ZIMBABWE

Ministry of Primary and Secondary Education

PHYSICS

SYLLABUS

2024-2030

FORMS 5 - 6

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A LEVEL PHYSICS DRAFT SYLLABUS

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1.0Preamble

1.1Introduction

The forms 5 - 6 Physics syllabus document is designed to put greater emphasis on the heritage based technological concepts acquired through a hands-on learner centred approach. The syllabus is hinged on the rich cultural heritage of our community and focuses to stimulate interest, imagination and critical thinking. Traditional scientific knowledge and modern innovations are used to connect scientific concepts to everyday lives and global challenges through hands on activities. By integrating physics syllabus with cultural relevant, learners are empowered to investigate, innovate, solve problems and become informed, responsible citizens who appreciate our heritage and promote sustainable development. The learners will be assessed through a continuous assessment system in the form of project-based assessments, hands on experiences and demonstrations.

1.2Rationale

The Heritage-Based Physics syllabus provides an integration of traditional knowledge and contemporary technologies learners will develop essential critical thinking, problem solving and collaborations skills through hands on enquiry-based learning to apply scientific principles to real world challenges and impact the society positively. The syllabus fosters responsible stewardship of natural resources and cultural heritage.

1.3 Summary of Content

The Physics syllabus emphasizes integrating heritage-based knowledge into secondary education and supports diversity. The syllabus covers various topics aimed at fostering a deep connection with cultural roots while promoting scientific curiosity and technological skills. It encourages hands-on, learner-centred activities such as constructing, drawing, designing, programming, promoting critical thinking and problem-solving skills. The syllabus also addresses cross-cutting themes like digital competencies, climate change and disaster risk management, ensuring a holistic approach to learner development. Continuous assessment is based on academic performance, projects, presentations and observations to evaluate the understanding of both the scientific and cultural aspects of the learning area.

1.4Assumptions

The Heritage-Based Physics syllabus for Zimbabwe has taken deliberate consideration of several assumptions critical for socio-economic transformation. The assumptions are based on the context of Zimbabwe's heritage, educational system, societal needs and aspirations. It therefore becomes critical to consider that learners:

- are exposed to scientific experiences
- live in diverse social contexts
- use technological devices
- are conscious of their environment
- are aware of their obligation towards health and well-being

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The general assumption is that a Heritage-Based Physics syllabus can effectively integrate science and technology education, fostering a deeper understanding of scientific concepts, technological innovations and their relationship with Zimbabwe's heritage.

1.5 Cross- Cutting Themes

This phase will develop an appreciation of:

- Environmental management
- Enterprise Education
- Gender Equality
- Health and wellbeing
- Child rights and responsibilities
- Climate Change
- Disaster risk management

2.0PRESENTATION OF THE SYLLABUS

The Upper Secondary Physics syllabus is a single document covering Forms 5 - 6. It contains the Preamble, Aims, Syllabus Objectives, Syllabus Topics, Methodology and Time Allocation, Scope and Sequence, Competency Matrix and Assessment. The Scope and Sequence chart shows the progression of topics from Forms 3 - 4, while the syllabus matrix gives details of the content to be covered.

3.0AIMS

The syllabus aims to enable learners to:

3.1 become confident citizens in a technological world and be able to take or develop an informed interest in matters of scientific import, and technology, through a heritage-based approach.

3.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;

3.3 be suitably prepared for studies beyond A-Level.

3.4 develop abilities and skills that are relevant to the study and practice of Physics, are useful in everyday life, encourage efficient and safe practice as well as effective communication.

3.5 develop attitudes relevant to Physics such as concern for accuracy and precision, objectivity, integrity, the skills of enquiry, initiative and inventiveness

3.6 stimulate interest in, and care for, the environment in relation to the environmental impact of Physics and its applications

3.7 incorporate indigenous knowledge, cultural practices, historical perspectives and national endowments into science and technology education.

3.8 create a sustained interest in Physics so that the study of the subject is enjoying and satisfying

3.9 promote an awareness, as guided by Ubuntu /Unhu/ Vumunhu philosophy, that:

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- the study and practice of Physics are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations.
- the implications of Physics may be both beneficial and detrimental to the individual, the community and the environment.

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4.0 OBJECTIVES OF THE SYLLABUS

Learners should be able to:

4.1 follow instructions in practical work in order to manipulate record observations and analyse data to confirm or establish relationships.
4.2 demonstrate knowledge about physical phenomena, facts, laws, definitions and concepts of Physics.
4.3 measure and express physical quantities in SI units to a given level of accuracy and precision.
4.4 solve problems using calculations
4.5 generate and transform information in Physics, from one form to another for presentation, interpretation and problem solving.
4.6 design a practical solution through a Physics project to solve a real life problem.
4.7 use ICT to simulate Physics phenomena, present and analyse Physics data.
4.8 apply safety measures in all practical work.
4.9 explore the connections among heritage, science and technology.
4.10 explain and apply procedures in Physics to protect the environment.

5.0METHODOLOGY AND TIME ALLOCATION

SUGGESTED METHODS

It is envisaged that teaching and learning programmes based on this heritage based Physics syllabus could feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science and life. Teachers are encouraged to use a combination of appropriate strategies to effectively and equitably engage and challenge their learners through:

- Planned experiments
- Problem based learning
- Individual and group work
- Educational tours
- Project based learning
- Design based learning
- Learning by discovery
- E-learning such as simulation
- Collaboration with museums and heritage sites.

N.B. Ortho-didactic principles, such as visual tactile, simulation and self-activity, will be applied when need arises to cater for diverse needs of learners.

Safety precautions must always be observed.

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TIME ALLOCATION:

A minimum of **12** periods of 40 minutes each in a week should be allocated as double periods for adequate coverage of the syllabus

6.0TOPICS

- **General Physics**
- **Newtonian Mechanics**
- **Oscillations and Waves**
- **Electricity and Magnetism**
- **Electronics**
- **Matter**
- **Modern Physics**

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7.0 SCOPE AND SEQUENCE

TOPIC	FORM 5	FORM 6
General Physics	• Physical Quantities and Units • Errors and uncertainties	
Newtonian Mechanics	• Kinematics • Dynamics • Forces • Work, Energy and Power • Circular Motion • Gravitational Field	
Robotics	• Principles of robotic systems • Robot design methodologies • Robot construction and programming	
Oscillations And Waves	• Oscillations • Waves • Superposition	
Electricity and Magnetism	• Electricity • D.C. Circuits • Electric fields • Capacitance	
	•	• Electro magnetism • Electromagnetic Induction • Alternating Currents

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TOPIC	FORM 5	FORM 6
Electronics		▪ Analogue Electronics ▪ Digital electronics
Matter		▪ Phases of Matter ▪ Deformation of Solids ▪ Temperature ▪ Thermal Properties of Materials ▪ Ideal gases ▪ Non-viscous Fluid Flow ▪ Transfer of Thermal Energy
Modern Physics		▪ Charged Particles ▪ Quantum Physics ▪ Atomic Structure ▪ Radioactivity ▪ Communication

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8.0 COMPETENCE MATRIX

FORM 5: General Physics

Topic	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
Physical quantities and units	• express derived units as products or quotients of the base units and use the named units listed in the appendix • use base units to check the homogeneity of physical equations • Derive physical equations using base units • Demonstrate understanding and use the conventions for labelling graph axes and table columns. • use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T) • Determine the resultant of two or more coplanar vectors. • represent a vector as two perpendicular components	• Physical quantities and equations • Base Quantities • SI units • Data presentation • Vectors	• Deriving units from base units • Carrying out planned experiment in measurement • checking of the homogeneity of physical equations • Measuring and expressing physical quantities in multiple/sub multiple units • adding and subtracting two or more coplanar vectors • Resolving vectors	• "ASE publication SI Units, Signs, Symbols and Abbreviations" (The ASE Companion to 5-16 Science, 1995).
Errors and uncertainties	• Distinguish between systematic and random errors • Differentiate between precision and accuracy • Assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties (a rigorous statistics treatment is not required)	• Data presentation • Errors • uncertainties	• Differentiating between systematic and random errors. • Demonstrating precision and accuracy • Combining errors	• Graphs • ICT

