IM SYLLABUS (2021)

PHYSICS IM 26

SYLLABUS

IM26 Physics

Syllabus Addendum

Mitigating factors for 2021 MATSEC Examinations Session

Changes in Subject Content	The following content will not be assessed: Parts of: Section 3.1.2 – Thermometry; Section 6.4.4 – Force on a charged particle moving through a magnetic field. Note changes indicated in the document hereunder as follows: • Content which will not be assessed - strikethrough
Changes in Coursework	N/A
Changes in Exam Paper(s)	No changes.

MATSEC Board
October 2020

3.1.2 Thermometry	Candidates should be able to: (a) ~~Define thermometric property.~~ (b) ~~Give examples of physical properties that may be used for the measurement of temperature.~~ (c) ~~Explain what is meant by a temperature fixed point.~~ (d) ~~Define the ice point and the steam point of water.~~ (e) ~~State and use the equation $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100°C$ where θ is the temperature on the Celsius scale, X is a thermometric property assumed to vary linearly with temperature, and subscripts indicate temperatures on the Celsius scale. Examinable thermometric properties are the length of a liquid column, the resistance of a wire or the pressure (or the corresponding height of a column) of gas at constant volume. Ranges and structures of thermometers are not examinable.~~ (f) ~~Explain why using different thermometric properties can lead to different temperatures. Comparison of thermometers is not examinable.~~ (g) Convert between degrees Celsius and kelvin using the equation $T(\text{K}) = \theta(°\text{C}) + 273.15$ K. (h) State and use $\Delta\theta = \Delta T$.
6.4.4 Force on a charged particle moving through a magnetic field	Candidates should be able to: (a) ~~Derive and~~ use the equation $F = Bqv\sin(\theta)$ where q is the charge, v is the velocity and θ is the angle between B and v. (b) Relate the direction of the force to that of a charged particle in motion and the magnetic field. (c) Identify the magnetic force on a charged particle moving in a plane perpendicular to that of a uniform magnetic field as a centripetal force. (d) Derive and use $mv = Bqr$ where m is the mass and r is the radius of the path.

Physics IM 26 (Available in September)
Syllabus 1 Paper (3hrs)

Aims of the Intermediate Level Physics Curriculum

A course of study intended to prepare students for the Intermediate Level Matriculation Examination in Physics should:

- promote an understanding of the nature and essence of physical principles;
- foster implementation of the scientific approach in the analysis of real life situations;
- encourage the development of problem solving techniques;
- foster an appreciation and enjoyment of physics as a part of universal human culture;
- encourage the development of practical skills;
- provide an appreciation that physical laws are universal;
- cultivate an appreciation of the influence of physics in everyday life;
- encourage an understanding of technological applications of physics and its importance as a subject of social, economic and industrial relevance;
- encourage effective scientific communication and presentation.

Assessment Objectives

- Knowledge with understanding (40%)
- Applications of concepts and principles (35%)
- Communication and presentation (10%)
- Analysis of experimental data (15%)

Grade Descriptions

The grade descriptions indicate the criteria for awarding grades A, C and E. These criteria indicate the extent to which the assessment objectives are attained.

Objective/s	A	C	E
The candidate recalls and uses **knowledge** of Physics from…	the whole syllabus	most of the syllabus	some parts of the syllabus
The demonstration of the **understanding** of the principles and concepts is…	excellent	fair	poor
The candidate **applies appropriately physical concepts and principles** in situations…	which are both familiar and unfamiliar	which are familiar or unfamiliar but some guidance is provided	which are familiar or closely related to them
The candidate's level of **communication and presentation** is…	clear, concise and direct	satisfactory	decent
The candidate's **analysis of given experimental data** is…	rigorous	adequate	mediocre

Examination

The examination consists of ONE three-hour written paper having the following structure.

Section A - 8 to 10 short compulsory questions, which in total carry 50% of the marks (90 minutes).
Section B - 1 compulsory question on data analysis, which carries 14% of the marks (25 minutes).
Section C - 4 longer structured questions to choose 2, each carrying 18% of the marks i.e. 36% allotted for the Section (65 minutes).

