods	
Numerical Interpolation	**5 Lectures**
Newton’s forward and backward interpolation, Lagrange interpolation method	
Numerical Integration	**8 Lectures**
Newton-Cote’s formula, Trapezoidal rule, Simpson’s ⅓ rule, Simpson’s ⅜ rule and their composite versions	

Numerical Solution of First Order Differential Equations	8 Lectures
Euler’s method, Second and Fourth order Runge-Kutta method, Boundary value problems	
Numerical Linear Algebra	**8 Lectures**
General solution of a system of equations with *n* number of unknowns: Gauss-Elimination method, Gauss-Seidal method and Gauss-Jordon method	
Curve Fitting Technique	**6 Lectures**
Linear, Polynomial, exponential etc. function fitting to a given dataset by the Least square technique	

General Topics

Computer architecture and organization, memory and Input/output devices; Basics of scientific computing: Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods; Errors and error Analysis: Truncation and round off errors, Absolute and relative errors, Floating point computations.

List of Practical

Use of Fortran or Python programming languages to write and test the codes for the following problems:

1. Plotting of functions and data; fitting etc. using gnu plot/XmGrace.
2. Finding roots of an arbitrary algebraic equation
3. Numerical differention at an arbitrary point from a given data set
4. Use of numerical interpolation technique to find …
5. Solution of a definite integration by different numerical techniques and comparison of efficiency
6. Solving first order ordinary differential equations by numerical techniques
7. Fitting an arbitrary analytic function to a given data set
8. Solving simultaneous linear algebric equations by different numerical techniques
9. Matrix diagonalisation and matrix inversion (eigenvalue problem) by numerical techniques
10. Applications of Monte Carlo methods for (i) Random number generation from different distributions: uniform, Gaussian etc., (ii) Numerical integration and (iii) 1D and 2D Ising model
11. Error analysis of all the numerical methods use in item no. 2-10 given above

Note: A list of suggestive numerical problems will be circulated from time to time.

Reference Books

- Fortran 90/95 Programming Manual, Tanja van Mourik
- Fortran 90 Course Notes, A. C. Marshall, J. S. Morgan and J. L. Schonfelder
- Computer Oriented Numerical Methods, V. Rajaraman
- Numerical Methods in Fortran, J.M. McCulloch and M.G. Salvadori
- Numerical Methods, R. L. Burden and J. D. Faires
- Introduction to Numerical Analysis, S. S. Sastry
- Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey
- Introduction to computation and programming using Python, J. Guttag
- Effective Computation in Physics: Field guide to research with Python, A. Scopata and K.D. Huff
- A first course in Numerical Methods, U.M. Ascher & C. Greif
- Elementary Numerical Analysis, K. Atkinson
- Numerical Methods for Scientists & Engineers, R. W. Hamming
- An Introduction to computational Physics, T. Pang
- Computational Physics, Darren Walker
- Numpy beginners guide, Idris Alba
- Computational Physics, D. Walker

- Simulation of OD /PD Models with MATLAB, OCTAV and SCILAB: Scientifc and Engineering Applications: V. Wouwer, P. Saucez, C.V. Fernandez.

Course Outcome:
On completion of this course students are expected to,

CO1: Gain substantial knowledge in the field of numerical calculus techniques viz. Numerical differentiation and integrations

CO2: Enable them to apply the numerical root searching techniques in various Classical and Quantum Mechanical problems

CO3: Understand the basics of interpolation techniques and the numerical curve-fitting methods, their applicability in various physical problems

CO4: Gain basic understanding to solve first order differential equation by various iterative methods.

CO5: Learn other important attributes of numerical computations, such as linear algebra, Monte-carlo simulation etc.

Course Name: Photonics
Course Code: PHYUGMDS3601
Credit: 4 [3 (Theory) + 1 (Practical)]
Course type: Major/Core
Lectures: 45

Course Objective:
The course aims to provide students with a comprehensive understanding of laser physics and photonics, covering the principles, operation, and applications of lasers, as well as the fundamentals of fiber optics, photon optics, acousto-optics, electro-optics, and nonlinear optics.

Laser and Holography	**20 Lectures**

MASER and historical background of LASER; Characteristics of Laser light; Einstein's A and B coefficients; Stimulated absorption, Spontaneous and Stimulated Emissions; qualitative discussion on vacuum fluctuation, Light amplification; Optical pumping and Population inversion; Rate equations: two-level, three-level and four-level systems; Optical Resonator, Modes of resonators; Metastable states; Solid State Laser-Ruby laser; Gas Laser- He-Ne and CO_2 lasers; Liquid laser- Dye laser; Semiconductor laser: homo and heterostructures, Pulsed Laser; Application of laser. Holography: Principle of holography, holographic code (theory), Importance of coherence in holography, Recording (construction) and reconstruction of hologram; classification of hologram and applications.

Fiber Optics	**12 Lectures**

Physical nature of optical fiber: core, cladding and jacket; Critical angle, Acceptance angle, Total internal reflection and Numerical aperture; Skip distance: number of internal reflections; Classification of optical fibers: step index and graded index fiber, Fiber V parameter, single and multimode fibers; TE and TM modes; Attenuation and dispersion in optical fiber; Holey and photonic crystal fibers, Analog and digital communication through optical fibers.

Acousto-Optics and Electro-Optics	**5 Lectures**

(a) Interaction of light and sound: Bragg diffraction; Acousto-optic devices: Modulators, Scanners, Frequency shifters. (b) Principle of electro-optics: Pockels and Kerr effects, electro-optic modulators and switches.

Nonlinear Optics	8 Lectures
Linear and nonlinear optical media, Non-linear optical phenomena: Second and third order nonlinear optics, Harmonic generation: Second and Third harmonic generation (SHG, THG), optical mixing, parametric generation of light, Self-focusing of light	

Reference Books

- Fundamentals of Photonics, B.E.A. Saleh and M. C. Teich
- Optical Electronics, A. Ghatak & K. Thyagarajan
- Lasers: Principles and Applications, J. Wilson and J. F. B. Hawkes
- An Introduction to Optical Fibers, Allen H. Cherin
- Optical Fibers and Fiber optics Communication systems, Subir Kumar Sarkar
- Lasers: Fundamentals and Application, K Thyagarajan, A. Ghatak
- Lasers and Non-Linear Optics, B B Laud
- An Introduction to Fiber Optics, K Thyagarajan, A. Ghatak
- Nonlinear Optics, Robert W. Boyd

List of Practical

- To determine the wavelength of laser source using diffraction of double slit.
- Determination of numerical aperture (N.A.) and bending loss of an optical fiber using laser light.
- To determine (i) wavelength and (ii) angular spread of He-Ne laser/solid state laser using plane diffraction grating.
- Determination of wavelength of laser light using Michelson's interferometer.
- Characteristic study of diode laser (i) To study Gaussian nature of laser beam. (ii) To evaluate the diameter of laser beam (beam spot size). (iii) To measure the divergence angle of laser beam. (iv) To study the polarization nature of the laser.
- To study the V-I and response characteristics of Phototransistor and LDR.
- Diffraction experiments using single slit, single wire, cross wire, wire mesh, pinhole, grating.
- Determination of size of a tiny particle and groove spacing of CD using diode laser.

Reference Books

- Fundamentals of Photonics, B.E.A. Saleh and M. C. Teich
- Lasers and Non-Linear Optics, B B Laud
- Optical Electronics, A. Ghatak & K. Thyagarajan
- Lasers: Fundamentals and Application, K Thyagarajan, A. Ghatak
- An Introduction to Fiber Optics, K Thyagarajan, A. Ghatak

Course Outcome:

On completion of this course, students are expected to,

CO1: Understand the historical background and characteristics of laser light, including Einstein's coefficients, stimulated absorption, spontaneous and stimulated emissions, optical pumping, and population inversion.

CO2: Explain the principles of fiber optics, including the physical nature of optical fibers, critical angle, total internal reflection, numerical aperture, and various types of optical fibers, as well as their applications in analog and digital communication.

CO3: Describe the theory of photon optics, including the photon's energy, polarization, momentum, interference, quantum states of light, and photon streams, along with their practical implications.

CO4: Analyze the principles and applications of acousto-optics, electro-optics, and nonlinear optics, including the interaction of light and sound, Bragg diffraction, electro-optic effects, and nonlinear optical phenomena, such as harmonic generation and self-focusing of light.

