M.Sc. Physics

(Two Year Programme)

Curriculum, Programme Structure and Course contents

(Prepared in conformity with LOCF & CBCS)

(2022-2023 onwards)

DEPARTMENT OF PHYSICS
Manonmaniam Sundaranar University
Tirunelveli

Manonmaniam Sundaranar University

Learning Outcome based Curriculum

Vision of the University

To provide quality education to reach the un-reached

Mission of the University

- To conduct research, teaching and outreach programmes to improve conditions of human living
- To create an academic environment that honours women and men of all races, caste, creed, cultures and an atmosphere that values intellectual curiosity, pursuit of knowledge, academic freedom and integrity
- To offer a wide variety of off-campus educational and training programs, including the use of information technology, to individuals and groups.
- To develop partnership with industries and government so as to improve the quality of the workplace and to serve as catalyst for economic and cultural development
- To provide quality / inclusive education, especially for the rural and un-reached segments of economically downtrodden students including women, socially oppressed and differently abled

Department of PHYSICS

Vision of the Department

- In pursuit of excellence on to provide higher education in Physics.

Mission of the Department

- By the way of innovation in teaching, inculcating problem-solving skills for the application, and empowering the students' independence.
- By the way of carrying out research on thrust areas, generating facilities through grants from research projects, and competing internationally.
- By the way of extension activities for knowledge dissemination, societal obligation, and leadership role.
- By the way of promoting human values, social harmony, and justice for moulding into responsible citizens.

1. Name of the Programme : **M.Sc. Physics**

2. Preamble of the Programme : M.Sc. Physics programme offers advanced courses as a smooth continuation of passionate learning of Physics in a holistic approach. Core Physics courses are given equal weightage in terms of contact hours and credits. Therefore, pure theoretical courses are augmented with tutorials which are extensions/applications/problem-solving on what was learned in core courses. The nature of the courses are core, elective, supportive, skill-development, internship, project, value-added and are learned as theory, tutorial, and practical respectively to instill understanding, to train on applications, and to enhance the ability of a learner. All theory courses have the same method of Internal assessment and end-semester examination. The practical and tutorials have the flexible student-centric assessment, and end-semester examinations. The student can avail of different options to earn internal assessments to nurture the area of strength. Course contents are mostly from a single textbook-based while many reference books are provided to widen the students' interest. Value-added certificate courses are mandatory and the credits earned through them are not included in the 90 credits. Therefore, these are extra-credit courses and students will get a certificate for the two courses.

3. **Programme Structure:**

Semester	Course Code	Course	Course Nature	Credits	Contact Hours per Week	continuous Internal Assessment (CIA)	End Semester Exam
I	PPHC11	Classical Mechanics*	Core 1-Theory	4	4	25	75
I	PPHT11		Core 1-Tutorial**	1	1	25	25
I	PPHC12	Mathematical Physics-I	Core 2-Theory	4	4	25	75
I	PPHT12		Core 2-Tutorial	1	1	25	25
I	PPHC13	Quantum Mechanics-I	Core 3-Theory	4	4	25	75
I	PPHT13		Core 3-Tutorial	1	1	25	25
I	PPHC14	Electronics	Core 4-Theory	4	4	25	75
I	PPHL14		Core 4-Practical	1	2	25	25
I	PPHEAX	Elective – I	Elective-Theory	3	3	25	75
I	PPHSAX	Skill Development Course - I	Skill - Practical	1	2	25	25
				24	**29**		
II	PPHC21	Mathematical Physics-II	Core 5-Theory	4	4	25	75
II	PPHT21		Core 5-Tutorial	1	1	25	25
II	PPHC22	Quantum Mechanics-II	Core 6-Theory	4	4	25	75
II	PPHT22		Core 6-Tutorial	1	1	25	25
II	PPHC23	Electromagnetic Theory	Core 7-Theory	4	4	25	75
II	PPHL23		Core 7-Tutorial	1	1	25	25
II	PPHEBX#	Elective – II	Elective-Theory	3	3	25	75
II	PPH	Supportive Course(ONLINE)	Supportive-Theory	3	3	25	75
II	PPHVX	Value-added course – I	Value added-Theory	2^{ψ}	2	25	25
				21	**27**		
III	PPHC31	Thermodynamics and Statistical Mechanics	Core 8-Theory	4	4	25	75
III	PPHT31		Core 8-Tutorial	1	1	25	25
III	PPHC32	Condensed Matter Physics - I	Core 9-Theory	4	4	25	75
III	PPHL32		Core 9-Practical	1	2	25	25
III	PPHC33	Nuclear and Elementary Particle Physics	Core 10-Theory	4	4	25	75
III	PPHL33		Core 10-Practical	1	2	25	25
III	PPHECX	Elective – III	Elective-Theory	3	3	25	75
III	PPH	Supportive Course(ONLINE)	Supportive-Theory	3	3	25	75
III	PPHVX	Value-added course – II	Value added-Theory	2^{ψ}	2	25	25
III	PPHIA	Internship	Skill - Practical	2		25	25
				23	**27**		
IV	PPHC41	Condensed Matter Physics – II*	Core 11-Theory	4	4	25	75
IV	PPHL41		Core 11-Practical	1	2	25	25
IV	PPHC42	Spectroscopy	Core 12-Theory	4	4	25	75
IV	PPHL42		Core 12-Practical	1	2	25	25
IV	PPHEDX	Elective – IV	Elective-Theory	3	3	25	75
IV		Project and Viva-voce	Project - Practical	8	12	50	50
IV	PPHSDX	Skill Development course - II	Skill - Practical	1	2	25	25
				22	**29**		
				90		**925**	**1825**

*e-pg pathshala courses,

**For tutorial class students will be divided into two groups by the respective course teachers

#X in the elective and skill courses shall be substituted by A/B/C depending on the choice of the courses from the respective list of courses.

ψ Value-added courses are certificate courses and the credits earned through them are not included in the 90 credits. These are mandatory extra-credit courses.

CORE THEORY COURSES:

The core theory courses are respectively augmented with tutorials or practical courses to have an effective student-centric learning process. Further, theory-based core courses are fundamental courses that build generic formalism while experiment-based core courses are applied in nature. Therefore, it is important to have an equal amount of contact hours and credits. Content of the core courses are chosen such that they have continuity in what had been learned by the students during higher secondary and undergraduate programme. Further, contents are chosen preferably from a single book so that the students undergo coherent learning.

CORE TUTORIAL COURSES:

Tutorial topics are selected in such a way that they are extension/application / solving problems of/on the concepts learned in each of the core courses. Any number of tutorials shall be selected from the list to strengthen the students' understanding and to judiciously conduct internal assessments and end-semester examinations. Tutorials shall preferably be handled by the same core course teacher. Application/extension of topics is, in general, problem-solving or simulations in computers with the use of reference books, e-contents, reading materials, MOOC course clippings, and web resources. Participative and experiential learning are the main methodology followed in tutorials class hours in terms of group discussions, working exercises in groups, oral presentations, quizzes in groups, and multiple-choice questions setting competition among groups which are to be employed by the course teacher according to the topic. Students shall give oral presentations on the topic using web resources and real-life implications. Special attention shall be given to a single student or group of students for grasping the concepts in their entirety.

CORE PRACTICAL COURSES:

Practical courses either demonstration of the concepts learned in core theory courses or simple experiments with known-aim and known-results performed by turn-key instruments, circuits, and trainer kits, etc. Scope of demonstration of the concepts gives students an opportunity for creativity and therefore yields a depth of understanding. Because of this, assessment and evaluation of the student's performance in laboratory courses are having flexible components up to fourty percent of the CIA score (10 marks) shall be earned by the student by (i) designing a new demonstration (ii) designing a new experiment (iii) preparing a review on the experiment from Physics pedagogical journals (iv) preparing a presentation on the concepts with animation, etc

ELECTIVE COURSES:

Four elective courses (I, II, III, and IV) are offered to the students of this Department in each of the four semesters and are as given below in the four groups. One course shall be taken by each student from each group for every semester:

Group – 1

(a) Physics of Semiconductor Devices
(b) Numerical Methods and Programming
(c) General Relativity and Cosmology

Group – 2

(a) Quantum Field Theory
(b) Density Functional Theory
(c) Introductory Astronomy, Astrophysics & Cosmology

Group – 3

(a) Material Processing and characterization Techniques
(b) X-ray Crystallography
(c) Data Analysis and Techniques

Group – 4

(a) Thin film Physics
(b) Materials Science
(c) Medical Physics

SUPPORTIVE COURSES:

Supportive courses provide an opportunity for the student to select any course of choice for horizontal expansion of knowledge other than the major courses. A student can learn two courses with three credits each in this programme. The choice here is vast for the students and selects a course from the list of courses avail in NPTEL/MOOC. The courses are learned through ONLINE mode and with the help of the Mentor assigned by the concerned department.

SKILL COURSES:

Skill development practical courses (I and II) are offered to the students of this programme and are as given below in the two groups. One course shall be taken by each student from two groups for two semesters:

Group – 1 (First Semester)

(a) Matlab Programming
(b) Arudino- Applications

Group – 2 (Fourth Semester)

(a) PicMicrocontroller Applications
(b) NI Labview - Applications

VALUE-ADDED COURSES:

Value-added mandatory certificate courses (I and II) are offered to the students of this programme and are as given below in the two groups. One course shall be taken by each student from two groups for two semesters:

Group – 1 (Second Semester)

(a) Powder x-ray diffraction analysis and Rietveld refinement
(b) NMR spectral Analysis
(c) Raman spectral analysis

Group – 2 (Third Semester)

(a) SEM- microstructure analysis and EDS - composition analysis
(b) Single crystal X-ray diffraction analysis with SHELX
(c) Characterization of Battery, Supercapacitors, and Fuel cell

INTERNSHIP:

Each student shall carry out an internship during summer vacation in any Science Department of any University other than the Physics Department or any National Laboratory or any Registered Industry for 10 working days with one department faculty member as a mentor. Attendance shall be produced for the same from the higher authority of the Department/ institution/industry. The student shall submit a report with a minimum of 15 pages during the first week of the third semester and followed by an open presentation. Department Mentor will provide CIA for 12.5 marks (25%) while other departments/institution/industry mentors will provide CIA for 12.5 marks (25%).

PROJECT:

The project work shall be based on any research-oriented topics, both in the fields of theoretical and experimental physics under the guidance of a faculty member of the Department as a Project Supervisor. After completion of the project work at the end of semester VI, each student should submit two copies of the project report/thesis to the Department on or before a date as notified for the same.

4 Scheme of Evaluation:

(a) Continuous Internal Assessment (CIA)

Theory Courses & Elective courses:

Continuous Internal Assessment is carried out for **25 marks** (25%) and it is divided into **15 marks** for the internal written test (average of the marks from the best two tests out of three tests), **5 marks** for Seminar, and **5 marks** for the assignment (At least one assignment in each unit shall be submitted by a student) as learning activities. There is no passing minimum in the internal test marks for each paper. The question paper pattern for the internal assessment test of each theory paper is given below. The questions for the internal assessment test shall be distributed to assess all the cognitive levels of Bloom's taxonomy and the same shall be tabulated at the top of the question paper.

Section	Type of Questions	Marks
Part A	MCQ Type - 5 Questions	5 × 1 = 5
Part B	Answer any two out of three questions of either problems or descriptive type	2 × 5 = 10
Part C	Answer any one out of two questions of either problems or descriptive type	1 × 10 = 10
	Total Marks	**25**

Practical:

Continuous Internal Assessment is carried out for **25 marks** (50%) and it is divided into **15 marks** for internal tests and **10 marks** for (i) designing a new demonstration (ii) designing a new experiment (iii) preparing a review on the experiment from Physics pedagogical journals (iv) preparing a presentation with animation, etc. Two internal tests shall be conducted and an average of the two test marks shall be equated to 10 marks of CIA. The remaining marks shall be awarded to the student based on his choice and the course teacher shall maintain a record of the assessment process. There is no passing minimum in the Continuous Internal Assessment.

Tutorial:

Continuous Internal Assessment is carried out for **25 marks** (50%) and it is divided into **15 marks** for internal tests and **10 marks** for (i) Solving problems (ii) setting MCQs (iii) preparing a review on the concepts (iv) preparing a presentation with animation, (v) designing new tutorials, etc. Two internal tests shall be conducted and an average of the two test marks shall be equated to 10 marks of CIA. Question patterns for internal tests for tutorials shall be decided by the course teacher and shall be informed to the students at the beginning of the semester itself. The remaining marks shall be awarded to the student based on his choice from any one of the four mentioned above and the course teacher shall maintain a record of the assessment process. There is no passing minimum in the Continuous Internal Assessment.

Project: Continuous Internal Assessment is carried out for **50 marks** (50%) and it is divided into **30 marks** for internal review and **20 marks** for (i) designing a piece of new equipment (ii) designing a new measurement methodology (iii) preparing a review on the project topic from the literature review (iv) preparing a presentation for the project progress with animation, etc. The project viva-voce examination for the students will be conducted individually. Two internal reviews in open shall be conducted and the average of the two reviews mark shall be scaled to 30 marks of CIA. The remaining marks shall be awarded to the student based on his choice from any one of the four mentioned above and the Project supervisor shall maintain a record of the assessment process. There is no passing minimum in the Continuous Internal Assessment.

Internship: Continuous Internal Assessment is carried out for **25 marks** (50%) and it is divided into two components as (i) **15 marks** by the mentor from another science Department/Institution/Industry and (ii) **10 marks** by the Department mentor. There is no passing minimum in the Continuous Internal Assessment.

Supportive Course: Continuous Internal Assessment is carried out for **25 marks** (25 %). ONLINE course teacher assesses the progress of the student by providing assignments every week and the assignments are valued for marks. The mentor shall take an average of the best eight assignment marks. There is no passing minimum in the Continuous Internal Assessment.

Skill courses: Continuous Internal Assessment is carried out for **25 marks** (50%) and it is divided into **15 marks** for internal tests and **10 marks** for (i) designing a new demonstration (ii) designing a new experiment (iii) preparing a review on the experiment from Physics pedagogical journals (iv) preparing a presentation with animation, etc. Two internal tests shall be conducted and an average of the two test marks shall be equated to 15 marks of CIA. The remaining marks shall be awarded to the student based on his choice from any one of the four mentioned above and the course teacher shall maintain a record of the assessment process. There is no passing minimum in the Continuous Internal Assessment.

Value-added courses: Continuous Internal Assessment is carried out for **25 marks** (50%) and it is divided into **15 marks** for the internal written test (average of the marks from the best two tests out of three tests), **5 marks** for Seminar, and **5 marks** for the assignment (At least five assignment shall be submitted by a student from different modules) learning activities. There is no passing minimum in the internal test marks for each paper. The question paper pattern for the internal assessment test of each theory paper is given below. The questions for the internal assessment test shall be distributed to assess all the cognitive levels of Bloom's taxonomy and the same shall be tabulated at the top of the question paper.

Section	Type of Questions	Marks
Part A	Answer any two out of three questions of either problems or descriptive type	3 × 1 = 3
Part B	Answer any three out of four questions of either problems or descriptive type	2 × 3 = 6

Part C	Answer any two out of three questions of either problems or descriptive type	1 × 6 = 6
	Total Marks	**15**

(b) End Semester Examination (ESE)

Theory Course, Elective course & Supportive course:

The question paper pattern for the end-semester examination of each theory paper is given below. The questions for the internal assessment test shall be distributed to assess all the cognitive levels of Bloom's taxonomy and the same shall be tabulated at the top of the question paper. The duration of the end-semester examination for each theory course is 3 hours. There is a passing minimum of 50% in the End semester examinations in each theory & elective course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination.

