ZIAUDDIN UNIVERSITY
EXAMINATION BOARD

HSSC A
Physics Syllabus

For exams in 2026 & onwards

INTRODUCTION TO ZUEB

The Ziauddin University Examination Board (ZUEB) is not only an awarding body but also a solution-driven educational organization dedicated to upholding the highest standards of academic excellence. ZUEB believes in excellence, integrity, and innovation in education. Established with a vision to foster a robust educational environment, ZUEB is committed to nurturing intellectual growth and development that meets international standards in an effective manner. The Ziauddin University Examination Board (ZUEB) was established through the Government Gazette No. XLI on June 6th, 2018. Its purpose is to ensure high quality, maintain global standards, and align the syllabi with national integrity within Pakistan's examination system. ZUEB manages student appeals, regulates assessments, and reviews policies to maintain high standards.

WHY CHOOSE HSSC-A AT ZUEB?

Ziauddin University Examination Board (ZUEB) offers the HSSC-A (Higher Secondary School Certificate Advance) program, designed for students from international educational backgrounds. This program provides a structured, affordable, and academically strong pathway for learners to align with Pakistan's education system. It allows students to fulfil national curriculum requirements, including Urdu, Islamiyat, Pakistan Studies, or Sindhi, with academic integrity and flexible learning options. ZUEB believes no student should be left behind due to financial limitations or cross-system transitions, and HSSC-A serves as a bridge between past efforts and future ambitions. It is the trusted choice for higher education in Pakistan

HSSC-ADVANCE PHYSICS

HSSC–Advance Physics at ZUEB is a foundation for exploring the laws of nature and the principles that govern matter, energy, and motion, designed for students aspiring to pursue higher education in engineering, medicine, computer science, and pure or applied sciences. The course offers a rigorous, concept-driven curriculum aligned with both national and international standards, covering key topics such as mechanics, thermodynamics, waves, electricity and magnetism, optics, and modern physics. Students develop a strong understanding of physical concepts and their real-world applications while enhancing their experimental, analytical, and problem-solving skills, ensuring they are both examination-ready and future-ready.

Aligned with national and international standards, HSSC–Advance Physics at ZUEB equips students with a comprehensive understanding of scientific theories, methods, and applications that are essential for technological and industrial advancement. Designed for students aiming for careers in engineering, research, healthcare, and academia, the course builds essential skills in observation, quantitative reasoning, and critical thinking.

Whether you are preparing for admission into top universities in engineering, medicine, or physical sciences, or planning a career in research, technology, or applied physics, HSSC–Advance Physics ensures you are academically prepared and nationally aligned, with a flexible, student-focused learning approach. Explore more on what HSSC–Advance Physics offers ZUEB HSSC–Advance Official Page.

SYLLABUS OVERVIEW

No.	Content	XII	XIII	AO	Exam
1	Units, prefixes, measurement errors, and the application of force through Newton's Laws.	P1	-	AO1, AO2 and AO3	Combination of written exam papers (externally set and marked) and a practical demonstration of skills. **XII** **Paper 1:** Multiple Choice Questions, Theoretical Questions, and Practical Questions Duration:1 hour 45 minutes Weighting: 25% **Paper 2:** Multiple Choice Questions, Theoretical Questions, and Practical Questions Duration:1 hour 45 minutes Weighting: 25% **XIII** Paper 3: Essay Questions Duration: 2 Hours 30 minutes Weighting: 50%
2	Momentum, density and moments	P1	-	AO1, AO2 and AO3	
3	Stress, strain and the Young Modulus	P1	-	AO1, AO2 and AO3	
4	Electrical current, basic circuits and resistivity	P1	-	AO1, AO2 and AO3	
5	Nuclear physics, fundamental particles and radioactivity	P1	-	AO1, AO2 and AO3	
6	Circular motion and Simple harmonic motion (SHM)	-	P3	AO1, AO2 and AO3	
7	Kinetic Theory of Gases and the Ideal Gas Equation	P2	-	AO1, AO2 and AO3	
8	Capacitance	-	P3	AO1, AO2 and AO3	
9	Photons, photoelectric effect and spectra	-	P3	AO1, AO2 and AO3	
10	Waves, polarisation and Doppler effect	P2	-	AO1, AO2 and AO3	
11	Refraction, Diffraction, Interference and wave-particle duality	-	P3	AO1, AO2 and AO3	
12	Energy and work	P2	-	AO1, AO2 and AO3	

13	Thermodynamics and specific heat capacity/latent heat	P2	-	AO1, AO2 and AO3	
14	Binding Energy, Nuclear Fission, and Nuclear Fusion	-	P3	AO1, AO2 and AO3	
15	Fields and their sources	-	P3	AO1, AO2 and AO3	
16	Interactions Of Charges Masses and Fields	-	P3	AO1, AO2 and AO3	

Description of Assessment Objectives

AO1 – Show knowledge and understanding of:

- scientific concepts and principles
- relevant methods, techniques, and procedures

AO2 – Apply knowledge and understanding to:

- use scientific ideas in various contexts
- perform and explain investigations, techniques, and procedures

AO3 – Analyse and interpret to:

- evaluate information and data
- draw reasoned conclusions and judgements
- suggest improvements to experimental methods

Weighting of Assessment Objectives

Assessment Objectives	P1 (%)	P2 (%)	P3 (%)
AO1	**30**	**30**	**30**
AO2	**40**	**40**	**50**
AO3	**30**	**30**	**20**