Semester: VII	
Course Name: Advanced Mathematical Physics **Course Code: PHYUGMCC4716** **Credit: 4 [3(Theory)+1(Tutorial)]** **Course type: Major/Core** **Lectures: 45+15** **(For both Physics Honors with Research and Without Research)**	
Course Objective: The course aims to provide students with a comprehensive understanding of advanced mathematical concepts essential for theoretical physics, including complex analysis, abstract algebraic structures, tensors, integral transformations, and the theory of differential equations. Through theoretical discussions and practical applications, students will develop proficiency in analyzing and solving complex mathematical problems encountered in physics.	
Complex analysis	**14 Lectures**
Brief Revision of Complex Numbers. and their Graphical Representation. Euler's formula, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.	
Abstract algebraic structures	**14 Lectures**
Basics of abstract algebra *e.g.* Set, Group, Ring, Field. Group multiplication table, Conjugates elements and classes, Isomorphism & Homomorphism, Vector space, Inner product space, Schmidt's orthogonalisation method, Schwartz inequality. Linear operators, Matrix representation of operators. Special operators-conjugate operators, Adjoint and Self adjoint operators, Unitary operators, Orthogonality.	
Tensors	**14 Lectures**
General definition, Contravariant, Covariant and Mixed tensors and their ranks; outer product of tensors, Contraction of Tensors, Inner product of tensors; Symmetric and anti-symmetric tensors; Isotropic tensors, Metric tensor, raising and lowering of indices; Cartesian tensors.	
Integral transformation	**14 Lectures**
Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. *Laplace Transforms:* Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations: Damped	

Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1st order. Solution of heat flow along infinite bar using Laplace transform.	
Theory of differential equations	**4 Lectures**
Second order linear homogeneous differential equations, Linear independence of solutions, Wronskian, second solution. Sturm-Liouville theory; Solution of Inhomogeneous differential equations by Green's functions technique	

Reference Books

- Mathematical Methods for Physics, Arfken & Weber
- Introduction to Mathematical Physics, C. Harper
- Mathematical Methods, M. C. Potter and J. Goldberg
- Mathematical Methods of Physics, J. Mathews and R.L. Walker
- Mathematics for Physicists, P. Dennery and A. Krzywicki
- Vector Analysis, M. R. Spiegel, (Schaum's Outline Series)
- Complex variables and Applications, R.V. Churchill and J.W. Brown
- Theory and Problems of Complex Variables, M.R. Spiegel
- Matrices and Tensors in Physics, A.W. Joshi
- Elements of Group Theory for Physicists, A.W. Joshi
- Differential Equations, S.L. Ross
- A Text book of Mathematical Physics, Suresh Chandra
- Group Theory in a Nutshell for Physicists, Anthony Zee

Course Outcome:

On completion of this course, students are expected to,

CO1: Understand the fundamentals of complex analysis, including complex numbers, Euler's formula, analytic functions, and integration techniques in the complex plane, and apply them to solve problems involving singular functions and definite integrals.

CO2: Gain proficiency in abstract algebraic structures, such as groups, rings, fields, and vector spaces, along with their properties, operations, and applications in physics, including linear operators and special operators.

CO3: Demonstrate knowledge of tensors, including contravariant, covariant, and mixed tensors, their ranks, operations, and applications in physics, such as Cartesian tensors and metric tensors.

CO4: Master integral transformation techniques, including Fourier and Laplace transforms, and apply them to solve differential equations encountered in physics, including wave equations, heat flow equations, and harmonic oscillators.

CO5: Understand the theoretical underpinnings of differential equations, including second-order linear homogeneous equations, singular points, and Sturm-Liouville theory.

Course Name: Advanced Statistical Mechanics
Course Code: PHYUGMCC4717
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15
(For both Physics Honors with Research and without Research)

Course Name: Advanced Statistical Mechanics
Course Code: PHYUGMIN4707
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Minor (Offered by the Physics department for the students of other departments)

Course Objective: This course aims to provide students with an in-depth understanding of advanced concepts in statistical mechanics. The course covers various statistical ensembles, quantum statistical mechanics, ideal Bose and Fermi gases, phase transitions, and non-equilibrium statistical mechanics. Students will develop the ability to apply these concepts to solve complex problems in thermodynamics and statistical mechanics, enhancing their analytical and problem-solving skills.	
Recapitulation	**7 Lectures**
(a) Macrostate, microstate; phase space, volume in phase space, phase cells, density of states and Liouville's theorem; Ensembles and ensemble average. Ergodic hypothesis. MB, BE, FD distribution function; Partition function. (b) Microcanonical distribution, Principle of equal priori probability, Calculation of internal energy, entropy and chemical potential of a perfect gas, Sackur-Tetrode equation and Gibb's paradox.	
Canonical Ensemble	**6 Lectures**
System in contact with a heat reservoir, canonical distribution, canonical partition function and its correlation with thermodynamic quantities- expression of entropy, Helmholtz free energy, total energy, specific heat (C_v), fluctuation of internal energy. Canonical partition function for perfect monatomic gas and calculation of entropy, Helmholtz free energy and internal energy.	
Grand Canonical Ensemble	**6 Lectures**
System in contact with a particle reservoir, chemical potential, grand canonical distribution, grand canonical partition function, grand potential, fluctuation of particle number, chemical potential of ideal gas. Chemical equilibrium and Saha ionization equation	
Classical non-ideal gas	**6 Lectures**
Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer-Ursell expansion.	
Quantum statistical mechanics	**10 Lectures**
Density matrix, density operator in statistical mechanics, quantum Liouville's theorem. Density matrices for microcanonical, canonical and grand canonical ensembles, simple examples of density matrices- one electron in a magnetic field, particle in a box, linear harmonic oscillator. Statistics of identical and indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics- a comparison, Pauli's exclusion principle.	
Ideal Bose and Fermi gas	**8 Lectures**
Calculation of energy and pressure of ideal Bose gas, gas degeneracy, Bose-Einstein condensation, calculation of entropy and specific heat of Bose gas, superfluidity. Calculation of energy and pressure of ideal Fermi gas, weak and strong degeneracy, Fermi gas at finite T, calculation of entropy, specific heat, free energy. Pauli's theory of paramagnetism.	
Phase Transition and critical phenomena	**12 Lectures**
General theory of phase transition, examples of phase transition and critical phenomena, magnetic phase transitions. Ising model: partition function for one dimensional case and exact solution in one	

dimension; Bragg-Williams theory; Critical exponents; Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension.	
Non-equilibrium Statistical Mechanics	**5 Lectures**
Brownian motion, Langevin approach, Diffusion, Kinetics of magnetic relaxation.	

Reference Books

- Statistical Mechanics, R. K. Pathria
- Fundamentals of Statistical and Thermal Physics, F. Reif
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich
- Statistical Mechanics, K. Huang
- Statistical Physics, F. Mandle
- Statistical Mechanics, R. P. Feynman
- Statistical Physics, J.K. Bhattacharyya
- An Introductory Course of Statistical Mechanics, Palash B. Pal
- Statistical Mechanics of Phase Transitions, J.M. Yeomans
- Introduction to Modern Statistical Mechanics, D. Chandler:
- Thermodynamics and Statistical Mechanics, P V Panat
- Statistical Mechanics, Gupta & Kumar
- Equilibrium and Non-Equilibrium Statistical Mechanics, Radu C. Balescu
- Statistical Mechanics, Donald A. McQuarrie
- Statistical Physics of Fields, Mehran Kardar

Course Outcomes:

On completion of this course students are expected to,

CO1: Understand and apply the fundamental principles of statistical mechanics, including phase space, ensembles, and classical statistical distributions (MB, BE, FD).

CO2: Apply the microcanonical, canonical, and grand canonical ensembles to calculate key thermodynamic quantities for various systems.

CO3: Explore classical non-ideal gasses, quantum statistical mechanics, and the statistics of indistinguishable particles, including the application of mean field theory and quantum statistics.

CO4: Analyze properties and behaviors of ideal Bose and Fermi gasses, including Bose-Einstein condensation and Fermi gas degeneracy.

CO5: Understand phase transitions, critical phenomena, and non-equilibrium statistical mechanics through models like the Ising model and Langevin theory.

Course Name: Advanced Electrodynamics
Course Code: PHYUGMDS4702
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Discipline Specific Elective Course (DSE)
Lectures: 45+15
(For both Physics Honors with Research and Without Research)

Course Objective:

The course aims to provide students with a comprehensive recapitulation of electrodynamics, focusing on field equations, potentials, gauge transformations, conservation laws, tensors in Minkowski space, and the electromagnetic field tensor. Additionally, it aims to deepen their understanding of the field produced by moving charges, radiating systems, and the scattering of radiation.