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TOPIC	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
Kinematics	• derive, from the definitions of velocity and acceleration, equations which represent uniformly accelerated motion in a straight line. • solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance. • describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction (Projectiles). • solve problems using standard equations for projectile motion. • identify and explain some everyday examples of rectilinear and non-linear motion	• Rectilinear motion $v = u + at$ $v^2 = u^2 + 2as$ $s = ut + ½at^2$ • Non-linear motion	• Deriving equations of linear motion • Solving problems using equations of linear motion • Analysing projectile motion • Solving projectile motion problems	• ICT • Charts

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TOPIC	Objectives Learners should be able to:	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
Dynamics	• define linear momentum as the product of mass and velocity. • solve problems using the relationship F= ma, appreciating that acceleration and force are always in the same direction. • state the principle of conservation of momentum. • use the principle of conservation of momentum on simple applications including elastic and inelastic collisions between two bodies in one dimension (calculations involving the use of coefficient of restitution are not required). • recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation. • define impulse as 'change in momentum'. • explain the significance of area under a force - time graph. • describe applications of Newton's laws of motion and conservation of linear momentum	• Linear momentum • Impulse • Newton's laws of motion	• Explaining the use of force-time graphs. • Demonstrating elastic and inelastic collisions using ICT simulations. • Determining area under force-time graph. • Applying Newton's laws of motion.	• ICTs • Trollies

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Forces	• describe the forces acting on a mass in motion or at rest. • State and explain the origin of the upthrust acting on a body in a fluid. • calculate the upthrust in terms of the weight of the displaced fluid (Archimedes Principle). • describe friction as a force which opposes motion (knowledge of coefficient of friction and viscosity is required). • use Stoke's law to explain quantitatively how a body falling through a viscous fluid under laminar conditions attains a terminal velocity. • describe an experiment, based on the measurement of terminal velocity, to determine the viscosity of a liquid. • describe a couple as a pair of forces tending to produce rotation only. • define and use the moment of a force and the torque of a couple • outline the conditions for a system to be in equilibrium • describe everyday application of forces in equilibrium	• Types of forces. • Equilibrium of forces. • Centre of gravity. • Terminal velocity. • Turning effect of a force.	• Using the vector triangle to represent forces in equilibrium • Investigating "three force" equilibrium using spring balances and weights • Carrying out experiments to measure terminal velocity • Carrying out experiments, to determine the viscosity of a liquid • Determining the moment and torque of a couple	• Spring balances • mass • Burette/ long glass tube • Metal Beads • Meter rule • Liquid paraffin • Masking tape/maker • Stop watch
WORK, ENERGY AND POWER	• define work in terms of the product of a force and displacement in the direction of the force. • calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure: W =PΔV. • derive, from the equations of motion, the formula $E_k = \frac{1}{2}mv^2$. • Apply the formula $E_k = \frac{1}{2}mv^2$. • distinguish between gravitational potential energy, electric potential energy and elastic potential energy. • derive, from the defining equation W = Fs, the formula Ep = mgh for potential energy changes near the Earth's surface.	• Energy conversion and conservation • Work • Potential energy, kinetic energy and internal energy	• Measuring work required for various tasks • Estimating kinetic energy of various objects • Investigating speed of a falling object (gravitational potential energy lost and kinetic energy gained)	• Force metre • Stop watch • Slotted masses • Light gates/ motion sensors • Metre rule/ tape measure

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	• use the formula Ep = mgh for potential energy changes near the Earth's surface. • explain the concept of internal energy.		• Heating and measuring the temperature change of substances	

Type equation here.

Topic	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
WORK, ENERGY AND POWER	• explain that there are energy losses in practical devices and use the concept of efficiency. • relate power to work done and time taken using appropriate examples. • derive and use power as the product of force and velocity. • describe and explain everyday examples of energy conversion (e.g. hydro, thermal, solar, wind, chemical electric power, and environmental concerns).	• Power	• Measuring power output of an electric motor • Visiting Power stations • Using solar panels for heating and lighting	• Electric motor • Solar panels • Solar bulbs

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TOPIC	Objectives Learners should be able to:	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
Circular Motion	• express angular displacement in radians. • define angular velocity, centripetal force and centripetal acceleration • understand the use of the concept of angular velocity. • derive and use $v = r\omega$. • describe qualitatively the motion in curved path due to a perpendicular force. • explain the centripetal acceleration in the case of uniform motion in a circle. • Derive and use centripetal acceleration $a = v^2/r$ and $a = r\omega^2$ • use centripetal force $F = mv^2/r$, $F = mr\omega^2$ • describe and explain everyday examples of motion in a circle (to include banked roads, geostationary orbits and their applications)	• Kinematics of uniform circular motion • Centripetal acceleration • Centripetal force	• Deriving the equations of circular motion • Demonstrating circular motion in vertical and horizontal circles using buckets with water. • Visiting centres where circular motion is used. • Riding bicycles at round about. • Deriving and using equations when solving a problem.	• Bucket • String • Pendulum • ICTs • Bicycles

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TOPIC	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
Gravitational Field	• show an understanding of a gravitational field as a field of force. • define gravitational field strength as force per unit mass. • state and use Newton's law of gravitation in the form $F = Gm_1m_2/r^2$. • analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes. • derive from Newton's law of gravitation and the definition of gravitational field strength, the equation $g = Gm/r^2$ for the gravitational field strength of a point mass. • use the equation $g = Gm/r^2$ for the gravitational field strength of a point mass. • explain that on the surface of the Earth g is approximately constant and is called the acceleration of free fall. • describe an experiment to determine the acceleration of free fall using a falling body. • define potential at a point as the work done in bringing unit mass from infinity to the point. • use the equation $\varphi = - Gm/r$ for the potential in the field of a point mass. • describe and explain everyday applications of the gravitational force of attraction (include satellite and period of rotation).	• Gravitational field • Force between point masses • Field of a point mass • Field near the surface of the earth • Gravitational potential	• Simulating planetary motion using ICT tools. • Carrying out experiments using falling objects and laser beams and timers. •	• ICT tools Electronic timers Motion sensors.

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TOPIC	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
ROBOTICS	• Identify sensors and actuators • Explain the functions of the sensors • Describe function of actuators • Identify tools and applications for robot design • apply tools and applications for robot design • Construct and code	• Temperature sensors, ultrasonic sensors, light sensor, pressure sensor, proximity sensor, camera. • Actuators • CAD tools, simulation software, micro controllers (ESP32, ESP8266, Arduino and raspberry pi) • Robot design and construction	• Identifying sensors and actuators • Discussing functions of sensors and actuators • Computer simulating and coding • Writing structured programs to control robots for defined tasks • Constructing robots	• ICT tools • Robotic kits • Resource persons • Braille/jaws software • ICs • 3D printer

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Oscillations And Waves	▪ describe simple examples of free oscillations such as the simple pendulum, spring-mass system and torsional pendulum. ▪ explain the terms amplitude, period, frequency, angular frequency and phase difference. ▪ express period in terms of frequency and angular frequency, $f = \frac{1}{T}$ and $T = \frac{2\pi}{\omega}$ ▪ express graphically the changes in displacement, velocity and acceleration for a simple oscillator. ▪ recognise and use ▪ $v = v_o \cos\omega t$ ▪ $v = \pm\, \omega(x_o^2 - x^2)^{1/2}$ ▪ prove that for simple oscillations $a = -\omega^2 x$. ▪ recall and use $x = x_0 \sin\omega t$ as a solution to the equation $a = -\omega^2 x$. ▪ describe analytically and graphically the inter-change between kinetic and potential (gravitational/elastic) energy in a simple oscillator. ▪ describe examples of damped oscillations such as car suspension systems and moving coil meters. ▪ describe graphically the degrees of damping. ▪ describe practical examples of forced vibrations and resonance. ▪ depict graphically how the amplitude changes with frequency near to the natural frequency of an oscillation system. ▪ state examples where resonance is useful and where it is a nuisance.	• Simple harmonic motion. • Damped and forced oscillations. • Resonance	▪ Carrying out experiments involving oscillatory systems. ▪ Deriving $a = -\omega^2 x$. ▪ Solving problems using the listed equations. ▪ Drawing and analysing displacement, velocity and accelerating graphs. ▪ Using Barton pendulums to analyse resonance.	▪ Spring-Mass system. ▪ Simple pendulum ▪ Loaded Cantilever. ▪ Barton pendulums. ▪ Stop watches.