Section	Type of Questions	Marks
Part A	MCQ Type - 10 Questions	10 × 1 = 10
Part B	Answer all the questions either/or type and questions of either problems or descriptive type	5 × 5 = 25
Part C	Answer all the questions either/or type and questions of either problems or descriptive type	5 × 8 = 40
	Total Marks	**75**

Practical :

The duration of the end-semester examination for each Practical Course may be **three** hours. There is a passing minimum of 50% in the end semester examination in each practical course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination for each practical course. The internal examiner and the external examiner shall evaluate for 25 marks each the performance of the student in practical in the end semester examination.

Tutorial :

There will be end semester examination for the Tutorials and will be conducted along with the end-semester practical schedule provided by the office of the controller of examinations. End semester questions shall be only problems for 25 marks (50%) and the question pattern shall be decided by the course teacher but the number of questions shall be twice that of the minimum required questions to be answered. A detailed scheme of marks shall be provided for each question to enable the student to choose. The duration of the examination is 90 minutes.

Project :

Project work shall be submitted as a dissertation. Open viva-voce shall be conducted to evaluate the performance of the student in the projects. Dissertation and viva-voce shall be evaluated for 50 marks (50%) and the evaluation shall be done for 20 and 30 marks respectively. Internal and external examiners shall evaluate the dissertation and viva-voce equally. There is a passing minimum of 50% in the end semester examination in each practical course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination for each practical course.

Internship : Internship work shall be submitted in form of a report duly certified by the external and department mentors. Open viva-voce shall be conducted to evaluate the performance of the student in the projects. The internship report and viva-voce shall be evaluated for 50 marks (50%) and the evaluation shall be done for 20 and 30 marks respectively. Internal and external examiners shall evaluate the report and viva-voce equally. There is a passing minimum of 50% in the end semester examination in each practical course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination for each practical course.

Skill course : End semester examination for skills shall be similar to the practicals. The duration of the end-semester examination for each Practical Course may be **two** hours. There is a passing minimum of 50% in the end semester examination in each practical course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination for each practical course. The internal examiner and the external examiner shall evaluate for 25 marks each the performance of the student in practical in the end semester examination.

Value-added course: The question paper pattern for the end-semester examination of each value-added course is given below. The questions for the end semester examination shall be distributed to assess all the cognitive levels of Bloom's taxonomy and the same shall be tabulated at the top of the question paper. The duration of the end-semester examination for each theory course is 90 minutes. There is a passing minimum of 50% in the End-semester examinations in each value-added course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the end semester examination.

Section	**Type of Questions**	**Marks**
Part A	Answer any two out of three questions of either problems or descriptive type	2 × 2 = 4
Part B	Answer any three out of four questions of either problems or descriptive type	3 × 3 = 9
Part C	Answer any two out of three questions of either problems or descriptive type	2 × 6 = 12
	Total Marks	**25**

(c) Model End Semester Question Paper*

Classical Mechanics

PART-A Answer all the questions (10×1=10)

1. If the generalized coordinate is angle θ, the corresponding generalized force has the dimension of
*(a)*force *(b)* momentum *(c)*torque *(d)* energy

2. The Lagrangian for a charged particle in an electromagnetic field is

(a) $L = T + q\phi + q (v \bullet A)$ *(b)* $L = T - q\phi - q (v \bullet A)$

(c) $L = T - q\phi + q (v \bullet A)$ *(d)* $L = T + q\phi - q (v \bullet A)$

Where *T* is the kinetic energy and ϕ and A are magnetic scalar and vector potentials.

3. The dimensions of generalized momentum

(a) q_k is cyclic coordinate. *(b)* p_k is cyclic coordinate.

(c) p_k, the generalized momentum, is a constant of motion. *(d)* q_k is always zero.

4. If the Lagrangian does not depend on time explicitly,

(a) the Hamiltonian is constant. *(b)* the Hamiltonian cannot be constant.

(c) the kinetic energy is constant. *(d)* the potential energy is constant.

5. A particle is moving on elliptical path under inverse square law force of the form $F(r) = - K/r^2$. The eccentricity of the orbit is

(a) a function of total energy. (b)independent of total energy.

(c) a function of angular momentum. (d) independent of angular momentum.

6. Rutherford's differential scattering cross-section

*(a)*has the dimensions of area. *(b)*has the dimensions of solid angle.

(c) is proportional to the square of the kinetic energy of the incident particle.

(d) is inversely proportional to $\text{cosec}^4 (\phi/2)$, where ϕ is the scattering angle.

7. Poisson brackets for angular momentum components (J_x, J_y, J_z) satisfy the relations,

(a) $[J_x, p_x] = 0$ *(b)* $[J_x, p_z] = -p_y$ *(c)* $[J_y, J_z] = J_x$ *(d)* $[J_y, p_z] = -J_x$.

8. For a one-dimensional harmonic oscillator, the representative point in two-dimensional phase space traces

*(a)*an ellipse, *(b)* a parabola, *(c)* a hyperbola, *(d)* always a straight line.

9. The law of conservation of momentum,

(a) is valid at relativistic speeds. *(b)* is not valid at relativistic speeds.

(c) is valid at nonrelativistic speeds. *(d)* is not valid at nonrelativistic speeds.

10. In Minkowski space

(a) the space interval between two points is invariant.

(b) the time interval between two points is invariant.

(c) the space-time interval between two points is invariant.

(d) the space-time interval between two points is different for different observers.

PART-B Answer all the questions from either (a) or (b) (5×5=25)

11. (a) What is D'Alembert's principle ? Derive Lagrange's equations of motion from it for conservation system. How will the result be modified for non-conservative system?

(Or)

(b) Two equal masses are connected by springs having each force constant *C*. The masses are free to slide on a frictionless table AB. The walls are at A and B to which the ends of the springs are fixed. Set up the Lagrangian and deduce the equations of motion of the vibrating system.

12. (a) If the Hamiltonian *H* is independent of time *t* explicitly, prove that it is, (a) constant and (b) equal to the total energy of the system.

(Or)

(b) (*i*) A particle is moving near the surface in the earth's gravitational field. Write down the Hamiltonian and equation of motion of the particle by neglecting the earth's rotation.
(*ii*) Whenever the Lagrangian function does not contain the coordinate q_k explicitly, the generalized momentum p_k is a constant of motion. Explain.

13. (a) Discuss the scattering of α-particles under a central force field and hence obtain the expression for Rutherford scattering cross-section.

(Or)

(b) The eccentricity of the earth's orbit is 0.0125. Calculate the ratio of the maximum and minimum speeds of the earth.

14. (a) What are the Poisson and Lagrange's brackets ? Show that Lagrange's bracket is invariant under canonical transformation.

(Or)

(b) Show that the following transformations are canonical:
(*i*) Q = p, P = -q (*ii*) Q = q tan p, P = log (sin p) (*iii*) Q = p tan q, P = log (sin p)

15. (a) Deduce the eigen value equation for small oscillations. How will you obtain the eigen values (ω^2) and eigenvectors from this equation?

(Or)

(b) Find the velocity that an electron must be given so that its momentum is 10 times its rest mass times the speed of light. What is the energy at this speed?

PART-C Answer all the questions from either (a) or (b) 8×5=40)

16. (a) What is Hamilton's principle ? Derive Lagrange's equation of motion from it. Find the Lagrangian equation of motion for a L-C circuit and also deduce the time period.

(Or)

(b) (*i*) Two point masses m are connected by a rod of length 2a, the centre of which moves on a circle of radius r. Write down kinetic energy in generalized coordinates.
(*ii*) Obtain the Lagrangian of a particle moving in a force free field in spherical coordinate and cylindrical coordinate systems.

17. (a) (*i*) What is a cyclic coordinate? Illustrate with examples.
(*ii*) Whenever the Lagrangian function does not contain the coordinate q_k explicitly, the generalized momentum p_k is a constant of motion. Explain.
(*iii*) Prove that the total energy of the system is constant if for a conservative system, the Lagrangian does not depend explicitly on time.

(Or)

(b) A particle of mass *m* moves on the inside of a frictionless cone having equation $x^2+y^2=z^2\tan^2\alpha$.
(a) Write the Hamiltonian and (b) Hamilton's equations using cylindrical coordinates.

18. (a) Derive the equation for orbit of a particle moving under the influence of an inverse square central force field. Also calculate the time period of motion in elliptical orbit.

(Or)

(b) How will you reduce the two-body problem into one-body problem? Hence explain the concept of reduced mass. Give its two examples. Calculate reduced mass of the hydrogen atom and positronium.

19. (a) Derive the Euler-Lagrange's equations of motion using the calculus of variations and hence obtain Lagrange's equations of motion for a system of particles.

(Or)

(b) State and prove Hamilton-Jacobi equation for Hamilton's principal function and explain how it can be used to solve Kepler's problem for a particle in an inverse square central force field.

20. (a) Assuming the law of conservation of momentum to be correct in every inertial frame, show that by the use of transformation of energy and momentum, the relativistic energy is conserved in a two particle system.

(Or)

(b) (*i*) Explain Minkowski's four dimensional space.
(*ii*) Write notes on 'Four-dimensional space-like and time-like intervals and their significance'.
(*iii*)Show that four-dimensional volume element *dxdydzdt* is invariant under Lorentz transformations.

*Any one of the Core papers (testing all Cognitive Levels) in the first semester decided by the Department.
(Remember – 25%, Understand – 25%, Apply – 20%, Analyze – 10%, Evaluate – 10%, Create – 10%)

(d) Passing Minimum

CIA – No passing minimum
ESE – 50%
Cumulative Aggregate – 50%

4. Programme Outcomes (POs):

On the successful completion of the Master of Science programme, the student will be able to

PO1	Plan the career prospects based on the knowledge acquired, skill set developed, and abilities imbibed through the programme
PO2	Describe the development of experimental discoveries and relate them to the formulation of theory through models by delineating the assumptions and the approximation in the theory
PO3	Design and perform experiments and validate the experimental results with its error for testing the theory & hypotheses
PO4	List the fundamental concepts of courses provided in the programme and their implications on disclosing the nature
PO5	Relate the variables and the measurable quantities in the form of equations/reactions for the predictions through mathematical deductions and computer simulations
PO6	Identify the interesting areas of the programme to further as a professional scientist by competing in the national level competitive examinations; CSIR-NET, GATE & JEST
PO7	Figure out the applications of the structured learning to industry and harness the skill set in the narrow and unexplored fields for setting up the career trajectory

PO8	Propose an innovative procedure/product/devices for the real-life problems and to provide an avenue to become an entrepreneur for the endeavour of humanity

6. Programme Specific Outcomes (PSO):

On the successful completion of the M.Sc. Physics programme, the learner will be able to

PSO1	Reproduce the solutions of Lagrangian, Hamiltonian, Schrodinger, and Maxwell field & wave equations to dynamical models and apply them to the real systems from hardron to galaxies and their interaction with the other for the understanding of the nature
PSO2	Apply statistical approximations to microscopic systems and calculate various macroscopic physical quantities using ensemble concept
PSO3	Remember and compare the characteristics of discrete components and integrated circuits for the design of new circuits to simplify the human tasks
PSO4	Synthesis of novel materials/devices for the enhancement of their properties/performance and propose a suitable mechanism in the form of a scientific writing
PSO5	Employ linear algebra, differential equations, complex variables, integral transforms, and group theory techniques to a variety of physical problems for obtaining the solution analytically or numerically and draw inferences
PSO6	Critical application of the concepts through the relations for solving Physics problems in CSIR-NET, JEST, and GATE
PSO7	Evaluate the structural, thermal, electrical, and magnetic properties of solids by employing a dynamical approach and extend structured learning to current fields such as nanomaterials, sustainable energy materials, etc to pursue career goals
PSO8	Operate the simple turn-key type of equipment, sophisticated instruments, and industrial production parts and evaluate the results for practical, project and internship and develop the skill-sets

Course Description
Core 1: CLASSICAL MECHANICS (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC11

b. Course Objectives
1. To learn the equation of motion using Lagrangian, Hamilton and Hamilton-Jacobi equations for a system of particles and apply to simple example systems
2. To study the dynamics of two-body central force field problems, Kepler's laws and scattering
3. To apply to theory of small oscillations to get normal modes and their frequencies of simple systems and explore the four vectors in the context of relativity

c. Learning Progression:
Newton's Laws and applications, motion of connected bodies, conservation of linear momentum, circular motion, work, energy and power, collisions, motion of system of particles, centre of mass, torque, angular momentum, moment of inertia, rotational dynamics, conservation of angular momentum

d. Theoretical Foundations of the course
Generalized coordinates, DÁlembert's priniciple, Hamilton principle, Coordinate transformations, Poisson brackets, Central force fields, Normal coordinates

e. Course Outcomes (COs)
At the end of the Course, the student will be able to -

CO1: State the Lagrangian, Hamiltonian, Hamilton-Jacoby, Euler equations of motions, momentum & energy conservation laws

CO2: Describe generalized coordinates, constraints, DÁlemberts and Hamilton principles, coordinate transformation, Poisson brackets, centre of mass, central force fields

CO3: Solve the equations of motion of free particles in space, Atwood's machine, harmonic oscillator, Kepler problem, vibrational frequencies of a tri-atomic linear molecule, symmetric top, artificial satellites, etc and solve any new system

CO4: Contrast study of mechanics of a systems using Lagrangian, Hamiltonian, Hamiltonian-Jacoby, Euler equations, Laboratory & Centre of mass frames

CO5: Evaluate the equations of motion for a new system and deduction of the inferences

CO6: Formulate a new dynamical problem and propose a methodology to get the solution

f. Course Outline:
UNIT – I: LAGRANGIAN DYNAMICS
Module 1.1: Mechanics of system of particles, conservation of linear and angular momentums and energy (2 lectures)
Module 1.2: Coordinate systems, configuration space, constraints, generalized coordinates (2 lectures)
Module 1.3: Principle of virtual work, D'Alembert's principle, general form Lagrangian equation (2 lectures)

Module 1.4: Lagrange equation for conservative systems, Applications; simple pendulum, Atwood's machine, compound pendulum, radial and tangential components of force, L-C circuits and motion in central force (3 lectures)
Module 1.5: Lagrangian equation for non-conservative forces, Rayleigh dissipation function, generalized potential and gyroscopic force (2 lectures)
Module 1.6: Gauge invariance of Lagrangian, homogeneity and isotropic of space and homogeneity of time, conservation laws (3 lectures)

UNIT – II: HAMILTONIAN DYNAMICS
Module 2.1: Generalized momentum, cyclic coordinates, conservation of linear and angular momentum, and energy, Hamiltonian function (3 lectures)
Module 2.2: Hamilton's equations in different coordinate systems, Applications; Harmonic oscillator, motion of a particle in central force field, charged particle in electromagnetic field, compound pendulum, two dimensional harmonic oscillator (6 lectures)
Module 2.3: Routhian and application (1 lecture)

UNIT – III: CENTRAL FORCE PROBLEM
Module 3.1: Reduction two-body problem to equivalent one-body problem, reduced mass, central force and motion in a plane, equation of motion under central force and first integral (2 lectures)
Module 3.2: Differential equation for an orbit, Inverse square law of force, Deduction Kepler's laws, Stability and closure of orbits, Problems, Artificial satellites (5 lectures)
Module 3.3: Virial theorem, scattering in central force field, Rutherford scattering cross-section, Applications (3 lectures)

UNIT – IV: VARIATIONAL PRINCIPLE, CANONICAL TRANSFORMATION AND POISSON BRACKETS
Module 4.1: Calculus of variations and Euler-Lagrangian equation, Hamilton principle (2 lectures)
Module 4.2: Modified Hamilton's principle, deduction of Hamilton's equations, simple pendulum using Lagrange's method (2 lectures)
Module 4.3: Δ-variation, principle of least action, other forms (2 lectures)
Module 4.4: Canonical transformation, Legendre transformation, generating functions, procedure for application of CT, condition of CT, harmonic oscillator (3 lectures)
Module 4.5: Infinitesimal contact transformation, Poisson's bracket, properties, Lagrange brackets, relation between PB and LB (3 lectures)
Module 4.6: Hamilton-Jacobi equation and harmonic oscillator (2 lectures)

UNIT – V: SMALL OSCILLATIONS AND THEORY OF RELATIVITY
Module 5.1: One dimensional oscillator, two coupled oscillators, Normal modes and normal coordinates, symmetric and anti-symmetric modes, KE and PE in normal coordinates (3 lectures)
Module 5.2: Two coupled pendulums, double pendulum and linear tri-atomic molecule (3 lectures)
Module 5.3: Conservation of momentum at relativistic speed, mass-energy relation, examples, Lagrangian and Hamiltonian of a particle in relativistic mechanics (3 lectures)
Module 5.4: Minkowski space and Lorentz transformation, world point and line, four-vectors, examples (3 lectures)

BOOKS FOR STUDY:

1. J. C. Upadhayaya, Classical Mechanics, Himalaya Publishing House Pvt. Ltd, Bangalore, Second edition, 2017
2. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=+4mIqRALksfwQH9v8YSMrw==

BOOKS FOR REFERENCE:

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, Pearson Education Asia, New Delhi, Third Edition, 2002.