Recapitulation of electrodynamics	**15 Lectures**

Recapitulation of field equations, scalar & vector potentials, Lorentz and Coulomb gauge, Conservation laws, Tensors in Minkowski space, electromagnetic field tensor, covariance of electrodynamics, transformation of electromagnetic fields, Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.	
Field of moving charges and radiations	**25 Lectures**
Retarded potentials, Lienard-Wiechert potentials, Field produced by arbitrary moving charged particle at low velocity and at high velocity, Larmor's formula, Radiation loss from an accelerated charge particle (for linear and circular accelerator), Angular distribution of radiation emitted by an accelerated charge, Total power radiated by an accelerated charge, cyclotron and synchrotron radiation, Electromagnetic field due to a uniformly moving relativistic charge, virtual photon, Energy transfer in a coulomb collision.	
Radiating System	**10 Lectures**
Oscillating electric dipole, radiation from an oscillating electric dipole, Magnetic dipole and electric quadrupole radiation, radiation due to a small current element, radiation from a linear antenna.	
Scattering of radiation	**10 Lectures**
Differential scattering cross-section, Thomson and Rayleigh scattering, Radiation reaction, Abraham-Lorentz model, Line width of radiation spectrum due to radiation reaction.	

Reference Books

- Classical Electrodynamics, J.D. Jackson
- Introduction to Electrodynamics, D. J. Griffith
- Classical Electrodynamics, W. Panofsky and M. Phillips
- The Classical Theory of Fields, L.D. Landau & E.M. Lifshitz
- Electromagnetic Theory and Electrodynamics, Satya Prakash
- Foundations of Electromagnetic Theory (3rd Edi.), J. R. Reitz, F. J. Milford & R. W. Christy
- The Feynman Lectures on Physics, Vol. II
- Electromagnetism and Classified Theory, A. D. Barut
- Introduction to Electrodynamics, A. Z. Capri and P. V. Panat
- Classical Theory of Electricity and Magnetism: A Course of Lectures, Amal Kumar Raychaudhuri
- Modern Electrodynamics, Andrew Zangwill

Course Outcome:

On completion of this course, students are expected to,

CO1: Gain a thorough understanding of field equations, scalar and vector potentials, and gauge transformations, and their significance in electrodynamics. Develop proficiency in applying Lorentz and Coulomb gauges and understanding conservation laws.

CO2: Master the concepts of tensors in Minkowski space and the electromagnetic field tensor, and understand their role in formulating Maxwell's equations in relativistic electrodynamics. Gain insight into the covariance of electrodynamics and the transformation of electromagnetic fields under Lorentz transformations.

CO3: Develop a deep understanding of the field produced by moving charges, including retarded potentials, Lienard-Wiechert potentials, and radiation from accelerated charges. Analyze the radiation loss and power radiated by accelerated charges in various scenarios, such as linear and circular accelerators.

CO4: Understand the behavior of radiating systems, including oscillating electric dipoles, magnetic dipoles, electric quadrupoles, and linear antennas. Gain knowledge of the radiation mechanisms and properties associated with these systems.
CO5: Explore the scattering of radiation phenomena, including the scattering of electromagnetic waves by various objects. Understand the principles governing scattering processes and their applications in different fields.

Course Name: Condensed Matter Physics/General Theory of Relativity/Laser Spectroscopy
Course Code: PHYUGMDS4703
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Discipline Specific Elective Course (DSE)
Lectures: 45+15
(For both Physics Honors with Research and Without Research)

Condensed Matter Physics

Course Objective:
This course aims to provide students with a comprehensive understanding of the electronic structure of materials, covering both theoretical principles and experimental techniques. Beginning with the basics of electrons in periodic potentials and the many-electron problem, the course progresses to electronic characterization methods and the electronic properties of organic materials and devices.

Application of band theory of Solid	**10 Lectures**
Electrons in periodic potentials: Bloch's theorem, Kronig Penney model, concept of energy bands, NFE model, TB model.	
Magnetism	**12 Lectures**
Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Magnetic exchange interaction-Ferro, Antiferro & Ferrimagnetism. ESR and NMR.	
Electronic Structure of Solids	**14 Lectures**
Adiabatic approximation (Born Oppenheimer); Classical nuclei approximation (Ehrenfest Theorem). Hartree approximation, LCAO method; Hartree Fock approx: Slater determinantal wavefunction & its properties, Hartree Fock equation, Fock operator, Energy of the ground state, Koopman's theorem; Going beyond Hartree Fock (introductory), absence of correlation in H F theory.	
Functional Materials: Dielectric, optical and functional properties	**24 Lectures**
Theory of electronic polarization and optical absorption, ionic polarization; Optical phonon mode in an ionic crystal; Interaction of electromagnetic waves with optical modes, Polariton, Dispersion curves of Transverse Optical (TO) phonon and optical phonon in diatomic ionic crystal, LST relation, Dielectric function of the electron gas: Plasmon, Exciton, Metal-insulator transition. Crystallographic structure of ferroelectric materials, inorganic and organic ferroelectrics, Theory of ferroelectric-paraelectric transition: first and second order phase transitions; Antiferroelectricity, Pizo-electricity, Electrostriction; Luminescence, Fluorescence, Phosphorescence, Raman scattering, Second Harmonic Generation (SHG) techniques	

Reference Books

- Photoelectron Spectroscopy, Principles and Applications, Stefan Hüfner
- X-Ray Scattering from Soft Matter Thin Films, Springer Tracts in Modern Physics; M. Tolan
- Electrical Characterization of Organic Electronic Materials and Devices, Peter Stallinga
- Electrical Properties of Materials, Laszlo Solymar, Donald Walsh
- Organic Electronics: Materials, Manufacturing, and Applications, Hagen Klauk
- Physics of Organic Semiconductors, edited by W.Brütting and C. Adachi
- Solid State Physics, Ashcroft &Mermin
- Solid State Theory, Grosso & Pastore-Parravicini
- Electronic Structure of Solids, Kaxiras
- Electronic Structure of Materials, Sutton
- Lecture Notes on Electron Correlation and Magnetism, Patrik Fazekas
- Electronic Structure, Richard M. Martin
- Condensed Matter in a Nutshell, Gerald D. Mahan

Course Outcomes:

Upon completing this course, students will be able to:

CO1: Develop a solid understanding of the theoretical foundations of electronic structure, including Bloch's theorem, the Kronig Penney model, and the Hartree-Fock approximation. Gain proficiency in applying theoretical models to describe the behaviour of electrons in materials.

CO2: Explain the principles of magnetism, including ferromagnetism, antiferromagnetism, ferrimagnetism, and the magnetic exchange interaction, as well as phenomena such as spontaneous magnetization and hysteresis.

CO3: Understand the foundational concepts of superconductivity, including the Born-Oppenheimer approximation, Hartree and Hartree-Fock approximations, and the energy of the ground state, and discuss the limitations and extensions beyond the Hartree-Fock theory.

CO4: Analyse the dielectric, optical, and functional properties of materials, including electronic and ionic polarization, optical phonon modes, plasmons, excitons, and metal-insulator transitions.

CO5: Describe the crystallographic structure and phase transitions of ferroelectric materials, and understand related phenomena such as piezoelectricity, electrostriction, luminescence, fluorescence, and Raman scattering, along with second-harmonic generation techniques.

General Theory of Relativity

Course Objective:

This course aims to provide students with a comprehensive understanding of the principles of relativity, starting from the basics of special relativity and progressing to the advanced concepts of general relativity. Students will learn about the geometric framework of general relativity, solutions to Einstein's equations, and various applications of general relativity in astrophysics and cosmology.

