CALICUT UNIVERSITY – FOUR-YEAR UNDER GRADUATE PROGRAMME (CU-FYUGP)

BSc APPLIED PHYSICS HONOURS

Programme	**B.Sc. Applied Physics Honours**				
Course Title	**ELECTRODYNAMICS I**				
Type of Course	**Core in Major**				
Semester	**IV**				
Academic Level	**200 – 299**				
Course Details	Credit	Lecture per week	Tutorial per week	Practical per week	Total Hours
	4	3	-	2	75
Pre-requisites	A strong foundation in mathematics, including algebra, trigonometry, and calculus. Additionally, a basic understanding of physics concepts such as electricity, magnetism, and mechanics would be beneficial for grasping the principles covered in the course.				
Course Summary	The course provides a foundational exploration of electromagnetism, encompassing topics like electric fields, magnetic fields and electromagnetic induction. Through simplified explanations, illustrative examples, and conceptual exercises, students gain insight into the behavior and interactions of electric and magnetic fields, preparing them for more advanced studies in physics or related fields at the undergraduate level.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Apply vector analysis techniques to solve problems in electromagnetics	Application	Conceptual Understanding	Problem-solving assignments, quizzes

CO2	Analyze and calculate electric fields and potentials for various charge distributions	Analysis	Procedural Knowledge	Homework assignments, exams, simulation exercises
CO3	Investigate the behavior of magnetic fields and solve problems involving magnetostatics	Evaluation	Conceptual Understanding	Laboratory reports, group projects, exams
CO4	Utilize electrical measurement instruments to quantify electric and magnetic phenomena	Application	Procedural Knowledge	Laboratory experiments, instrument operation tests, practical assessments
CO5	Demonstrate an understanding of Maxwell's equations and their implications in electromagnetism	Comprehension	Conceptual Understanding	Concept maps, oral presentations, written exams
CO6	Apply theoretical knowledge to analyze and design simple electromagnetic systems	Synthesis	Procedural Knowledge	Design projects, case studies, final projects
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	**Unit**	**Content**	**Hrs (45 +30)**	**Marks (70)**
I		**VECTOR ANALYSIS**	**12**	**20**
	1	Vector Algebra	2	
	2	Differential Calculus	4	
	3	Integral Calculus	4	
	4	Curvilinear Coordinates	2	
		Sections 1.1.1 – 1.1.4, 1.2.1 – 1.2.7, 1.3.1 – 1.3.6, 1.4.1 – 1.4.2 of chapter 1 of Book 1		
II		**ELECTROSTATICS**	**15**	**20**
	5	The Electric Field	3	
	6	Divergence and Curl of Electrostatic Field	4	

	7	Electric Potential; Electrostatic Boundary Conditions	4	
	8	Work and Energy in Electrostatics	2	
	9	Conductors	2	
	Sections 2.1.1 – 2.1.4, 2.2.1, 2.2.3, 2.2.4, 2.3.1 – 2.3.5, 2.4.1 – 2.4.4, 2.5.1 – 2.5.4 of chapter 2 of Book 1 (section 2.2.2 is excluded)			
III		**MAGNETOSTATICS**	**9**	**15**
	10	The Lorentz Force Law	2	
	11	The Biot – Savart Law	2	
	12	The Divergence and Curl of B (up to the derivation of Eqn. 5.50); Ampere's Law	2	
	13	Magnetic Vector Potential; Magnetostatic Boundary Conditions	3	
	Sections 5.1.1 – 5.1.3, 5.2.1, 5.2.2, 5.3.1 – 5.3.4, 5.4.1, 5.4.2 of chapter 5 of Book 1			
IV		**ELECTRICAL MEASUREMENTS**	**9**	**15**
	14	Kirchoff's laws and Wheatstone's Bridge	1	
	15	Carey Foster Bridge	1	
	16	Potentiometer	1	
	17	Network Analysis: Superposition Theorem	1	
	18	Thevenin's Theorem, Norton's theorem	1	
	19.	Maximum power transfer theorem	1	
	20	Maxwell's Loop Current Method	1	
	21	Torque on a Current loop in a Unifor, Magnetic field	1	
	22	Moving Coil Ballistic Galvanometer	1	
	Sections 6.6 – 6.8, 6.12 – 6.17 of chapter 6, and sections 10.10, 10.11 of chapter 10 of Book 2			
V		**PRACTICALS**	**30**	
	Conduct any 6 experiments from the given list (two from experiment 1-4 and four from 5-16) and 1 additional experiment, decided by the teacher-in-charge, related to the content of the course. The 7th experiment may also be selected from the given list. Other experiments listed here may be used as demonstrations of the concepts taught in the course.			
	1	**Plotting of the 2D functions using Python** ● Plot the 2D function in Problem 1.12 of Book 1 and find the maximum value and the location of maxima from the plot.		