It should be noted that while the students will not be tested in a formal practical examination, it is expected that they will have some opportunity to familiarise themselves with some basic experimental techniques and experiments illustrating the syllabus content during their studies. Questions may be set testing the students' familiarity with the main experiments mentioned in the syllabus.

Notes:

(i) Scientific calculators may be used throughout the examination. Nevertheless, the use of graphical and/or programmable calculators is prohibited. Disciplinary action will be taken against students making use of such calculators.

(ii) A Data and Formulae Booklet published by the MATSEC Board will be made available during the examination.

Mathematical Requirements

Sufficient mathematical background is necessary for one to be able to understand and apply the principles of physics at this level. Below is a list of abilities the candidate should be able demonstrate. These should be considered an integral part of the subject and can be examined directly or indirectly.

Topic	**Abilities and comments**
(A) Arithmetic and computation	Candidates should be able to: (a) Express numbers using decimal and standard form. (b) Use electronic calculators to carry out calculations involving (i) addition, subtraction, multiplication and division; (ii) angles in degrees; (iii) reciprocals, squares, $\sin(\theta)$, $\cos(\theta)$, $\tan(\theta)$, x^n, and their inverses, i.e. square roots, $\sin^{-1}(\theta)$, $\cos^{-1}(\theta)$ and $\tan^{-1}(\theta)$; (iv) arithmetic means. (c) Manipulate numerical data appropriately. (d) State numerical answers to an appropriate number of significant figures. (e) Make approximate estimated to find the order of magnitude of numerical expressions. (f) Convert between seconds, minutes, hours, days and years. One year should be taken to be 365.25 days.
(B) Algebra	Candidates should be able to: (a) Manipulate algebraic expressions. For example, changing the subject of a formula; this can include terms having positive or negative, integer or fractional powers. (b) Solve algebraic equations including those involving inverse relationships and inverse square relationships. (c) Construct and use simple mathematical equations to model a physical situation. (d) Identify situations where the use of a given mathematical model is inadequate. (e) Identify the meaning of and use the following symbols: $=$, $>$, $<$, $\gg$, $\ll$, $\approx$, $\propto$, Σx, Δx and δx.
(C) Geometry and trigonometry	Candidates should be able to: (a) State and use the equations for: (i) the area and perimeter of triangles, rectangles, circles and composite shapes; (ii) the surface areas and volumes of rectangular blocks, cylinders and spheres. (b) State and use Pythagoras' theorem. (c) Identify and use adjacent angles, vertically opposite angles, corresponding angles, alternate angles (or Z angles).

Topic	Abilities and comments
	(d) Identify similar triangles and use the ratio of their sides. (e) State and use the sum of the angles on a straight line. (f) State and use the sum of the internal angles of a triangle and a quadrilateral. (g) Define and use the sine, cosine and tangent functions. (h) State and use the relation $\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$.

Syllabus

Content	Learning outcomes and comments
1. Physical quantities	
1.1 Quantities and units of the S.I. system	Candidates should be able to: (a) Explain what physical quantities and units are. (b) List and use the following S.I. base quantities and their corresponding units: mass (kilogram, kg), length (metre, m), time (second, s), current (ampere, A), temperature interval (kelvin, K), amount of substance (mole, mol). (c) Distinguish between base and derived quantities and units giving examples. (d) Express the unit of a quantity in terms of the base units using given or standard equations or the definition of the quantity. (e) Express a numerical value using the following SI prefixes: pico (p), nano (n), micro (μ), milli (m), centi (c), kilo (k), mega (M) and giga (G). (f) Recognise, use and express the following SI prefixes as powers of 10: pico (p), nano (n), micro (μ), milli (m), centi (c), kilo (k), mega (M) and giga (G).
1.2 Homogeneity of physical equations	Candidates should be able to: (a) Identify quantities and constants that have units and those which do not in a given equation. (b) Determine if an equation is homogeneous by using base units. (c) Distinguish between the concepts of physically correct and homogenous equations, giving examples of homogenous equations that are not physically correct.
1.3 Scalar and vector quantities	Candidates should be able to: (a) Define vector and scalar quantities, giving examples of each. (b) State whether a given quantity is a vector or a scalar. (c) Define the resultant of a set of vectors. (d) Define a sign convention or use a given sign convention to add (subtract) vectors. (e) Resolve a vector into two perpendicular components. (f) State and use the fact that mutually perpendicular vectors can be treated separately. (g) Determine the resultant (giving both the magnitude and direction) of any set of coplanar vectors.