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TOPIC	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
Super position	▪ Explain the principle of superposition in simple application. ▪ Rays in matter ▪ Understand the purpose of tomography or CT scan ▪ Understand the principles of CT scanning ▪ Understand the image of an 8-Voxel cube can be developed using CT scanning. ▪ slit experiment). ▪ explain the term coherence. ▪ scribe how stationary waves are formed. ▪ explain and identify nodes and antinodes. ▪ distinguish between stationary and progressive waves. ▪ determine the wavelength of sound using stationary waves. ▪ show an understanding of experiments which demonstrate two-source interference (Young's two- ▪ explain the conditions required if two-source interference fringes are to be observed. ▪ use the equation, for fringe spacing $x=\lambda D/a$ ▪ demonstrate experiments on diffraction use the formula $n\lambda = d\sin\theta$ to determine the wavelength of light.	• CT Scanning • Stationary waves • Diffraction • Interference • Two-source interference pattern ▪ Diffraction order	▪ Experimenting on superposition and stationary wave formation. ▪ Measuring wavelength. ▪ Solving problems using listed formulae ▪ Carrying out experiments on diffraction	▪ ▪ ICT Tools ▪ CRO ▪ Signal generator, micro-phone, slinky spring, rope, meter rule ▪ ripple tank and diffraction grating

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ELECTRICITY AND MAGNETISM

TOPIC	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
Electricity	▪ describe practical applications of electrostatic phenomena in photo-copying, paint spraying and dust extraction.	• Simple electrostatic phenomena	• Carrying out visits to places where electrostatics spray painting, and photocopying and dust extraction is done	• Resource Person • Photocopier • ICT tools
	▪ define charge and the coulomb. ▪ define potential difference and the volt. ▪ solve problems using $Q = It$, $V = W/Q$, $P = VI$, $P = V^2/R$ and $P = I^2R$. ▪ define resistance and the ohm. ▪ recall and solve problems using $R = \rho l/A$ ▪ define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit. ▪ Use appropriate equipment in trouble shooting electrical circuits ▪ distinguish between e.m.f. and p.d in terms of energy considerations. ▪ describe the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power. ▪ calculate the internal resistance of a source of e.m.f. using $V = E - Ir$. ▪ Determine practically the internal resistance (r) of a power source.	• Electric current • Potential difference • Resistance and resistivity • Circuit faults • electromotive force • Power • Internal resistance	• Solving circuit problems using listed equations • Taking measurements to distinguish between e.m.f. and p.d • Identifying and fixing faulty circuits • Testing basic circuit components • Carrying out experiments to measure internal resistance	• Power sources. • Carbon resistors, voltmeters, ammeters and constantan wires • Multimeter • CRO

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TOPIC	Objectives	**Content** (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
DC circuits	▪ Learners should be able to: ▪ state Kirchhoff's first law and explain the link to conservation of charge. ▪ state Kirchhoff's second law and explain the link to conservation of energy. ▪ derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series. ▪ solve problems using the formula for the combined resistance of two or more resistors in series. ▪ derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel. ▪ solve problems using the formula for the combined resistance of two or more resistors in parallel. ▪ apply Kirchhoff's laws to solve simple circuit problems. ▪ use potential divider as a source of variable p.d. ▪ describe and explain the use of the thermistor, LDR, and strain gauge in potential divider circuits to provide voltage representatives of physical quantities. ▪ use the principle of the potentiometer as a means of comparing potential differences.	• Kirchhoff's laws • use potential divider • principle of the potentiometer	• Solving problems using Kirchhoff's laws • Using Kirchhoff's laws to derive formulae for resistors • Using potential divider in circuits. • Carrying out experiments to determine unknown e.m.f.s and to compare p.d.s	▪ ICT tools ▪ Power sources, carbon resistors, LDR, thermistor, strain gauge, potentiometer, galvanometer, jockey

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TOPIC	**Objectives** Learners should be able to:	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
Electric Fields	▪ describe an electric field as an example of a field of force and define electric field strength as force per unit positive charge. ▪ use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation. ▪ calculate the forces on charges in uniform electric fields. ▪ describe the effect of a uniform electric field on the motion of charged particles. ▪ use Coulomb's law in the form $F = Q_1Q_2/4\pi\varepsilon_o r^2$ for the force between two point charges in free space or air. ▪ use $E = Q/4\pi\varepsilon_o r^2$ for the field strength of a point charge in free space or air. ▪ define potential at a point in terms of the work done in bringing a unit positive charge from infinity to the point. ▪ state that the field strength of the field at a point is numerically equal to the potential gradient at that point. ▪ use the equation $V = Q/4\pi\varepsilon_o r^2$ for the potential in the field of a point charge. ▪ compare qualitative and quantitative aspects of electric and gravitational fields.	• Concept of an electric field and an electric field strength • Uniform electric fields • Force between point charges • Electric field of a point charge • Electric potential • Potential gradient	▪ Solving problems using the stated formulae ▪ Simulating the electric fields. ▪ Indicating similarities between electric and gravitational fields	▪ ICT tools ▪ ICT tools

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TOPIC	Objectives Learners should be able to:	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
Capacitances	▪ describe the function of capacitors in simple circuits. ▪ define capacitance and the farad. ▪ solve problems using C = Q/V. ▪ derive, using the formulae C = Q/V, conservation of charge and the addition of p.d's, the formulae for capacitors in series and parallel. ▪ solve problems using formulae for capacitors in series and in parallel. ▪ deduce from the area under a potential-charge graph, the equation W = ½QV and hence W = ½CV^{2}. ▪ describe charging and discharging of capacitors in RC circuits.	• Capacitors and capacitance • Energy stored in a capacitor	• Discussing the use of capacitors in electronic circuits • Solving problems using the stated formulae • Deriving W = ½QV using graphs • Charging and discharging capacitors in circuits.	• Resistors. • Capacitors • Power source • ammeters

FORM 6:
ELECTRICITY AND MAGNETISM

Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
Electromagnetism	• explain that a force might act on a current-carrying conductor placed in a magnetic field. • solve problems using the equation F = BILsinθ with directions as interpreted by Fleming's left-hand rule. • define magnetic flux density and the Tesla. • demonstrate how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance.	• Force on current-carrying conductor • Force on a moving charge	▪ Carrying out experiment to verify F = BILsinθ ▪ Solving problems using F = BILsinθ & $F = Bqv \sin\theta$.	• Permanent magnets • Metallic rods • Rider • Half meter rule • Protractor • power pack • ammeter

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	• predict the direction of the force on a charge moving in a magnetic field. • solve problems using $F= Bqv \sin\theta$. • sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid. • show that the field due to a solenoid may be influenced by the presence of a ferrous core. • describe the principle of the electromagnet and state its uses. • explain the force between current-carrying conductors and predict the direction of the force. • describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate. • describe how a calibrated Hall probe can be used to measure flux density	• Magnetic fields due to currents • Force between current-carrying conductors • Electromagnet • Hall Probe	• Determining directions using Fleming's left-hand rule. • Carrying out experiment to determine flux density using current balance • Sketching flux field patterns • Simulating force on a moving charge in B field using computer • investigating the effect of a ferrous core in a solenoid • Measuring flux density using a calibrated Hall probe	• Electronic balance • Computer • solenoid • soft iron core • calibrated Hall probe
▪ **Electromagnetic Induction**	• define magnetic flux and the Weber • solve problems using $\varphi = BA$. • define magnetic flux linkage • deduce from appropriate experiments on electromagnetic induction ✚ that a changing magnetic flux can induce an e.m.f. in a circuit, ✚ that the direction of the induced e.m.f. opposes the change producing it ✚ the factors affecting the magnitude of the induced e.m.f.	• Laws of electromagnetic induction ✚ Faraday's law ✚ Lenz law	• Solving problems using $\varphi = BA$. • measuring voltage and current generated by a dynamo • Verifying Lenz law	• Dynamo • Voltmeter • ammeter • solenoid/ coil • magnet • center zero galvanometer