1. Units, prefixes, measurement errors, and the application of force through Newton's Laws

Aim: Demonstrate the correct use of SI units and prefixes, apply methods for calculating errors and combined errors in formulae, and explain the principles of Newton's Laws.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand SI units and multiples	1.1.1	**Summarise** the correct use and notation of base SI units.	AO1
		1.1.2	**Analyse** SI units for a variety of base and derived physical quantities.	AO2
		1.1.3	**Use** dimensional analysis to verify the validity of given formulae.	AO2
		1.1.4	**Apply** appropriate SI prefixes (e.g., milli- , kilo- , nano-) to express quantities accurately.	AO1
2	Understand errors	1.2.1	**Distinguish** between precision and accuracy in the context of measurement and data collection.	AO1
		1.2.2	**Analyse and compare** the characteristics and impacts of systematic and random errors.	AO3
		1.2.3	**Determine** absolute, fractional, and percentage uncertainties, including their combination in multi- step calculations.	AO2
3	Understand scalars, vectors, components and resultants	1.3.1	**Identify** and give examples of scalar and vector quantities.	AO1
		1.3.2	**Construct** and **interpret** vector polygons to determine resultant vectors graphically.	AO2

		1.3.3	**Resolve** vectors into horizontal and vertical components using trigonometric methods.	AO2
4	Understand Newton's Laws	1.4.1	**Define** the term force and recall the use of F = ma.	AO2
		1.4.2	**Explain** and justify the concept of force as an interaction between two bodies, supported by physical examples.	AO3
5	Apply Newton's Laws	1.5.1	**Recognise** and describe the application of each of Newton's Laws in varied physical contexts.	AO1
6	Apply the concepts of force and Newton's Laws in practical contexts	1.6.1	**Compare** and contrast different types of forces observed in a practical setting, such as gravitational, reaction, pressure, and molecular forces.	AO3
		1.6.2	**Identify and justify** which of Newton's Laws apply to specific observed phenomena in classroom or real- world contexts.	AO2

2. Momentum, density and moments
Aim: To understand how momentum is transferred between bodies, explore the role of impulse in collisions, develop an understanding of density, and analyse turning forces.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand how momentum is exchanged between interacting bodies	2.1.1	**State** the principle of conservation of momentum for isolated systems.	AO1
		2.1.2	**Select** the appropriate form of the conservation of momentum principle for different collision outcomes.	AO2
		2.1.3	**Solve** numerical problems using the conservation of momentum.	AO2
		2.1.4	**Calculate** impulse from the change in momentum over a specified time interval.	AO2
2	Understand density	2.2.1	**Explain** why density is an intrinsic property of a material, independent of its shape or mass.	AO3
		2.2.2	**Determine** the density of a material from its mass and volume.	AO2
3	Understand moments	2.3.1	**Define** a moment as the product of force and perpendicular distance from a chosen pivot point.	AO1
		2.3.2	**Identify** and justify the most suitable pivot point for taking moments in systems with multiple pivots.	AO3
		2.3.3	**Formulate** the equation for equilibrium by equating total clockwise and anticlockwise moments.	AO2

		2.3.4	**Use** moment equations to calculate unknown masses or distances in equilibrium problems.	AO2
4	Apply the principles of momentum transfer and moments in practical situations	2.4.1	**Conduct** a practical investigation of a balanced system to determine unknown masses or distances using moment principles.	AO3
		2.4.2	**Conduct** a practical investigation into momentum transfer by observing and analysing collisions between different types of balls and other movable objects (such as a golf ball colliding with a ping pong ball).	AO3

3. Stress, strain and the Young Modulus

Aim: Understand stress and strain in materials, along with Hooke's Law and Young's Modulus. This topic also explores the different classes of materials and examines the strengths and limitations specific to each.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand Hooke's law	3.1.1	**Define** the spring constant and state its SI units.	AO1
		3.1.2	**Apply** Hooke's Law to calculate force, extension, or spring constant in elastic systems.	AO2
		3.1.3	**Compare** the effective spring constant for springs connected in series and parallel configurations.	AO2
		3.1.4	**Determine** the spring constant from the gradient of a force–extension graph.	AO2
2	Understand stress, strain and the Young Modulus	3.2.1	**Use** formulae for stress, strain, and Young's Modulus to solve problems involving materials under force.	AO2
		3.2.2	**Combine** stress and strain equations to calculate unknown quantities such as original length or cross-sectional area.	AO2
		3.2.3	**Justify** that Young's Modulus is an intrinsic property of a material, independent of its size or mass.	AO3
		3.2.4	**Interpret** stress–strain graphs to identify key features such as yield point, elastic limit, and breaking point.	AO3

		3.2.5	**Compare** and evaluate stress–strain graphs for different materials in terms of mechanical properties.	AO3
3	Develop an understanding of the various classes and properties of materials	3.3.1	**Compare** the structural and bonding characteristics of crystalline, amorphous, and polymeric materials.	AO1
		3.3.2	**Evaluate** the behaviour of ductile, brittle, and elastic materials under stress, comparing their strengths and limitations.	AO3
		3.3.3	**Identify** material type by interpreting key features of its stress–strain graph.	AO2
4	Apply Hooke's Law and the concepts of stress, strain, and Young's Modulus in practical investigations	3.4.1	**Conduct** a practical investigation to determine the spring constant of a spring under varying loads, accounting for measurement uncertainties.	AO3
		3.4.2	**Investigate** and analyse the stress–strain behaviour of different materials through experimental methods.	AO3

4. Electrical current, basic circuits and resistivity

Aim: Understand electric current, drift velocity, resistance, and potential difference, along with potential divider circuits, resistor combinations, variable resistors, and components such as thermistors and diodes. Learners will also develop an understanding of Ohm's Law and the resistivity of conducting materials.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Develop an understanding of the nature and behaviour of electric current	4.1.1	**Define** electric current as the rate of flow of charge carriers (electrons) across a conductor, each carrying charge e.	AO1
		4.1.2	**Define** drift velocity and derive the current equation $I=nAve$.	AO2
		4.1.3	**Use** the relationship $Q=I\times t$ to interpret and analyse charge–time and current–time graphs.	AO2
2	Understand Ohm's law	4.2.1	**Justify** Ohm's Law as a linear relationship between voltage and current for a constant resistance.	AO3
		4.2.2	**Determine** resistance from the gradient of an I–V graph.	AO2
		4.2.3	**Interpret** I–V graphs to identify and explain non-Ohmic behaviour in components such as filament lamps.	AO3
		4.2.4	**Define** resistance and describe how it varies with material properties, cross-sectional area, and temperature.	AO1
3	Understand resistivity	4.3.1	**Justify** that resistivity is an intrinsic property of a material, independent of its dimensions, unlike resistance.	AO3