Content	Learning outcomes and comments
2. Mechanics	
2.1 Rectilinear motion	
2.1.1 Distance, displacement, speed, velocity and acceleration	Candidates should be able to: (a) Distinguish between distance and displacement. (b) Define speed, velocity and acceleration. (c) Identify $\frac{ds}{dt}$ as the velocity and $\frac{dv}{dt}$ as the acceleration where s is the displacement, v is the velocity and t is the time.
2.1.2 Distance (displacement)-time, speed (velocity)-time and acceleration-time graphs	The candidate should be able to: (a) Draw distance (displacement)-time, speed (velocity)-time and acceleration-time graphs. (b) Identify which section(s) in a distance (displacement)-time graph indicate(s) a state of rest, or constant speed (velocity) or acceleration. (c) Identify which section(s) in a velocity-time graph indicate(s) an object moving with constant velocity, an object moving with a constant acceleration and an object moving with a variable acceleration. (d) Identify which section(s) in an acceleration-time graph indicate(s) an object moving at constant velocity, at constant acceleration and varying acceleration. (e) Determine the speed (velocity) and the average speed (velocity) from a distance (displacement)-time graph. (f) Determine the distance travelled, the displacement and the acceleration from a velocity-time graph. (g) Determine the change in velocity from an acceleration-time graph. (h) Relate the sign of the velocity, displacement and acceleration obtained from displacement-time and velocity-time graphs to directions specified by a sign convention.
2.1.3 Equations for uniformly accelerated motion	The candidate should be able to: (a) Derive the equations of uniformly accelerated motion along a straight line. (b) Use the equations of rectilinear motion for uniformly accelerated motion to solve problems. (c) Use the equations of uniformly accelerated motion to solve problems involving projectiles, projected either vertically or horizontally.

Content	Learning outcomes and comments
2.1.4 Experiment	The candidate should be able to: (a) Describe in detail an experiment to measure the acceleration of free fall. This includes providing a diagram, the procedure, adequate precautions, measurements made and how to determine the acceleration of free fall from the graph.
2.1.5 Newton's first law of motion	Candidates should be able to: (a) State and apply Newton's first law of motion. (b) Link inertial mass with Newton's first law of motion. (c) Define density. (d) State the equation for density and use it to solve problems. (e) Name the two fundamental forces that can act outside the nucleus. (f) Draw free body diagrams. The object can be represented using a sketch or a simple shape such as a box. (g) Explain what is meant by centre of mass. (h) Distinguish between smooth and rough surfaces.
2.1.6 Newton's second law of motion.	Candidates should be able to: (a) Define linear momentum. (b) State Newton's second law of motion in terms of the rate of change of momentum. (c) Express Newton's second law of motion as, $F = \frac{dp}{dt} = \frac{d(mv)}{dt}$ where F is the resultant force, p is momentum, m is mass, v is velocity and t is time. (d) Derive the equation $F = ma$, where m is the mass taken to be constant and a is the acceleration. (e) Define the newton using Newton's second law of motion. (f) Write down the equation representing Newton's second law of motion and use it to solve problems where only the mass is changing or only the velocity is changing, but not both changing at the same time.
2.1.7 Time of impact	The candidate should be able to: (a) Explain what is meant by time of impact. (b) Discuss how changing the time of impact affects the force of impact.
2.1.8 Common forces	The candidate should be able to: (a) Determine the weight of an object given its mass and the acceleration due to gravity.