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Alternating Currents**	▪ define and use the terms period, frequency, peak value and root-mean-square (r.m.s) value as applied to an alternating current or voltage. ▪ deduce that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current. ▪ represent an alternating current or an alternating voltage by an equation of the form $x = x_o \sin\omega t$. ▪ distinguish between r.m.s and peak values and solve problems using the relationship $I_{rms} = I_o/\sqrt{2}$ for the sinusoidal case. ▪ show an understanding of the principle of operation of a simple iron-cored transformer and solve the problems using $N_s/N_p = V_s/V_p = I_p/I_s$ for an ideal transformer. ▪ Explain the use of oil in transformer ▪ show an appreciation of the scientific and economic advantages of alternating current and of high voltages for the transmission of electric energy. ▪ state the scientific and economic advantages of alternating current and of high voltage. ▪ distinguish graphically between half-wave and full-wave rectification. ▪ explain the use of a single diode for the half-wave rectification of an alternating current. ▪ explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current. ▪ analyse the effect of a single capacitor in smoothing, including the effect of the value	• Characteristics of alternating currents • The transformer • Transmission of electrical energy • Rectification	• using a CRO to display and measure peak voltage/current and determining root-mean-square • investigating the effect of number of turns on output voltage/current • making prototype transformer ▪ connecting diodes to display half-wave and full-wave rectification.	• CRO • A.C power source • prototype transformer • diodes • CRO • A.C power source

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ELECTRONICS

Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Analogue Electronics**	▪ describe the use of the light-emitting diode (LED), the buzzer and the relay as output devices. ▪ describe the properties of the ideal amplifier as a comparator. ▪ explain the use of an operational amplifier as a comparator. ▪ discuss the principles of negative and of positive feedback in an amplifier. ▪ describe the circuit diagrams for both the inverting and the non-inverting amplifier for single signal input. ▪ use the virtual earth approximation to derive an expression for the gain of inverting amplifiers. ▪ use expression for the voltage gain of inverting and non-inverting amplifiers. ▪ discuss the effect of negative feedback on the gain and on the bandwidth of an operational amplifier. ▪ describe the use of an operational amplifier as a summing amplifier in the inverting mode. ▪ describe the use of an operational amplifier as a voltage follower. ▪ describe the use of an operational amplifier as a non-inverting Schmitt-trigger, with positive feedback provided by a potential divider.	▪ Transducers ▪ The ideal operational amplifier ▪ Operational amplifier circuits	• Constructing circuits to show functioning of control systems e.g burglar alarms, automated street lightning system, • Assembling circuits to show the effect of negative feedback on gain and bandwidth	• operational amplifiers ICs • circuit boards • LED • Buzzer • relay • CRO • carbon resistors • Signal generator

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
• **Digital Electronics**	▪ describe the function of each of the following gates: NOT, AND, NAND, OR, NOR and represent these functions by means of truth tables (limited to a maximum of two inputs, where appropriate). ▪ describe how to combine AND, NOT and OR gates, or NAND gates only, to form EXOR and EX-NOR gates. ▪ analyse circuits using combinations of logic gates to perform control functions. ▪ explain how to construct and interpret truth tables for combinations of logic gates. ▪ describe the function of simple electronic devices and systems which are found in the home, in industry and in communications. ▪ appreciate the impact of electronic devices and systems on domestic and industrial activities. ▪ appreciate the impact of electronic devices and systems on modern communications	▪ Logic gates ▪ Logic gates combinations ▪ The impact of electronics in society and industry	• Assembling circuits to show functionality of NOT, AND, NAND, OR, NOR • Making circuits with a mesh of logic gates to open a safe, or other control functions • Discussing and explaining how electronics has made life easier	• ICs • power source • switches • CRO • logic gates

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MATTER

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Phases of Matter**	• relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering and motion of molecules. • describe a simple kinetic model for solids, liquids and gases. • distinguish between the process of melting, boiling and evaporation. • define the term pressure and using the kinetic model explain the pressure exerted by gases. • derive, from the definitions of pressure and density the equation $p = pgh$. • use the equation $p = pgh$.	• Density • States of matter • Change of phase • Pressure in fluids	• carrying out experiment to observe the random movement of molecules. • Carrying out experiments to determine the pressure due to a liquid column.	• transparent glass tube • Ice Cube • Laboratory thermometer • A beaker • Bunsen burner
▪ **Deformation of Solids**	▪ explain how the deformation is a result of deformation tensile or compressive. ▪ describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension). ▪ define and use the terms stress, strain and the Young modulus. ▪ describe an experiment to determine the Young Modulus of a metal in the form of a wire.	▪ Stress, strain ▪ Elastic and plastic behavior ▪ Young Modulus	• carrying out experiments to determine the spring constant for springs connected in series and in parallel • loading materials to identify plastic	• Helical springs • Clamps • stands • different materials • rubber bands

	▪ distinguish between elastic and plastic deformation of a material. ▪ deduce the strain energy in a deformed material from the area under the force-extension graph. ▪ sketch and compare the force-extension graphs for the typical ductile, brittle and polymeric materials, (consider ultimate tensile stress). ▪ explain fatigue as a consequence of cyclic stress insufficient to cause immediate failure, describe situations which lead to fatigue failure. ▪ describe creep as failure due to sustained stress, below that required for immediate failure, combined with elevated temperature. ▪ Demonstrate knowledge with reference to properties of materials to the solving of simple engineering problems.	▪ Force extension graph ▪ structure and metals ▪ Deterioratio n and failure	and elastic behavior • sketching graphs. • Visiting engineering companies	• coat hanger wire • Resource persons • ICT tools
▪ **Temperature**	▪ show that a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties. ▪ use the equation $\frac{\theta}{100} = \frac{x_\theta - x_o}{x_{100} - x_o}$ to calibrate a thermometer where X is a proportionally varying physical property. ▪ explain the principal features and operation of a liquid-in-glass, resistance, constant-volume gas and thermocouple thermometers and state the advantages and disadvantages of each. ▪ describe the thermodynamic scale and explain the concept of absolute zero. (Existence of an absolute scale of temperature which does not depend on the property of any particular substance) ▪ express temperatures in Kelvin and degree Celsius.	▪ Temperature scales ▪ Fixed points ▪ Thermometri c properties ▪ Types of thermometer s	• measuring the e.m.f of a thermocouple and using it to determine the temperature associated with the e.m.f • Discussing different types of thermometers	• thermocouple • Bunsen burner • Ice • Liquid in glass • Resistance thermometer • Constant volume gas

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Thermal Properties of Materials**	▪ relate a rise in temperature of a body to an increase in internal energy. ▪ define and use specific heat capacity, and show an awareness of the principles of its determination by electrical methods or any other suitable method. ▪ define and use specific latent heat, and show an awareness of the principles of its determination by electrical methods. ▪ describe and explain the cooling which accompanies evaporation both in terms of specific latent heat and in terms of the escape of high energy molecules. ▪ explain that internal energy is determined by the state of the system and can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system. ▪ state the first law of thermodynamics expressed in terms of the changes in internal energy, the heating of the system and the work done on the system.	▪ Specific heat capacity ▪ Specific latent heat ▪ Internal energy ▪ First law of thermodynamics	• carrying out experiments to determine the nature of the cooling curve for metallic samples and other materials • Determining specific latent heat of fusion and vaporization. • Determining the specific heat capacity of a liquid and a solid using electrical methods or any other suitable method. • Simulating internal energy using ICT	• samples of different materials • thermometer • heating element • stopwatch • ammeter • voltmeter • electronic balance • bomb calorimeter