		4.3.2	**Use** the resistivity formula to calculate unknown quantities, accounting for experimental uncertainties.	AO2
		4.3.3	**Analyse** resistance–length graphs to determine resistivity or cross-sectional area from the gradient.	AO3
4	Understand basic circuits	4.4.1	**Distinguish** between voltage measured ‘across’ components and current flowing ‘through’ them in circuit analysis.	AO1
		4.4.2	**Represent** voltage drops across two series resistors using annotated circuit diagrams.	AO2
		4.4.3	**Draw** and **explain** voltage distribution across two parallel resistors using circuit diagrams.	AO2
		4.4.4	**Construct** circuit diagrams showing voltage drops across mixed series–parallel resistor networks.	AO2
		4.4.5	**Analyse** complex circuits using voltage drop sketches and Ohm’s Law to calculate unknown quantities.	AO3
5	Understand electromotive force and internal resistance	4.5.1	**Define** electromotive force (emf) as the energy transferred per unit charge in a source.	AO1
		4.5.2	**Incorporate** internal resistance into circuit calculations as an additional resistor.	AO2
		4.5.3	**Distinguish** between voltage lost due to internal resistance and voltage across external components.	AO3
		4.5.4	**Use** the linear form of a V–I graph to determine emf and internal resistance from gradient and intercept.	AO3

6	Be able to demonstrate a practical application of resistivity and basic circuits	4.6.1	**Conduct** a practical investigation to determine resistivity of a wire, accounting for measurement uncertainties.	AO3
		4.6.2	**Investigate** a multi-resistor (atleast 4) circuit using voltage drop diagrams to calculate currents, voltages, and unknown resistances.	AO3

5. Nuclear Physics, fundamental particles and radioactivity

Aim: To understand the nuclear structure of elements, the role of conservation laws in nuclear reactions, and the existence of antimatter, while analyzing how conservation applies to fundamental particles across different classifications. To study radioactivity as a process leading to stability, the types of radioactive decay, and methods of performing decay calculations.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Gain an understanding of the fundamental principles of nuclear physics	5.1.1	**Justify** the nuclear model of the atom using evidence from Rutherford's alpha particle scattering experiment.	AO3
		5.1.2	**Use** nucleon and atomic numbers to represent elements accurately in nuclear reaction equations.	AO2
		5.1.3	**Apply** conservation laws of charge and nucleon number to analyse nuclear reactions.	AO2
		5.1.4	**Justify** the existence of antiparticles using experimental evidence such as opposite deflection in mass spectrometry.	AO3
2	Understand fundamental particles	5.2.1	**Identify** and classify the six types of quarks (up, down, top, bottom, charm or strange).	AO1
		5.2.2	**Compare** hadrons, baryons, leptons, and mesons based on their quark composition.	AO2
		5.2.3	**Use** conservation laws of charge, baryon number, and lepton number to analyse particle interactions and decays.	AO2
		5.2.4	**Evaluate** the characteristics and roles of strong, weak, and electromagnetic forces in particle interactions.	AO3
		5.2.5	**Compare** particle interactions based on whether quark identity changes or remains constant.	AO2

3	Develop an understanding of the nature and behaviour of radioactivity	5.3.1	**Justify** the conditions under which elements become radioactive using data from decay patterns and stability curves.	AO3
		5.3.2	**Compare** alpha, beta, and gamma decay in terms of properties and penetration through different materials.	AO2
		5.3.3	**Justify** the existence of background radiation using Geiger counter data.	AO3
		5.3.4	**Define** and use the Becquerel (Bq) as the unit of radioactive activity (decays per second).	AO1
4	Understand the process and principles of radioactive decay	5.4.1	**Determine** the half-life of a radioactive source from an Activity–time graph.	AO2
		5.4.2	**Choose** suitable units for expressing half-life based on context.	AO1
		5.4.3	**Justify** the role of the decay constant as a proportionality factor in radioactive decay.	AO3
		5.4.4	**Justify** exponential decay behaviour using data for activity and number of undecayed nuclei.	AO3
		5.4.5	**Manipulate** the exponential decay formula using logarithmic methods.	AO2
		5.4.6	**Derive** the half-life formula $T(\frac{1}{2})=\ln 2/\lambda$ from the exponential decay equation.	AO2
		5.4.7	**State** that N represents the number of undecayed nuclei in a radioactive sample.	AO1
5	Demonstrate practical applications involving fundamental particles and radioactive decay	5.5.1	**Identify** particles based on interaction type, charge, and conservation of baryon and lepton numbers.	AO2
		5.5.2	**Conduct** an investigation using Geiger counter data to plot a linearised decay graph and determine the decay constant.	AO3

6. Circular motion and Simple harmonic motion (SHM)

Aim: Understand circular motion with emphasis on centripetal acceleration, and understand simple harmonic motion (SHM), including system modelling, damping, and resonance.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand circular motion	6.1.1	**Convert** angles between radians and degrees using appropriate conversion factors.	AO1
		6.1.2	**Contrast** between angular and tangential velocity.	AO2
		6.1.3	**Calculate** centripetal acceleration for bodies in circular motion with or without physical linkage to the centre.	AO2
2	Understand the nature of SHM	6.2.1	**Apply** the SHM formula (acceleration is directly proportional to the negative of the displacement) to systems exhibiting simple harmonic motion.	AO2
		6.2.2	**Examine** a system undergoing SHM by representing its motion on a straight-line graph, where the slope is negative and corresponds to the square of the angular velocity.	AO3
		6.2.3	**Justify** the conditions required for SHM, including displacement from equilibrium and the presence of a restoring force.	AO3
		6.2.4	**Use** SHM equations to solve problems involving ideal pendulums and spring systems.	AO2
3	Understand modelling of SHM	6.3.1	**Represent** SHM using sine or cosine functions, including phase shifts where appropriate.	AO2