		• Simulations of section 1.2 of Book 3 can be referred.		
	2	**Mapping of 2D vector fields using Python** • Map the vector fields in Example 1.4 and 1.5 of Book 1. • Map $\frac{\hat{r}}{r}$ and $\frac{\hat{r}}{r^2}$ • Simulations of section 3.1 of Book 3 can be referred.		
	3	**Mapping of electric and magnetic field lines using Python** • Plot the field of an electric charge, dipole and magnetic dipole. • Simulations of section 4.1, 4.2 and Appendix D of Book 3 can be referred.		
	4	**Simulation of particle trajectory under Lorentz force law using Python** • Simulate the trajectory of charged particle moving under Lorentz force law. • Problem 5.66 of Book 1 and Chapter 6 of Book 3 can be referred		
	5	**Mapping of the magnetic field lines of a bar magnet.** • Fix a paper on a drawing board kept on a table and place the bar magnet at the center along the magnetic meridian. • Using a small compass needle, map the magnetic field lines of the magnet placed with (a) north pole pointing south and (b) north pole pointing north. • Mark the null points (where the horizontal component of Earth's magnetic field, Bh cancels the field due to magnet) along the axial/equatorial line and measure the distance, 2d, between them. • Calculate the moment of the magnet. (a) $m = \frac{4\pi}{\mu_0}\frac{(d^2-l^2)^2}{2d}B_h$ (b) $m = \frac{4\pi}{\mu_0}(d^2+l^2)^{3/2}B_h$		
	6	**Study the variation of the magnetic field strength of a bar magnet using a smartphone magnetometer.** • Using a smartphone magnetometer, measure the strength of the magnetic field of a bar magnet, along the axial and equatorial lines and plot the data. • Magnetometer in the Phyphox app may be used to get the data after locating the approximate position of the magnetometer sensor. https://phyphox.org/wiki/index.php?title=Sensor:_Magnetic_field • Fit the theoretical formulae to the data and obtain magnetic dipole moment. Along the axial line $B = \frac{\mu_0}{4\pi}\frac{2md}{(d^2-l^2)^2}$ and along the equatorial line $B = \frac{\mu_0}{4\pi}\frac{m}{(d^2+l^2)^{3/2}}$		

	7	**Determine the moment of a bar magnet and Bh using a deflection magnetometer and a box type vibration magnetometer.** ● Determine m/Bh using deflection magnetometer in Tan A position and mBh using box type vibration magnetometer. Hence calculate the moment of the magnet and Bh. ● If the same magnet was used, compare the dipole moment with that of experiment 2 and 3.		
	8	**Circular coil- Verification of Biot Savart's law and determination of Bh.** ● Move a compass through a platform along the axis of the coil carrying a study current. Note the deflection of the needle and plot magnetic flux density ($B = B_h tan\theta$) as a function of distance. ● Optional: Smartphone magnetometer may be used to measure the strength of the magnetic field along the axial line and plot the data. https://phyphox.org/experiment/magnetic-field/ ● By varying current and (or) distance of the compass box along the axial line of the coil, note the deflection and hence determine the value of Bh.		
	9	**Reduction factor of TG using potentiometer.** ● Standardize the given potentiometer using a Danial cell or any other constant voltage source and use the standardized potentiometer to find the current through the TG. ● By observing the deflection in the TG for different currents, calculate the reduction factor. ● From the magnetic field at the center of a circular coil, deduce the value Bh.		
	10	**Verification of Kirchoff's laws / Superposition theorem.** ● Verify Kirchoff's current law at a junction where a minimum of three branches meet. ● Verify Kirchoff's current law for a network with two loops. **OR** ● Verify the superposition theorem for a network with two sources, S1 and S2. ● First set particular voltage values in S1 and S2 and note down the ammeter reading. ● Set the same voltage in S1 and short circuit S2 and vise versa, note down the ammeter readings and verify the superposition theorem.		
	11	**Verification of Thevenin's theorem and maximum power transfer theorem** **Thevenin's theorem** ● Measure the current through the load resistance of the network. ● Estimate the values of R_{TH} and V_{TH}, construct the Thevenin's equivalent circuit and measure the current through load		