Principles of relativity	**10 Lectures**

Overview of Special Relativity, Unit conversion between SI and GR units, space-time interval and Lorentz metric, proper time, action for free particle, relativistic dynamics, four vectors, electrodynamics in 4 dimensional language. Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of space-time

Geometrical framework of General Relativity	**10 Lectures**

Curved spaces, tensor algebra, Metric tensor, it’s properties and affine connection, Geodesics, covariant derivatives and parallel transport, Curvature-Riemann tensor, Bianchi identities, Ricci tensor, Energy momentum tensors, Einstein’s field equations

Solutions to Einstein's equations and their properties	10 Lectures
Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles. Innermost stable circular orbit (ISCO), Precession of the Perihelion, Schwarzschild Embedding Diagram, Deflection of Light, Gravitational lensing, Image Brightness	
Applications of GTR	**30 Lectures**
Alternative co-ordinates Event horizon, Tortoise co-ordinates, Eddington-Finkelstein co-ordinates, Kruskal-Szekeres metric **Black holes** Kerr metric in Boyer-Lindquist co-ordinates, Energy extraction from a rotating black hole-Penrose process, Reissner-Nordstrom black hole, Kerr-Newmann blackhole (no derivation of the metric required), Black Hole thermodynamics and Hawking radiation. **Gravitational Waves** Linearized field equations - Gravitational Waves-polarization, helicity, energy momentum; Generation of Gravitational waves; effect on a test particle; Binary pulsar; detection of gravitational radiation.	
Reference Books ● Gravity: An introduction to Einstein's General Relativity, James B. Hartle ● Gravitation and Cosmology, Steven Wienberg ● Gravitation, Misner, Thorne and Wheeler ● An introduction to Relativity, J. V. Narlikar ● Gravitation, Vol 1, 2, 3, T. Padmanavan ● A General Relativity Workbook, Thomas A. Moore ● A Student's Guide to Vectors and Tensors, Daniel A. Fleisch ● Lecture Notes on General Relativity, Sean M. Carroll ● Einstein Gravity in a Nutshell, A. Zee	
Course Outcome: On completion of this course, students are expected to, **CO1:** Gain a deep understanding of the principles and foundations of special relativity, including concepts like Lorentz transformations, proper time, and relativistic dynamics. Develop proficiency in applying relativistic concepts to describe the behavior of particles and electromagnetic fields. **CO2:** Acquire a solid grasp of the geometrical framework of general relativity, including curved spaces, tensor algebra, and the properties of the metric tensor. Understand the mathematical formalism underlying Einstein's field equations and their solutions. **CO3:** Explore the properties and solutions of Einstein's field equations, including the Schwarzschild solution for spherically symmetric systems and the Kerr metric for rotating black holes. Understand the gravitational effects predicted by these solutions, such as gravitational lensing and black hole thermodynamics. **CO4:** Develop analytical and problem-solving skills in applying general relativity to various astrophysical phenomena, such as black holes, gravitational waves, and cosmology. Understand the theoretical principles behind the generation, propagation, and detection of gravitational waves. **CO5:** Gain familiarity with alternative coordinate systems used in general relativity, such as Eddington-Finkelstein and Kruskal-Szekeres coordinates. Understand their significance in describing spacetime properties and simplifying the analysis of gravitational phenomena.	

Laser Spectroscopy	
Course objective: This course aims to provide students with a comprehensive understanding of laser spectroscopy, covering topics such as basic laser system, coherent atom-laser interactions and spectroscopic techniques. Students will learn theoretical principles and experimental methods used in atomic and laser physics and their applications in quantum science and technology.	
Basics	**10 Lectures**
Absorption, induced and spontaneous emission, polarization of light, Jones vector and Jones matrices, Absorption and emission spectra, transition probabilities (lifetimes, spontaneous and radiationless transition), coherence of atomic system (coherent excitation).	
Nonlinear Spectroscopy	**30 Lectures**
(a) Pure and mixed states; Density operator and Density matrix (b) Semi-classical theory of interaction of two-level atom with light: rate equations of c-coefficients and density matrix elements; inclusion of phenomenological aspects of population and depopulation in a two-level system, electric-dipole approximation (EDA), rotating wave approximation (RWA), Rabi oscillation/flopping, Oscillating dipoles. (c) Width and properties of spectral line: Natural linewidth, Doppler linewidth, colliosinal broadening, transit time broadening, saturation and power broadening, spectral line profiles (Lorentzian and Gaussian). (d) A moving two-level atom in a travelling wave, Bennett hole/hole burning, Physical significance of saturation phenomena; A moving two-level atom in a standing wave, Lamb dip, crossover resonance dips. (e) Absorption and saturation absorption spectroscopy in Rb atomic medium-hyperfine and crossover resonance transitions. (f) Basic principle of polarization spectroscopy (Light induced birefringence/anisotropy) and line profiles of polarization signal. Analog between the polarization spectroscopy and Faraday magneto-optical effect	
Instrumentation for spectroscopy experiment	**20 Lectures**
(a) Semiconductor diode laser, homojunction and heterojunction diode; Tunable laser: external cavity diode laser, Littrow and Littmann-Metcalf configurations, laser frequency tuning, Single and multi-mode laser. Laser frequency locking technique: Lock-in-amplifier and PID controller. (b) Michelson, Mach-Zehnder and Febry-Perot interferometer; Wavelength meter. (c) Detection of light: photodetector- photoconductive and photovoltaic diode, fast photodetector, photomultipliers, balanced photodetector; Optical power meter. (d) Polarization plates (half-wave plate, quarter-wave plate), waveplate retarders, Rb vapor cell, beam splitter- cubic beam spillter (CBS) and polarizer beam splitter (PBS), neutral density filter, etalon, optical isolator, AOM and EOM working principle (qualitatively).	
Reference Books ● Laser Physics, M. Sargent, M.O. Scully and W.E. Lamb ● Foundations of Laser Spectroscopy, S. Stenholm ● Laser Spectroscopy, W. Demtroder ● Atom Optics, P. Meystre ● Laser Cooling and Trapping, H. Metcalf and P. Straten ● Elements of Quantum Optics, P. Meystre and M. Sargent III	

- Elements of Quantum Optics, R. Loudon
- Laser Physics and Spectroscopy, P.N. Ghosh
- Lectures on Light: Nonlinear and Quantum Optics using Density Matrix, S Rand
- Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain
- Atomic Physics, C. J. Foot.

Course Outcomes:
Upon completing this course, students will be able to:
CO1: Understand the basics elements of of light-atom interaction phenomena
CO2: Explain the concepts of coherent spectroscopy, including density operator and matrix, Rabi oscillation, saturation phenomena, and polarization spectroscopy.
CO3: Conduct absorption and saturation absorption spectroscopy experiments with rubidium atomic media, interpreting hyperfine and crossover resonance transitions.
CO4: Identify and use key instrumentation for spectroscopy experiments, including polarization plates, vapor cells, lasers, beamsplitters, and photodetectors.

Course Name: Electronics and Instrumentation
Course Code: PHYUGMDS04
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Discipline Specific Elective Course (DSE)
Lectures: 45+15
(For only Physics Honors Without Research)

Course Objectives:
This course aims to provide students with a comprehensive understanding of semiconductor physics and communication electronics. The course covers the fundamentals of semiconductor materials, various semiconductor devices, and their applications. Additionally, it includes an introduction to communication electronics, focusing on modulation techniques and their practical implementations.

Fundamentals of semiconductor	**6 Lectures**

Idea of energy band, the Fermi level and energy distribution of carriers inside bands, temperature dependence of carrier concentration, carrier transport in semiconductors, generation and recombination process of excess carriers in semiconductor and idea of quasi Fermi levels, basic equation of semiconductor device operations.

P-N junction devices	**10 Lectures**

p-n junction physics- Fabrication steps, thermal equilibrium condition, depletion capacitance; current-voltage characteristics, charge storage and transient behaviour, junction breakdown, Majority carrier diodes, Tunnel diodes: principle of operations & I-V characteristics. Schottky barrier diodes: Metal semiconductor contacts, Schottky-Mott theory & surface states, Schottky effect, current flow mechanism, I-V characteristics, Rectifying contacts, Ohmic contacts.

Field effect transistors (FET)	**8 Lectures**

Classification of various types of FETs, construction of junction FET, Principle of operation drain characteristics, biasing, operating region, pinch-off voltage. Structure and principle operation of MOSFET, depletion & enhancement type, I-V characteristics.

Semiconductor devices	**8 Lectures**

Principle and structure of Photoconductor, Solar cell, Photodiode, LED, Semiconductor laser, Photodiode, Phototransistor,Thyristor, p-n-p-n switch,Gunn diode,IMPATT diodes, GaAs-InP	
Power and coupled Amplifier	**10 Lectures**
Multistage amplifiers, gain and bandwidth and their product, operating point of class A,B,AB and C amplifiers, analysis of single tuned voltage amplifiers, requirement of power amplifiers, class B push-pull amplifiers. frequency response of a two stage R-C coupled amplifier,	
Elements of Communication Electronics	**13 Lectures**
Review of modulation and detection, Principles of analog modulation (AM); comparison among different techniques; power, bandwidth and noise. Principle of amplitude modulation (AM) and frequency modulation (FM) and phase modulation (PM), AM spectrum and FM spectrum, channel bandwidth and signal bandwidth, side band frequency, Demodulation: Principles of detection of different types of modulated signals, detection of A.M. wave and F.M. wave. Modulation techniques in some practical communication systems: AM and FM radio.	
Electronic Measuring Instruments	**5 Lectures**
Electronic multimeter, Cathode-ray oscilloscope: CRT, brightness and focusing control, deflection sensitivity, vertical and horizontal amplifiers, time-base circuit , measurement of voltage, frequency and phase with CRO. digital multimeter, L and C measurements.	