		6.3.2	**Manipulate** SHM equations to solve for unknown quantities using inverse trigonometric functions.	AO2
		6.3.3	**Use** gradient relationships to derive velocity–time and acceleration–time graphs from displacement and velocity data.	AO2
		6.3.4	**Determine** velocity or displacement by calculating area under acceleration–time or velocity–time graphs.	AO2
4	Understand damping and resonance	6.4.1	**Compare** over-damping, under-damping, and critical damping in terms of system response.	AO2
		6.4.2	**Represent** the motion of damped SHM systems.	AO2
		6.4.3	**Analyse** amplitude–frequency graphs to identify resonant frequency and system response.	AO3
		6.4.4	**Evaluate** how damping and system parameters influence resonance behaviour.	AO3
		6.4.5	**Identify and differentiate** between beneficial and harmful examples of resonance.	AO1
5	Be able to demonstrate a practical application of circular motion, SHM and resonance	6.5.1	**Investigate** rotational motion using a marked bicycle wheel to observe angular displacement and velocity.	AO3
		6.5.2	**Investigate** centripetal force through practical observation of a ball in a rotating drum.	AO3
		6.5.3	**Conduct** a pendulum investigation by varying parameters(length, mass and material) analysing data, and modelling SHM behaviour.	AO3
		6.5.4	**Investigate** resonance in musical nstruments by demonstrating sympathetic vibration between strings.	AO3

7. Kinetic Theory of Gases and the Ideal Gas Equation

Aim: Understand the three basic assumptions of kinetic theory, the fundamental equations relating pressure, volume, and temperature, and the application of the ideal gas equation in different systems.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand kinetic theory of gases	7.1.1	**Perform** calculations involving moles, molar mass, relative molecular mass, and Avogadro’s constant to determine particle quantities and the relationships between them.	AO2
		7.1.2	**State** the three fundamental assumptions of the kinetic theory for an ideal gas.	AO1
		7.1.3	**Use** the kinetic definition of pressure to calculate pressure, force, or area exerted by gas molecules.	AO2
		7.1.4	**Justify** the use of root-mean-square or mean-square speed in kinetic theory calculations.	AO3
		7.1.5	**Apply** kinetic theory equations to calculate pressure, volume, or mass for gases using molecular speed relationships.	AO2
		7.1.6	**Calculate** root-mean-square or mean-square speed from velocity data of gas particles.	AO2
2	Understand the ideal gas equation	7.2.1	**Use** the ideal gas law $pV=nRT$ to calculate unknown quantities for different gases.	AO2
		7.2.2	**Distinguish** between isovolumetric, isobaric, and isothermal processes in thermodynamics.	AO1
		7.2.3	**Rearrange** and apply the gas law $pV/T=\text{constant}$ to identify if a process is isovolumetric, isobaric or isothermal.	AO2

		7.2.4	**Convert** pV=nRT into pV=NkT using k=R/Avogadro's constant	AO2
		7.2.5	**Analyse** p-V graphs to find unknown value of p, V, T or to check is a process is isovolumetric, isobaric or isothermal	AO3
3	Demonstrate practical applications of kinetic theory and the ideal gas law	7.3.1	**Investigate** the behaviour of a sealed gas under changes in volume and temperature, using sensors to measure pressure and temperature	AO3

8. Capacitance

Aim: Enable an understanding of the nature of capacitance and its function in electrical circuits.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the nature of capacitors	8.1.1	**Describe** the structure of a parallel-plate capacitor, including the role of the dielectric material.	AO1
		8.1.2	**Justify** the relationship Q=VC using data showing proportionality between charge and voltage.	AO3
		8.1.3	**Justify** how capacitance depends on plate area, separation distance, and dielectric constant using experimental data.	AO3
2	Understand capacitors in circuits	8.2.1	**Calculate** total capacitance for capacitors connected in series or parallel.	AO2
		8.2.2	**Distinguish between** the operational state of a capacitor as charging, storing, or discharging.	AO1
		8.2.3	**Design** a simple RC circuit capable of switching between charging and discharging modes.	AO3
		8.2.4	**Analyse** an RC circuit to determine its time constant and interpret its significance.	AO3
		8.2.5	**Interpret** discharging graphs of voltage or charge versus time to assess capacitor behaviour.	AO3
		8.2.6	**Interpret** charging graphs of voltage or charge versus time.	AO3

		8.2.7	**Manipulate** exponential equations for capacitor charging/discharging to solve for unknown quantities using logarithmic methods.	AO2
3	Be able to demonstrate practical applications of capacitance in electrical circuits	8.3.1	**Conduct** an investigation of an RC circuit, collect voltage data, linearise the results, and determine the time constant with consideration of experimental errors.	AO3