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Ideal Gases**	▪ List the assumptions of the kinetic theory of gases. ▪ state and use the equation of state for an ideal gas expressed as $pV = nRT$ (n = number of moles). ▪ explain how molecular movement causes the pressure exerted by a gas and provide a simple derivation of $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$ (N = number of molecules). ▪ compare $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a molecule is proportional to T. ▪ calculate work done by an ideal gas from p - V graphs.	▪ Kinetic theory of gases ▪ Equation of state ▪ Pressure of a gas ▪ Kinetic energy of a molecule ▪ Work done by an ideal gas	• measuring the pressure of gas from a gas cylinder using a manometer • Solving problems using the equation of state • comparing different pressures from two different sources of gas • Deriving $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$ • Determining work done by ideal gas.	• gas cylinders • U-tube manometer • meter rule
▪ **Non-Viscous Fluid Flow**	▪ Explain what is meant by the terms steady (laminar, streamline) flow, incompressible flow, non-viscous flow, as applied to the motion of an ideal fluid ▪ explain how the velocity vector of a particle in an ideal fluid in motion is related to the streamline associated with that particle. ▪ describe how streamlines can be used to define a tube of flow. ▪ derive and use the equation Av = *constant* (the equation of continuity)	▪ Ideal fluids in motion ▪ Streamlines and the equation of continuity ▪ Horizontal streamline	▪ Using ICT simulation to show that Av=constant. ▪ Visiting airports to consult with resource persons to explain aerofoil motion ▪ Investigating the effect of creating a partial vacuum ▪ Solving problems using $p_1 + \frac{1}{2}pv_1^2 = p_2 + \frac{1}{2}pv_2^2$ ▪ Using ICT simulation to show how atomizers operate. ▪ Using Pitot tube to measure velocity	• resource person • ICT tools • Pitot tube

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	for the flow of an ideal, incompressible fluid. ▪ prove that the equation of continuity is a form of the principle for conservation of mass. ▪ Explain how pressure differences can arise from different rates of flow of a fluid (the Bernoulli effect). ▪ derive the Bernoulli equation in the form $p_1 + ½pv_1^2 = p_2 + ½pv_2^2$ for the case of a horizontal tube to flow. ▪ show that the Bernoulli equation is a form of the principle of conservation of mass. ▪ explain how the Bernoulli effect is applied in the filter pump, in the Venturi meter, in atomizers and in the flow of air over an aerofoil.	▪ The Bernoulli effect		
▪ **Transfer of Thermal Energy**	▪ demonstrate that thermal energy is transferred from a region of higher temperature to a region of low temperature. ▪ state and explain the Zeroth law of thermo-dynamics ▪ explain the process of convection as a consequence of change of density. ▪ demonstrate a qualitative understanding that bodies emit electromagnetic radiation at a rate which increases with increasing temperature.	▪ Thermal equilibrium ▪ Thermal conduction ▪ Convection ▪ Radiation	▪ investigating the direction of heat flow based on temperature gradient ▪ simulating emission of electromagnetic radiation	• ICT tools • thermometer • various materials

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	▪ describe simple applications involving the transfer of thermal energy by conduction, convection and radiation.			

MODERN PHYSICS

Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Charged Particles**	▪ interpret the experimental evidence for quantisation of change. ▪ understand the principles of determination of charge e by Millikan's experiment. ▪ describe and analyse quantitatively using ▪ the deflection of beams of charged particles by uniform electric and uniform magnetic fields. ▪ explain how electric and magnetic fields can be used in velocity selection. ▪ explain the principles of one method for the determination of v and e/m_e for electrons.	▪ Electrons ▪ Beams of charged particles ▪ Crossed fields ▪ Mass spectrometry	▪ carrying out experiments to show the deflection of electrons ▪ Carrying out calculations involving charged particles in uniform fields. ▪ Explaining methods for the determination of v and e/m_e	• vacuum tube • electron gun • permanent magnets • ICT tools

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Topic	Objectives	Content	Suggested activities	Suggested resources

		(knowledge, skills, values and attitudes)		
▪ **Quantum Physics**	▪ explain the particulate nature of electromagnetic radiation. ▪ state and use $E = hf$. ▪ describe the phenomena of the photoelectric effect. ▪ describe the significance of threshold frequency. ▪ explain why the maximum photoelectric energy is independent of intensity, and why the photoelectric current is proportional to intensity. ▪ explain photoelectric phenomena in terms of photon energy and work function energy. ▪ use and explain the significance of $hf = ø + ½mv^2_{max}$. ▪ explain the photoelectric effect as evidence for the particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provides evidence for a wave nature. ▪ describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles. ▪ derive and use the relation for the de Broglie wavelength $\lambda = h/p$. ▪ explain the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and explain how this leads to spectral lines. ▪ distinguish between emission and absorption line spectra.	▪ Energy of a photon ▪ Photoelectric emission of electrons ▪ Wave particle duality ▪ Energy levels in atoms ▪ Line spectra	▪ demonstrating photoelectric emission using a charged gold leaf and a suitable metal and electromagnetic radiation ▪ simulating to show energy levels	• gold leaf electroscope • UV source • metal plates • Computer • ICT tools

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	▪ state and use the relation $hf = E_1 - E_2$.			

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Topic	Objectives	Content (knowledge, skills, values and attitudes)	Suggested activities	Suggested resources
▪ **Atomic Structure**	▪ describe qualitatively the α - particle scattering experiment and the evidence it provides for the existence and small size of the nucleus. ▪ use the usual notation of the presentation of nuclides. ▪ show an appreciation of the association between energy and mass as represented by $E = mc^2$. ▪ Illustrate graphically the variation of binding energy per nucleon with nucleon number. ▪ describe the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission. ▪ verify that nucleon number, proton number, energy and mass are all conserved in nuclear processes.	▪ The nuclear atom ▪ The nucleus ▪ Isotopes ▪ Mass excess and nuclear binding energy ▪ Nuclear processes	▪ Describing the size of the nucleus ▪ Simulation ▪ Sketching a graph to show variation of binding energy per nucleon with nucleon number ▪ Balancing nuclide equations	• ICT tools

	▪ represent simple nuclear reactions by nuclear equations of the form $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$.			
Radioactivity	▪ Explain the spontaneous and random nature of nuclear decay. ▪ Describe the scientific and environmental importance of background radiation with reference to its existence and origin. ▪ illustrate the random nature of radioactive decay by observation of the fluctuations in count rate. ▪ describe the environmental hazards of ionisations and the safety ▪ list precautions which should be taken in the handling and disposal of radioactive material. ▪ define the terms activity and decay constant and use $A = \lambda N$. ▪ recognise, use and represent graphically solutions of the decay law based on $x = x_o\exp(-\lambda t)$. ▪ define half-life ($t½$). ▪ use the relation $\lambda = (\ln 2)/t½$ ▪ describe the use of radioisotopes, providing one example of each of the following: the use of tracers, the use of penetrating properties of radiation, the use of ionising radiation in radiotherapy and leak detection.	▪ Types of ionising radiation ▪ Background radiation ▪ Hazards and safety precautions ▪ Radioactive decay ▪ Radioisotopes	▪ Simulating nuclear decay ▪ Discussing nature of nuclear decay ▪ Solving problems using the listed formulae ▪ Measuring background radiation ▪ Visiting industries which make use of radio activity ▪ Discussing procedures in the handling and disposal of radioactive waste.	• ICT tools • Resource persons • GM tube

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Topic	**Objectives**	**Content** (knowledge, skills, values and attitudes)	**Suggested activities**	**Suggested resources**
▪ Communication	▪ appreciate that information may be carried by a number of different channels, including wire-pairs, coaxial cables, radio and microwave links, optic fibres ▪ define the term modulation and be able to distinguish between amplitude modulation (AM) and frequency modulation (FM) ▪ recall that a carrier wave, amplitude modulated by a single audio frequency, is equivalent to the carrier wave frequency together with two sideband frequencies ▪ understand the term bandwidth ▪ recall the frequencies and wavelengths used in different channels of communication ▪ demonstrate an awareness of the relative advantages of AM and FM transmissions ▪ state the advantages of the transmission of data in digital form, compared with the transmission of data in analogue form ▪ understand that the digital transmission of speech or music involves analogue-to-digital conversion (ADC) before transmission and digital-to-analogue conversion (DAC) after reception ▪ understand the effect of the sampling rate and the number of bits in each sample on the reproduction of an input signal	▪ Communication Channels ▪ Modulation ▪ Digital Communication ▪ Relative merits of channels of communication ▪ Attenuation	▪ Visiting Broadcasting stations. ▪ Comparing transmissions of data in digital form and analog form. ▪ Inviting resource persons who know deal with satellite	• ICT tools • Resource persons • Encoders • Decorders

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	▪ discuss the relative advantages and disadvantages of channels of communication in terms of available bandwidth, noise, crosslinking, security, signal attenuation, repeaters and regeneration ▪ recall the relative merits of both geostationary and polar orbiting satellites for communicating information ▪ understand and use signal attenuation expressed in dB and dB per unit length ▪ recall and use the expression *number of dB* = 10 $\log(P_1/P_2)$ for the ratio of two powers			

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9.0 ASSESSMENT

The Upper Secondary Physics syllabus learning area for Form 6 shall be assessed through School Based Continuous Assessment (SBCA) and Summative Assessment (SA). These assessments shall be guided by the principles of inclusivity, practicability, authenticity, transparency, flexibility, validity, and reliability. The principles are crucial for creating a supportive and effective learning environment that fosters growth and development in learners at the secondary school level. Arrangements, accommodations, and modifications shall be visible to enable candidates with special needs to access assessments.