Reference Books

- S.M. Sze: Physics of Semiconductor Devices
- B.G. Streetman and S. Banerjee: Solid State Electronic Devices
- Integrated Electronics, J. Millman and C. C. Halkias
- Electronics Fundamentals and Applications, J. D. Ryder
- Electronic Device and Circuit Theory, R. Boylestad and L. Nashelsky
- Digital Logic and Computer Design, M. Moris Mano
- Microelectronics, Milman and Grable
- Analog Electronics, B. C. Sarkar and S. Sarkar
- Radiation, Detection and Measurement, G.F. Knoll
- Electronic Circuit analysis, Chattopadhyay and Rakshit,
- Electronic and Radio Engineering, F. E Terman
- Networks lines and fields, John D. Ryder
- Radio Frequency Principles and applications, A. A Smith
- Electronic communications, D. Roody J.Coolen

Course Outcomes:

On completion of this course students are expected to,

CO1: Gain a deep understanding of semiconductor fundamentals, including the concept of energy bands, the Fermi level, and the behavior of carriers within semiconductors. Understand carrier transport mechanisms, generation and recombination processes, and the quasi Fermi levels.

CO2: Acquire a solid grasp of p-n junction devices, including the fabrication steps, equilibrium conditions, and current-voltage characteristics. Understand the principles of operation for tunnel diodes, Schottky barrier diodes, and the mechanisms of rectifying and ohmic contacts.

CO3: Develop a thorough understanding of field-effect transistors (FETs), including the construction and operation of junction FETs and MOSFETs. Understand their I-V characteristics, biasing methods, and operating regions.

CO4: Explore the principles and applications of various semiconductor devices such as photoconductors, solar cells, photodiodes, LEDs, semiconductor lasers, and other specialized devices like Gunn diodes and IMPATT diodes. Understand their basic principles and practical applications.

CO5: Understand the elements of communication electronics, including the principles of analog modulation and detection. Compare different modulation techniques in terms of power, bandwidth, and noise. Learn about the generation and detection of AM and FM signals, and their applications in practical communication systems such as AM and FM radio.

Course Name: Literature Review and Presentation
Course Code: PHYUGPRJ4701
Credit: 4
Course type: Dissertation
(For only Physics Honors with Research)

Each student has to carry out a literature review on a topic related to recent research interest in physics under the supervision of one supervisor. In this review project, the student is expected to perform some investigation in the theoretical/experimental domain to study the pedagogical advancement and development of a particular subject matter. In some exceptional cases the project may concentrate on an extensive review of a suitable advanced topic related to the curriculum but well beyond the scope of the M. Sc. syllabus. The student has to submit a dissertation (both soft and hard copies) presenting the findings of the work. The student, at the end of the course, has to present their respective literature review in the form of an oral presentation

Semester: VIII

Course Name: Advanced Quantum Mechanics
Course Code: PHYUGMCC4818
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15
(For both Physics Honors with Research and without Research)

Course Name: Advanced Quantum Mechanics
Course Code: PHYUGMIN4808
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Minor (Offered by the Physics department for the students of other departments)

Course Objectives:
This course aims to provide students with a thorough understanding of advanced concepts in quantum mechanics. Students will learn about three-dimensional quantum problems, operator and matrix methods, quantum dynamics, and angular momentum. The course will cover various approximation methods for bound states, symmetries in quantum mechanics, and the behavior of identical particles. Additionally, the course includes an introduction to quantum theory of potential scattering, relativistic quantum mechanics, and field quantization.

Operator and Matrix method in Quantum Mechanics	**14 Lectures**

Linear vector space; Linear operators; Hilbert space; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of Quantum Mechanics in vector space language;

Uncertainty principle for two arbitrary operators; co-ordinate and momentum representation.	
Quantum dynamics	**8 Lectures**
Equation of motion in Schrödinger, Heisenberg and interaction picture; One dimensional harmonic oscillator by operator method, time development of the oscillator, coherent state.	
Angular momentum	**8 Lectures**
Angular momentum operators, spherical harmonics, commutation relations between angular momentum operators, angular momentum by operator method, raising and lowering operators, matrix representation for j=1/2 and j=1, Pauli spin matrices, addition of two angular momenta, Clebsch-Gordan coefficients; Construction of spin eigen-functions, Wigner D functions	
Approximation methods	**14 Lectures**
Time independent perturbation theory: First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory. Fine structure of one-electron systems, Zeeman effect and Stark effect. *Variational method*: Trial wavefunction, application to He atom as example, Exchange degeneracy *WKB Approximation*: Quantization rule, tunnelling through a barrier, qualitative discussion of alpha-decay and related problems *Time-dependent Perturbation Theory*: Constant and harmonic perturbations; Fermi's Golden rule; Sudden and adiabatic approximations	
Symmetric in quantum mechanics	**6 Lectures**
Conservation principles and degeneracy associated with symmetry, Continuous symmetries- spatial translation, rotation and time evolution, Discrete symmetries- Parity, time reversal and permutation, Meaning of identity and consequences, symmetric and antisymmetric wavefunctions, Slater determinant	
Quantum theory of potential scattering	**10 Lectures**
Laboratory and center of mass frames, scattering cross-section amplitude, partial wave analysis, phase shift and resonance, scattering length, optical theorem, scattering by attractive square well and hard sphere, integral equation of scattering, Green's function, Lippmann-Schwinger equation, Born approximation, scattering by Yukawa potential, Coulomb scattering	
Reference Books ● Quantum Mechanics, J. L. Powell and B. Crasemonn ● Quantum Mechanics, F. Schwabl ● Quantum Mechanics, A. K. Ghatak and S. Lokenathan ● A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan ● Modern Quantum Mechanics, J. J. Sakurai ● B. H. Bransden and C. J. Joachain : Quantum MechanicsQuantum Mechanics, L.I. Schiff ● Modern Quantum Mechanics, J.J. Sakurai ● A Text Book of Quantum Mechanics, P.M. Mathews and K. Venkatesan ● Relativistic Quantum Mechanics, J.D. Bjorken and S.D. Drell ● Relativistic Quantum Mechanics, W. Greiner ● A First Book of Quantum Field Theory, A. Lahiri and P.B. Pal ● Quantum Mechanics, B. H. Bransden and C. J. Joachain ● Quantum Mechanics, A. K. Ghatak and S. Lokenathan	

- Introduction to Field Theory, S. Weinbrg
- Lectures on Quantum Mechanics, Steven Weinberg
- Quantum Mechanics, Volume 1 & 2, Claude Cohen-Tannoudji, Bernard Diu, Franck Laloë

Course Outcomes:
On completion of this course students are expected to,
CO1: Understand and solve three-dimensional quantum mechanical problems using Cartesian and spherical polar coordinates. Apply techniques such as the radial equation for free particles and the 3-D harmonic oscillator.
CO2: Utilize operator and matrix methods in quantum mechanics, including the concepts of linear vector spaces, Hermitian and unitary operators, and the formulation of quantum mechanics in vector space language. Apply these methods to solve problems involving the uncertainty principle, coordinate, and momentum representation.
CO3: Analyze quantum dynamics through the Schrödinger, Heisenberg, and interaction pictures. Solve the one-dimensional harmonic oscillator problem using the operator method and understand the concept of coherent states.
CO4: Apply angular momentum operators and understand their commutation relations. Use the operator method for angular momentum, understand the matrix representation for different angular momenta, and explore applications such as the Pauli spin matrices, addition of angular momenta, and Clebsch-Gordan coefficients.
CO5: Implement various approximation methods for bound states, including time-independent and time-dependent perturbation theories, the variational method, and the WKB approximation. Apply these methods to practical quantum mechanical systems and phenomena such as the Zeeman effect, Stark effect, tunneling, and radiative transitions.

Course Name: Advanced Classical Mechanics
Course Code: PHYUGMCC4819
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Major/Core
Lectures: 45+15
(For both Physics Honors with Research and Without Research)

Course Objective:
The course aims to equip students with a deep understanding of advanced classical mechanics concepts, focusing on Lagrangian and Hamiltonian formulations, canonical transformations, Hamilton-Jacobi theory, rigid body dynamics, and small oscillations. Students will develop proficiency in applying these theoretical frameworks to analyze and solve complex problems in classical mechanics encountered in physics.

Lagrangian and Hamiltonian Formulation	**15 Lectures**

Review of D'Alembert's principle, Calculus of variations, Euler-Lagrange's equations, concept of symmetry, homogeneity and isotropy, conservation principles, Lagrange's equations for non holonomic systems, Lagrange's equations for impulsive forces, invariance under Galilean transformation, Hamiltonian formulation-simple applications.