9. Photons, photoelectric effect and spectra

Aim: Understand the photoelectric effect and its role in establishing the particle nature of light (photons); recognise the different regions of the electromagnetic spectrum and their applications; and understand absorption and emission spectra.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the Photoelectric (PE) effect	9.1.1	**Sketch** the experimental setup for the photoelectric effect experiment.	AO3
		9.1.2	**Justify**, using data, that light cannot behave purely as a wave since intensity does not affect photoelectron emission below a threshold frequency.	AO2
		9.1.3	**Justify** the need for a particle model of light to explain the photoelectric effect.	AO2
		9.1.4	**Justify** how the photon model of light accounts for the observed behaviour in the photoelectric effect.	AO2
		9.1.5	**Use** the stopping potential to calculate the maximum kinetic energy of photoelectrons.	AO2
		9.1.6	**Analyse** a KE–frequency graph to determine the work function and maximum kinetic energy of photoelectrons.	AO2
2	Understand the electromagnetic spectrum	9.2.1	**Apply** the photon energy equations $E=hf$ and $E=hc/\lambda$ to solve problems involving electromagnetic radiation.	AO2
		9.2.2	**State** the typical frequency and wavelength ranges for different regions of the electromagnetic spectrum.	AO1
		9.2.3	**Use** the electron-volt (eV) as a unit of energy in photon-related calculations.	AO2

3	Understand atomic spectra	9.3.1	**Justify** how electron transitions between atomic energy levels result in photon emission or absorption.	AO2
		9.3.2	**Compare** emission and absorption spectra to identify elements.	AO2
		9.3.3	**Use** E=hf to calculate energy changes during electron transitions within atoms.	AO2
		9.3.4	**Apply** the concept of ionisation energy to describe atomic energy levels and electron removal.	AO2
4	Be able to demonstrate a practical application of Photoelectric effect and atomic spectra	9.4.1	**Investigate** the photoelectric effect using a gold leaf electroscope and explain results based on incident wavelength and photon energy.	AO3
		9.4.2	**Use** sound wave analogies to illustrate the principles of spectral analysis and frequency-based identification.	AO3

10. Waves, polarisation and Doppler effect

Aim: Enable understanding of wave types and their characteristics, along with the concepts of polarisation and the Doppler effect.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the different types of waves and their characteristics	10.1.1	**Compare** transverse, longitudinal, progressive, and stationary waves.	AO2
		10.1.2	**Distinguish** between electromagnetic waves and mechanical waves based on their propagation mechanisms.	AO2
		10.1.3	**Use** the concept of intensity to explain how wave energy is distributed over distance.	AO2
		10.1.4	**Perform** calculations involving wave speed, frequency, wavelength, and intensity in practical scenarios.	AO2
		10.1.5	**Demonstrate** how multiple polarising filters affect the intensity and orientation of unpolarised light.	AO2
2	Understand stationary waves	10.2.1	**Define** nodes, antinodes, and phase difference.	AO1
		10.2.2	**Illustrate** harmonic patterns for a string fixed at both ends, showing wavelength distribution.	AO2
		10.2.3	**Illustrate** harmonic patterns for open tubes with different boundary conditions(node at one end and an antinode at the other; or antinodes at both ends).	AO2
3	Understand Doppler effect	10.3.1	**Justify** the observed frequency shift in sound due to relative motion between source and observer (Doppler effect).	AO3
		10.3.2	**Use** the Doppler effect to explain redshift and blueshift in light from moving sources.	AO2

		10.3.3	**Calculate** source velocity or emitted frequency using Doppler effect equations and provided data.	AO2
4	Demonstrate practical applications of polarisation, the Doppler effect, and stationary waves	10.4.1	**Conduct** an investigation to observe how multiple polarising filters affect light intensity.	AO3
		10.4.2	**Investigate** the Doppler effect using a rotating sound source and analyse frequency changes from a fixed point.	AO3
		10.4.3	**Investigate** stationary waves on a stringed instrument (e.g., guitar or double bass) using the strobe effect, and explore harmonics by fixing a clamp at different points along the string.	AO3

11. Refraction, Diffraction, Interference and wave-particle duality

Aim: Enable understanding of how waves travel through materials of different densities, diffract around obstacles, and interfere with themselves; and recognise how such experiments revealed the wave nature of electrons and the concept of photon momentum.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand refraction	11.1.1	**Justify** how changes in wave speed at a material boundary affect wavelength while frequency remains constant.	AO3
		11.1.2	**Define** refractive index as the ratio of wave speeds across two media.	AO1
		11.1.3	**Use** Snell's Law to calculate angles of incidence and refraction for waves crossing boundaries.	AO2
		11.1.4	**Illustrate** the critical angle between media.	AO2
		11.1.5	**Explain** total internal reflection and illustrate its application in fibre optic communication.	AO2
2	Understand diffraction and interference	11.2.1	**Compare** gap size and wavelength effects.	AO2
		11.2.2	**Justify** the fringe pattern in Young's experiment using wave interference principles.	AO3
		11.2.3	**Analyse** fringe spacing and visibility using path difference calculations.	AO3
		11.2.4	**Use** Young's fringe formula to calculate slit separation, wavelength, fringe spacing, or screen distance.	AO2
		11.2.5	**Use** the diffraction grating equation to determine slit spacing, wavelength, fringe order, or diffraction angle.	AO2

3	Understand wave-particle duality	11.3.1	**State** that electrons produce an interference pattern when passed through a diffraction grating.	AO1
		11.3.2	**Justify** the wave-like nature of electrons based on observed interference patterns.	AO3
		11.3.3	**Use** the photon momentum equation to calculate momentum.	AO2
		11.3.4	**Justify** the feasibility of solar sails using the concept of photon momentum transfer.	AO3
4	Demonstrate practical applications of refraction, diffraction, and interference	11.4.1	**Investigate** laser light refraction through different materials and measure angles to determine refractive index.	AO3
		11.4.2	**Investigate** diffraction using strings with markers to model the peaks and troughs of light waves.	AO3