		resistance and compare the two results with the theoretical values. **Maximum power transfer theorem** ● Measure the current through load resistance and estimate the power. Plot $R_L - P$ graph and find the R_L corresponding to the maximum power. ● Calculate the % of error with the theoretical value.		
	12	**Determination of resistivity of a thin wire using Carey-Foster's Bridge** ● Find the resistance per unit length of the bridge wire. ● Determine resistance of the thin wire using the bridge, thickness of the wire using screw gauge and hence determine the resistivity.		
	13	**Calibrate the ammeter using potentiometer** ● Standardize the potentiometer using a Danial cell or any other standard voltage source. ● Determine the current for at least 8 trials and draw the calibration graph.		
	14	**Conversion of Galvanometer to voltmeter and calibration using potentiometer** ● Determine the value of high resistance required to connect in series with the galvanometer so as it can read 0.1V or 0.2V per scale division. ● Standardize the potentiometer using a Danial cell or any other standard voltage source. ● Determine the voltage for at least 6 trials and draw the calibration graph.		
	15	**BG-Determination of the figure of merits for current** ● Determine the figure of merits for current of the given ballistic galvanometer. ● Measure a small current using BG and verify with ammeter.		
	16	**BG-Comparison of capacitance- Desauty's method** ● Compare the capacitance of two given capacitors by forming De-Sauty bridge.		

Book for Reference:

1. Introduction to Electrodynamics (5th Edn.) by David J Griffiths, Cambridge University Press (Book 1)
2. Electricity and Magnetism (10 Edn.) by R Murugeshan, S. Chand and Company (Book 2)
3. Electrodynamics Tutorials with Python Simulations by Taejoon Kouh, Minjoon Kouh -CRC Press 1st Edition (Book 3)
4. Electricity and Magnetism, Berkeley Physics Course Vol.2, by E M Purcell, Mc Graw Hill Edn.
5. Electricity and Magnetism, by D C Pandey, Arihand Prakashan Series
6. Classical Electromagnetism by H C Verma, Bharathi Bhavan Publishers and Distributers

7. The Feynman Lectures on Physics, Vol-2, Pearson Education India

8. NPTEL lectures on Electrodynamics/ Classical Electrodynamics https://archive.nptel.ac.in/courses/115/105/115105132/

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO 4	PSO 5	PS O6	PO 1	PO2	PO 3	PO 4	PO 5	P O6	PO 7
CO 1	2	1	3	2	3	0	2	3	3	2	3	2	0
CO 2	1	3	2	3	3	0	2	3	3	2	3	2	0
CO 3	3	2	3	1	3	0	3	3	3	2	3	2	0
CO 4	1	3	2	3	2	1	2	3	3	2	3	2	0
CO 5	2	2	3	1	3	0	3	3	3	2	3	2	0
CO 6	3	1	3	3	3	0	3	3	3	2	3	2	0

Correlation Levels:

Level	Correlation
0	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Quiz / Discussion / Seminar
- Internal Theory / Practical Exam
- Assignments / Viva
- End Semester Exam (70%)

Mapping of COs to Assessment Rubrics

	Internal Theory / Practical Exam	Assignment / Viva	Practical Skill Evaluation	End Semester Examinations
CO 1	✓	✓		✓
CO 2	✓	✓		✓
CO 3	✓	✓		✓
CO 4	✓	✓		✓
CO 5	✓	✓		✓
CO 6		✓	✓	