Content	**Learning outcomes and comments**
	(b) Solve simple problems involving frictional force between two surfaces that do not include the coefficient of friction.
2.1.9 Drag and terminal velocity	Candidates should be able to: (a) Explain qualitatively what drag and viscosity are. (b) Explain qualitatively how the drag depends on area, viscosity and velocity. Knowledge of the equations governing drag is not examinable. The candidate is only expected to be able to state if the drag decreases or increases with these quantities. (c) Draw the velocity (speed)-time graph of a body falling in a viscous medium. (d) State what is meant by terminal velocity (speed) and explain how this can be attained by a body falling in a viscous fluid.
2.1.10 Pressure	Candidates should be able to: (a) Define pressure in terms of the force and the area on which it acts. (b) Write down the equation $P = \frac{F}{A}$, where P is pressure and A is area and use it to solve problems. (c) State the equation for hydrostatic pressure and use it to solve problems.
2.1.11 Newton's third law of motion	Candidates should be able to: (a) State and use Newton's third law of motion. (b) Identify and give examples of Newton's third law pairs of forces, i.e. the action and the reaction.
2.1.12 Conservation of linear momentum	Candidates should be able to: (a) State the principle of conservation of linear momentum. (b) Describe in detail an experiment that verifies the principle of conservation of momentum. This includes providing a diagram, the procedure, adequate precautions and calculations to be made. (c) Solve problems using the principle of conservation of momentum in one dimension that may not involve quadratic equations. (d) Distinguish between perfectly elastic and inelastic collisions and determine if a given collision is perfectly elastic or inelastic.
2.2 Work, energy and power	
2.2.1 Work	Candidates should be able to:

Content	Learning outcomes and comments
	(a) Define mechanical work in terms of the force and the displacement in the direction of the force. (b) Recognise the joule as the unit of work and energy. (c) Calculate the mechanical work done by a force in a number of situations, including the work done by forces that are not in the direction of motion and by varying forces using the area under a force-displacement graph only.
2.2.2 Energy	Candidates should be able to: (a) Identify and give examples of different forms of energy. (b) Recognise energy transformations in mechanical systems. (c) State and apply the principle of conservation of energy. (d) Distinguish between gravitational potential energy, electrical potential energy and elastic potential energy. (e) Recognise that the gravitational acceleration, *g*, may be assumed constant near the Earth surface**.** (f) Use the equation for gravitational potential energy changes/differences ($mg\Delta h$) near the Earth's surface where Δh is the change/difference in height. (g) State and use the equation for the kinetic energy ($\frac{1}{2}mv^2$). The derivation is not required.
2.2.3 Power	Candidates should be able to: (a) Define power in terms of work done and time. (b) Derive the equation $P = Fv$ where *P* is the power, *F* is the applied force and *v* is a velocity. (c) State and use the equations $P = \frac{W}{t} = Fv$ where *W* is the work done and *t* is the time. (d) Identify and use the watt as the unit of power.
2.2.4 Efficiency	Candidates should be able to: (a) Identify energy losses from a given system. (b) Define the efficiency of a system. (c) State and use the equations $\text{efficiency} = \frac{\text{useful output energy}}{\text{total energy input}} \times 100\% = \frac{\text{useful power output}}{\text{total power input}} \times 100\%$.

Content	**Learning outcomes and comments**
2.3 Circular motion	
2.3.1 Kinematics of uniform circular motion	Candidates should be able to: (a) Recognise the need of a resultant force known as the centripetal force for a particle to move at constant speed in a circular path. (b) Describe and explain why the motion in a curved path is due to a centripetal force in the case of uniform motion in a circle. (c) Explain why an object moving at a constant speed in a circular path still undergoes acceleration, known as centripetal acceleration, and which is equal to $a = \frac{v^2}{r}$, where v is the speed and r is the radius. (d) Define the terms frequency and periodic time in relation to circular motion. (e) Derive and use the equation $v = \frac{2\pi r}{T}$, where r is the radius and T is the periodic time.
2.4 Static Equilibrium	
2.4.1 Static equilibrium at a point	Candidates should be able to: (a) State the conditions for static equilibrium on a point object under the action of a set of coplanar forces. (b) Explain how equilibrium at a point is linked with Newton's first law of motion. (c) Solve problems involving forces in equilibrium at a point.
3. Thermal physics	
3.1 Temperature and heat	
3.1.1 Thermal equilibrium and temperature	Candidates should be able to: (a) Define thermal equilibrium. (b) Explain the relation between thermal equilibrium and temperature.
3.1.2 Thermometry	Candidates should be able to: (a) Define thermometric property. (b) Give examples of physical properties that may be used for the measurement of temperature. (c) Explain what is meant by a temperature fixed point. (d) Define the ice point and the steam point of water. (e) State and use the equation $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100$ °C where θ is the