Canonical Transformation and Hamilton-Jacobi Theory	**15 Lectures**

Canonical transformations, generating functions, examples of canonical transformation. Poisson Bracket,

relations of P.B., Conservation theorems in P.B. Formulation. Hamilton-Jacobi equation, separation of variables, cyclic variables and the Kepler problem, Action angle variables, harmonic oscillator and Kepler problem in action-angle variables.	
Rigid Body Dynamics	**15 Lectures**
Euler angles, finite and infinitesimal rotations, inertia tensor, motion of a heavy symmetric top rotating about a fixed point in the body under gravity.	
Small oscillations	**8 Lectures**
Condition of stability near equilibrium, the eigenvalue equation & principal axes transformation, normal modes and coordinates, vibrations of molecules	
Continuous systems and fields	**7 Lectures**
Lagrangian and Hamiltonian formulation for continuous systems, symmetry and conservation principles, Noether's theorem, classical field theory.	

Reference Books

- Theoretical Mechanics, M. R. Spiegel, (Schaum's Outline Series)
- Mechanics, K. R. Symon
- Classical Mechanics, H. Goldstein
- Classical Mechanics, N. C. Rana and P. S. Joag
- Padarther Dharma, D. P. Ray Chaudhuri
- An Introduction to Mechanics, D. Keppner and R.J. Kolenkow
- Mechanics, H. S. Hans and S. P. Puri
- Classical Mechanics, A. K. Roychaudhuri
- Classical Mechanics, J. C. Upadhyaya
- Classical Mechanics, Tom Kibble, Frank H Berkshire
- Analytical Mechanics, Louis N. Hand, Janet D. Finch
- Mechanics: Course of Theoretical Physics, L. D. Landau, E. M. Lifshitz

Course Outcome:

On completion of this course, students are expected to,

CO1: Understand and apply D'Alembert's principle, calculus of variations, and Euler-Lagrange equations to derive Lagrange's equations and analyze the dynamics of mechanical systems. Gain insight into conservation principles and their implications for dynamical systems.

CO2: Master the concepts of canonical transformations, generating functions, and Poisson brackets, and apply them to formulate Hamilton's equations of motion. Understand the significance of Poisson brackets in classical mechanics and their role in expressing conservation laws.

CO3: Develop proficiency in Hamilton-Jacobi theory, including the Hamilton-Jacobi equation, separation of variables, and action-angle variables. Apply these concepts to solve problems such as the Kepler problem and harmonic oscillator in action-angle variables.

CO4: Gain knowledge of rigid body dynamics, including Euler angles, inertia tensor, and motion of a symmetric top under gravity. Analyze the dynamics of rotating bodies and understand the implications of conservation laws in rigid body motion.

CO5: Understand the theory of small oscillations, including stability near equilibrium, eigenvalue equations, normal modes, and vibrations of molecules. Apply these concepts to analyze the behavior of systems undergoing small oscillations and predict their dynamic behavior.

Course Name: Nano Science and Technology/Astrophysics and Cosmology/Quantum Optics **Course Code: PHYUGMDS4805** **Credit: 4 [3(Theory)+1(Tutorial)]** **Course type: Discipline Specific Elective Course (DSE)** **Lectures: 45+15** **(For both Physics Honors with Research and Without Research)**
Course Objective: This course aims to provide students with a comprehensive understanding of the physics and technology underlying low-dimensional systems and nanostructured materials. The course will cover the unique properties of materials at the nanoscale, their synthesis, fabrication, and characterization techniques, as well as their applications in various fields. Students will gain the knowledge required to explore the fascinating world of nanoscience and nanotechnology, and the skills to apply this knowledge in practical and research settings.
Nano Science and Technology

Physics at low dimensions	**10 Lectures**
Reviews of quantum mechanics in reduced dimensions and solid state physics, Background to Nanoscience: Definition of Nano, Scientific revolution-Atomic Structure and atomic size, emergence and challenge of nanoscience and nanotechnology, carbon age-new form of carbon (CNT to Graphene), influence of nano over micro/macro, size effects and crystals, large surface to volume ratio, surface effects on the properties.	
Design and synthesis of nanostructure materials	**15 Lectures**
Physics of nanoscale engineering, nanofabrication, Processing of organic, inorganic and bio-based nanoparticles, nano composites. Common techniques for nano-structure fabrication, Top down and bottom up approach, Chemical process: Sol-gel method, plating, ion exchanged and reduction electro deposition technique, Langmuir-Blodgett (L-B) technique; Templated self assembly Electrochemical approaches, Spin coating, Physical processes: vaporization, sputtering, chemical vapour deposition (CVD), Vapor- liquid - solid (VLS) technique, molecular beam epitaxy and laser ablation and related theories and technology for thin film growth.	
Nanostructured Materials and their Applications	**12 Lectures**
Organic nano materials and devices: General Overview of Organic Semiconductors, Structural and Electronic Properties of Organic Semiconductors: recapitulations of BO approximation, Atomic and Molecular Orbitals, LCAO, Bonding and antibonding orbitals, Orbital hybridization, HOMO and LUMO levels. Charge transport in Organic Semiconductors materials; Exciton Processes in Organic Solids, Charge-transfer Exciton, Electronic Conduction in Organic Solids Conductivity: (carrier concentration versus mobility), Carrier generation, Hopping transport, Mobility measurements, Traps etc. Some basic organic Electronics devices; Organic Light Emitting Diodes, Organic Solar Cells and organics Thin Film Transistors.	

Advanced Characterization Techniques for nanomaterials	23 Lectures

Compound optical microscope, different parts and operation principle. Scanning Electron microscope (SEM), fundamental principles of SEM, basic components, sample preparation for SEM, applications, advantages and disadvantages. Atomic force microscope (AFM), Basic principles of AFM, different components, static and dynamic mode operation, advantages and disadvantages. Principle of Scanning Tunneling microscope (STM),

X-Ray Diffraction and structural characterization: X-ray diffraction techniques, Principle and applications, Bragg‟s law, Determination of accurate lattice parameters, structure analysis, profile analysis, particle size analysis using Scherer formula.

X-ray and electronic characterization: X-ray sources, synchrotron radiation, X-ray optics, monochromatizating, collimation, and focusing, X-ray detectors, point, linear and area detectors, physical and geometrical factors affecting X-ray intensity.

X-ray photoelectron spectroscopy (XPS), Ultra-violet photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), and inverse photoelectron spectroscopy; Theory of Photoemission, Core-level and valence level photoemission, three step consideration, Photoexcitation and photoionization, Core Levels (XPS) and Final States, Photoemission spectroscopy to measure the elemental composition, empirical formula, chemical state, and electronic state of the elements in a compound. Depth profiling, Instrumentation, Applications

X-ray Absorption;Theory of inner shell excitation and X-ray absorption spectroscopy, near edge X-ray absorption. Its application to electronic structures

Electrical measurements: I-V/C-V characteristics, Hall effects, FET characteristics, R-T measurements, Dielectric measurements.

Reference Books

- Materials science and Engineering, V. Raghavan
- Materials Science & Engineering, William D. Callister
- Engineering Materials by Kenneth G. Budinski
- Handbook of nanoscience, Engg and Technology, W. Gaddand, D. Brenner, S. Lysherski and G. J. Infrate
- Naostructures and Nanomaterials, Synthesis, properties and applications, G.Cao
- Nanocrystals: Synthesis, properties and applications, C. N. R. Rao, P. J. Thomas, G. U. Kulkarni
- Nanostructures and Nanomaterials, Synthesis, Properties, and Applications, G. Cao, Z. Wang
- Diffraction analysis of the microstructure of materials by E. J. Mittemeijere and P. Scardi
- Modern techniques of surface science, D. P. Woodruff & amp; T. A. Delchar
- Electron Microscopy and Analysis (3rd Ed.), P. J. Goodhew, J. Humphreys, R. Beanland
- Transmission Electron Microscopy: A Textbook for Materials Science, D. B. Williams and C. B. Carter

Course Outcomes:

On completion of this course students are expected to,

CO1: Understand the fundamental concepts of nanoscience, including the definition, significance, and unique properties of nanoscale materials, and how they differ from their bulk counterparts.

CO2: Analyze the principles and processes involved in the growth and development of nanostructured materials, including thin films, quantum structures, and carbon-based nanomaterials.

CO3: Explore various techniques for the design, synthesis, and fabrication of nanostructure materials using both top-down and bottom-up approaches, and understand their applications in different fields. Explore the electronic properties of organic materials, including semiconductors, and devices. Understand concepts such as orbital hybridization, HOMO-LUMO levels, charge transport mechanisms, and exciton processes in organic solids. Gain insights into the operation of organic electronic devices like organic light-emitting diodes (OLEDs), organic solar cells, and thin-film transistors.