CALICUT UNIVERSITY – FOUR-YEAR UNDER GRADUATE PROGRAMME (CU-FYUGP)

BSc APPLIED PHYSICS HONOURS

Programme	**B.Sc. Applied Physics Honours**				
Course Title	**MECHANICS -II**				
Type of Course	**Core in Major**				
Semester	**IV**				
Academic Level	**200 – 299**				
Course Details	Credit	Lecture per week	Tutorial per week	Practical per week	Total Hours
	4	3	-	2	75
Pre-requisites	PHY3CJ201: Mechanics -I				
Course Summary	This course explores Newton's Laws of Motion and how they can be applied to solve different mechanical systems.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Explain the principles of central force motion and derive key results related to Kepler's laws and planetary motion.	U	C	Instructor-created exams / Quiz
CO2	Apply Newton's laws and the work-energy theorem to solve problems involving rotational and oscillatory motion.	Ap	P	Instructor-created exams / Home Assignments
CO3	Analyze the dynamics of damped and forced harmonic oscillators.	An	C,P	Instructor-created exams / Home Assignments
CO4	Analyze travelling and standing waves and the transport of energy in wave motion.	An	C	Instructor-created exams / Home Assignments
CO5	Evaluate effects of accelerated and rotating frames, including fictitious forces.	E	C,P	Seminar Presentation / Group Tutorial Work

CO6	Design and perform experiments and computational simulations related to mechanics, using smartphone-based sensors and Python tools.	Ap	P	Practical Assignment / Observation of Practical Skills / Viva Voce
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F), Conceptual Knowledge (C), Procedural Knowledge (P), Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Marks (70)
I	**CENTRAL FORCE MOTION: THE KEPLER PROBLEM**		**14**	**20**
	1	Kepler's Laws	1	
	2	Central Forces	2	
	3	The Equation of Motion	2	
	4	Energy and the Effective Potential Energy	2	
	5	Solving the Radial Equation of Motion	1	
	6	The Equation of the Obit	2	
	7	The Equation of an Ellipse	2	
	8	Kepler's Laws Revisited	2	
	Sections 10.1 – 10.9 of chapter 10 of Book 1			
II	**HARMONIC MOTION**		**13**	**20**
	9	Springs and Pendulums	1	
	10	Solving the Differential Equation – Undamped Harmonic Oscillator	2	
	11	Damped Harmonic Oscillator – Underdamped, Overdamped and Critically Damped Oscillators	4	
	12	The Forced Harmonic Oscillator – Forced Undamped and Forced Damped Oscillators	4	
	13	The Q Factor	1	
	14	Resonance in Electrical Circuits	1	
	Sections 11.1 – 11.4 of chapter 11 of Book 1			

III		**WAVES**	**8**	**14**
	15	A Wave in a Stretched String	1	
	16	Direct Solution of the Wave Equation	1	
	17	Fourier Series	1	
	18	Standing Waves and Traveling Waves	2	
	19	Standing Waves as a Special Case of Traveling Waves	1	
	20	Energy and Energy Flow	2	
		Sections 13.1 – 13.6 of chapter 13 of Book 1		
IV		**ACCELERATED REFERENCE FRAMES**	**10**	**16**
	21	A Linearly Accelerating Reference Frame	1	
	22	A Rotating Coordinate Frame	1	
	23	Fictitious Forces	2	
	24	Centrifugal Force and the Plumb Bob	1	
	25	The Coriolis Force – A Falling Body and A Projectile	3	
	26	The Foucault Pendulum	2	
		Sections 15.1 – 15.6 of chapter 15 of Book 1		
V		**PRACTICALS**	**30**	
		Conduct any 6 experiments from the given list and 1 additional experiment, decided by the teacher-in-charge, related to the content of the course. The 7th experiment may also be selected from the given list. ● The necessary theory of the experiments can be given as an Assignment/ Seminar. ● Calculate the percentage error and standard deviation in each experiment. ● Plot the graphs using Python. ● Smartphones are exclusively intended for educational lab use. Necessary care should be taken to safeguard them during the experiments. ● Smartphone experiments primarily serve demonstration purposes, with result accuracy contingent upon the precision of phone sensors and experimental setups.		
	1	**Flywheel- Determination of the Moment of Inertia.** ● This experiment aims to help students grasp the concept of energy conservation and the dynamics of rotation. ● Do at least 9 trials for different masses and number of turns wound on the axil.		