2. G. Aruldhas, Classical Mechanics, PHI Learning Private Limited, New Delhi, 2015
3. S. L. Gutpa, V. Kumar and H.V. Sharma, Classical Mechanics, Pragati Prakashan, Meerut, 2016.
4. R.G. Takwale and P.S. Puranik, Introduction to Classical Mechanics, Tata Mc Graw Hill, New Delhi,1989.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1 (K1)	H	L	L	M	M	H	L	L
CO2 (K2)	H	M	L	M	M	H	L	L
CO3 (K3)	H	M	L	M	H	H	L	H
CO4 (K4)	H	M	L	M	H	H	L	H
CO5 (K5)	H	L	L	L	H	L	L	H
CO6 (K6)	H	L	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1 (K1)	H	L	L	L	H	H	L	L
CO2 (K2)	H	L	L	L	H	H	L	L
CO3 (K3)	H	L	L	L	H	H	M	M
CO4 (K4)	H	L	L	L	H	H	M	L
CO5 (K5)	H	L	L	L	H	H	L	L
CO6 (K6)	H	L	L	L	H	H	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6-Create)

Core 1: CLASSICAL MECHANICS (Tutorial)

L	T	P	C
-	1	-	1

a. Course Code:
PPHT11

b. Course Objectives

1. To solve problems using Lagrangian & Hamilton equations, first integrals, transformations, Poisson brackets and theory of small oscillations to solve problems

c. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Solve the dynamical problems using Lagrangian & Hamiltonian equations of motion

CO2: Evaluate the normal modes and normal frequencies

d. List of Tutorials:

1. Three particles are located at the vertices of an equilateral triangle of side *l*. Each of the particles starts to move with constant speed *v*, with the first particle heading continuously for

the second, the second for the third, and the third for the first. When will the particles meet each other?

2. A pendulum bob of radius r is rolling on a circular track of radius R. Set up the Lagrangian, derive the equation of motion and compare its period of small oscillations with that of a simple pendulum of string length (R-r).

3. (a) A bead of mass m slides on a smooth uniform circular wire of radius r which is rotating with a constant angular velocity ω about a fixed vertical diameter. Set up the Lagrangian and find the equation of motion of the bead.

   (b) In the above problem, if the bead is released with no vertical velocity from a point on the level of the centre of the circular wire, show that it will not reach the lowest point if $\omega = \sqrt{2g/r}$

4. A mass m_2 hangs at one end of a string which passes over a fixed frictionless non-rotating pulley. At the other end of the string there is a non-rotating pulley of mass m_1 over which there is a string carrying masses m'_1 and m'_2. Set up the Lagrangian of the system and find the acceleration of the mass m_2.

5. For a system with the Lagrangian $L=\frac{1}{2}(q_1^2 + q_1q_2 + q_2^2) - V(q)$, show that the Hamiltonian is $H=\frac{2}{3}(p_1^2 - p_1p_2 + p_2^2) + V(q)$.

6. Find the Lagrangian for the case when the Hamiltonian is $H(p, r) = \frac{p2}{2m} - (a.p)$, a = constant.

7. Show that the velocity of a planet at any point of its orbit is the same as it would have been if it had fallen that point from rest at a distance from the sun equal to the length of the major axis.

8. A particle moves in a bounded orbit under an attractive inverse force. Prove that the time average of the kinetic energy is half the time average of the potential energy.

9. Use the variational principle to show that the shortest distance between two points in space is a straight line joining them.

10. A particle is acted by the force $f = -kq - \frac{\alpha}{q3}$. Show that the Hamiltonian is $H = \frac{p2}{2m} + \frac{kq2}{2} + \frac{cp}{q}$, where c is a constant. Show that the transformation $Q = \tan^{-1}(\frac{\lambda q}{p})$, $P = \frac{p2 + \lambda 2q2}{2\lambda} + R(q,p,t)$ is canonical, where R is a homogeneous function of q, p, and t. Find the transformed Hamiltonian and hence solve for the motion of the particle.

11. Evaluate the Poisson brackets :
    (a) (i) $[J_x, x]$, (ii) $[J_x, y]$, (iii) $[J_y, Z]$
    (b) (i) $[J_x, p_x]$, (ii) $[J_x, p_z]$, (iii) $[J_z, p_x]$
    (c) (i) $[J_x, J_y]$, (ii) $[J_y, J_z]$

12. If x_1, x_2, x_3 are the Cartesian components of r, p_1, p_2, p_3 those of p and J_1, J_2, J_3 those of J, prove that $[J_i, x_j] = -\sum_k e_{ijk} x_k$, $[J_i, p_j] = -\sum_k e_{ijk} p_k$, and $[J_i, J_j] = -\sum_k e_{ijk} J_k$ where e_{ijk} is the completely antisymmetric tensor : $e_{123} = e_{231} = e_{312} = 1$, $e_{312} = e_{213} = e_{321} = -1$, all other components of e_{ijk} vanish.

13. Triple pendulum**:** Show that the normal mode frequencies of a triple pendulum are given by $\omega_1 = \omega_2 = \sqrt{\frac{g}{l}} + \sqrt{\frac{2k}{m}}$ and $\omega_3 = \sqrt{\frac{g}{l}} - \sqrt{\frac{k}{m}}$.

14. The photon energy in the frame *S* is equal to *E*. Find its energy *E* in frame *S''*, moving with a velocity v relative to the frame *S* in the photon's motion direction. At what value of *v* is the energy of the photon equal to *E' = E/2.*

15. In a frame *S*, two events have the space-time coordinates (0, 0, 0, 0) and (10*c*, 0, 0, 6). Find the space time interval between them. Calculate the velocity of a frame in which
    (i) the two events are simultaneous,
    (ii) the first event occurs 8 sec. earlier than the second, and
    (iii) the second event occurs 8 sec earlier than the first.

16. Any others

e. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1 (K3)	H	L	L	L	L	H	M	L
CO2 (K4)	H	L	L	M	L	H	M	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1 (K3)	H	L	L	L	H	H	L	L
CO2 (K4)	H	L	L	L	H	H	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 2: MATHEMATICAL PHYSICS – I (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC12

b. Course Objectives

1. To learn theorems, concepts, procedures and transformations of linear algebra for deriving expressions in various courses of Physics
2. To know the properties of complex variables and to apply it in condensed matter physics
3. To construct the character table and to apply it in spectroscopy

c. Learning Progression:

HSc Mathematics	HSc Mathematics	B.Sc. Allied Mathematics	B.Sc. Allied Mathematics
Vector algebra: resolution of vectors, position vectors, direction cosines and product of vectors; Matrices: matrices and their determinants	Application of vectors and determinants; Applications of vector algebra; Complex numbers, basic algebra, conjugate, polar and Euler forms;	Eigen values and eigen vectors, Cayley-Hamilton Theorem, simple problems	Grad, div, Curl, double, triple vector integration, Green's, Stoke's and Gauss divergence theorems (without proof) and simple problems

d. Theoretical Foundations

Gradient, divergence, curl, stokes and Gauss theorems, Curvilinear coordinates, Rank, diagonalization, eigenvalues & eigenvectors, Tensor algebra, Cauchy theorem, Integral formula, residue theorem and Orthogonality theorem

e. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: State the Gauss, Greens, Stokes, Cauchy, orthogonality theorems, Taylor & Laurent series and define tensors, C-R equations, analyticity

CO2: Explain gradient, divergence, curl, curvilinear coordinates, tensors, group, class, linear dependence& independence, special tensor notations

CO3: Apply theorems, orthogonalization of vectors, rank, diagonalization, eigenvalues & eigenvectors of matrices

CO4: Analyse the poles complex integration, symmetry of molecules

CO5: Evaluate gradient, divergence, curl, complex integrals of any new functions

CO6: Construct character table of any linear molecules

f. Course Outline:

UNIT-I: VECTOR ANALYSIS AND VECTOR SPACES

Module 1.1: Vector differential calculus - Concept of gradient, divergence and curl; directional derivative, surface normal, tangent, solenoid and irrotational vectors (4 lectures)

Module 1.2: Vector integral calculus - Gauss's divergence theorem, Green's theorem and Stoke's theorem; work done, path independence, conservative field, verification of the three theorems (4 lectures)
Module 1.3: Orthogonal curvilinear coordinates - Expression for gradient, divergence, curl and Laplacian in cylindrical and spherical co-ordinates (2 lectures)
Module 1.4: Linearly dependent and independent sets of vectors - Inner product- Schmidt's orthogonalization; problems (2 lectures)

UNIT- II: MATRICES
Module 2.1: Square matrices, definitions, examples (1 lecture)
Module 2.2: Elementary transformations - Gauss-Jordan method for inverse of a matrix, rank of matrix normal form and upper triangle matrix (3 lectures)
Module 2.3: Solutions of simultaneous equations, consistency, homogeneous equations, Cramer's rule (3 Lectures)
Module 2.4: Eigenvalues and eigenvectors – properties, problems, Cayley Hamilton theorem, Diagonalisation of different matrices (4 lectures)
Module 2.5: Complex matrices – Hermitian, Unitary matrices (1 lecture)

UNIT - III: TENSORS ANALYSIS
Module 1.1: Tensors in index notation, Kronecker tensors, inner and outer products (2 lectures)
Module 1.2: Contraction, symmetric, antisymmetric tensors, quotient law, metric tensors (2 lectures)
Module 1.3: Covariant and contravariant tensors, vectors, the tangent space, dual vectors, tensors products, the Levi-Civita tensor, tensors in Riemann spaces (2 lectures)
Module 1.4: Vector-fields, tensor-fields, transformation of tensors, gradient and Laplace operator in general coordinates , covariant derivatives and Christoffel connection (3 lectures)

UNIT-IV: COMPLEX VARIABLE
Module 4.1: Complex variable – function, limit, continuity, differentiability (2 lectures)
Module 4.2: Analyticity – Cauchy-Riemann equations in Cartesian ad polar forms problems (3 lectures)
Module 4.3: Orthogonal curves, Harmonic functions, conjugate functions, Miline-Thomson method (3 Lectures)
Module 4.4: Complex line integral – Cauchy integral theorem, Cauchy integral formula (2 Lectures)
Module 4.5: Singular Points- Cauchy's residue theorem - poles - evaluation of residues - evaluation of definite integrals (3 lectures)
Module 4.6: Taylor and Laurent expansions (1 Lecture)

UNIT-V: GROUP THEORY
Module 5.1: Definition – group multiplication table (1 Lectures)
Module 5.2: Subgroups - Cyclic groups and abelian groups - Homomorphism and isomorphism of groups (2 Lectures)
Module 5.3: Classes - Symmetry operations and symmetry elements (2 Lectures)
Module 5.4: Representations of groups - Reducible and irreducible representations – great orthogonality theorem (2 Lectures)
Module 5.5: Character tables for simple molecular types (C_{2v} and C_{3v} point group molecules) (3 Lectures)

BOOKS FOR STUDY:

1. H.K. Dass, Advanced Engineering Mathematics, S. Chand & Company, New Delhi, 21st revised Edition, 2013.

BOOKS FOR REFERENCE:

1. B.D. Gupta, Mathematical Physics, Vikas Publishing House Pvt. Ltd, 1995.
2. B.S.Rajput, Mathematical Physics, 20th Edition, Pragati Prakashan, 2008.
3. P.K. Chattopadhyay, Mathematical physics, Wiley Eastern Limited,1990.
4. Charlie Harper, Introduction to Mathematical physics, Prentice Hall of India Pvt.Ltd, 1993.
5. L.A. Pipes and L.R. Havevill, Applied Mathematics for Engineers and Physicists, McGraw Hill Publications Co., 3rd Edition, 1971.
6. Murray R. Spigel, Theory and Problems of Laplace Transforms, Schaum's outline series, McGraw Hill,1986.
7. A.W. Joshi, Matrices and Tensors in Physics, Wiley Eastern limited, 3rd Edition,1995.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K1)	H	H	L	M	H	H	L	L
CO2(K2)	H	H	L	H	H	H	L	L
CO3(K3)	H	H	L	M	H	H	L	L
CO4(K4)	H	H	L	L	H	H	L	L
CO5(K5)	H	H	L	L	H	H	L	L
CO6(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K1)	H	L	L	L	H	H	L	L
CO2(K2)	L	L	L	L	H	H	L	L
CO3(K3)	H	L	L	L	H	H	L	L
CO4(K4)	H	L	L	L	H	H	L	L
CO5(K5)	H	L	L	L	H	H	L	L
CO6(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 2: MATHEMATICAL PHYSICS – I (Tutorial)

L	T	P	C
-	1	-	1

a. Course Code:
PPHT12

b. Course Objectives

1. To learn theorems, concepts, procedures and transformations of linear algebra for deriving expressions in various courses of Physics
2. To know the properties of complex variables and to apply it in condensed matter physics
3. To construct the character table and to apply it in spectroscopy

c. Course outcome

CO1: Analyse the equipotential curves, lines, roots (K4)

CO2: Evaluate surface integral, eigenvalues and eigenvectors, contour integration (K5)

CO3: Construct character table of NH_3 (K6)

d. List of tutorials

1. Equipotential curves: Plot some isotherms and indicate directions of heat flow by arrows. When the temperature are equal.
2. Visualizing the divergence: Plot the given velocity filed v of a fluid flow in a square centered at origin.
3. Plotting surfaces: Plotting the surfaces of the given problems and experience the changes in the surfaces as the parametric changes.
4. Writing review on Geometrical meaning and Physical interpretation of gradient, divergence and curl.
5. Writing a program for evaluating surface integral to the given problems.
6. Experiments with Hilbert matrices: A n×n Hilbert matrix is $H_{jk}=[h_{jk}]$ and the elements are $h_{jk}=1/(h+k-1)$.
7. Eigen values and eigen vectors of the normal vibrational modes of H_2O.
8. Roots of unity and their plots.
9. Plotting functions.
10. Equipotential lines.
11. Integration through the programs in computers.
12. Contour integration.
13. Character table for NH_3.
14. Any other

REFERENCE BOOKS:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition (2005), John Wiley & Sons, Singapore

e. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	H	L	L	H	H	L	L
CO2(K5)	H	H	L	L	H	H	L	L
CO3(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	L	L	L	H	H	L	L
CO2(K5)	H	L	L	L	H	H	L	L
CO3(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 3: QUANTUM MECHANICS – I (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC13

b. Course Objectives

1. To learn operators, wave function normalization, expectation values, bra-ket notation, identical particles
2. To find solutions of the exactly solvable problems such as particle in a box, harmonic oscillator, hydrogen atom using Schrödinger equations and draw inference for the extension to other problems
3. To apply operators to angular momentum and their addition

c. Learning Progression:

In High secondary school, the details of mechanics have been introduced by curriculum and hence, the students' progress is known with little knowledge about mechanics from school to college level. The learning pathway is to make sense of basic concepts of quantum mechanics at undergraduate level and builds understanding of basic classical mechanics to quantum mechanical approach, it means from de Broglie to Schrodinger wave functions. The course prerequisites are, (a) Inadequacy of classical mechanics to explain for the experimental observations, (b) Wave-particle duality, de Broglie relation, uncertainty relation, Schrodinger equations, wave functions, (3) Linear vector space, matrices, special functions; Hermite and Legendre.

d. Theoretical Foundations

Heisenberg's Uncertainty Principle, De Broglie relation, Schrödinger equations

e. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: State the postulates of QM, Schrödinger equations, Pauli's exclusion principle, Uncertainty principle, operators, bra-ket notation, Pauli matrices, total and differential cross-sections, Born approximation

CO2: Describe wave function, degeneracy, expectation values, probability density, Hilbert space, orthogonal wave functions

CO3: Solve the exactly solvable problems such as particle in a box, harmonic oscillator, hydrogen atom, rigid rotator using Schrödinger equations and draw inference for the extension to other problems, solve scattering process

CO4: Infer quantum mechanical tunnelling, alpha emission, stationary states, bound states, phase shift,

CO5: Compare the harmonic oscillator in matrix theory, analytically and operator

CO6: Formulate a exactly solvable problems with a tweaking its assumptions

f. Course Outline:

UNIT – I: BASIC CONCEPTS AND WAVE MECHANICS FORMALISM (13 H)
Module 1.1 De Broglies' hypothesis;Principle of Linear superposition (2 h)
Module 1.2 Heisenberg uncertainty Principle, Probabilistic Interpretations(2h)
Module 1.3 Rutherford Planetary Model of the Atom; Bohr Model of the Hydrogen Atom,

Quantization Rules(2h)
Module 1.4 Localized Wave Packets, uncertainty Relations, Motion of Wave Packets (2 h)
Module 1.5 Hilbert space and Wave Functions, Dirac Notation, Operators (2h)
Module 1.6 Representation in discrete and continuous bases, matrix and Wave mechanics (3 h)

UNIT – II: EIGEN FUNCTIONS AND EIGEN VALUES (12 H)
Module 2.1 Postulates of Quantum Mechanics (2 h)
Module 2.2 Probability Density, Superposition,Observables (2 h)
Module 2.3 Measurement of Expectation values, commuting operators, Uncertainty Relations (3 h)
Module 2.4 Time evaluation of the System's state: Time – Independent potentials – Schrödinger equation, conservation of probability (3 h)
Module 2.5 Symmetries and conservations laws (2 h)

UNIT – III: ONE DIMENSIONAL SCHRÖDINGER EQUATION (13)
Module 3.1 One dimensional problem: Properties,Bound and unbound states (3 h)
Module 3.2 Symmetric potentials and parity (2 h)
Module 3.3 The Free particle - continuous state of engine values (3h)
Module 3.4 Potential step, barrier, well and tunneling effect; Infinite and finite square well potential(5 h)

UNIT - IV: MEASUREMENTS (12 H)
Module 4.1 Harmonic Oscillator – Energy Eigen values andEigen states (2h)
Module 4.2 Energy eigenstates in Position space (2 h)
Module 4.3 Matrix representation of various operators (2 h)
Module 4.4 Expectation values of various operators (2 h)
Module 4.5 Numerical Solution of the Schrödinger equations- Poisson Brackets and commentators- The Ehrenfest Theorem (4h)

UNIT - V: THREE-DIMENSIONAL SCHRÖDINGER EQUATION (10 H)
Module 5.1 3D problems in cartesian coordinates: Variables, Free particles, box potentials (3 h)
Module 5.2 3D problems in spherical coordinates: Central potentials, free particles, square well potentials (3 h)
Module 5.3 Measurements: isotropic harmonic oscillator, hydrogen atom (2 h)
Module 5.4 Effect of magnetic fields on central potentials (2h)

BOOKS FOR STUDY:

1. Nouredine Zettili, Quantum Mechanics, Concepts and Applications, Wiley, 2nd edition (February 24, 2009).

BOOKS FOR REFERENCES:

1. L.I. Schiff, Quantum Mechanics, Tata McGraw-Hill Edition 2010, Third Edition, New Delhi.
2. P. M. Mathews and Venkatesan, A Text book of Quantum Mechanics, Tata McGraw-Hill, New Delhi, 1976.
3. V. Devanathan, Quantum Mechanics, Narosa Publishing House Pvt. Ltd., 2005.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	M	M	L	L
CO2	L	H	M	M	M	M	L	L
CO3	L	L	H	M	H	M	L	L
CO4	L	L	H	M	H	M	L	L
CO5	L	L	L	L	H	M	L	L
CO6	L	L	L	L	L	M	H	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	H	L	M	L	M	M	L	L
CO2	H	L	L	L	M	M	L	L
CO3	M	M	L	H	M	M	L	L
CO4	L	M	L	L	H	M	L	L
CO5	M	L	L	L	M	M	L	L
CO6	M	L	L	L	M	H	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 3: QUANTUM MECHANICS – I (Tutorial)

L	T	P	C
-	1	-	1

a. **Course Code:**
NPHT13

b. **Course Objectives**
1. To apply the Schrödinger equations and the find solutions of the exactly solvable problems such as particle in a box, harmonic oscillator, hydrogen atom
2. To develop the knowledge on wave functions
3. To apply operators to angular momentum and their addition

c. **Learning Progression:**
In continuation of Quantum mechanics course, the students can develop their knowledge to the quantum mechanical problems independently.

d. **Course Outcomes (COs)**

At the end of the Course, the student will be able to

CO1: Demonstrate the angular momentum in terms of operators, notations and matrices. (K4)

CO2: Explain theoretical and experimental approach. (K2)

CO3: Construct solvable problems and design the measurable approximations. (K6)

e. **List of Tutorials:**

1. Representing spin states
2. Addressing the notation – Dirac, matrix notations
3. Angular momentum in quantum mechanics
4. Interplay between theoretical and experimental structures
5. The probability distribution of a glider in harmonic oscillation using pseudo-random picture method by computer and show the actual probability regions in theoretical curve.
6. Visualizing the phonon wave function- theoretical approach
7. Imagine a real and imaginary parts of a position-space wave function representing a free particle wave packet, along with the absolute value of $\mathbf{\Psi}$(x,t). As time progress, wave packets appear to be more wiggly in the leading edge of the wave then in the trailing edge. Why?

8. Photon Energy from a transition in an infinite square well potential. Wave function and position probability for a particle in an infinite square well potentials.
9. Energy levels for a particle in a finite and semi-finite square well potential.
10. Application of quantum mechanics to a macroscopic object.
11. Any others

BOOKS FOR REFERENCES:

1. Nouredine Zettili, Quantum Mechanics, Concepts and Applications, Wiley, 2nd edition (February 24, 2009).
2. L.I. Schiff, Quantum Mechanics, Tata McGraw-Hill Edition 2010, Third Edition, New Delhi.
3. P. M. Mathews and Venkatesan, A Text book of Quantum Mechanics, Tata McGraw-Hill, New Delhi, 1976.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	L	M	H	H	M	M	L	L
CO2(K2)	L	H	M	M	M	M	L	L
CO3(K6)	L	H	H	H	H	H	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	M	M	L	M	H	L	L
CO2(K2)	H	H	L	L	M	M	L	L
CO3(K6)	M	H	M	L	M	H	M	L

Core 4: ELECTRONICS (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC14

b. Course Objectives

1. To discuss the characteristics, operation and applications of LEDs, quantum dots and photodiodes and to describe the basic structure of BJT, operation, characteristics and phototransistor.

2. To analyze the operation common source FET amplifier ad to examine how MOSFET can be used in analog switching and to examine the basic structure, operation of SCR & UJT.

3. To describe and analyse the operation of summing amplifiers, integrator & Differentiators. To identify the function of Flip-Flop as a basic element of sequential logic system that are widely used in digital systems such as Registers & Counters.

4. To acquire knowledge for converting A/D and D/A signals required for many applications includes Control, Communication, Computer, Instrumentation etc. since many applications of Digital systems, the signals are not available in the digital form.

5. To demonstrate Pin configuration &Architecture of 8085microprocessors and 8051 Microcontroller and their working function.

c. Learning Progression (Course Prerequisites):
N-Type and P-Type Semiconductor, PN and Zener Diode operation, Rectifiers, Basic Digital circuits, Number systems & Codes, Digital Logic Families

At UG Level	At PG Level
Unit –I: **Linear Circuit Analysis**	Progression in this contents are not included due to CSIR NET syllabus is adopted.
Unit –II: **SEMICONDUCTOR DEVICES ANDDEVICES** PN Junction - V – I characteristics of PN Junction - Crystal diode as a rectifier - Zener diode - V – I characteristics of Zener diode - Tunnel diode. Half wave rectifier, centre- tap full wave rectifier -Full wave bridge rectifier - Comparison of Rectifiers - Zener diode as voltage stabilizer.	These are Prerequisites for studying Unit I **SEMICONDUCTOR DEVICES AND STRUCTURE**
UNIT - III: **TRANSISTOR AMPLIFIERS** Transistor action - Transistor connections - common emitter - common base -common collector -Analysis of amplifiers using h- parameters - RC coupled amplifier - transformer coupled amplifier - power amplifier - classification of power amplifiers (Class A, Class B and Class C) - Push pull amplifier.	Application based amplifier in Unit II **OPERATIONAL AMPLIFIER AND APPLICATIONS**

UNIT - IV: **OSCILLATIONS AND WAVE SHAPINGCIRCUITS** Feedback principle and Barkhauson criterion - Hartley, Colpitt's, and Phase shift oscillators using transistors – Astable - Monostable and Bistable multi vibrators using transistors - Schmitt trigger –clipping and clamping circuits – Differentiating circuit – Integrating circuit.	Prepared as per CSIR NET syllabus: UNIT-III: REGISTERS, COUNTERS UNIT-IV: A/D AND D/A CONVERTER UNIT-V: MICROPROCESSOR & MICROCONTROLLER
UNIT - V: **OPERATIONAL AMPLIFIER** Op-Amp -pin diagram- characteristics of ideal Op - Amp - DC and A.C analysis of Op-Amp - Bandwidth of an Op-Amp - Slew rate - Frequency response - Op- Amp with negative feedback – applications –Inverting amplifier – Input and output impedance of Inverting amplifier – Non inverting amplifier- Voltage followerSumming amplifier - Adder – Subtractor – Integrator – Differentiator – low pass, high pass and band pass filters.	

d. Theoretical Foundations

Solar cell, LED, Transistors, Amplifier, Voltage to Frequency conversion and Voltage to Time conversion, Architecture of Microprocessor & Microcontroller

e. Experimental Foundations

Analysis of IV characteristics of Solar cell characteristics, Analysis of IV characteristics of LED, SCR, UJT, OP-Amp Characteristics & applications, Square wave, Sine wave generation, A/D & D/A conversion, Programmes in Microprocessor & Microcontroller

f. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Identify the schematic symbol, working function, interpret data sheet, demonstrate applications in traffic lights and Displays of LED, and also demonstrate the process of electroluminescence and unique features of quantum dots.

CO2: Identify the schematic symbol, IC package terminals, uses of OP-Amp and acquire knowledge on conversion of current to voltage and vice versa.

CO3: Design clocked sequential circuits such as counters and registers using standard ICs for counting normal binary sequence and natural BCD for different modules.

CO4: Demonstrate the conversion process of A/D involves a sequence of process such as Sampling, Holding, Quantizing, and Encoding.

CO5: Compare the Architecture of Microprocessor 8085 & Microcontroller 8051 and its operational functions.

g. Course Outline:

UNIT-I: SEMICONDUCTOR DEVICES AND STRUCTURE

Module 1.1 Optical diodes: Solar cell structure and operation - LED – Quantum dot diode – Photo diode (Lecture 3 hour).

Module 1.2 Bipolar junction Transistor: Structure – operation – Characteristics & Parameters -Phototransistor (Lecture 3 hour).

Module 1.3 Field effect transistor: Characteristics & Parameters (Lecture 3 hour).

Module 1.4 MOSFET: Characteristics & Parameters (Lecture 3 hour).
Module 1.5 Four- layer diode - SCR– UJT (Lecture 3 hour).

UNIT-II: OPERATIONAL AMPLIFIER AND APPLICATIONS
Module 2.1 Operational Amplifier input modes and parameters (Lecture 2 hour).
Module 2.2 Comparators (Lecture 2 hour).
Module 2.3 Summing Amplifier (Lecture 2 hour).
Module 2.4 Integrators and Differentiators (Lecture 3 hour).
Module 2.5 Instrumentation amplifier (Lecture 3 hour).
Module 2.6 Converters: Constant current source–current to voltage converter – voltage to current converter (Lecture 3 hour).

UNIT-III: REGISTERS, COUNTERS
Module 3.1 Shift Registers: Serial I/O – Parallel I/O - Applications: Delay line (Lecture 3 hour).
Module 3.2 Ring counter: Sequence generator–Ripple counter–UP/Down counter (Lecture 3 hour).
Module 3.3 Synchronous counter (Lecture 3 hour).
Module 3.4 Synchronous sequential circuits (Lecture 3 hour).
Module 3.5 Asynchronous sequential circuits (Lecture 3 hour).

UNIT-IV: A/D AND D/A CONVERTER
Module 4.1 DAC: Weighted resistor method – R-2R Ladder method – Specifications for D/A converters (Lecture 5 hour).
Module 4.2 ADC: Quantization & Encoding – Parallel comparator (Flash) method – successive approximation, counting method (Lecture 5 hour).
Module 4.3 AD converter using Voltage to Frequency conversion and Voltage to Time conversion (Lecture 5 hour).

UNIT-V: MICROPROCESSOR & MICROCONTROLLER
Module 5.1 Memory interfacing, interfacing the 8155 – memory segment (Lecture 3 hour)
Module 5.2 Interfacing input, output displays – Memory - Mapped I/O (Lecture 3 hour)
Module 5.3 Pin configuration & Architecture of 8085 (Lecture 3 hour).
Module 5.4 8051Assembly language programming, structure of assembly language – Assembling and running an 8051program - Program counter and ROM space in 8051 (Lecture 3 hour).
Module 5.5 8051 Data types and directives –8051 flag bits and PSW register– 8051 Register Banks and Stack (Lecture 3 hour).