12. Energy and work

Aim: Understand the different forms of energy in physics, their characteristics, and perform calculations using the relevant formulae.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the principles of energy, work, and power	12.1.1	**Use** energy equations to calculate kinetic, gravitational potential, and elastic potential energy, applying conservation principles.	AO2
		12.1.2	**Compare** kinetic, potential, and elastic potential energy in terms of their physical origins and dependencies.	AO2
		12.1.3	**Justify** the concept of work as a transferable form of energy applicable across mechanical systems.	AO3
		12.1.4	**Calculate** work done in mechanical systems involving friction, inclined planes, and elastic deformation.	AO2
		12.1.5	**Compare** elastic and inelastic collisions based on whether kinetic energy is conserved.	AO2
		12.1.6	**Define** power as the rate of energy transfer or conversion over time.	AO1
		12.1.7	**Calculate** the efficiency of energy systems using input and output energy data.	AO2
2	Understand the different forms of energy in Physics	12.2.1	**Use** the formula for energy to calculate energy stored in a spring.	AO2
		12.2.2	**Use** the formula $P=VI$ to calculate power dissipation in electrical circuits.	AO2
		12.2.3	Use the formula $U = \frac{1}{2} QV$ to calculate energy stored in a capacitor.	AO2

3	Be able to demonstrate practical applications of different forms of energy in Physics	12.3.1	**Conduct** an investigation tracking energy transformations between kinetic, gravitational potential, and elastic potential energy.	AO3
		12.3.2	**Investigate** an RC circuit to measure voltage and current, calculate power dissipation and capacitor energy, and compare results with literature and peer data.	AO3

13. Thermodynamics and specific heat capacity/latent heat

Aim: Understand thermodynamic processes and p–V graphs, and explain how materials behave under temperature changes or when bodies of different temperatures are combined.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand thermodynamics	13.1.1	**Define** internal energy as the total kinetic energy of the molecules in a gas.	AO1
		13.1.2	**Use** the internal energy formula to calculate energy, temperature, or particle/mole count.	AO2
		13.1.3	**State** the first law of thermodynamics relating internal energy, heat, and work.	AO1
		13.1.4	**Apply** the first law of thermodynamics to analyse different thermodynamic processes.	AO2
		13.1.5	**Illustrate** isobaric, isovolumetric, and zero-work ($W=p\Delta V$) processes using pressure–volume graphs.	AO2
		13.1.6	**Calculate** work done in thermodynamic processes using area under p–V graphs.	AO2
		13.1.7	**Identify** isothermal processes from the shape of a p–V graph.	AO2
		13.1.8	**Identify** adiabatic processes using p–V graphs and apply the first law to justify.	AO3
		13.1.9	**State** the zeroth law of thermodynamics.	AO1
2	Understand specific heat capacity (SHC) / latent heat (LH)	13.2.1	**Calculate** specific heat capacity or latent heat for a substance undergoing temperature or phase change.	AO2

		13.2.2	**Analyse** temperature–absorbed heat graphs to determine when to apply SHC or LH equations.	AO3
		13.2.3	**Determine** reasons for the flat regions on temperature–heat graphs using the first law and latent heat concepts.	AO3
3	Apply the principles of thermodynamics and specific heat capacity in practical situations	13.3.1	**Investigate** adiabatic processes, such as the ‘fire-syringe’ and the reversible ‘cloud in a bottle’, and calculate approximate work done in these experiments.	AO3
		13.3.2	**Calculate** the final equilibrium temperature when a pan at room temperature is mixed with hot water, assuming negligible heat loss to the surroundings, and compare the experimental result with the theoretical prediction.	AO3

14. Binding Energy, Nuclear Fission and Nuclear Fusion

Aim: To enable understanding of nuclear binding energy and how it changes in fission and fusion.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand binding energy per nucleon and mass defect	14.1.1	**Calculate** the mass defect of nuclear reactions using atomic mass units (u).	AO2
		14.1.2	**Apply** E = mc^2 to determine energy released in nuclear reactions.	AO2
		14.1.3	**Interpret** the binding energy per nucleon against the nucleon number graph.	AO3
		14.1.4	**Identify** regions of the binding energy graph that correspond to fusion and fission processes.	AO2
2	Understand fission and fusion	14.2.1	**Compare** energy generation methods from fusion and fission, including nuclear reactors, tokamaks, and fast ignition systems.	AO2
		14.2.2	**Justify** how nuclear fission and fusion lead to increased binding energy and energy release.	AO3
		14.2.3	**Use** binding energy graphs to calculate energy released during fusion or fission reactions.	AO2
		14.2.4	**Create** a real-world analogy to illustrate how binding energy changes during nuclear reactions.	AO3

15. Fields and their sources

Aim: Understand the nature of fields and how different types of fields can be created and controlled.

	The learner will:	SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the nature of fields	15.1.1	**Conclude** that all fields are invisible, three-dimensional, and vector-based in nature.	AO1
		15.1.2	**Justify** the presence of sources and sinks in electric and magnetic fields, and explain why gravitational fields have only sources.	AO3
		15.1.3	**Calculate** the resultant field vector when multiple fields of the same type act on the point.	AO2
		15.1.4	**Represent** fields using both field lines and equipotential surfaces to show direction and energy levels.	AO2
		15.1.5	**Justify** that work is required to move an object or charge across equipotential surfaces within a field.	AO3
2	Understand gravitational fields	15.2.1	**Justify** that gravitational fields are inherently attractive.	AO3
		15.2.2	**Use** Newton's law of gravitation (inverse square law) to calculate the force between two masses.	AO2
		15.2.3	**Calculate** gravitational field strength using mass and distance from the source.	AO2
		15.2.4	**Calculate** gravitational potential at a point.	AO2
		15.2.5	**Calculate** potential energy of a mass.	AO2
		15.2.6	**Conclude** that gravitational potential energy results from a mass being within another mass's field.	AO1