	2	**Torsion Pendulum- Determination of the Moment of Inertia and Rigidity Modulus.** ● Using identical masses on the disc, determine the moment of inertia of the disc. ● Verify the moment of inertia by direct method, $I = \frac{1}{2}MR^2$ ● Using I, calculate rigidity modulus of the material of the wire, $n = \frac{8\pi I}{r^4}\frac{L}{T^2}$		
	3	**Compound Pendulum- Acceleration Due to Gravity and Moment of Inertia and Verification of Parallel Axis Theorem.** ● Plot a graph of distance of knife edge from one end Vs period of oscillations. Using the measurement from the graph, calculate g. ● Calculate the radius of gyration and hence the moment of inertia about CM. Compare the result obtained by the direct calculation $I_{CM} = \frac{ML^2}{12}$ ● Measure the period of oscillation about an arbitrary pivot point which is at a distance d from the CM. Calculate $I_{pivot} = mgd\frac{T^2}{4\pi^2}$. ● Verify the result using parallel axes theorem, $I_{pivot} = I_{CM} + md^2$		
	4	**Kater's Pendulum- Determination of Earth's Gravity.** ● To determine g for both the cases (a) T1 ≈ T2 and (b) T1 ≠ T2 and discuss the relative merits of both cases by estimation of error in the two cases.		
	5	**Melde's String - Determination of the Frequency of the Turing Fork** ● Determine the frequency of electrically maintained tuning fork by means of Melde's apparatus in longitudinal and transverse mode of vibration. ● Verify $\lambda^2 - T$ law.		
	6	**Sonometer - Determine the Frequency of AC.** ● Estimate the linear mass density of the wire. ● Draw $L^2 - m$ graph and from the slope calculate the frequency.		
	7	**Fourier Analysis of the Modes of Vibration in a Stretched String.** ● Record the sound produced by guitar string (or similar arrangement) using a microphone and analyze the spectrum by taking Fast Fourier Transform (FFT). ● Audio Spectrum in the Pyphox, Audacity, ExpEYES or any other tools can be used to record the sound and get the FFT. ● Vary the length and tension of the string and analyze the harmonics. ● https://phyphox.org/experiment/audio-spectrum/		

		● https://www.youtube.com/watch?v=bl7jf2myEvM ● https://expeyes.in/experiments/sound/beats.html		
	8	**Determination of the Velocity of Sound in Air.** ● Sound wave of known frequency is generated using a wave generator(WG) and piezo buzzer and are recorded using a microphone(MIC). ● Phase differences between the WG and MIC waveforms were analyzed in a CRO and the distance between them were adjusted to make both of them in phase and hence calculate velocity of sound. ● Phase difference can be analyzed from the Lissajous figure obtained by X-Y plotting of WG and MIC waves. ● ExpEYES may be used. ● https://expeyes.in/experiments/sound/velocity.html ● https://expeyes.in/experiments/electrical/xyplot.html		
	9	**Transformation of Energy from One Form to Another.** ● Roll a hollow cylinder from a height, in an inclined plane, without pushing. ● Measure radius of the cylinder and record the velocity of the cylinder using the gyroscope of the phone inserted into the cylinder. ● Calculate the total energy before the cylinder starts to roll (Potential Energy, mgh) ● Calculate the total energy (Translational KE + Rotational KE) when the cylinder reaches the bottom of the plane. ● Estimate the energy lost as heat and sound. Repeat the experiment for different heights. ● Experiment 23 for Book 2 ● https://phyphox.org/experiment/roll/#more-509		
	10	**Pendulum- Limits on Angular Displacement and Study of Damped Oscillations.** ● Estimate limits on angular displacement for SHM by measuring the time period at different angular displacements and compare it with the expected value of time period for SHM. Example 12.1 of Book 1. ● Study damped oscillations. Plot amplitude as a function of time and determine the damping coefficient and Q factor. ● Digitized data can be used for the study. ● https://www.youtube.com/watch?v=jcpvm95bhXw ● https://expeyes.in/experiments/school-level/sr04.html ● https://phyphox.org/experiment/pendulum/		
	11	Realize the computational Projects in chapters 10, 11, 12, 13, 15 of Book 1 or any other related projects using Python		