Content	Learning outcomes and comments
	temperature on the Celsius scale, X is a thermometric property assumed to vary linearly with temperature, and subscripts indicate temperatures on the Celsius scale. Examinable thermometric properties are the length of a liquid column, the resistance of a wire or the pressure (or the corresponding height of a column) of gas at constant volume. Ranges and structures of thermometers are not examinable. (f) Explain why using different thermometric properties can lead to different temperatures. Comparison of thermometers is not examinable. (g) Convert between degrees Celsius and kelvin using the equation $T(\mathrm{K}) = \theta(°\mathrm{C}) + 273.15\ \mathrm{K}$, where T is the thermodynamic temperature. (h) State and use $\Delta\theta = \Delta T$.
3.1.3 Heat	Candidates should be able to: (a) Define heat in terms of energy transfer due to a temperature difference ΔT. (b) Explain how the direction of the net heat flow depends on temperature if no work is done. (c) Define and use a sign convention of the candidate's choice to distinguish between heat transferred to or from the system.
3.1.4 Heating matter	Candidates should be able to: (a) Define the heat capacity C and the specific heat capacity c. (b) State and use the equations $Q = C\Delta\theta$ and $Q = mc\Delta\theta$ where Q represent the heat transferred and m is the mass. (c) Describe simple experimental setups and procedures required to measure the specific heat capacity of a metal and of a liquid using an electrical heating method. The method should emphasise the conservation of energy but should not involve constant flow techniques. Identification of experimental error is expected even though the calculations of heat losses to the surroundings will not be examined. (d) Define the latent heat and the specific latent heat of fusion and vaporization. (e) State and use the equation $Q = mL$ where L is the specific latent heat. (f) Describe the experimental setup and procedure required to measure the latent heat of vaporization using an electrical heating method. The method should emphasise the conservation of energy. Identification of

Content	Learning outcomes and comments
	experimental error is expected even though calculations of heat losses will not be examined.
3.2 Energy transfer	
3.2.1 Energy transfer by mechanical and electrical processes	Candidates should be able to: (a) Determine whether work is done on (by) a system and relate this to energy transferred to (from) the system that is not due to a temperature difference. (b) Define and use a sign convention of the candidate's choice to distinguish between work done on or by the system. (c) State and use an equation relating the work done at constant pressure to the pressure and the change in volume.
3.2.2 The first law of thermodynamics	Candidates should be able to: (a) Define internal energy in terms of the sum of the kinetic energy and potential energy within the system. (b) State the first law of thermodynamics (c) State and use an equation representing the first law of thermodynamics identifying the symbols used. (d) Define and use a sign convention of the candidate's choice to distinguish between increases and decreases in internal energy. (e) Determine how the internal energy of a system changes with a change in temperature and with a change in phase. (f) Apply the first law of thermodynamics to a gas enclosed in a cylinder with moveable piston and boiling of a liquid.
3.2.3 Isochoric and isobaric processes involving gases	Candidates should be able to: (a) Define isochoric (isovolumetric) and isobaric processes (b) Apply the first law of thermodynamics to an isochoric (isovolumetric) process ($\Delta W = 0$) process and an isobaric process.
3.2.4 Pressure-volume (*p*-*V*) graphs involving gases	Candidates should be able to: (a) Use *p*-*V* graphs to illustrate isochoric and isobaric processes. (b) Recognize the area under a *p*-*V* graph as the work done on or by a system.
3.3 Heat transfer	
3.3.1 Heat transfer mechanisms	Candidates should be able to: (a) Identify and describe qualitatively conduction, convection, radiation and evaporation as modes of heat transfer.