This section covers the assessment objectives, the assessment model, the scheme of assessment, and the specification grid.

9.1 Assessment Objectives

By the end of the Upper Secondary Physics syllabus learning area for Form 6, learners will be assessed on their ability to:

9.1.1 Show knowledge and understanding.
9.1.2 Handle information and solve problems.
9.1.3 Display experimental skills and investigations.

9.2 Assessment Model

Assessment of learners at the Upper Secondary school level for Form 6 Syllabus shall be both Continuous and Summative as shown in Figure 1. School Based Continuous Assessment shall include recorded activities from the School Based Projects. The mark shall be included on the learner’s end of term and year report. Summative assessment at school level shall include terminal examinations which are at the end of the term and year.

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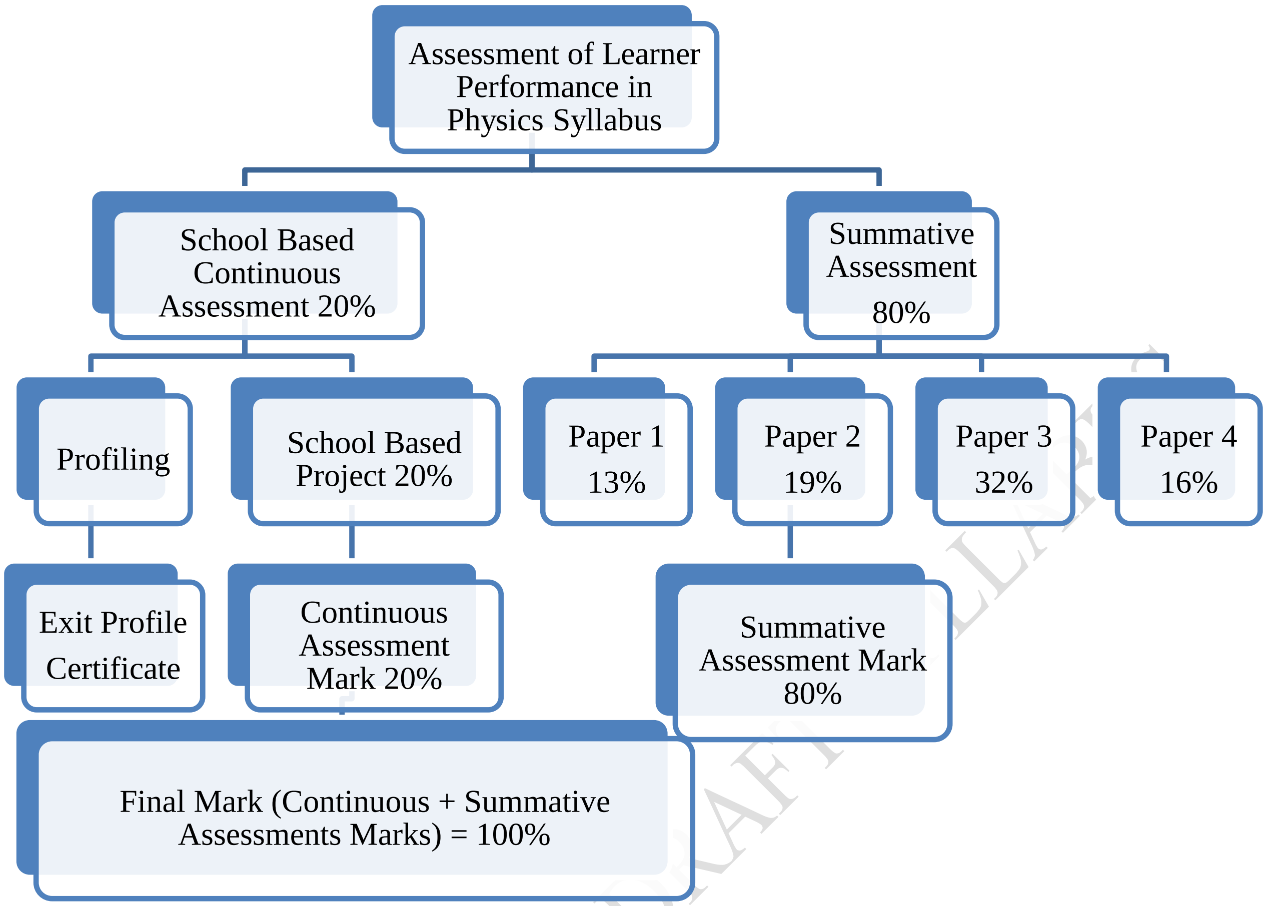

In addition, learners shall be profiled and learner profile records established. Learner profile certificates shall be issued for checkpoints assessment in schools as per the dictates of the Teacher's Guide to Learning and Assessment. The aspects to be profiled shall include learner's prior knowledge, values and skills, and subsequently the new competences acquired at any given point.

9.3 Scheme of Assessment

The Assessment Model shows that learners shall be assessed using both School Based Continuous Assessment and Summative Assessment for both School and ZIMSEC assessments.

The table shows the Scheme of Assessment where 20% is allocated to School Based Continuous Assessment and 80% to School or ZIMSEC Summative Assessment.

FORM OF ASSESSMENT	WEIGHTING
School Based Continuous Assessment	**20%**
Summative Assessment	**80%**
Total	**100%**

9.3.1 Description of School Based Continuous Assessment

Learners shall do one school-based project per Form which contributes to 20% of the end of year final mark. The end of year summative assessment shall then contribute 80%. However, for ZIMSEC public examinations, two (2) school-based projects shall be considered as School Based Continuous Assessment at Form 6. The two School Based Projects shall include those done during Form 5 and Form 6 sessions. Each will contribute 10%.

9.3.1.1: School – Based Project Continuous Assessment Scheme

The Table given below shows the Learning and Assessment Scheme for the School Based Project.

Project Execution Stages	Project Stage Description	Timelines	Marks
1	Problem Identification	January	5
2	Investigation of related ideas to the problem/innovation	February	10
3	Generation of possible solutions	March	10
4	Selecting the most suitable solution	April-May	5
5	Refinement of selected solution	June	5
6	Presentation of the final solution	July	10
7	Evaluation of the solution and Recommendations	August-September	5
	TOTAL		**50**

The assessment scheme shows the stages that shall be executed by pupils and the timeline at which each stage shall be carried out. Possible marks, totalling 50, are highlighted to indicate how much can be allocated.

9.3.2 Description of the ZIMSEC Summative Assessment

ZIMSEC Summative Assessment shall be a public examination at Form 6 The examination shall consist of four papers of different weighting

Paper	Paper type	Marks	Duration	Weighting
1	Multiple Choice	40	1 hr	13
2	Structured	60	1hr 30mins	19

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3	Free Response	100	2hr30 mins	32
4	Practical	50	2hr30mins	16
TOTAL		**250**		**80%**

Paper 1
Duration:1 hour

The paper consists of 40 compulsory multiple-choice items of the direct choice type. Each question shall have 4 response items.

Paper 2
Duration: 1-hour 30mins.

This paper consists of a variable number of questions of variable mark value. Candidates will answer all questions. Candidates will answer on the question paper [60 marks].

Paper 3: Free Response Questions
Duration: 2 hours 30minutes

This paper consists of 5 free response questions. Each question carries [25 marks]
Question 1: covers General Physics and Newtonian Mechanics,
Question 2: covers Oscillations and Waves,
Question 3 covers Electricity and Magnetism,
Question 4 covers Matter, and
Question 5 covers Modern Physics.