		15.2.7	**Calculate** work done when a mass moves through a gravitational potential difference.	AO2
3	Understand the behaviour of electric fields and electrostatics	15.3.1	**Use** inverse square law to calculate the force between two point charges.	AO2
		15.3.2	**Calculate** electric field strength at a point due to a charge.	AO2
		15.3.3	**Calculate** electric potential at a point in a field surrounding a charge.	AO2
		15.3.4	**Calculate** electric potential energy of a charge in a field.	AO2
		15.3.5	**Conclude** that electric potential energy results from a charge being within another charge's field.	AO1
		15.3.6	**Calculate** work done when a charge moves through an electric potential difference.	AO2
		15.3.7	**Compare** the origins of electric fields from isolated charges and from potential differences in systems like capacitors.	AO2
		15.3.8	**Calculate** the force acting on a charge placed in an electric field.	AO2
4	Understand magnetic fields	15.4.1	**Recall** that magnetic poles always exist in pairs, unlike electric or gravitational fields.	AO1
		15.4.2	**Compare** magnetic field generation from permanent magnets and moving charges.	AO2
		15.4.3	**Calculate** magnetic flux density around a straight current-carrying wire.	AO2
		15.4.4	**Calculate** magnetic flux density inside a solenoid carrying current.	AO2

		15.4.5	**Apply** the right-hand grip rule to determine magnetic field direction around a wire.	AO2
		15.4.6	**Define** magnetic flux as the product of magnetic flux density and area perpendicular to the field.	AO1
5	Demonstrate understanding of gravitational, electric, and magnetic fields	15.5.1	**Investigate** planetary motion using gravitational principles and circular motion to calculate orbital periods and compare with known data.	AO3
		15.5.2	**Investigate** the deflection of an electron beam in a cathode ray tube under a controlled electric field, by usage of 2 metal plates and voltage supply	AO3
		15.5.3	**Investigate** how the magnetic effect of a solenoid with an iron core varies with current, by testing when a paperclip is held in balance between gravity and magnetism.	AO3

16. Interactions Of Charges, Masses and Fields
Aim: To enable an understanding of how charges interact with electric and magnetic fields, and how masses interact with gravitational fields to produce projectile motion.

The learner will:		SLO #	Assessment Criteria - The learner can:	Cognitive levels
1	Understand the behaviour of charges in electric/magnetic fields	16.1.1	**Calculate** the magnetic force on a moving charge.	AO2
		16.1.2	**Compare** scalar and vector products in terms of mathematical operation and physical interpretation.	AO2
		16.1.3	**Calculate** the magnetic force on a charged particle near a current-carrying wire.	AO2
		16.1.4	**Calculate** the force between two parallel current-carrying wires.	AO2
		16.1.5	**Evaluate** the use of Fleming's left and right-hand rules in predicting force and current direction in electromagnetic systems.	AO3
		16.1.6	**State** Faraday's and Lenz's laws governing electromagnetic induction.	AO1
		16.1.7	**Apply** Faraday's and Lenz's laws to explain the operation of electric motors and generators.	AO2
		16.1.8	**Summarise** how transformers and the Hall effect operate using concepts of fields and charge movement.	AO2
		16.1.9	**Summarise** the principles behind particle accelerators using electric and magnetic field interactions.	AO2

2	Understand the behaviour of masses in gravitational fields (projectiles/SUVAT)	16.2.1	**State** the standard equations of motion.	AO1
		16.2.2	**Justify** that equations of motion apply universally regardless of mass or shape.	AO3
		16.2.3	**Distinguish** between horizontal and vertical components in projectile motion problems.	AO2
		16.2.4	**Categorise** projectile motion into distinct phases of flight and identify the relevant section for calculations.	AO2
		16.2.5	**Analyse** and compare motion graphs to understand relationships between displacement, velocity, and acceleration.	AO3
		16.2.6	**Use** graphical methods to calculate displacement, velocity, or acceleration from motion graphs.	AO2
3	Demonstrate the practical applications of charge–mass–field interactions	16.3.1	**Investigate** the deflection of an electron beam in a cathode ray tube under combined electric and magnetic fields using Helmholtz coils.	AO3
		16.3.2	**Conduct** a projectile motion experiment and compare measured flight parameters including height, time and distance, with theoretical predictions.	AO3

Formula Sheet

$\rho = \frac{m}{V}$	$v = u + at$	$x = \frac{1}{2}(u + v)t$	$x = ut + \frac{1}{2}at^2$
$\Sigma F = ma$	$p = mv$	$W = Fx\cos\theta$	$E = \frac{1}{2}kx^2$
$E = \frac{1}{2}mv^2$	$P = \frac{W}{t} = \frac{\Delta E}{t}$	$F = kx$	$\sigma = \frac{F}{A}$
$\varepsilon = \frac{\Delta l}{l}$	$E = \frac{\sigma}{\varepsilon}$	$W = \frac{1}{2}Fx$	$I = \frac{\Delta Q}{\Delta t}$
$I = nAve$	$R = \frac{V}{I}$	$P = IV$	$R = \frac{\rho l}{A}$
$V = E - Ir$	$\frac{V}{V_{total}} = \frac{R}{R_{total}}$	$T = \frac{1}{f}$	$c = f\lambda$
$\lambda = \frac{a\Delta y}{D}$	$d\sin\vartheta = n\lambda$	$n = \frac{c}{v}$	$n_1 v_1 = n_2 v_2$
$n_1 \sin\vartheta_C = n_2$	$E_{k\,max} = hf - \varphi$	$p = \frac{h}{\lambda}$	$\omega = \frac{\vartheta}{t}$
$v = \omega r$	$a = \omega^2 r$	$a = \frac{v^2}{r}$	$F = \frac{mv^2}{r}$
$a = -\omega^2 x$	$x = A\cos(\omega t + \varepsilon)$	$T = \frac{2\pi}{\omega}$	$v = -A\omega\sin(\omega t + \varepsilon)$