Books and References:

1. Intermediate Dynamics (Edn.2) by Patrick Hamill (Book 1)

2. Smartphones as Mobile Minilabs in Physics(Edn. 1) by Jochen Kuhn & Patrik Vogt, Springer, (Book 2)
3. An Introduction to Mechanics by Daniel Kleppner and Robert J. Kolenkow
4. Mechanics by Keith R. Symon
5. Mechanics: Berkeley Physics Course, Volume 1 by Charles Kittel, Walter D. Knight and Malvin A. Ruderman
6. Mechanics: From Newton's Laws to Deterministic Chaos by Florian Scheck
7. NPTEL video lectures: https://nptel.ac.in/courses/115106090

Mapping of COs with PSOs and POs :

	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	0	2	0	0	0	2	0	0	0	0	0	0
CO 2	2	2	2	0	0	0	2	2	0	0	0	0	0
CO 3	0	2	2	0	0	0	0	2	0	0	0	0	0
CO 4	0	2	2	2	0	0	0	2	2	0	0	0	0
CO 5	0	0	2	0	0	0	0	0	2	0	0	0	0
CO 6	0	2	2	2	0	2	0	2	2	0	0	0	0

Correlation Levels:

Level	Correlation
0	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Quiz / Discussion / Seminar
- Internal Theory / Practical Exam
- Assignments / Viva
- End Semester Exam (70%)

Mapping of COs to Assessment Rubrics

	Internal Theory / Practical Exam	Assignment / Viva	Practical Skill Evaluation	End Semester Examinations
CO 1	✓	✓		✓
CO 2	✓	✓		✓
CO 3	✓	✓		✓
CO 4	✓	✓		✓
CO 5	✓	✓		✓
CO 6		✓	✓	

CALICUT UNIVERSITY – FOUR-YEAR UNDER GRADUATE PROGRAMME (CU-FYUGP)

BSc APPLIED PHYSICS HONOURS

<table>
<tr><td>Programme</td><td colspan="5">B.Sc. Applied Physics Honours</td></tr>
<tr><td>Course Title</td><td colspan="5">MODERN PHYSICS</td></tr>
<tr><td>Type of Course</td><td colspan="5">Core in Major</td></tr>
<tr><td>Semester</td><td colspan="5">IV</td></tr>
<tr><td>Academic Level</td><td colspan="5">200 – 299</td></tr>
<tr><td rowspan="2">Course Details</td><td>Credit</td><td>Lecture per week</td><td>Tutorial per week</td><td>Practical per week</td><td>Total Hours</td></tr>
<tr><td>4</td><td>3</td><td>-</td><td>2</td><td>75</td></tr>
<tr><td>Pre-requisites</td><td colspan="5">Foundation in classical mechanics and electromagnetism. Additionally, students should have a solid understanding of calculus and differential equations to effectively engage with the mathematical concepts presented in the course.</td></tr>
<tr><td>Course Summary</td><td colspan="5">The course integrates key principles of modern physics, including the Special Theory of Relativity, wave-particle duality, and the Bohr Atom Model, to provide students with a comprehensive understanding of fundamental concepts and their applications in diverse scientific fields. Through theoretical discussions and experimental investigations, students develop critical thinking skills and the ability to analyse complex physical phenomena at both macroscopic and microscopic levels.</td></tr>
</table>

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the principles of the Special Theory of Relativity	Comprehension	Conceptual	Written exams, quizzes