BOOKS FOR STUDY:

1. Thomas L. Floyd, Electronic Devices Conventional current version , Ninth Edition, 2017, Pearson Education, Inc. ISBN: 978-93-325-4549-6
2. R.P. Jain, Modern Digital Electronics –, 4th Edition, Tata McGraw Hill Education Pvt. Ltd. , 2010. ISBN: 978-0-07-066911-2.
3. Ramesh Gaonkar, Microprocessor Architechture, Programming and Applications with The 8085 Penram International Publishing (India) Provate Limited, Fifth edition, 2012
4. Muhammed Ali Mazidi, Janice Gillispie and Rolin D.McKinlay – The8051 Microcontroller and Embedded systems – Pearson Education,S econdEdition,2008

BOOKS FOR REFERENCE:

1. R.F. Coughlin and F.F, Driscol Op-Amp and linear integrated circuits, Prentice Hall of India, New Delhi,1996.
2. Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits, Pearson Education: Fourth

Edition, 2015.
3. Albert Malvino and David J Bates, Electronic Principles, 7th Edition, McGraw Hill, 2007.
4. V.K. Mehta, Principles of Electronics-, 6th Revised Edition, S. Chand and Company, 2001.
5. David A. Bell, Electronic Devices and Circuits, 4th Edition, Prentice Hall.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	H	L	H	L	L	H	L	H
CO2	H	L	H	L	L	H	L	H
CO3	H	L	H	L	L	M	L	H
CO4	H	L	H	L	L	M	L	H
CO5	H	L	H	L	L	L	L	H
CO6	H	L	H	L	L	L	L	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	H	H	L	H	L	M
CO2	L	L	H	H	L	H	L	M
CO3	L	L	H	M	L	M	L	M
CO4	L	L	H	M	L	M	L	M
CO5	L	L	H	H	L	L	L	M
CO6	L	L	H	H	L	L	L	M

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core4: ELECTRONICS (Practical)

L	T	P	C
-	-	2	1

a. Course Code:
PPHL14

b. Course Objectives
1. To analysis of IV characteristics of Solar cell, LED,SCR,UJT
2. To evaluate OP-Amp Characteristics & applications,
3. To generate square wave, Sine wave
4. To convert A/D & D/A signals,
5. To run simple programmes in Microprocessor &Microcontroller

c. Course Outcomes (COs)

At the end of the Course, the student will be able to-

CO1: Compare IV characteristics of Solar cell, LED, SCR, UJT

CO2: Design new circuits using OP amp for real time applications.

CO3: Write program for real time applications using Microprocessor &Microcontroller

d. List of Experiments:

a. Analysis of IV characteristics of Solar cell
b. Analysis of IV characteristics of LED
c. Analysis of IV characteristics of SCR
d. Analysis of IV characteristics of UJT
e. Construct OP-Amp circuits for studying characteristics & applications
f. Generate Square wave / Sine wave generation
g. Convert A/D & D/A circuits
h. Write assembly language Programmes in Microprocessor & Microcontroller
i. Any others

BOOKS FOR Experiments:

1. Thomas L. Floyd, Electronic Devices Conventional current version –Ninth Edition, 2017, Pearson Education, Inc.ISBN:978-93-325-4549-6
2. P.Jain, Modern Digital Electronics, 4th Edition, Tata McGraw Hill Education Pvt. Ltd., 2010. ISBN:978-0-07-066911-2.
3. Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications with the 8085 Penram International Publishing (India) Provate Limited, Fifth edition, 2012
4. Muhammed Ali Mazidi, Janice Gillispie and Rolin D. McKinlay – The 8051 Microcontroller and Embedded systems–Pearson Education, Second Edition, 2008

. **e. Mapping of COs to Pos & PSOs with correlation level and Cognitive level of COs**

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	L	H	L	L	M	L	H
CO2(K5)	H	L	H	L	L	L	L	H
CO2(K6)	H	L	H	L	L	L	L	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	L	L	H	M	L	M	L	M
CO2(K5)	L	L	H	H	L	H	L	M
CO2(K6)	L	L	H	H	L	H	L	M

(L–Low,M–Medium,H–High;K_1–Remember,K_2–Understand,K_3–Apply,K_4–Analyze,K_5–Evaluate,K_6–Create)

Group - I
ELECTIVE COURSES – Theory courses

Group – 1

(a) Physics of Semiconductor Devices
(b) Numerical Methods and Programming
(c) General Relativity and Cosmology

(a) PHYSICS OF SEMICONDUCTOR DEVICES

L	T	P	C
3	-	-	3

a. Course Code:
PPHEAA

b. Course Objectives

1. To learn the electronic materials and devices with the fundamentals of semiconductor devices

c. Course prerequisites:
Minimum familiar with calculus, algebra, differential equations, Prior knowledge of electronics

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Understand the device concept and performances of the semiconductor devices
CO2: Apply the physics knowledge's to study the characteristics of all major bipolar, field-effect, microwave, photonic and sensor devices
CO3: Explain the latest developments of new devices such as 3D, MOSFET, SET, Real time space transfer device.
CO4: Evaluate the future device performance and limitations.
CO5: Solve the theoretical problems to experimental measurement.

e. Course Outline:

UNIT – I: INTRODUCTION: PROPERTIES OF SEMICONDUCTORS (8 H)
Module 1.1 Crystal Structure, Energy Bands and Energy Gap (2 h)
Module 1.2 Carrier concentration and carrier transport phenomena (2 h)
Module 1.3 Phonon, optical and thermal properties (2h)
Module 1.4 Heterojunction and Nanostructures (2)

UNIT – II: DEVICE BUILDING BLOCKS (10 H)
Module 2.1 p-n Junction: Depletion region, I-V characteristics (2 hr)
Module 2.2 p-n Junction: Breakdown, Transient Behavior and Noise, Terminal Functions Heterojunction (2 h)
Module 2.3 Metal-Semiconductor Contacts: Formation of Barrier, Transport processes, device structure, ohmic contact (4)
Module 2.4 Capacitors: Ideal MIS and Silicon MOS capacitor (s) (2 h)

UNIT - III: TRANSISTORS: (9 H)
Module 3.1 Bipolar Transistors: Characteristics, Structures, Heterojunction (3 h)
Module 3.2 MOSFETs: Characteristics, Structures, circuit applications (3h)
Module 3.3 JFET, MESFET, MODFET (3 h)

UNIT – IV: NEGATIVE RESISTANCE AND POWER DEVICES (9 H)
Module 4.1 Tunnel Diode, Tunnel Devices (2h)
Module 4.2 IMPATT Diodes:Characteristics, power, efficiency, noise behaviour, Device design(3h)
Module 4.3 Transferred electron device and real space transfer devices (2 h)
Module 4.4 Thyristor characteristics and variations (2 h)

UNIT – V: DEVICES (9 H)

Module 5.1 LED and Lasers (3 h)
Module 5.2 Photodetectors and solar cell (3 h)
Module 5.3 Sensors (3h)

BOOKS FOR STUDY:

1. S. M. Sze, Physics if Semiconductor Devices Wiley, 3nd edition
2. David A Bell, Electronic Devices and Circuits, 4^{th} Edition, Prentice Hall

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H
CO5	L	L	H	L	H	M	M	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H
CO5	H	M	H	L	H	M	H	H

(b)NUMERICAL METHODS AND PROGRAMMING

L	T	P	C
3	-	-	3

a. Course Code:
PPHEAB

b. Course Objectives

1. To learn numerical methods to find roots of polynomial, simultaneous equations, integration, interpolation, ODE and PDE
2. To learn least squares methods to fit the data linear and non-linear equations
3. To write simple programs in Fortran with a few applications

c. Learning Progression:
Zeros of Polynomial, solutions of simultaneous equations, first and second order ordinary & partial differential equations and integral calculus

d. Course Outcomes (COs)
At the end of the Course, the student will be able to -

CO1: Recall the analytical methods to find zeros of polynomial and solutions of simultaneous and the differential equations

CO2: Explain the method of least squares, normal equations and curve fitting

CO3: Apply different numerical methods to find roots of polynomial and simultaneous equation and solution of differential equations

CO4: Analyse the poles complex integration, symmetry of molecules

CO5: Evaluate the eigenvalues of the matrices numerically

CO6: Compile a Fortran program for simple mathematical equation by employing numerical methods

e. Course Outline:

UNIT I: ROOTS OF POLYNOMIAL AND SOLUTION OFSIMULTANEOUS EQUATIONS

Module 1.1: Finding Roots of a Polynomial-Bisection Method-Newton Raphson Method-with desired order of convergence (4 lectures)

Module 1.2: Solution of Simultaneous Linear Equations – existence of solution, Gauss Elimination Method- Gauss-Jacobi method Solution (4 lectures)

UNIT II: CURVE FITTING AND INTERPOLATION

Module 2.1: Method of least squares – straight line, parabola, $y = ax^n$, $y = ae^{bx}$, $y = a+bx^n$ type of equationss – sum of squares of residuals for straight line and parabola fit –Weighted least squares approximation (5 lectures)

Module 2.2: Polynomial Interpolation – Lagrange polynomial – Newton polynomial, Forward and Backward differences – Gregory Newton forward and backward interpolation formula for equal intervals, Linear spline – Quadratic spline interpolation(5 lectures)

UNIT III: EIGEN VALUES AND NUMERICAL INTEGRATION

Module 3.1: Power method to find dominant Eigen value - Jacobi method (3 lectures)

Module 3.2: Newton – cotes formula – Trapezoidal rule, Simpson's rule, Simpson's 3/8 rule, Boole's rule – Error estimates in trapezoidal and Simpson's rule – Gauss quadrature- Adaptive quadrature – Romberg Integration (4 lectures)

UNIT IV: NUMERICAL SOLUTIONS TO ODE AND PDE

Module 4.1 Solution by Taylor's series – Picard's method for successive approximation - Basic Euler method – Runge Kutta fourth order method – RK4 method for simultaneous first order differential equation - RK4 Method for second order differential equation (5 lectures)

Module 4.2: Classification of partial differential equation of the 2nd order - Difference quotients – Graphical representations of partial quotients – standard and diagonal five-point formula for Laplace equations – solution of Laplace's equation (Liebman's iteration) – Parabolic equations – Bender Schmidt recurrence relation (5 lectures)

UNIT V: FORTRAN PROGRAMMING TO APPLICATIONS

Module 5.1: Algorithms - Flowcharts – Character Set - Constants - Variables – Subscripted variables – Operations - Input and output statements – File processing -Control statements (Do, If, Go to structures) - Function subprogram – Subroutine subprogram (5 lectures)

Module 5.2: Applications: Ascending, descending order, matrix manipulation, Root of an equation using Newton Raphson method - Matrix inversion using Gauss elimination – Straight line curve fitting – Newton's polynomial interpolation – Power method– Trapezoidal & Simpson's rule. (5 lectures)

BOOKS FOR STUDY:

1. John H. Matthews, Numerical methods for mathematics, science and engineering, Prentice Hall of India, 2nd Edition, 2000
2. S. S. Shastry, Introductory methods of numerical analysis, Prentice Hall of India,

3. Ram Kumar, Programming with Fortran 77, Tata Mc Graw Hill, 1994

BOOKS FOR REFERENCE:

1. J. B. Scarborough, Numerical Mathematical Analysis, Oxford Publishing, 6th Edition,1990
2. S. Chandra, M.K. Sharma, Computer Applications in Physics, Narosa, 3rd Edition, 2014

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K1)	H	H	L	M	H	H	L	L
CO2(K2)	H	H	L	H	H	H	L	L
CO3(K3)	H	H	L	M	H	H	L	L
CO4(K4)	H	H	L	L	H	H	L	L
CO5(K5)	H	H	L	L	H	H	L	L
CO6(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K1)	H	L	L	L	H	H	L	L
CO2(K2)	L	L	L	L	H	H	L	L
CO3(K3)	H	L	L	L	H	H	L	L
CO4(K4)	H	L	L	L	H	H	L	L
CO5(K5)	H	L	L	L	H	H	L	L
CO6(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

(c) GENERAL RELATIVITY AND COSMOLOGY

L	T	P	C
3	-	-	3

a. Course Code:

PPHEAC

b. Course Objectives

1. To learn relevant basics of Tensors and apply it to elasticity, general relativity and cosmology
2. To learn the models of Universe, its structure and dark matter

c. course prerequisites:

Algebra and conventions in Tensors, special relativity

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: State the postulates of QM, Schrödinger equations, Pauli's exclusion principle, Uncertainty principle, operators, bra-ket notation, Pauli matrices, total and differential cross-sections, Born approximation

CO2: Describe wave function, degeneracy, expectation values, probability density, Hilbert space, orthogonal wave functions

CO3: Solve the exactly solvable problems such as particle in a box, harmonic oscillator, hydrogen atom, rigid rotator using Schrödinger equations and draw inference for the extension to other problems, solve scattering process

CO4: Infer quantum mechanical tunnelling, alpha emission, stationary states, bound states, phase shift,

CO5: Compare the harmonic oscillator in matrix theory, analytically and operator

e. Course Outline:

UNIT-I: TENSORS PRELIMINARIES
Module 1.1: Tensors in index notation, Kronecker tensors, inner and outer products (2 lectures)
Module 1.2: Contraction, symmetric, antisymmetric tensors, quotient law, metric tensors (2 lectures)
Module 1.3: Covariant and contravariant tensors, vectors, the tangent space, dual vectors, tensors products, the Levi-Civita tensor, tensors in Riemann spaces (2 lectures)
Module 1.4: Vector-fields, tensor-fields, transformation of tensors, gradient and Laplace operator in general coordinates , covariant derivatives and Christoffel connection (3 lectures)

UNIT-II: GENERAL RELATIVITY
Module 2.1: Elasticity: Field tensor - field energy tensor - strain tensor - tensor of elasticity (3 lectures)
Module 2.2: Curvature tensor, the spacetime interval, the metric, Lorentz transformations , space time diagrams, world lines (2 lectures)
Module 2.3: Proper time, energy-momentum vector, energy-momentum tensor, perfect fluids, energy, momentum conservation , parallel transport ,the parallel propagator , geodesics, affine parameters (5 lectures)

UNIT-III: APPLICATIONS TO EINSTEIN'S THEORY
Module 3.1: The Riemann curvature tensor - symmetries of the Riemann tensor - the Bianchi identity - Ricci and Einstein tensors - Weyl tensor - Killing vectors (3 lectures)
Module 3.2: The Principle of Equivalence - gravitational redshift - gravitation as spacetime curvature - the Newtonian limit - physics in curved spacetime (3 lectures)
Module 3.3: Einstein's equations - the Weak Energy Condition - causality - spherical symmetry - the Schwarzschild metric – perihelion precession (3 lectures)

UNIT-IV: SOME MODELS OF THE UNIVERSE
Module 4.1: Expansion of the Universe - thermal history (3 lectures)
Module 4.2: The standard cosmological model – Friedmann - Robertson-Walker type models of the Universe (3 lectures)
Module 4.3: Primordial inflation and the theory of cosmological fluctuations (3 lectures)

UNIT-V: COSMOLOGY
Module 5.1: Theory and observations of the cosmic microwave background and of the large-scale structure of the Universe (3 lectures)
Module 5.2: Dark matter and dark energy - theoretical questions and observational evidence – inflation (3 lectures)
Module 5.3: Origin of galaxies and other open problems (3 lectures)

BOOKS FOR REFERENCE:

1. M. R. Spiegel, Vector Analysis, Schaum'a outline series, McGraw Hill, NewYork, (1974)
2. James Hartle, Gravity: An introduction to Einstein's general relativity, San Francisco, Addison-Wesley,(2002)

3. Sean Carroll, Space time and Geometry: An Introduction to General Relativity, (Addison-Wesley,(2004).
4. Jerzy Plebanski and Andrzej Krasinski, An Introduction to General Relativity and Cosmology, Cambridge University Press (2006)
5. J V. Narlikar, General relativity and cosmology, The Macmillan Company of India Ltd.,(1978)
6. Robert M Wald, General Relativity, Univ. of Chicago Press.(1984)
7. J. V. Narlikar, Introduction to Cosmology, Jones & Bartlett (1983)
8. Steven Weinberg, Gravitation and Cosmology, New York, Wiley, (1972).
9. Jerzy Plebanski and Andrzej Krasinski, An Introduction to General Relativity and Cosmology, Cambridge University Press (2006).