Candidates will answer question 1 and any three questions from the remaining 4 questions. Question 1 is compulsory.
Candidates will answer on separate answer sheets. [100 marks]

Paper 4: Practical
Duration:2 hours 30minutes
This paper requires candidates to carry out practical work in timed conditions. The paper will consist of two experiments and one design practical drawn from different areas of Physics. The candidates will be assessed on their practical skills rather than their knowledge of theory. Candidates will answer all questions. Candidates will answer on the question paper. **[50 marks]**

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9.4 Specification Grid

Skill	Paper 1	Paper 2	Paper 3	Paper 4
Knowledge and comprehension	15%	15%	15%	
Application and Analysis	45%	45%	45%	
Problem solving	40%	40%	40%	
Practical				100%
TOTAL	100%	100%	100%	100%

10.0 APPENDIX

(a) **MATHEMATICAL REQUIREMENTS**

Arithmetic

Candidates should be able to:

- recognise and use expressions in decimal and standard form (scientific) notation
- recognise and use binary notation
- use an electronic calculator for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions), exponentials and logarithms (lg and ln)
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
- make approximate evaluations of numerical expressions (e.g. $\pi^2 \approx 10$) and use such approximations to check the magnitude of calculated results.

Algebra

Candidates should be able to:

- change the subject of an equation. Most relevant equations involve only the simpler operations but may include positive and negative indices and square roots.
- solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. Linear simultaneous equations and the use of the formula to obtain the solutions of quadratic equations are required.
- substitute physical quantities into physical equations using consistent units and check the dimensional consistency of such equations
- set up simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models
- recognise and use the logarithms of expressions like ab, a b, xn, ekx and understand the use of logarithms in relation to quantities with values that range over several orders of magnitude

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- express small changes or uncertainties as percentages and vice versa
- understand and use the symbols <, >, ≤, ≥, «, », /, ∝, <x>, Σ, Δx, δx, √

Geometry and trigonometry

Candidates should be able to:

- calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of cuboids, cylinders and spheres
- use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle
- use sines, cosines and tangents of angles (especially for 0°, 30°, 45°, 60°, 90°)
- use the trigonometric relationships for triangles:
  - Sine rule
  - Cosine rule
- use $sin\theta \approx tan\theta \approx \theta$ and $cos\theta \approx 1$ for small θ ; $sin2\theta + cos2\theta = 1$
- understand the relationship between degrees and radians, convert from one to the other and use the appropriate system in context.

Vectors

Candidates should be able to:

- find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate
- obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs

Candidates should be able to:

- translate information between graphical, numerical, algebraic and verbal forms
- select appropriate variables and scales for graph plotting
- determine the gradient, intercept and intersection of linear graphs
- choose, by inspection, a straight line which will serve as the line of best fit through a set of data points presented graphically
- draw a curved trend line through a set of data points presented graphically, when the arrangement of these data points is clearly indicative of a non-linear relationship
- recall standard linear form $y = mx + c$ and rearrange relationships into linear form where appropriate
- sketch and recognise the forms of plots of common simple expressions like $1/x$, x^2, $1/x^2$, $sin x$, $\cos x$, e^{-x}
- draw a tangent to a curve, and understand and use the gradient of the tangent as a means to obtain the gradient of the curve at a point
- understand and use the area below a curve where the area has physical significance.

Treatment of uncertainties

Candidates should be able to:

- convert absolute uncertainty estimates into fractional or percentage uncertainty estimates and vice versa

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- show uncertainty estimates, in absolute terms, beside every value in a table of results
- calculate uncertainty estimates in derived quantities
- show uncertainty estimates as error bars on a graph
- estimate the absolute uncertainty in the gradient of a graph by recalling that absolute uncertainty = gradient of line of best fit – gradient of worst acceptable line
- estimate the absolute uncertainty in the y-intercept of a graph by recalling that absolute uncertainty = y-intercept of line of best fit – y-intercept of worst acceptable line
- express a quantity as a value, an uncertainty estimate and a unit.

(b) Summary of key quantities, symbols and units

Quantity	Usual symbols	Usual unit
Base quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol

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Quantity	**Usual symbols**	**Usual unit**
electric field strength	E	$\mathrm{N\,C^{-1}}$, $\mathrm{V\,m^{-1}}$
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
electron mass	m_e	kg, u
elementary charge	e	C
energy	E, U, W	J
force	F	N
frequency	f	Hz
gravitational constant	G	$\mathrm{N\,m^2\,kg^{-2}}$
gravitational field strength	g	$\mathrm{N\,kg^{-1}}$
gravitational potential	ϕ	$\mathrm{J\,kg^{-1}}$
half-life	$t_{\frac{1}{2}}$	s
Hall voltage	V_H	V
heating	q, Q	J
intensity	I	$\mathrm{W\,m^{-2}}$
internal energy change	ΔU	J
kinetic energy	E_k	J
magnetic flux	Φ	Wb
magnetic flux density	B	T
mean-square speed	$\langle c^2 \rangle$	$\mathrm{m^2\,s^{-2}}$
molar gas constant	R	$\mathrm{J\,mol^{-1}\,K^{-1}}$
molar mass	M	$\mathrm{kg\,mol^{-1}}$
moment of force	T	N m
momentum	p	N s
neutron mass	m_n	kg, u
neutron number	N	
nucleon number	A	
number	N, n, m	
number density (number per unit volume)	n	$\mathrm{m^{-3}}$
period	T	s
permeability of free space	μ_0	$\mathrm{H\,m^{-1}}$
permittivity of free space	ε_0	$\mathrm{F\,m^{-1}}$
phase difference	ϕ	°, rad
Planck constant	h	J s
potential energy	E_p	J

Quantity	Usual symbols	Usual unit
power	P	W
pressure	p	Pa
proton mass	m_p	kg, u
proton number	Z	
ratio of powers		dB
relative atomic mass	A_r	
relative molecular mass	M_r	
resistance	R	Ω
resistivity	ρ	Ω m
specific acoustic impedance	Z	$kg\,m^{-2}\,s^{-1}$
specific heat capacity	c	$J\,kg^{-1}\,K^{-1}$
specific latent heat	L	$J\,kg^{-1}$
speed	u, v, w, c	$m\,s^{-1}$
speed of electromagnetic waves	c	$m\,s^{-1}$
spring constant	k	$N\,m^{-1}$
strain	ε	
stress	σ	Pa
torque	T	N m
velocity	u, v, w, c	$m\,s^{-1}$
volume	V, v	m^3
wavelength	λ	m
weight	W	N
work	w, W	J
work function energy	Φ	J
Young modulus	E	Pa

A LEVEL

Other quantities		
acceleration	a	$m\,s^{-2}$
acceleration of free fall	g	$m\,s^{-2}$
activity of radioactive source	A	Bq
amplitude	x_0	m
angle	θ	°, rad
angular displacement	θ	°, rad
angular frequency	ω	$rad\,s^{-1}$
angular speed	ω	$rad\,s^{-1}$
angular velocity	ω	$rad\,s^{-1}$
area	A	m^2
atomic mass	m_a	kg, u
attenuation/absorption coefficient	μ	m^{-1}
Avogadro constant	N_A	mol^{-1}
Boltzmann constant	k	$J\,K^{-1}$
capacitance	C	F
Celsius temperature	θ	°C
decay constant	λ	s^{-1}
density	ρ	$kg\,m^{-3}$
displacement	s, x	m
distance	d	m
efficiency	η	
electric charge	q, Q	C

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Quantity	Usual symbols	Usual unit
electric field strength	E	$N C^{-1}$, $V m^{-1}$
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
electron mass	m_e	kg, u
elementary charge	e	C
energy	E, U, W	J
force	F	N
frequency	f	Hz
gravitational constant	G	$N m^2 kg^{-2}$
gravitational field strength	g	$N kg^{-1}$
gravitational potential	ϕ	$J kg^{-1}$
half-life	$t_{\frac{1}{2}}$	s
Hall voltage	V_H	V
heating	q, Q	J
intensity	I	$W m^{-2}$
internal energy change	ΔU	J
kinetic energy	E_k	J
magnetic flux	Φ	Wb
magnetic flux density	B	T
mean-square speed	$\langle c^2 \rangle$	$m^2 s^{-2}$
molar gas constant	R	$J mol^{-1} K^{-1}$
molar mass	M	$kg mol^{-1}$
moment of force	T	N m
momentum	p	N s
neutron mass	m_n	kg, u
neutron number	N	
nucleon number	A	
number	N, n, m	
number density (number per unit volume)	n	m^{-3}
period	T	s
permeability of free space	μ_0	$H m^{-1}$
permittivity of free space	ε_0	$F m^{-1}$
phase difference	ϕ	°, rad
Planck constant	h	J s
potential energy	E_p	J