$T=2\pi\sqrt{\frac{m}{k}}$	$T=2\pi\sqrt{\frac{l}{g}}$	$pV=nRT$	$pV=NkT$
$p=\frac{1}{3}\rho\bar{c}^2$	$p=\frac{1}{3}\frac{N}{V}m\bar{c}^2$	$U=\frac{3}{2}nRT$	$U=\frac{3}{2}NkT$
$W=p\Delta V$	$\Delta U=Q-W$	$Q=mc\Delta\theta$	$C=\frac{Q}{V}$
$C=\frac{\varepsilon_0 A}{d}$	$E=\frac{V}{d}$	$U=\frac{1}{2}QV$	$Q=Q_0\left(1-e^{\frac{-t}{RC}}\right)$
$Q=Q_0 e^{\frac{-t}{RC}}$	$F=\frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$	$F=\frac{GM_1M_2}{r^2}$	$E=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$
$g=\frac{GM}{r^2}$	$V_E=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	$PE=\frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r}$	$V_g=\frac{-GM}{r}$
$PE=\frac{-GM_1M_2}{r}$	$W=q\Delta V_E$	$W=m\Delta V_g$	$\frac{\Delta\lambda}{\lambda}=\frac{v}{c}$
$A=\lambda N$	$N=N_0e^{-\lambda t}$	$A=A_0e^{-\lambda t}$	$N=\frac{N_0}{2^x}$
$A=\frac{A_0}{2^x}$	$\lambda=\frac{ln2}{T_{\frac{1}{2}}}$	$E=mc^2$	$F=BIlsin\theta$
$F=Bqvsin\theta$	$B=\frac{\mu_0 I}{2\pi a}$	$B=\mu_0 nI$	$\Phi=ABcos\theta$

Safety in the laboratory

Personal Preparation

- Wear a lab coat/apron, safety goggles, and closed-toe shoes at all times.
- Tie back long hair and secure loose clothing or accessories.
- Avoid eating, drinking, chewing gum, or applying cosmetics in the laboratory.
- Read the experiment instructions fully before starting.

General Conduct

- Work only under supervision, never alone in the laboratory.
- Keep your workspace tidy; store bags and books away from benches.
- Handle all equipment and materials with care; report any damage immediately.
- Follow your teacher's instructions exactly; do not improvise procedures.

Equipment and Chemical Safety

- Use apparatus only after proper training.
- Check glassware for cracks before use; handle hot glass with tongs or heat-resistant gloves.
- Never touch electrical equipment with wet hands.
- Read chemical labels carefully; know the hazard symbols.
- Use fume cupboards for volatile, toxic, or strong-smelling chemicals.

Biological Safety

- Wash hands before and after handling biological specimens.
- Wear gloves when dealing with biological materials.
- Dispose of biological waste in designated containers.

Fire and Heat Safety

- Keep flammable materials away from open flames.
- Light Bunsen burners only when ready to use; turn them off immediately after.
- Know the location of fire extinguishers, fire blankets, and emergency exits.

Waste Disposal

- Dispose of chemicals, broken glass, and biological waste in the correct containers, never down the sink unless instructed. Follow your school's waste segregation rules.

Emergency Procedures

- Report all accidents, spills, or injuries to the teacher immediately.
- Know the location of first-aid kits and emergency contact numbers.
- In case of evacuation, follow the designated route calmly.

Practical Endorsement Requirements

Candidates are required to complete and internally document a series of practical activities that collectively demonstrate proficiency across five key competencies. These competencies are outlined below:

1. Adherence to Written Instructions

- Accurately follows written protocols to execute experimental techniques and procedures.

2. Investigative Methods and Instrumentation

- Utilizes appropriate instruments, apparatus, and materials (including ICT tools) to conduct investigations with minimal guidance.
- Performs procedures methodically and sequentially, adapting to practical challenges as needed.
- Identifies and manages significant quantitative variables, and plans for variables that are not easily controlled.
- Selects suitable equipment and measurement strategies to ensure reliable and accurate results.

3. Safe Handling of Equipment and Materials

- Recognizes potential hazards and evaluates associated risks, implementing necessary safety measures during laboratory or fieldwork.
- Employs appropriate safety equipment and practices with minimal prompting.

4. Observation and Data Recording

- Makes precise and relevant observations during experimental procedures.
- Collects accurate and sufficient data, recording it systematically using correct units and scientific conventions.

5. Research, Referencing, and Reporting

- Uses appropriate digital tools to analyze data, conduct research, and present findings.
- Properly cite sources to validate research efforts and support planning and conclusions.

Practical Experience Expectations

- Candidates are expected to consistently demonstrate these competencies across multiple practicals throughout the course.
- Not all competencies must be evidenced in every individual practical.
- A minimum of **10 practical activities** should be completed over the **2-year programme**, covering the following representative skills:

Required Practical Techniques

- Use of apparatus to measure mass, time, volume, temperature, length, voltage, and current.
- Use of precision instruments (e.g., Vernier calipers) for quantitative measurements.
- Accurate design and implementation of electrical circuits and meter setups.
- Construction of appropriate graphs to represent collected data.

MATHEMATICAL REQUIREMENTS

Calculators may be used in all parts of the examination.

Candidates should be able to:

1. Complete equations involving addition, subtraction, multiplication, and division
2. Understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\propto$, $\sim$.
3. Calculate percentages
4. Calculate percentage change
5. Translate information between graphical, numerical and algebraic forms
6. Manipulate a range of formulas to identify the unknown variable.
7. Deduce and determine uncertainties in measurements.
8. Carry out unit conversions
9. Solve algebraic equations using substitution and appropriate units.
10. Judge appropriate orders of magnitude and scale.
11. Use a calculator to find and use power, exponential and logarithmic functions.
12. Calculate circumferences, surface area and volume of a range of shapes circle, square, rectangle and triangle
13. Calculate rate of change from graphs
14. Apply standard form to data
15. Able to sufficiently round data correctly
16. Provide answers to significant figures
17. Present values in line with equipment measurements
18. Understand that $y = mx + c$ represents a linear relationship
19. Determine the intercept of a graph
20. Rearrange log and exponential formulae
21. Derive useful data from both gradient and area beneath certain graphs