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H
CO5	L	L	H	L	H	M	M	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H
CO5	H	M	H	L	H	M	H	H

SKILL COURSES – Practical course

Group – 1 (First Semester)

(a) Matlab Programming

(b) Arudino - Applications

(a) MATLAB PROGRAMMING

L	T	P	C
-	-	2	1

a. **Course Code:**
PPHSAA

b. **Course objectives:**
1. To learn the matrix creation, shape changes, numeric types, formats, character and string by performing practicals
2. To write a simple programs with operators, m-file creation, simple programes and to import data for plotting

c. **Course prerequisites:**
Algebra of Matrices and definition of square matrices

d. **Course Outcome**

On the successful completion of the value added course, the learner will be able to

CO1: Perform the simple matrix operations and prgroms (K4)

CO2: Evaluate the numeric, logic types, characters and strings (K5)

CO3: Construct a m-file and plots (K6)

e. **Course outline(contact hours: 15)**

1. Create a matrices, concatenate and form block diagonal matrix
2. Apply different functions to transpose, rotate, flip matrics
3. Identify the numeric types, complex numbers and convert character string to numeric and numeric to string
4. Perform simple arithmetic, logical operations using operators
5. Write programs with loop controls; for, while, continue and break
6. Create a simple m-file for different operations of matrix
7. Import data, analyse and plotting and exporting

Book for Reference:

1. MATLAB programming: The Language of Technical Computing , The MathWorks (2005)

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	L	H	L	L	L	H	M
CO2(K5)	H	L	H	L	M	L	H	M
CO3(K6)	H	L	H	L	L	L	H	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	L	H	L	L	L	H	L
CO2(K5)	H	L	H	L	M	L	H	L
CO3(K6)	H	L	H	L	L	L	H	L

(b) ARDUINO - APPLICATIONS

L	T	P	C
-	-	2	1

a. **Course Code:**
PPHSAB

b. **Course objectives:**
1. To learn the basics of Arduino and its programming
2. To create different application Arduino circuits

c. **Course prerequisites:**
Basics of discrete components, LEDs and LCDs

d. **Course Outcome**

On the successful completion of the value added course, the learner will be able to

CO1: Use simple circuits in Arduino (K4)

CO2: Evaluate the working of application circuits (K5)

CO3: Create new circuit to simplify the process (K6)

e. **Course outline(contact hours: 15)**

1. Construct LED circuit with PUSH button switch.
2. Construct brightness controlled LED bar graph
3. Construct light and sound alarm by sensing moisture using analog sensor
4. Construct a piezoelectric buzzer
5. Construct a joystick-controlled laser pan-and-tilt
6. Construct LCD screen to display messages
7. Construct a weather monitoring station

Book for Reference:

1. Mark Geddes, ARDUINO project Handbook, No starch press, San Francisco (2016)

f. **Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs**

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	L	H	L	L	L	H	H
CO2(K5)	H	L	H	L	M	L	H	H
CO3(K6)	H	L	H	L	L	L	H	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	L	H	L	L	L	H	H
CO2(K5)	H	L	H	L	M	L	H	H
CO3(K6)	H	L	H	L	L	L	H	H

SECOND SEMESTER

Core 5: MATHEMATICAL PHYSICS – II (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC21

b. Course Objectives

1. To learn the methods to find the solutions of second order ordinary differential equations by the use of special functions and also partial differential equations
2. To learn the definitions and various distributions in probability
3. To learn the integral transforms and Greens functions

c. Learning Progression:

HSc Mathematics	HSc Mathematics	B.Sc. Allied Mathematics	B.Sc. Allied Mathematics
Vector algebra: resolution of vectors, position vectors, direction cosines and product of vectors; Matrices: matrices and their determinants	Application of vectors and determinants; Applications of vector algebra; Complex numbers, basic algebra, conjugate, polar and Euler forms;	Eigen values and eigen vectors, Cayley-Hamilton Theorem, simple problems	Grad, div, Curl, double, triple vector integration, Green's, Stoke's and Gauss divergence theorems (without proof) and simple problems M.Sc. Physics Mathematical Physics-I

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: State the Bessel, Legendre, Hermite, Laugurre, definitions in probability, simple formulae in Beta, Gamma functions, Laplace and Fourier transforms

CO2: Explain the solution to power series problems and Frobenius method

CO3: Apply different methods of finding solution to first and second order differential equations and apply inverse Laplace transform to find solutions initial and boundary conditions and Green's functions

CO4: Analyse the solutions obtained and also analyse the probabilities of events

CO5: Evaluate the solutions of ODE with variable coefficient by the use of special functions

CO6: Construct solutions to PDE

e. Course outline

UNIT-I: DIFFERENTIAL EQUATIONS

Module 1.1: First order differential equations – electrical circuits, vertical motion, heat conduction, chemical reaction (3 lectures)

Module 1.2: Linear equations of second order with constant coefficients, complete solution, complementary function, particular integral, general method for finding particular integrals, applications (4 lectures)

Module 1.3: Linear ordinary second order differential with variable coefficients and their solution by power series and Frobenius methods (3 lectures)

Module 1.4: Bessel differential equation, Bessel function, generating function, recurrence relation, orthogonality (3 lectures)

UNIT-II: SPECIAL FUNCTIONS – I

Module 2.1: Legendre's differential equation - Legendre polynomials, generating functions, recurrence relation, Rodrigue's formula, orthogonality (3 lectures)

Module 2.2: Hermite differential equation – generating functions, Hermite polynomials, recurrence relations, Rodrigue's formula, Orthogonality (3 lectures)

Module 2.3: Laguerre differential equations – generating functions, Laguerre polynomials, recurrence relation, Rodrigue's formula, Orthogonality (3 lectures)

Module 2.4: Gamma function and Beta functions (2 lectures)

UNIT-III: PROBABILITY AND PARTIAL DIFFERENTIAL EQUATIONS

Module 3.1: Probability – definitions, addition and multiplication law, conditional probability, Bayes theorem (3 lectures)

Module 3.2: Binomial distribution – mean, standard deviation, moments, central moments, recurrence formula (2 lectures)

Module 3.3: Poisson distribution – mean, standard deviation, recurrence formula (2 lectures)

Module 3.4: Normal distribution – mean, standard deviation, moments (2 lectures)

Module 3.5: Solution of Laplace Differential Equation - Two dimensional flow of heat in cartesian and cylindrical co-ordinates. Solution of heat flow equation in one dimension (3 lectures)

UNIT - IV: INTEGRAL TRANSFORMS

Module 4.1: Fourier sine, cosine and complex integrals, Fourier cosine and sine transforms, properties (3 lectures)

Module 4.2: Convolution, Parseval's identity (2 lecturers)

Module 4.3: Laplace transform – important formula, properties, first and second shifting (2 lectures)

Module 4.4: Laplace transform of derivatives and integrals (2 lectures)

Module 4.5: Inverse Laplace transform - first and second shifting, partial fractions (2 lectures)

Module 4.6: Inverse Laplace transform – derivatives and integrals, solution to differential equations (3 lectures)

UNIT - V: GREENS FUNCTION

Module 5.1: Green's function – properties, method of solution in one, two and three dimensions, Applications (4 lectures)

Module 5.2: Linear integral equations – Hilbert-Schmidt kernels (2 lectures)

Module 5.3: Fredholm alternative – Neumann series, applications (2 lectures)

BOOKS FOR STUDY:

1. Advanced Engineering Mathematics, H.K. Dass, S. Chand & Company, New Delhi, 21st revised Edition (2013)

BOOKS FOR REFERENCE:

1. Mathematical Physics, B.D. Gupta, Vikas Publishing House Pvt. Ltd,1995.
2. Mathematical Physics, B.S.Rajput, 20th Edition, Pragati Prakashan,2008.
3. Mathematical physics, P.K. Chattopadhyay, Wiley Eastern Limited,1990.
4. Introduction to Mathematical physics, Charlie Harper, Prentice Hall of India Pvt.Ltd, 1993.
5. Applied Mathematics for Engineers and Physicists, L.A. Pipes and L.R. Havevill, McGraw Hill Publications Co., 3rd Edition,1971.
6. Theory and Problems of Laplace Transforms, Murray R. Spigel, Schaum's outline series, McGraw Hill,1986.
7. Matrices and Tensors in Physics, A.W. Joshi, Wiley Eastern limited, 3rd Edition,1995.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K1)	H	H	L	M	H	H	L	L
CO2(K2)	H	H	L	H	H	H	L	L
CO3(K3)	H	H	L	M	H	H	L	L
CO4(K4)	H	H	L	L	H	H	L	L
CO5(K5)	H	H	L	L	H	H	L	L
CO6(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K1)	H	L	L	L	H	H	L	L
CO2(K2)	L	L	L	L	H	H	L	L
CO3(K3)	H	L	L	L	H	H	L	L
CO4(K4)	H	L	L	L	H	H	L	L
CO5(K5)	H	L	L	L	H	H	L	L
CO6(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 5: MATHEMATICAL PHYSICS – II (Tutorial)

a. Course Code:
PPHT21

b. Course Objectives
1. To learn theorems, concepts, procedures and transformations of linear algebra for deriving expressions in various courses of Physics
2. To know the properties of complex variables and to apply it in condensed matter physics
3. To construct the character table and to apply it in spectroscopy

c. Course outcome
CO1: Analyse the equipotential curves, lines (K4)

CO2: Evaluate surface integral, eigenvalues and eigenvectors, contour integration (K5)

CO3: Construct character table of NH_3 (K6)

d. List of tutorials

1. Linear dependence and independence of solutions of the ODE and Wronskian
2. Plotting direction fields (isoclines) by hand using lineal elements for an approximate solution of given differential equation
3. Prepare a brief write-up on initial value problems and boundary value problems with examples from physics
4. Modeling free, damped and forced oscillations; mass-spring and pendulum
5. Harmonic oscillations and Visualizing the divergence: Plot the given velocity filed v of a fluid flow in a square centered at origin. (1-p456)
6. Orthogonal polynomial: Sturm-Liouville problems
7. Laplace transform of unit step function and Dirac delta functions – problems
8. Fourier transform – Physical interpretation of spectrum
9. One dimensional wave equation – Fourier solutions to initial and boundary conditions; normal modes, eigenfunctions and eigenvalues
10. Random sampling – maximum likelihood method and confidence interval
11. Any other

REFERENCE BOOKS:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition (2005), John Wiley & Sons, Singapore

e. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	H	L	L	H	H	L	L
CO2(K5)	H	H	L	L	H	H	L	L
CO3(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	L	L	L	H	H	L	L
CO2(K5)	H	L	L	L	H	H	L	L
CO3(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 6: QUANTUM MECHANICS – II (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
NPHC22

b. Course Objectives

1. To learn about the approximation methods for time independent and time dependent perturbation theory.
2. To understand the kinematics of scattering process and partial wave analysis
3. To study the theory of relativistic quantum mechanics and field quantization
4. To study the quantum theory of atomic and molecular structures.

c. Learning Progression:
A learning progression in Understanding the basic quantum mechanics formalism is from de Broglie to Schrodinger wave functions in the first semester courses such as classical mechanics, quantum mechanics -1.

d. Theoretical Foundations

- Harmonic Oscillator, Schrödinger equations, Hamiltonian Perturbations, Operators

e. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Understand the modern aspects of quantum mechanics, difference between time dependent/independent perturbation theory, different approximations, and relativistic/non relativistic theory.
CO2: Use the matrix formulation / operators and study the first and second order degeneracy of Hydrogen and Helium molecule
CO3: Apply the approximation to find the different state of hydrogen atom.
CO4: explain the relativistic quantum mechanical equations, such as Klein-Gordon equation and Dirac equation
CO5: Knowledge of the basic concepts in quantum theory of atomic and molecular Structure and how these can be applied.
CO6: elucidate the formalism of relativistic quantum field theory.

f. Course Outline:

UNIT - I: ANGULAR MOMENTUM (12 H)
Module 1.1 General Formalism, Orbital, Matrix Representation, Geometrical representation (3 h)
Module 1.2 Spin Angular Momentum- Theory of spin- spin ½ andpauli matrices (2 h)
Module 1.3 Eigen functions of Orbital angular momentum, eigenfunctions& eigenvalues of L_z, L^2 (3 h)
Module 1.4 properties of Spherical Harmonics (2 h)
Module 1.5 properties of rotation operator (2h)

UNIT - II: IDENTICAL PARTICLES (13 H)
Module 2.1 Many particle systems: Schrödinger equation, interchange symmetry, systems of non-interacting particles (4h)
Module 2.2 Identical particles in classical and quantum mechanics, exchange degeneracy, summarization postulates, Constructing symmetric and antisymmetric functions (5 h)
Module 2.3 Pauli Exclusion Principle and explain with periodic table (3h)

UNIT III:APPROXIMATION METHODS: TIME-INDEPENDENT PERTURBATION THEORY (11 H)

Module 3.1 Non-degenerate, Degenerate (2 h)

Module 3.2 Spin-spin coupling, fine structure, anomalous Zeeman effect (3h)

Module 3.3 vibrational Method (2 h)

Module 3.4 Wentzel-Kramers-Brillouin method: bound state for potential well, tunnelling through a potential barrier (4 h)

UNIT - IV: APPROXIMATION METHODS: TIME-DEPENDENT PERTURBATION THEORY(13 H)

Module 4.1 Pictures of Quantum Mechanics: Schrodinger, Heisenberg, interaction (2 h)

Module 4.2 Time-dependent perturbation theory: transition probability with constant and harmonic perturbation (3 h)

Module 4.3 Adiabatic and sudden approximations (3 h)

Module 4.4 interaction with atoms with radiation: incident radiation, quantization, transition rates of absorption and emission, within the dipole approximation (3 h)

Module 4.5 Selection rule for electric dipole; spontaneous emission (2)

UNIT - V: SCATTERING THEORY (11 H)

Module 5.1 Scattering and cross section (1.5 h)

Module 5.2 Scattering amplitude of spinless particles (2.5 h)

Module 5.3 Born approximation (2 h)

Module 5.4 Partial wave analysis (2.5 h)

Module 5.5 Scattering of identical particles (2.5 h)

BOOKS FOR STUDY:

1. NouredineZettili, Quantum Mechanics, Concepts and Applications, Wiley, 2nd edition (February 24, 2009).
2. L.I. Schiff, Quantum Mechanics, Tata McGraw-Hill Edition 2010, Third Edition, New Delhi.

BOOKS FOR REFERENCES:

1. G. Aruldhas, Quantum Mechanics, Prentice Hall of india, New Delhi, 2002.
2. V. Devanathan, Angular momentum techniques in Quantum Mechanics, Kluwer academic publishers, Dordrecht/Boston/London, 1999.
3. P. M. Mathews and Venkatesan, A Text book of Quantum Mechanics, Tata McGraw-Hill, New Delhi, 1976.
4. J.L. Powell and B. Crasemann, Quantum Mechanics, Addison-Wesley Mass, 1998.
5. V. Devanathan, Quantum Mechanics, Narosa Publishing House Pvt.Ltd., 2005.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	H	L	M	L	M	M	L	L
CO2	L	L	H	L	H	M	L	L
CO3	L	H	L	L	M	M	L	L
CO4	L	H	L	L	L	H	L	L
CO5	L	L	L	H	L	M	L	L
CO6	L	L	L	M	L	M	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	H	H	L	L	M	M	L	L
CO2	L	H	L	L	M	M	L	L
CO3	L	H	L	L	L	M	L	m
CO4	L	M	L	L	L	M	L	L
CO5	L	M	L	M	M	M	L	M
CO6	L	M	L	L	L	M	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 6: Quantum Mechanics – II (Tutorial)

L	T	P	C
-	1	-	1

a. Course Code:

NPHT22

b. Course Objectives

1. To learn about the approximation methods for time independent and time dependent perturbation theory.
2. To understand the kinematics of scattering process and partial wave analysis

c. Learning Progression:

In continuation of Quantum mechanics courses, the students can construct the solvable quantum mechanical problems.