CO2	Explain the dual nature of particles and waves	Comprehension	Conceptual	Problem sets, essays
CO3	Apply relativistic principles to solve problems	Application	Procedural	Problem-solving exams, simulations
CO4	Analyse experimental evidence supporting wave-particle duality	Analysis	Conceptual	Laboratory reports, case studies
CO5	Compare and contrast classical and quantum mechanical models	Analysis	Conceptual	Research papers, presentations
CO6	Critically evaluate the limitations of the Bohr atom model	Evaluation	Conceptual	Research projects, discussions
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	**Unit**	**Content**	**Hrs (45 +30)**	**Marks (70)**
I		**THE SPECIAL THEORY OF RELATIVITY**	**16**	**22**
	1	Classical Relativity	1	
	2	The Michelson – Morley Experiment	1	
	3	Einstein's Postulates and Its Consequences– Relativity of Time, Relativity of Length, Relativistic Velocity Addition, Relativistic Doppler Effect	4	
	4	The Lorentz Transformation and Derivations of Relativistic Effects from Lorentz Transformations – Length Contraction, Velocity Transformation, Time Dilation, Simultaneity and Clock Synchronization	3	
	5	The Twin Paradox	1	
	6	Relativistic Dynamics – Relativistic Momentum	1	
	7	Relativistic Kinetic Energy, Total Energy and Rest Energy	2	
	8	Conservation Laws in Relativistic Decays and Collisions	2	

	9	Experimental Tests of Special Relativity	1	
	Sections 2.1 – 2.9 of chapter 2 of Book 1			
II		**THE PARTICLE – LIKE PROPERTIES OF ELECTROMAGNETIC RADIATION**	**10**	**16**
	10	Review of Electromagnetic Waves, Interference and Diffraction, Crystal Diffraction of X-Rays	2	
	11	The Photoelectric Effect	2	
	12	Thermal Radiation	2	
	13	The Compton Effect	2	
	14	Other Photon processes	1	
	15	Particles or Waves	1	
	Sections 3.1 – 3.6 of chapter 3 of Book 1.			
III		**THE WAVE – LIKE PROPERTIES OF PARTICLES**	**10**	**16**
	16	De Broglie's Hypothesis	1	
	17	Experimental Evidences for De Broglie waves	3	
	18	Uncertainty Relationships for Classical waves	1	
	19	Heisenberg Uncertainty Relationships	2	
	20	Wave Packets and the Motion of a Wave Packet	2	
	21	Probability and Randomness, and the Probability Amplitude	1	
	Sections 4.1 – 4.7 of chapter 4 of Book 1			
IV		**THE RUTHERFORD – BOHR MODEL OF THE ATOM**	**9**	**16**
	22	Basic Properties of Atoms – Scattering Experiments and the Thomson Model – The Rutherford Nuclear Atom – Rutherford Scattering Formula and Its Experimental Verification – The Closest Approach of a Projectile to the Nucleus	2	
	23	Line Spectra	1	
	24	The Bohr Model	3	
	25	The Franck – Hertz Experiment	1	
	26	The Correspondence Principle	1	
	27	The Failure of the Bohr Model	1	
	Sections 5.1 – 5.8 of chapter 5 of Book1. Excluded: sections 5.2.1, 5.3.1, derivation of Rutherford scattering formula			

V	**PRACTICALS**		**30**	
	Conduct any 6 experiments from the given list and 1 additional experiment, decided by the teacher-in-charge, related to the content of the course. The 7th experiment may also be selected from the given list. Other experiments listed here may be used as demonstrations of the concepts taught in the course.			
	1	**Determination of Plank's constant using LEDs** • Observe the turn-on voltage, V_0 of LEDs and calculate the value of h. Use at least 4 different colors of LED (with transparent casing) • Plot $\frac{1}{\lambda} - V_0$ graph using Python, fit a straight line to get the slope and estimate the value of h. • Calculate the %error. • Programmable voltage source of ExpEYES may be used to find the turn-on voltage.		
	2	**Continuous and line spectra- Determination of the wavelengths and photon energy.** • Familiarize the initial adjustments and measurements in the spectrometer. • Mount the grating at normal incidence on the spectrometer. • Determine the wavelengths of the sodium vapor lamp and calculate the associated photon energy. • Determine the approximate range of the wavelengths of the continuous spectrum of incandescent/white LED lamp or any one coloured LED and calculate the associated photon energy. • The readings of the first order spectrum will be enough. Number of lines/m of the grating can be given.		
	3	**Mercury spectrum- Determination of wavelength and photon energy.** • Determine wavelength of any four prominent lines and associated photon energy of the mercury spectrum using a spectrometer with grating at normal incidence. • The readings of the first order spectrum will be enough. Number of lines/m of the grating may be given.		
	4	**Hydrogen spectrum - Determination of wavelengths and calculation of the Rydberg's constant.** • Determine the wavelengths and photon energy in eV of the prominent lines of the Balmer series of the Hydrogen spectrum using a spectrometer with grating at normal incidence. • Calculate the Rydberg's constant and estimate the % error.		