Quantity	Usual symbols	Usual unit
power	P	W
pressure	p	Pa
proton mass	m_p	kg, u
proton number	Z	
ratio of powers		dB
relative atomic mass	A_r	
relative molecular mass	M_r	
resistance	R	Ω
resistivity	ρ	Ω m
specific acoustic impedance	Z	$\mathrm{kg\,m^{-2}\,s^{-1}}$
specific heat capacity	c	$\mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat	L	$\mathrm{J\,kg^{-1}}$
speed	u, v, w, c	$\mathrm{m\,s^{-1}}$
speed of electromagnetic waves	c	$\mathrm{m\,s^{-1}}$
spring constant	k	$\mathrm{N\,m^{-1}}$
strain	ε	
stress	σ	Pa
torque	T	N m
velocity	u, v, w, c	$\mathrm{m\,s^{-1}}$
volume	V, v	$\mathrm{m^3}$
wavelength	λ	m
weight	W	N
work	w, W	J
work function energy	Φ	J
Young modulus	E	Pa

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Quantity	Usual symbols	Usual unit
power	P	W
pressure	p	Pa
proton mass	m_p	kg, u
proton number	Z	
ratio of powers		dB
relative atomic mass	A_r	
relative molecular mass	M_r	
resistance	R	Ω
resistivity	ρ	Ω m
specific acoustic impedance	Z	$kg\,m^{-2}\,s^{-1}$
specific heat capacity	c	$J\,kg^{-1}\,K^{-1}$
specific latent heat	L	$J\,kg^{-1}$
speed	u, v, w, c	$m\,s^{-1}$
speed of electromagnetic waves	c	$m\,s^{-1}$
spring constant	k	$N\,m^{-1}$
strain	ε	
stress	σ	Pa
torque	T	N m
velocity	u, v, w, c	$m\,s^{-1}$
volume	V, v	m^3
wavelength	λ	m
weight	W	N
work	w, W	J
work function energy	Φ	J
Young modulus	E	Pa

(c) Glossary of Assessment command words

This glossary should prove helpful to candidates as a guide, although it is not exhaustive and it has deliberately been kept brief. Candidates should understand that the meaning of a term must depend in part on its context. The number of marks allocated for any part of a question is a guide to the depth required for the answer.

1. *Define* (the term(s) ...) is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, is required.

2. *What is meant by* ... normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The number of marks indicated will suggest the amount of supplementary comment required.

3. *Explain* may imply reasoning or some reference to theory, depending on the context.

4. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.

5. *List* requires a number of points with no elaboration. If a specific number of points is requested, this number should not be exceeded.

6. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. For particular phenomena, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended is suggested by the indicated mark value.

7. *Discuss* requires candidates to give a critical account of the points involved in the topic.

8. *Deduce/Predict* implies that candidates are not expected to produce the required answer by recall, but by making a logical connection between other pieces of information. Such information may be wholly given in the question, or may depend on answers extracted in an earlier part of the question.

9. *Suggest* is used in two main contexts. It may imply either that there is no unique answer or that candidates are expected to apply their general knowledge to a new situation (one that may not, formally, be in the syllabus).

10. *Calculate* is used when a numerical answer is required. In general, working should be shown.

11. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

12. *Determine* often implies that the quantity concerned cannot be measured directly, but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. the Young modulus, relative molecular mass.

13. *Show* is used where a candidate is expected to derive a given result. It is important that the terms being used by candidates are stated explicitly and that all stages in the derivation are stated clearly.

14. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make any necessary simplifying

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assumptions about points of principle and about the values of quantities not otherwise included in the question.

15. *Sketch* (applied to graph work) implies that the shape and/or position of the curve need only be qualitatively correct.
16. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

17. *Sketch* (applied to diagrams) implies that a simple, freehand drawing is acceptable, though care should be taken over proportions and the clear exposition of important details.

18. *Compare* requires candidates to provide both similarities and differences between things or concepts.

(D) Data and formulae

The following data and formulae will appear as pages 2 and 3 in Papers 1, 2 and 3.

DATA

speed of light in free space	$c = 3.00 \times 10^{8}\ \mathrm{ms^{-1}}$
permeability of free space	$\mu_o = 4\pi \times 10^{-7}\ \mathrm{Hm^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{Fm^{-1}}$ ($1/4\pi\varepsilon_0 = 8.99 \times 10^{9}\ \mathrm{mF^{-1}}$)
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ Js
unified atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31\ \mathrm{JK^{-1}\ mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ \mathrm{JK^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{Nm^{2}\ kg^{-2}}$
acceleration of free fall	$g = 9.81\ \mathrm{ms^{-2}}$

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FORMULAE

uniformly accelerated motion $s = ut + ½at^2$

$v^2 = u^2 + 2as$

work done on/by a gas $W = p\,\Delta V$

gravitational potential $\emptyset = -\,Gm/r$

hydrostatic pressure $p = \rho gh$

pressure of an ideal gas $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$

simple harmonic motion $a = -\omega^2 x$

velocity of particle in s.h.m. $v = v_o \cos \omega t$

$v = \pm\omega\sqrt{(x_o^2 - x^2)}$

Doppler effect $f_o = \frac{f_s v}{v \pm v_s}$

electric potential $V = \frac{Q}{4\pi\,\varepsilon_0 r}$

capacitors in series $1/C = 1/C_1 + 1/C_2 + \ldots$

capacitors in parallel $C = C_1 + C_2 + \ldots$

energy of charged capacitor $W = \frac{1}{2}QV$

electric current $I = Anvq$

resistors in series $R = R_1 + R_2 + \ldots$

resistors in parallel $1/R = 1/R_1 + 1/R_2 + \ldots$

Hall voltage $V_H = \frac{BI}{\mathrm{ntq}}$

alternating current/voltage $x = x_o \sin\omega t$

radioactive decay $x = x_o \exp(-\lambda t)$

decay constant $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

(E) **Commonly Used Materials And Apparatus**

The list is not exhaustive: other items are usually required, to allow for variety in the questions set.
Cells: 1.5 V
Connecting leads and crocodile clips
Digital ammeter, minimum ranges 0–1 A reading to 0.01 A or better, 0–200 mA reading to 0.1 mA or better, 0–20 mA reading to 0.01 mA or better (digital multimeters are suitable)
Digital voltmeter, minimum ranges 0–2 V reading to 0.001 V or better, 0–20 V reading to 0.01 V or better (digital multimeters are suitable)
Lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
Power supply: variable up to 12 V d.c. (low resistance)
Rheostat (with a maximum resistance of at least 8 Ω, capable of carrying a current of at least 4 A)
Switch Wire: constantan 26, 28, 30, 32, 34, 36, 38 s.w.g. or similar metric sizes
Long stem thermometer: –10 °C to 110 °C × 1 °C
Means to heat water safely to boiling (e.g. an electric kettle)
Plastic or polystyrene cup 200 cm3 Stirrer
Adhesive putty (e.g. Blu-Tack)

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Adhesive tape (e.g. Sellotape)
Balance to 0.1 g (this item may often be shared between sets of apparatus)
Bar magnet
Bare copper wire: 18, 20, 26 s.w.g. or similar metric sizes
Beaker: 100 cm3, 200 cm3 or 250 cm3
Card
Expendable steel spring (spring constant approx. 25 N m–1; unscratched length approx. 2 cm)
G-clamp
Magnadur ceramic magnets
Mass hanger
Micrometer screw gauge (this item may often be shared between sets of apparatus)
Modelling clay (e.g. Plasticine)
Newton-meter (1 N, 10 N)
Pendulum bob
Protractor
Pulley
Rule with a millimetre scale (1 m, 0.5 m, 300 mm)
Scissors Slotted masses (100 g, 50 g, 20 g, 10 g) or alternative Stand, boss and clamp
Stopwatch (candidates may use their wristwatches), reading to 0.1 s or better
Stout pin or round nail
String/thread/twine
Vernier or digital calipers (this item may often be shared between sets of apparatus)
Wire cutters

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