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: classify the time dependent and independent perturbation theories.
CO2: demonstrate the properties of delta functions.
CO3: Construct solvable problems and design the measurable approximations.

e. Course Outline:

1. Rotation matrices and the spherical harmonics
2. Calculation of the clebsch-gorden coefficients
3. Wigner-Eckart theorem for spherical tensor operators
4. Properties of delta function- one dimensional
5. Properties of delta function- three dimensional
6. Gradient in spherical coordinates
7. Laplacian in spherical coordinates
8. Angular momentum in spherical coordinates
9. Solving one dimensional SHO using computer programming
10. Use the Born approximation to discuss qualitatively the scattering by a crystal lattice of identical atoms
11. Show that the WKB approximation gives the correct energy eigenvalues for all states of the harmonic oscillator
12. Any other

BOOKS FOR REFERENCES:

1. NouredineZettili, Quantum Mechanics, Concepts and Applications, Wiley, 2nd edition (February 24, 2009).

2. L.I. Schiff, Quantum Mechanics, Tata McGraw-Hill Edition 2010, Third Edition, New Delhi.

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	H	H	M	M	L	L
CO2	L	H	M	M	M	M	L	L
CO3	L	H	H	H	H	H	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	H	M	M	L	M	H	L	L
CO2	H	H	L	L	M	M	L	L
CO3	M	H	M	L	M	H	M	L

Core 7: ELECTROMAGNETIC THEORY - (Theory)

L	T	P	C
4	-	-	4

a. Course Code:
PPHC23

b. Course Objectives

1. To calculate the electric and magnetic fields & their respective potentials of different charge and current geometries using special techniques
2. To study the growth and decay of current and voltage in direct and alternating circuits
3. To study electromagnetic induction and Maxwell field equations.

c. Learning Progression

HSc Physics	
Electrostatics: Coulomb's law, dipole, Electric field, potential, potential energy, Gauss law, capacitors Magnetostatics: Bar magnet, Biot-Savart law, Ampere law, Lorentz force law, torque, moving coil galvanometer Electromagnetic induction: Faraday's law, Lenz's law, Fleming's RH rule, motional emf, eddy current, self-induction, transformer Electromagnetic waves: Displacement current, Maxwell's equations, EM spectrum, absorption, emission	Direct electricity: ohm's law, Kirchoff rule, Joule's law, thermoelectric effects Alternating Current: resistive, inductive and capacitive circuits, RLC series circuit, power in ac circuits

d. Experimental and Theoretical Foundations of the course

Coulomb's law, Parallel plate capacitor, Faraday's experiment, Oersted's experiment, Poisson's equations, Maxwell field equations

e. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: State the relations among ρ, **E** & V and **J**, **B** & **A**, Maxwell's equations

CO2: Describe Faraday's experiment, Lorentz force, induced electric field, growth and decay characteristics of current and voltage in circuits

CO3: Apply the relations to get the desired fields from different geometries

CO4: Deduce the fields using special techniques originated due to sources of charge and current

CO5: Evaluate the fields at the boundaries of the medium

CO6: Formulate a new electrical energy storage configuration and new devices using the dielectrics and magnetic materials

f. Course Outline:

Unit – I DIELECTRIC AND MAGNETIC MATTERS (11 hours)
Module 1.1: Polarisation – Lorentz model, modern theory, auxillary field (2 lecture)
Module 1.2: Linear dielectric matter – fields and sources, parallel-plate capacitor, polarisation charge at simple interface, Classius-Mossoti relation (3 lectures)

Module 1.3: Energy of linear dielectric – origin of potential energy (1 lecture)
Module 1.4: Magnetization – spin, orbital and total magnetization, Lorentz model (1 lecture)
Module 1.5: Linear magnetic matter – field and sources, response to free current and fixed fields, potential theory (3 lectures)
Module 1.6: Energy of magnetic matter – total potential energy, linear magnet (1 lecture)

Unit – II ELECTROMAGNETIC FIELDS AND WAVES (13 hours)
Module 2.1: Symmetry in electromagnetism (1 lecture)
Module 2.2: Electromagnetic potentials, Coulomb, Lorentz gauges (2 lectures)
Module 2.3 Energy conservation, Poynting vector, linear momentum, center of energy, conservation of energy in simple matter (4 lectures)
Module 2.4: Wave equation, plane waves, transverse EM waves, phase velocity, monochromatic plane waves, intensity, linear, circular and elliptical polarization, Stoke's paramenter (4 lectures)
Module 2.5: wave packets, total energy, group velocity, spherical waves, TE and TM vector waves, charges particle motion in a plane wave (2 lectures)

Unit – III ELECTROMAGNETIC WAVES IN SIMPLE AND DISPERSIVE MEDIUM
Module 3.1: Plane waves and monochromatic plane waves in medium, Specular Reflection and Snell's law, Fresnel equations (4 lectures)
Module 3.2: Energy transport, polarization by reflection, TIR (2 lectures)
Module 3.3: Monochromatic plane waves in simple conductors, Frequency dispersion, energy in dispersive matter, transverse and longitudinal waves (4 lectures)
Module 3.4: Drude model of conducting matter, Lorentz model for dielectric matter (2 lectures)

Unit IV RETARDATION AND RADIATION
Module 4.1: Inhomogenous wave equations, Hertz vector, Fields of a point charge in uniform motion (3 lectures)
Module 4.2: Retardation, advanced and retarded waves (3 lectures)
Module 4.3: Radiation, birth of radiation, radiation field in time domain, Larmour formula (4 lectures)
Module 4.4: Dipole antenna, time domain and frequency domain (2 lectures)

Unit V RELATIVISTIC ELECTRODYNAMICS
Module 5.1: Relativity – particle and wave motion, invariant interval, (3 lectures)
Module 5.2: Four vectors – Velocity, acceleration, momentum and energy (3 lectures)
Module 5.3: Electromagnetic quantities – continuity equation, Lorentz gauge potential, field transformation laws, point charge in uniform motion, plane waves (4 lectures)
Module 5.4: Covariant electrodynamics – Lorentz tensor, Maxwell's equations (2 lectures)

BOOKS FOR STUDY:

1. Andrew Zangwill, Modern Electrodynamics, (2012), Cambridge University Press, New Delhi

BOOKS FOR REFERENCE:

1. R. Murugeshan, Electricity and Magnetism (2008) S. Chand & Co, New Delhi
2. BrijLal and Subramanyam, Electricity and Magnetism,(2005)
3. M.Narayanamurthy and N.Nagarathnam, Electricity & Magnetism, NPC pub., Revised edition.
4. K.K.Tiwari Electricity and Magnetism - (S. Chand &Co.)
5. D.Halliday, R.Resnick and J.Walker, Fundamentals of Physics – Electicity and Magnetism (2011), Wiley India,Pvt Ltd

g. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K1)	H	H	L	M	H	H	L	L
CO2(K2)	H	H	L	H	H	H	L	L
CO3(K3)	H	H	L	M	H	H	L	L
CO4(K4)	H	H	L	L	H	H	L	L
CO5(K5)	H	H	L	L	H	H	L	L
CO6(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K1)	H	L	L	L	H	H	L	L
CO2(K2)	L	L	L	L	H	H	L	L
CO3(K3)	H	L	L	L	H	H	L	L
CO4(K4)	H	L	L	L	H	H	L	L
CO5(K5)	H	L	L	L	H	H	L	L
CO6(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Core 4: ELECTROMAGNETIC THEORY - Tutorial

L	T	P	C
-	2	-	1

a. Course Code:

b. Course Objectives

1. To demonstrate the concepts learned in the theory and experience inferences learned in theory
2. To measure the physical quantities from the circuits and plot their variation

c. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Show Faraday's experiment, Oersted's experiment (K2)

CO2: Analyse the field patterns due to different source configurations (K4)

CO3: Measure various physical quantities in a circuits and their characteristic parameters (K5)

*Based on Bloom's Taxonomy (Refer Appendix 2) & it is suggestive

d. Course Outline:

List of Tutorial topics (Any Eight from the list)

1. Calculation of the electric field produced by a sphere of radius *R* with uniform polarization **P**.
2. Two spheres with radius *R* have uniform but equal and opposite charge densities $\pm\rho$. The centers of two spheres fail to coincide by an infinitesimal displacement vector $\boldsymbol{\delta}$. Show by direct superposition that the electric field produced by the spheres is identical to the electric field produced by a sphere with a suitably chosen uniform polarization **P**
3. A Dielectric Inclusion A dielectric body with permittivity in is embedded in an infinite volume of dielectric matter with permittivity out. The entire system is polarized by an external electric field **E**ext. If $\phi$is the exact electrostatic potential and *S* is the surface of the

embedded body, show that the dipole moment of the system can be written in the form $\boldsymbol{p} = (\varepsilon_{\rm out} - \varepsilon_{\rm in}) \int_{\boldsymbol{s}} \; ds\hat{n}\varphi(r_s)$.

4. Two Dielectric Interfaces. Two fixed-potential capacitors filled with equal amounts of two different types of simple dielectric matter. Use the stress tensor method to compare the force per unit area which acts on the two dielectric interfaces. Express your answer in terms of the electric field E_0 which would be present if the dielectric matter were absent.
5. A uniform external field B0 induces a uniform magnetization inside a simple magnetic sphere of radius a and permeability μand find its magnetic moment.
6. Prepare a brief note on electrical and magnetic shielding.
7. An infinitely large film of insulating magnetic material has permeability μ and thickness h. A uniformexternal magnetic field $\mathbf{B}_0$ is oriented perpendicular to the plane of the film. Find the magnetic field $\mathbf{B}$ at any point inside the film.
8. A cylindrical solenoid occupies the interval $-L/2 \leq z \leq L/2$, has radius R, and is wound tightly with N turns of a wire which carries current I . Use superposition and derive an expression for the magnetic field on the symmetry axis in the form $\mathbf{B}_0(z) = (\mu_0 NI/L)f(z)\,\hat{z}$. Compute the ratio $B_0(\pm L/2)/B_0(0)$ in the limit when $L >> R$.
9. The Poynting Vector Field**:** A point charge q sits at $(a, 0, 0)$, a point charge $-q$ sits at $(-a, 0, 0)$, and a uniform magnetic field $\mathbf{B} = B\hat{z}$ fills all of space. (a) Prove that the streamlines of the Poynting vector either close on themselves or begin and end at infinity. (b) Sketch several representative streamlines of the Poynting vector, including the one which passes through the origin of coordinates.
10. Faraday Rotation During Propagation. For propagation along the z-axis, a medium supports left circular polarization with index of refraction n_L and right circular polarization with index of refraction n_R. If a plane wave propagating through this medium has $\mathbf{E}(z = 0, t) = \hat{x}\, E \exp(-i\omega t)$, find the values of z where the wave is linearly polarized along the y-axis.
11. Invariance of the Scalar Product. Let $\boldsymbol{a} = (\mathbf{a}, a4)$ and $\boldsymbol{b} = (\mathbf{b}, b4)$ be two four-vectors. Show that the scalar product $\boldsymbol{a} \cdot \boldsymbol{b} = \mathbf{a} \cdot \mathbf{b} + a_4 b_4$ is a Lorentz invariant scalar. It will convenient to write $\mathbf{a} = \mathbf{a}_{\rm para} + \mathbf{a}_{\rm perp}$ and similarly for $\mathbf{b}$.
12. Any others.

e . Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	H	H	L	L	H	H	L	L
CO2(K5)	H	H	L	L	H	H	L	L
CO3(K6)	H	M	L	L	L	L	L	L

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	H	L	L	L	H	H	L	L
CO2(K5)	H	L	L	L	H	H	L	L
CO3(K6)	L	L	L	L	H	L	L	L

(L – Low, M – Medium, H – High; K_1 – Remember, K_2 – Understand, K_3 – Apply, K_4 – Analyze, K_5–Evaluate, K_6 – Create)

Group - II
ELECTIVE COURSES: Theory courses

(a) Quantum Field Theory
(b) Density Functional Theory
(c) Introductory Astronomy, Astrophysics & Cosmology

(a)QUANTUM FIELD THEORY (Theory)

L	T	P	C
3	-	-	3

a. Course Code:
PPHEBA

b. Course Objectives

1. To learn the canonical quantization approach to fields and to get exposure to path integral formalism
2. To learn relativistic Schrodinger equations for different spins
3. To learn the interaction between particles through annihilation, creation, and transmigration from one type to another.

c. Learning Progression:

Exactly solvable simple quantum mechanical systems; Particle in a box, Linear Harmonic Oscillator, Hydrogen atom and Rigid rotator. Lagrangian formulation (for particles, and importantly, also for fields), the Legendre transformation, special relativity, classical scattering and Poisson brackets learned in classical mechanics. Maxwell's equations, conservation laws, elm wave propagation, relativistic treatment, Maxwell's equations in terms of the four potential learned in electrodynamics.

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Recall the quantisation theories, K-G equation, various operators and three formalisms

CO2: Explain classical filed theory leading to QFT, negative energy, genral wave functions, phase peak amplitudes and Feynman postulates

CO3: Identify the various simplification of many body problems with reasonable conceptual assumptions, mathematical approximation in interactions

CO4: Analyse the results of different formalisms

e. Course Outline:

UNIT I: INTRODUCTION TO QFT

Module 1.1: First and Second quantization, comparison of three quantum theories, components of QFT (2 lectures)

Module 1.2: Natural units and dimension, hybrid units, unit conversion, notation (2 lectures)

Module 1.3: Plane waves in classical and quantum mechanics, classical particle theory and field theory, summary of classical mechanics (3 lectures)

Module 1.4: key concepts in field theory, Schrodinger and Heisenberg pictures and visualization, Poisson brackets and commutators, extrapolation to field theory (3 lectures)

UNIT-II: NON-INTERACTING FILEDS AND PARTICLES OF SPIN 0

Module 2.1: Spin 0 fields - Klein-Gordon equation and solution, probability density, negative energy (2 lectures)

Module 2.2: K-G equation in QFT, discrete and continuous plane wave equations, Commutation relations (3 lectures)

Module 2.3: Hamiltonian in QFT, number operators, zero-point energy, positive energy, expectation values (3 lectures)

Module 2.4: Creation and destruction operators, normalization factor for raising and lowering operator, normal ordering, four current operators and probability density in QFT (2 lectures)

UNIT-III: NON-INTERACTING FILEDS AND PARTICLES OF SPIN 1

Module 3.1: Review of classical electromagnetism, Maxwell's equation in 4D formulation, four vector potentials (3 lectures)

Module 3.2: First quantization and RQM for photons (1 lecture)

Module 3.3: Classical Electromagnetism to QFT, conjugate momentum and Hamiltonian density (2 lectures)

Module 3.4: QFT Hamiltonian for photons, photon propagator, Problem with Lorentz gauge, Gupta-Bleuler relaxation, weak Lorentz condition (3 lectures)

UNIT-IV: INTERACTIONS

Module 4.1: Maxwell's equations with sources, electromagnetic interaction in Lagrangian and quantum mechanics, Dirac equation (3 lectures)

Module 4.2: Interactions in QFT, interaction picture, third kind of picture, equations of motion in IP, benefits if IP and expectation value (3 lectures)

Module 4.3: S operator and S matrix, general states, finding S matrix from S operator, S operator from equation of motion, visualization of S operator (3 lectures)

UNIT-V: PATH INTEGRAL FORMALISM

Module 5.1: Functionals, it derivative and integral, kinds of integration with functional, general wave functions, deducing Feynman's phase peak amplitude, central idea, superimposing many paths graphically and mathematically and Feynman postulates, time and space slicing (6 lectures)

Module 5.2: Derivation of many path approach to QFT, time slicing in QFT (2 lectures)

BOOKS FOR STUDY:

1. Robert D. Klauber, Student Friendly Quantum Field Theory, Published by Sandtrove Press, Fairfield, Iowa (2013).

BOOKS FOR REFERENCE :

1. J D Bjorken and S Drell: Relativistic Quantum Mechanics
2. J D Bjorken and S Drell: Relativistic Quantum Field Theory
3. T P Cheng and L F Li : Gauge Theories of Elementary Particles

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H

(b)DENSITY FUNCTIONAL THEORY (Theory)

L	T	P	C
3	-	-	3

a. Course Code:
PPHEBB

b. Course Objectives

1. To learn the formalism for many electrons and foundations of density functional theory
2. To learn approximation leading to functionals
3. To familiarise with basis functions and potentials

c. Learning Progression:
Exactly solvable simple quantum mechanical systems; Particle in a box, Linear Harmonic Oscillator, Hydrogen atom and Rigid rotator

d. Course Outcomes (COs)
At the end of the Course, the student will be able to -

CO1: Recall the Born-approximation, Schrodinger equations, basis functions, Slater's rules, LD and GG approximations, KS equation, Euler-Lagrange equation

CO2: Explain matrix solutions of the time independent non-relativistic Schrodinger equation of many electrons, functionals

CO3: Identify the various simplification of many body problems with reasonable conceptual assumptions, mathematical approximation and implementation of it in computational

CO4: Analyse the total energy, Fermi surface, band gap, DOS, p-DOS

e. Course Outline:

UNIT - I: INTRODUCTION TO MANY ELECTRON PROBLEMS
Module 1.1: Hartree-Fock (HF) theory (2 lectures)
Module 1.2: Configuration Interaction (CI) – Fundamental concept – Variational theorem – Variational theorem for ground state – reducing the CI space – Determinant CI (7 lectures)

UNIT - II: FOUNDATIONS OF DFT
Module 2.1: The Thomas-Fermi model: precursor to modern DFT - Functional and functional derivatives, Euler Lagrange equation (3 lectures)
Module 2.2: Hohenberg-Kohn Theorem – degenerate ground state - N and υ representability of densities – Current Density Functional Theory (5 lectures)

UNIT III: KOHN-SHAM (KS) EQUATION
Module 3.1: Effective exact single particle method to the many body problem – Exchange and correlation energies – Interpretation of KS eigenvalues: Koopman's theorem, Ionization energy, Fermi surface, band gap(9 lectures)

UNIT IV: APPROXIMATIONS TO FUNCTIONALS
Module 4.1: Local approximation: local density approximation (LDA) – Semi-local approximation (3 lectures)
Module 4.2: Generalized gradient approximation (GGA) Non- local approximation (3lectures)

Module 4.3: hybrid functional – Self interaction Correction (3 lectures)

UNIT - V: INTRODUCTION TO TIME DEPENDENT DFT

Module 5.1: Runge-Gross Theorem - Time-Dependent Kohn- Sham Equations - Practical implementation of DFT methods- General scheme for solving Kohn-Sham - Full potential and pseudo potential methods (7 lectures)

Module 5.2: Basis functions: Gaussian, LAPW equation (2 lectures)

BOOKS FOR STUDY:

1. http://vergil.chemistry.gatech.edu/notes/ci.pdf (Unit I)
2. Density Functional Theory: An Advanced Course, Eberhard Engel and Reiner M. Dreizler, Springer-Verlag, 2011 Unit 2: chapter 2 and Unit 3: chapter 3 (relevant sections only) Unit 5: Chapter 7, Section 7.1, 7.2
3. http://www.lct.jussieu.fr/pagesperso/toulouse/enseignement/introduction_dft.pdf Unit 4: relevant sections

BOOKS FOR REFERENCE:

1. Computational Physics, J. M. Thijssen, Cambridge University Press, 1999
2. Introduction to Computational Chemistry, Frank Jensen, John Wiley and Sons, 2017 Computational Materials Science: An Introduction, Second Edition, June Gunn Lee, CRC Press, Taylor and Francis Group, 2017.

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f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H

(c)INTRODUCTORY ASTRONOMY, ASTROPHYSICS AND COSMOLOGY (Theory)

L	T	P	C
3	-	-	3

a. Course Code:
PPHEBC

b. Course Objectives

1. To develop analytical skills and the ability to understand the astronomical situation.
2. To achieve a good understanding of physical laws and principles.
3. To Gain experience with measurement techniques and equipment, and develop the ability to assess uncertainties and assumptions

c. Learning Progression:

Exactly solvable simple quantum mechanical systems; Particle in a box, Linear Harmonic Oscillator, Hydrogen atom and Rigid rotator

d. Course Outcomes (COs)

At the end of the Course, the student will be able to -

CO1: Recall the Kepler's laws, trigonometric parallax, inverse square law, Olber's paradox, Doppler effect, and Hubble's law

CO2: Explain curved space time, time dilation, bending of light, fusion reaction mechanism

CO3: Identify the types of the stars, stars, galaxies,

CO4: Analyse the CMBR, mass dependence of universe

e. Course Outline:

UNIT - I : HISTORY OF ASTRONOMY

Module 1.1: Introductory History of Astronomy – Ptolemy's Geocentric Universe – Copernicus' Heliocentric Universe - Tycho Brahe and Galileo's Observations (3 lectures)

Module 1.2: Kepler's Laws of Planetary Motion -Newtonian Concept of Gravity (3 lectures)

Module 1.3: Highlights of Einstein's Special and General Theory of Relativity - Curved Space Time - Evidence of Curved Space Time - Bending of Light – Time Dilation (3 lectures)

UNIT - II : STARS & GALAXIES

Module 2.1: Stars and Galaxies – Distances - Trigonometric Parallax - Inverse Square Law-Magnitude of Stars-Apparent Magnitude-Absolute Magnitude and Luminosity (3 lectures)

Module 2.2: Color and Temperature-Composition of Stars-Velocity, Mass and Sizes of Stars-Types of Stars (3 lectures)

Module 2.3: Temperature Dependence-Spectral Types-Hertz sprung- Russell (HR) Diagram-Spectroscopic Parallax (3 lectures)

UNIT - III : LIVES AND DEATH OF STARS

Module 3.1: Stellar Evolution - Mass Dependence - Giant Molecular Cloud - Protostar-Main Sequence Star - Subgiant, Red Giant, Supergiant-Core Fusion - Red Giant (Or) Supergiant - Planetary Nebula(Or) Supernova (3 lectures)

Module 3.2: White Dwarfs - Novae And Supernovae- Neutron Stars-Pulsars - Black Holes-Detecting Black Holes (3 lectures)

Module 3.3: The Sun- Its Size and Composition- Sun's Interior Zones – Sun's Surface-Photosphere – Chromosphere - Corona-Sun's Power Source- Fusion Reaction Mechanism (3 lectures)

UNIT - IV : COSMOLOGY I

Module 4.1: Introduction to Cosmology - Basic Observations and implications - Olber's Paradox - Expanding Universe-Gravitational Red shift - Doppler Effect-Hubble's Law and the Age of the Universe (4 lectures)

Module 4.2: Cosmological Principle -The Perfect Cosmological Principle- Observation and interpretation of Cosmic Microwave background Radiation (CMBR)- Evidence Supporting the General Big Bang Theory-Salient features of Steady State Theory (5 lectures).

UNIT – V : COSMOLOGY II

Module 5.1: Fate of the Universe - Dependence on Mass (Curvature of Space) - Critical density (3 lectures)

Module 5.2: Open Universe - Closed Universe - Homogenous and Isotropic Freidman-Robertson - Walker Universes - Deriving the Geometry of the Universe from the Background Radiation (3 lectures)

Module 5.3: Flatness Problem - Horizon Problem - Inflation and its effect on the universe-The Cosmological Constant (3 lectures)

BOOKS FOR REFERENCE:

1. Lectures on Astronomy, Astrophysics, And Cosmology-Luis A.Anchordoqu-
2. Lecture Notes of Department of Physics, University of Wisconsin-Milwaukee
3. Astrophysics of the Solar System -K.D.Abhayankar
4. An Introduction to Planetary Physics - Kaula.W.M.
5. Astrophysics of the Sun - HaroldZirin.

f. apping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H

Group - I
VALUE-ADDED COURSES – Theory course

Group – 1 (Second Semester)

(a) Powder x-ray diffraction analysis and Rietveld refinement
(b) NMR spectral Analysis
(c) Raman spectral analysis

(a) POWDER X-RAY DIFFRACTION ANALYSIS AND RIETVELD REFINEMENT

L	T	P	C
2	-	-	2

a. **Course Code:**
PPHVBA

b. Course objectives:

1. To learn the powder diffraction essentials and various factors contributions to inorganic samples to x-ray diffraction peaks
2. To learn unit cell parameters, structure, size and strain determination from diffraction pattern and elucidation of structural parameters from the Rietveld refinement

c. Course prerequisites:
Production and properties of x-rays, lattice, basis, crystal structure, Bravis lattice

d. Course Outcome

On the successful completion of the value added course, the learner will be able to

CO1: Understand the Bragg's law and factors contributing to the line profile of the diffracted XRD patterns (K4)

CO2: Evaluate crystal system from XRD patterns, lattice parameters, crystallite size, strain (K5)

CO3: Construct input file and carry out the Rietveld refinement on any powder XRD data (K6)

e. Course outline(contact hours: 30)

Module 1: Lattice and crystal systems, lattice planes and directions, planes of zone and interplanar spacing (4 Lectures)

Module 2: Diffraction from crystals, scattering by unit cell (3 lectures)

Module 3: X-ray diffractometer essentials, estimation of x-ray diffraction intensity from a polycrystalline sample, factors-structure, polarization, multiplicity, Lorentz, absorption, temperature and formula for diffracted intensity (5 lectures)

Module 4: Crystal structure determination – cubic, tetragonal and hexagonal systems and Hanawalt method (3 lectures)

Module 5: Determination of lattice parameter of polycrystalline sample, quantitative analysis of powder mixtures, determination crystal size and lattice strain (4 lectures)

Module 6: Packages Unit cell, Treor, Dicvol, (2 lectures)

Module 7: Rietveld refinement package FULLPROF suite and JANA2020

BOOK FOR REFERENCE:

1. Yoshio Waseda, Eiichiro Matsubara and Kozo Shinoda, X-ray Diffraction and Crystallography, Springer Heidelberg (2011)

2. Crystallographic softwares www.iucr.org
3. Rietveld refinement FULLPROF suite www.ill.eu
4. Rietveld refinement JANA2020 www.jana.fzu.cz

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K4)	L	M	L	H	L	M	M	L
CO2(K5)	L	H	M	L	L	M	M	M
CO3(K6)	L	M	H	L	L	L	M	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K4)	L	L	M	L	H	M	M	L
CO2(K5)	L	H	H	L	L	M	H	M
CO3(K6)	L	L	H	L	L	L	H	H

(b) NMR SPECTRAL ANALYSIS

L	T	P	C
2	-	-	2

a. Course Code:
PPHVBB

b. Course objective:
1. To learn the basics of NMR spectroscopy and analysis of 1D and 2D NMR spectra.

c. Couse prerequisites:
Basic knowledge of Quantum mechanics, Mathematics, Chemistry, and computer programming.

d. Course outcome
On the successful completion of NMR spectral analysis (value added certificate course), the learner will be able to

CO1 understand the concepts of new techniques, such as NMR

CO2 analysis and interpret the NMR spectra

CO3 Design the new problem and solve using NMR technique

CO4 Simulate the 1D NMR spectra using open-source software

CO5 Enhance the skill levels in the field of analysis NMR spectra

e. Course outline(contact hours: 30)

Module 1: Introducing NMR: Basic elements of NMR, sensitivity, relaxation, quantification (2 h)

Module 2: Theory: Angular Momentum, Energy level diagram, spin-spincoupling, magnetic and chemical equivalence (2 h)

Module 3: Operator Algebra, Chemical shift, Anisotropy of chemical shifts (2 h)

Module 4:	Instrumental aspects: principle, shimming, resolution, Free induction decay, Fourier Transform, resolution and hardware. (2 h)
Module 5:	1D methods: optimising 1D data, decoupling, interactions shift (3h)
Module 6:	Analysis of 1D NMR spectra (4 h)
Module 7:	2 D Methods: Homonuclear correlation spectroscopy (COSY, etc), Total correlation spectroscopy, 13C-13C correlations (3h)
Module 8:	Analysis of 2D NMR spectra (4 h)
Module 9:	2D Methods: Heteronuclear correlation spectroscopy (HSQC, HMQC, HSQC)(3 h)
Module 10:	Computer simulation: NMR spectra simulation using open-source software. (5h)

BOOK FOR REFERENCE:

1. M.H. Levitt, Spin dynamics: Basics of Nuclear Magnetic Resonance, 2nd edition, John Wiley & Sons Ltd, 2008.
2. Harald Günther, NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry, 3rd Edition, 2013
3. Open-source analysis software: DMFit, Edit NMR: https://nmr.cemhti.cnrs-orleans.fr/Dmfit/Default.asp

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	L	M	L	H	L	M	M	L
CO2	L	H	M	L	L	M	M	M
CO3	L	M	H	L	L	L	M	M
CO4	L	L	H	L	H	L	M	H
CO5	L	L	H	L	H	M	M	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1	L	L	M	L	H	M	M	L
CO2	L	H	H	L	L	M	H	M
CO3	L	L	H	L	L	L	H	H
CO4	L	L	H	L	M	L	H	H
CO5	H	M	H	L	H	M	H	H

(c) Raman Spectral Analysis

L	T	P	C
2	-	-	2

a. **Course Code:**
PPHVBC

b. Course objectives:

1. To learn the Raman scattering powder diffraction essentials and various factors contributions to inorganic samples to x-ray diffraction peaks
2. To learn unit cell parameters, structure, size and strain determination from diffraction pattern and elucidation of structural parameters from the Rietveld refinement

c. Course prerequisites:

Basics of group theory, normal coordinates and normal modes (theory of small oscillations), anharmonic oscillator, selection rules

d. Course Outcome

On the successful completion of the value added course, the learner will be able to

CO1: Explain the Stoke's and anti-Stoke's lines, polarisation, mode assignment (K2)

CO2: Analyse the effect of temperature, pressure, size, composition on the Raman spectra (K5)

CO3: Construct character table of NH_3 (K6)

e. Course outline(contact hours: 30)

Module 1: Classical theory of Raman scattering, quantum theory, normal vibrations in molecules, polarisation in molecules (5 Lectures)

Module 2: Normal vibrations in crystals, optical and acoustic branchs, factor group and site group analysis, polarisation in crystals (5 Lectures)

Module 3: Instrumentation, excitation sources, sample illumination, monochromators and detectors, FT Raman, Spectral fitting (5 Lectures)

Module 4: Raman spectral analysis of nanomaterials (3 lectures)

Module 5: Analysis of temperature-dependent Raman spectra (2 lectures)

Module 6: Analysis of Pressure-dependent Raman spectra (3 lectures)

Module 7: Analysis of Raman spectra of biological systems (4 lectures)

Module 8: Raman microscopy and in-situ measurements (3 lectures)

BOOK FOR REFERENCE:

1. John R. Ferraro, Kazuo Nakamoto and Chris Brown, Introductory Raman Spectroscopy, Second Edition, Elsevier (2003)

f. Mapping of COs to POs & PSOs with correlation level and Cognitive level of COs

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1(K2)	L	M	L	H	L	M	M	L
CO2(K5)	L	H	M	L	L	M	M	M
CO3(K6)	L	M	H	L	L	L	M	M

CO\PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8
CO1(K2)	L	L	M	L	H	M	M	L
CO2(K5)	L	H	H	L	L	M	H	M
CO3(K6)	L	L	H	L	L	L	H	H

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