		• The readings of the first order spectrum will be enough. Number of lines/m of the grating may be given.		
	5	**Thomson's e/m experiment - Determination of the specific charge of the electron.** • Measure the ratio of the electron charge-to-mass ratio (e/m) by studying the electron trajectories in a uniform magnetic field.		
	6	**Wave Packets - Analysis of beats in sound.** • The experiment is intended to understand the concept of wave packet, phase and group velocities. • Generate sounds waves of two near frequencies using smartphone/ExpEYES/Function generator and the superimposed wave can be recorded and analysed using smartphone/ExpEYES/CRO • Change the separation between the frequencies and compare the results with the theoretical values. • https://expeyes.in/experiments/sound/beats.html • Multi Tone generator and Audio scope tools of Phyphox may be used https://phyphox.org/experiment/tone-generator/		
	7	**Analysis of Hydrogen spectra using the Tracker Video Analysis tool**. • Calibrate the video of the Hydrogen spectra in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot the intensity profile, find the prominent wavelengths of the Balmer series and calculate the Rydberg's constant. • Estimate the %error. • Pre recorded video of the Hydrogen spectra can be used. • https://physlets.org/tracker/. • https://www.youtube.com/watch?v=UCCPkJpUQEw		
	8	**Black body spectrum of Sun -Estimation of surface temperature using the Tracker Video Analysis tool.** • Calibrate the video of the solar spectra in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot wavelength vs intensity, get λ_{max} and using Wein's law calculate the surface temperature. • Pre recorded video of the solar spectra can be used.		
	9	**Verification of Wein's displacement law and Stefan's law using incandescent bulb.** • Calibrate the video of the spectra of the incandescent bulb in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot wavelength vs intensity and note λ_{max} . • Repeat the experiment by increasing the operating voltage of the incandescent bulb(hence increasing the temperature of the source)		

		• From the plots, verify the Wein's displacement law and Stefan's law.		
	10	**Black body radiation- total energy output.** • Plot Planck's radiation formula. • Evaluate the area under the curve and x- axis(total radiance over all wavelengths) by numerical integration and hence verify Stephan's law		

Books and References:

1. Modern Physics (Fourth Edition, an Indian Adaptation) by Kenneth S. Krane (Book 1)
2. https://phyphox.org/
3. https://physlets.org/tracker/
4. https://expeyes.in/
5. Modern Physics for Scientists and Engineers by John Morrison
6. Concepts Of Modern Physics By Arthur Beiser
7. Modern Physics by Raymond A. Serway
8. Modern physics by Randy Harris

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO 3	PSO 4	PSO 5	PSO 6	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	0	0	0	0	0	2	0	0	0	0	0	0
CO 2	0	3	2	0	0	0	0	2	0	0	0	0	0
CO 3	0	0	3	2	0	0	0	0	2	0	0	0	0
CO 4	0	0	0	3	2	0	0	0	0	2	0	0	0
CO 5	0	0	0	0	3	2	0	0	0	0	2	0	0
CO 6	0	0	0	0	0	3	0	0	0	0	0	2	0

Correlation Levels:

Level	Correlation
0	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Quiz / Discussion / Seminar
- Internal Theory / Practical Exam
- Assignments / Viva
- End Semester Exam (70%)

Mapping of COs to Assessment Rubrics:

	Internal Theory / Practical Exam	Assignment / Viva	Practical Skill Evaluation	End Semester Examinations
CO 1	✓	✓		✓
CO 2	✓	✓		✓
CO 3	✓	✓		✓
CO 4	✓	✓		✓
CO 5	✓	✓		✓
CO 6		✓	✓	