CO4: Utilize advanced characterization techniques such as SEM, STM, TEM, AFM, and XRD to investigate and analyze the properties and structures of nanomaterials. Acquire practical skills in advanced X-ray and electron spectroscopy techniques for investigating the electronic structure of materials. Understand the principles behind X-ray photoelectron spectroscopy (XPS), ultraviolet photoelectron spectroscopy (UPS), and X-ray absorption spectroscopy (XAS), and their applications in material analysis.

Astrophysics and Cosmology

Course Objective:

This course aims to provide students with a comprehensive understanding of the fundamental concepts and principles of astronomy, covering topics ranging from celestial bodies like stars, galaxies, and black holes to the large-scale structure and evolution of the universe. Students will learn about the observational tools and techniques used in astronomy, as well as the physical processes governing the behavior and evolution of astronomical objects.

Astronomy	**20 Lectures**

Introduction of stars, galaxies, clusters, black holes, dark matter, dark energy, different type of galaxies including Milky Way galaxy, Super massive black holes in galaxies; Active galactic nuclei; Mass, length, time and magnitude scales in astronomy; Measurement of stellar parameters: distance parallax, Cepheid variables, nova and supernovae, red shift, stellar spectra, spectral lines; Radiative transfer (emission, absorption, radiative transfer equation, mean free path, optical depth); Thermal radiation and thermodynamic equilibrium, Boltzmann and Saha equation, Thermodynamics of black body radiation. Observational tools: telescope as a camera, optical telescopes (refracting and reflecting telescopes), radio telescopes, astronomical instruments and detectors, observations at other wavelengths (infrared, ultraviolet, X-ray and Gamma ray astronomy).

Stellar Physics	**25 Lectures**

Properties of stars (distance, brightness, size, mass, temperature, luminosity); The Hertzsprung-Russell diagram, luminosity and radius, binary system and mass determination, Main Sequence; Hydrostatic equilibrium and the virial theorem, radiative and convective energy transport inside stars, nuclear energy production. Equation of state, opacity, Derivation of scaling relations; Star formation, pre-main-sequence collapse (gravitational instability and mass scales, collapse of spherical cloud, contraction onto the Main Sequence, Brown Dwarfs), evolution of high-mass and low-mass stars (core and shell hydrogen burning, helium ignition), Jeans Criterion, late-stage evolution of stars, evolution of Sun-like stars and solar system; Relativistic Hydrodynamic equilibrium, Tolman-Oppenheimer-Volkoff equation, Degeneracy of matter, Stellar models, Polytropic Stars, Lane-Emden equation, Compact object like white dwarfs (electron-degeneracy pressure, mass-radius relation, Chandrashekhar mass limit), neutron stars (mass limit of neutron stars, neutron stars observable as pulsars), black holes as end point of stellar evolution, supernovae

Cosmology	**15 Lectures**

Introduction, Olber's paradox, Hubble's law and the expanding Universe, Big Bang theory, cosmological redshift, scale factor, Cosmological principle, homogeneity and isotropy, Robertson-Walker metric, Dynamics of Friedman- Robertson-Walker models: Solutions of Einstein's equations for sources with $p = \omega\ \rho$ and $\omega = -1, 0, 1/3$, discussion of closed, open and flat Universes. The Cosmic Microwave Background Radiation (CMBR).

Reference Books

- Modern Astrophysics, B. W. Carroll and D. A. Ostlie
- Introductory Astronomy and Astrophysics, Zeilik and Gregory
- The Physical Universe, F. Shu
- The Physics of Astrophysics, Volume I and II, F. Shu
- Theoretical Astrophysics, Volumes I, II and III, T. Padmanabhan
- Astrophysics, K D Abhayankar
- Modern Cosmology, S. Dodleson
- Introduction to Cosmology, J. V. Narlikar
- General Relativity and Cosmology, Benerji & Benerjee
- A General Relativity Workbook, Thomas A. Moore
- Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Steven Weinberg

Course Outcomes:
On completion of this course students are expected to,
CO1: Describe the properties and characteristics of celestial objects and explain their significance in understanding the universe.
CO2: Understand measurement techniques used in astronomy and interpret observational data to determine stellar parameters.
CO3: Explain physical processes such as radiative transfer, thermal radiation, and thermodynamic equilibrium in astronomical contexts.
CO4: Identify and describe observational tools and instruments used in astronomy, including telescopes and detectors for various wavelengths.
CO5: Analyze the properties and evolution of stars, including their formation, structure, energy transport mechanisms, and late-stage evolution.

Quantum Optics

Course objective:
This course aims to provide students with a comprehensive understanding of quantum optics, covering topics such as atom-laser interactions under the density matrix framework of semi-classical and quantum mechanical approach as well as laser cooling and trapping. Students will learn theoretical principles and experimental methods used in atomic and laser physics and their applications in quantum science and information technology.

Theory of Light-matter interaction: Semi-classical Approach	**20 Lectures**

(a) Recapitulation of Density matrix and Density operator, Oscillating dipoles. Rabi frequency.
(b) Coherent interaction of two-level atom with light under weak and strong field cases.
(c) Rate equations for density matrix (two-level atomic system), inclusion of decay phenomena, solution of density matrix equations, optical Bloch equations (OBEs), Bloch sphere and Bloch vector, weak probe field approximation, steady state solution and transient time
(d) Optical susceptibility: population and coherence (absorption and dispersion profile)

Theory of Light-matter interaction: Quantum Mechanical Approach	**25 Lectures**

(a) Linear Harmonic Oscillator, Quantization of the radiation (electromagnetic) field, Field states of single radiation field mode (Fock states and Coherent states), Quadrature operators and phase space of field states, Quantum beam splitter.
(b) Quantized Rabi oscillations, Quantized light-atom interaction, Jaynes-Cumming model, Interaction of two-level atom with a coherent state.
(c) Dressed states, Entangled state, Wigner-Weisskopf theory of spontaneous emission.

Laser Cooling and Trapping	**15 Lectures**

Dynamics of an atom in a laser field, light forces on atoms, radiation pressure forces, dipole force, optical potential, Doppler cooling, optical molasses, Doppler cooling limit, sub-Doppler cooling: Sisyphus cooling (qualitative), magnetic trap, optical trap, magneto-optical trap (MOT), brief discussion on experimental technique of laser cooling and trapping, Evaporative cooling, Bose-Einstein Condensation.

Reference Books

- Laser Physics, M. Sargent, M.O. Scully and W.E. Lamb
- Foundations of Laser Spectroscopy, S. Stenholm
- Laser Spectroscopy, W. Demtroder
- Atom Optics, P. Meystre
- Laser Cooling and Trapping, H. Metcalf and P. Straten
- Elements of Quantum Optics, P. Meystre and M. Sargent III
- Elements of Quantum Optics, R. Loudon
- Laser Physics and Spectroscopy, P.N. Ghosh
- Lectures on Light: Nonlinear and Quantum Optics using Density Matrix, S Rand
- Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain
- Atomic Physics, C. J. Foot.

Course Outcomes:

On completion of this course students are expected to,

CO1: Understand the semi-classical and quantum mechanical theory of atom-light interaction, including coherent interaction of two-level atoms with light under weak and strong field cases, and apply concepts such as Rabi oscillations and broadening of spectral lines.

CO3: Describe the density matrix formalism for describing atomic systems and the rate equations for density matrix, and analyze phenomena such as natural broadening, Doppler broadening, and collisional broadening in atomic spectroscopy.

CO4: Discuss the physical effects of strong fields on atomic matter and the basic concepts of light-induced effects on atomic systems, including phenomena such as saturation, Bennett hole burning, and Lamb dips in laser spectroscopy.

CO5: Explain the principles of laser cooling and trapping of atoms, including the dynamics of atoms in laser fields, radiation pressure forces, Doppler cooling, optical trapping techniques, and their experimental applications in atomic physics.

Course Name: Advanced Nuclear and Particle Physics
Course Code: PHYUGMDS4806
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Discipline Specific Elective Course (DSE)
Lectures: 45+15
(Only For Physics Honors Without Research)

Course Objective:

This course aims to provide students with a comprehensive understanding of nuclear interactions and reactions, covering topics such as nucleon-nucleon interaction, nuclear forces, decay processes, and elementary particle physics. Students will learn about the theoretical framework and experimental methods used to study nuclear phenomena and their applications in various fields.

Nuclear Interactions	**14 Lectures**

Nucleon interaction, exchange forces and tensor forces, Meson theory of nuclear forces, nucleon-nucleon scattering, effective range theory, spin dependence of nuclear forces, charge independent and charge symmetry of nuclear forces, isospin formalism, Yukawa interaction

Two-body Nuclear Problem	**8 Lectures**

Deuteron ground state, nuclear scattering, sources on neutrons, its detection, measurement of energy, neutron diffraction application, interaction of neutrons with matter.	
Alpha decay	**4 Lectures**
Gamow's theory	
Beta and Gamma decay	**7 Lectures**
Angular momentum and parity selection rules, allowed and forbidden transitions, selection rules, parity violation, two component theory of neutrino decay, detection and properties of neutrino, Gamma decay, multiple transitions in nuclei, angular momentum and parity selection rules, internal conversion, nuclear isomerism	
Direct and compound nuclear mechanisms	**7 Lectures**
Differential and total cross-sections, Cross-sections in terms of partial wave amplitudes, compound nucleus, scattering matrix, reciprocity theorem, Breit-Wigner one level formula, resonance scattering.	
Elementary Particle Physics	**14 Lectures**
Symmetry and conservation laws, elementary ideas of CP and CPT invariance, classification of hadrons, Lie algebra, SU(2), SU(3) multiplets, quark model, Gell-Mann-Okubo mass formula for octet and decuplet hadrons, charms, bottom and top quarks	
Nuclear Astrophysics	**6 Lectures**
Primordial nucleosynthesis, energy production in stars, pp chain, CNO cycle. Production of elements , r- and s- process path (qualitative discussion). Concept of Gamow window, Nuclear reactions of astrophysical importance, Astrophysical S-factor and its significance.	

Reference Books

- Nuclear Physics, Cottingham and Greenwood
- Nuclear and particle Physics, W.E. Burcham and M. Jobes
- Introduction to Elementary Particles, D.J. Griffiths
- Nuclear Physics, R.R. Roy and B.P. Nigam
- Atomic and Nuclear Physics (Vol. 2), S.N. Ghoshal
- Nuclear Physics: Principles and applications, J. S. Lilley
- Introduction to High Energy Physics, D.H. Perkins
- Nuclear Physics, Kaplan
- Introductory Nuclear Physics, K. S. Krane
- Nuclear Astrophysics-A Course of Lectures, Md. A. Khan
- Special and General Relativity: With Applications to White Dwarfs, Neutron Stars and Black Holes, Norman K. Glendenning

Course Outcomes:

On completion of this course students are expected to,

CO1: Explain the fundamental concepts of nucleon-nucleon interaction, including exchange forces, tensor forces, and the Yukawa interaction, and analyze their implications in nuclear physics.

CO2: Describe the direct and compound nuclear mechanisms, including cross-sections, scattering matrix, and resonance scattering, and apply Breit-Wigner's one-level formula to analyze resonance phenomena.

CO3: Understand the theories and mechanisms of alpha, beta, and gamma decay processes, including Gamow's theory for alpha decay and the selection rules for angular momentum and parity in beta and gamma decay.

CO4: Analyze the two-body nuclear problem, including the deuteron ground state, nuclear scattering, and interaction of neutrons with matter, and evaluate experimental techniques such as neutron diffraction.

CO5: Discuss elementary particle physics concepts, such as symmetry and conservation laws, quark model, and hadron classification, and examine their relevance to nuclear interactions and reactions.

Course Name: Atomic and Molecular Physics
Course Code: PHYUGMDS4807
Credit: 4 [3(Theory)+1(Tutorial)]
Course type: Discipline Specific Elective Course (DSE)
Lectures: 45+15
(Only For Physics Honors Without Research)

Course Objective: The course aims to provide a comprehensive understanding of the quantum mechanical principles underlying atomic and molecular structures and spectra. It covers detailed topics such as one-electron and many-electron atoms, fine and hyperfine structures, and the spectra of two-electron atoms. Additionally, it explores molecular electronic states, diatomic molecular spectra, electronic spectra, and Raman spectroscopy. This foundation prepares students for advanced research and practical applications in atomic, molecular, and optical physics.

One electron atoms	**7 Lectures**

One-electron atom (hydrogen) in an electromagnetic field: review on transition rates, absorption, stimulated emission, spontaneous emission, den7sity of states, Einstein's coefficients, selection rules, allowed and forbidden transitions, dipole approximation, spectrum of one electron atoms. Atomic life-time and metastable states, line shapes and line width- natural line width, Doppler broadening, pressure broadening.

Fine and hyperfine structure of one electron atoms	**10 Lectures**

Fine structure of hydrogen atom- relativistic corrections to the kinetic energy, spin-orbit term and Darwin corrections, fine structure splitting, selection rules and spectral lines, Lamb shift. Hyperfine interaction and isotope shift; hyperfine splitting of spectral lines and selection rules. Effect of external magnetic field- Strong, moderate and weak field.

Many-electron atoms	**10 Lectures**

Review on symmetric and anti-symmetric wavefunctions, wave functions for bosons and fermions, Pauli's exclusion principle, Slater determinant. Singlet and triplet states, para and ortho states. Schrodinger equation of two electron atoms, spin wave functions and role of Pauli's exclusion principle, level scheme of He atom. Calculation of ground state energy of He atom- perturbation theory.

Central field approximation-independent particle model, electron states in central field- configurations, shells and sub-shells. Energy levels and spectra for many electron atoms- LS and j-j couplings, equivalent and nonequivalent electrons, spectroscopic terms, Hunds rule, Lande interval rule. Spectra of alkali atoms- effective central potential, fine and hyperfine structures.	
Molecular Electronic States	**10 Lectures**
Review on molecular potential, separation of electronic and nuclear wave functions and, Born Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions; Shapes of molecular orbital; π and σ bond; Term symbol for simple molecules.	
Spectra of Diatomic Molecules (Rotation and vibration of molecules)	**10 Lectures**
Solution of nuclear equation; Molecular rotation: rigid and Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential. Transition matrix elements, Vibrationrotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions	
Electronic Spectra	**6 Lectures**
Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules.	
Raman spectroscopy	**7 Lectures**
Rotational, Vibrational, Rotational-Vibrational, electronics Raman spectra. Stokes and anti Stokes Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra	

Reference Books

- Atomic Spectra and atomic structure, G. Hertzberg
- Introduction to atomic spectra, H. White
- Optics and Atomic Physics, B. P. Khandelwal (Siblal Agarwala)
- Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain
- Atoms, Molecules and Lasers, K. P. R. Nair
- Physics of the Atom, M. R. Wehr, J. A. Richards, T. W. Adair
- Introduction to Atomic & Molecular Spectrocopy, V. K. Jain
- Molecular Physics (Kinetic Theory and Thermodynamics), S. K. Sinha, T. K. Dey
- Molecular Spectroscopy, Suresh Chandra*
- Atomic Physics, C. J. Foot
- Fundamentals of Molecular Spectroscopy, C. B. Banwell
- Molecular Spectroscopy, G. M. Barrow
- Atomic and Molecular Spectra,R. Kumar

Course Outcomes:

On completion of this course, students are expected to,

CO1: Understanding quantum states, atomic orbitals, wave function parity, and distribution functions. Insight into the behavior of one-electron atoms in electromagnetic fields, transition processes, and spectral characteristics.

CO2: Grasp of fine structure corrections, spin-orbit interactions, Lamb shift, hyperfine interactions, and effects of external magnetic fields.

CO3: Knowledge of wave functions for identical particles, Pauli's exclusion principle, and energy level calculations for helium atoms.

CO4: Understanding of electron configurations, coupling schemes, spectroscopic terms, and spectral characteristics of alkali atoms.

CO5: Comprehension of molecular potentials, Born-Oppenheimer approximation, electronic states of diatomic molecules, and molecular orbital theory.

CO6: Understanding molecular rotation and vibration, including rotational-vibrational spectra and related transitions.

CO7: Knowledge of electronic transitions, Franck-Condon principle, rotational structure, and dissociation energy of molecules.

CO8: Understanding Raman spectral phenomena, selection rules, and the impact of nuclear spin on Raman spectra.

Course Name: Project work and Presentation
Course Code: PHYUGPRJ4802
Credit: 8
Course type: Dissertation
(For only Physics Honors with Research)

Each student has to carry out a project work on a topic related to recent research interest in physics under the supervision of one supervisor. In the project work the student is expected to perform some theoretical/experimental/computational investigation. In some exceptional cases the project may concentrate on an extensive review of a suitable advanced topic related to the curriculum but well beyond the scope of the M. Sc. syllabus. The student has to submit a dissertation (both soft and hard copies) presenting the findings of the work. The student, at the end of the course, has to defend the Project work carried out by the student in the form of an oral presentation