Content	**Learning outcomes and comments**
4. Materials	
4.1 Forces, stresses and strains	Candidates should be able to: (a) Distinguish between tensile and compressive forces. (b) State Hooke's law in terms of force and change in length. (c) Define the spring/stiffness constant. (d) Write down Hooke's law in terms of forces and change in length and use it to solve problems. (e) Define stress, strain and the Young's modulus. (f) Write down and use the equations for stress and strain. (g) Write down and use Hooke's law in terms of stress and strain.
4.2 Force-extension and stress-strain graphs	Candidates should be able to: (a) Define the proportionality limit, the elastic limit, the yield point and the ultimate tensile strength (stress) and identify these points on force-extension and stress-strain graphs. (b) Define the notions of elastic behaviour, plastic behaviour, stiffness and tensile strength. (c) Explain how plastic behaviour leads to necking and identify the portion of force-extension and stress-strain graphs where necking occurs. (d) Explain how stiffness is related to the stiffness constant and to the Young's modulus. (e) Define brittle and ductile material and be able to identify such materials from their force-extension and stress-strain graphs. (f) Sketch the force-extension and stress-strain graphs of metals**,** rubber and brittle materials (e.g. glass). (g) Compare stress-strain and/or appropriate force-extension graphs to determine which materials are stiffer. (h) Determine the Young's modulus and the stiffness constant from force-extension and stress-strain graphs, where necessary using the original length and cross-sectional area of the wire. (i) Given the force-extension (strain-strain) graph of an object, determine the permanent extension (strain) the object would retain if it is extended beyond the elastic limit. (j) Describe the hysteresis behaviour of rubber and discuss situations where this behaviour is important.

Content	**Learning outcomes and comments**
4.3 Experiment	The candidate should be able to: (a) Describe in detail an experiment to measure the Young's modulus of a metal wire. This includes providing a diagram, the procedure, adequate precautions and calculations to be made.
4.4 Energy	Candidates should be able to: (a) State the equations that are valid when Hooke's law is obeyed for elastic potential energy and use them to solve problems. (b) State what the area under a force-extension graph represents during both loading and unloading. (c) Determine the work done from a force-extension graph. (d) Solve problems where the gravitational potential energy lost is not equal to the change in the stored elastic potential energy. (e) State what the area under a stress-strain graph represents during both loading and unloading.
5. Electric Currents	
5.1 Charge and current	Candidates should be able to: (a) Explain what is meant by charge carriers. (b) Define current as the rate of flow of charge. (c) Identify $\frac{dQ}{dt}$ as current, where Q is the quantity of charge and t is the time. (d) Identify the current from the slope of a charge-time graph. (e) Identify the area under a current-time graph as the charge. (f) State and use $Q = It$, for uniform current I. (g) Distinguish between the direction of conventional current and the direction of motion of the charge carriers. (h) Explain how the drift speed arises. (i) Derive and use, for a current-carrying conductor, the expression $I = nAvq$ where n is the number of charge carriers per unit volume, A is the uniform cross sectional area, v is the drift speed and q is the charge of the charge carrier.
5.2 Conductors, semiconductors and insulators	Candidates should be able to: (a) State and explain the difference between conductors, semiconductors and insulators using the equation $I = nAvq$.
5.3 Potential difference and electromotive force	Candidates should be able to:

Content	Learning outcomes and comments
	(a) Define electrical potential difference (p.d.) between two points in terms of energy. (b) Use this definition to calculate the potential difference in a circuit. (c) Define electromotive force (e.m.f.) of a power supply. (d) Distinguish between e.m.f. and p.d.
5.4 Resistances	
5.4.1 Ohm's law	Candidates should be able to: (a) Define resistance. (b) State Ohm's law. (c) State and use $V = IR$, where V is the voltage and R is the resistance.
5.4.2 Temperature dependence of resistance	Candidates should be able to: (a) State and explain the temperature dependence of resistance of metals.
5.4.3 Current-voltage (I-V) characteristics	Candidates should be able to: (a) Describe an experimental setup and the corresponding procedure required to investigate the I-V characteristic of an electronic component. The candidate will not be expected to include the use of the potential divider in the description of this experiment. (b) Sketch and discuss the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode, a thermistor (with a negative thermal coefficient of resistance) and a filament lamp.
5.4.4 Internal resistance	Candidates should be able to: (a) Define terminal p.d. and lost volts. (b) Explain and quantify the effects of internal resistance of a power supply on the terminal p.d. Knowledge of the maximum power transfer theorem will not be examined. (c) State and explain the practical importance of internal resistance in a car battery and extra-high tension supplies. (d) Describe a simple experimental setup, together with the corresponding procedure required and calculations needed to determine the internal resistance of a cell. The candidate will not be expected to include the description of a null method for this experiment.
5.5 Electric circuits	
5.5.1 Circuit diagrams	Candidates should be able to: (a) Draw the standard electronic symbols of: a wire, a cell or battery, an alternating current,

Content	Learning outcomes and comments
	a direct current power supply, an earthed point, a switch, a two-way switch, a resistor, a variable resistor, a voltmeter, an ammeter, a centre-zero galvanometer, a capacitor, a thermistor, a diode, a light dependent resistor and a bulb. (b) Draw simple electrical circuits. (c) Explain the use of a thermistor to control voltage.
5.5.2 Voltage current and resistance in circuit	Candidates should be able to: (a) State and use the equations showing how the current and the voltage distribute themselves for electronic components connected in parallel and in series. (b) State and use the equations for total resistance for resistors connected in parallel or in series. (c) Use the potential divider rule to solve problems.
5.5.3 The ammeter and voltmeter	Candidates should be able to: (a) Identify the correct wiring of ammeters and voltmeters in a circuit. (b) Explain why an ideal ammeter has zero resistance. (c) Explain why an ideal voltmeter has an infinitely high resistance. (d) Solve circuit problems involving non-ideal ammeters and voltmeters.
5.5.4 Energy and power in D.C. circuits	Candidates should be able to: (a) Define electrical power. (b) Calculate the power dissipated by different circuit components. (c) Define the kilowatt-hour and use it as a unit of energy. (d) Identify the kilowatt-hour as the unit used in the pricing of the household electrical energy consumption. (e) Convert energy from joules to kilowatt-hour and vice-versa.
6. Fields	
6.1 Gravitation	
6.1.1 Newton's law of universal gravitation	Candidates should be able to: (a) State Newton's law of universal gravitation. (b) Express and use Newton's law of gravitation in the form of $F = \frac{GMm}{r^2}$. Here F is the gravitational force between two bodies of masses M and m, r is the distance between their centres, while the constant of

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	proportionality G is known as the universal gravitational constant. (c) Relate the gravitational force to the weight.
6.1.2 Gravitational field strength	Candidates should be able to: (a) Define gravitational field in terms of a region of space where the gravitational force acts. (b) State the direction of the gravitational field lines. (c) Draw the gravitational field lines including the direction for radial gravitational fields. (d) Define gravitational field strength (intensity). (e) State and use the equation $g = \frac{GM}{r^2}$, where g is the gravitational field strength (intensity). (f) Describe and show using a graph how the gravitational field strength varies with distance from the Earth's centre. Only the variation above the Earth's surface will be examined. (g) Link the gravitational field strength (intensity) to the acceleration due to gravity.
6.1.3 Satellites	Candidates should be able to: (a) Identify the gravitational force acting on a satellite as a centripetal force. (b) Derive and use the equation $v^2 = \frac{GM}{r}$ for a satellite moving in a circular orbit with a velocity v and a periodic time T.
6.2 Electrostatic fields	
6.2.1 Simple electrostatics phenomena	Candidates should be able to: (a) State the conditions for electrical attraction and repulsion between charges. (b) Describe how to charge an insulator by friction. (c) Describe how to charge a metal by induction.
6.2.2 Coulomb's law of electrostatics	Candidates should be able to: (a) State Coulomb's law of electrostatics. (b) Express and use Coulomb's law of electrostatics in the form $F = \frac{Qq}{4\pi\varepsilon r^2}$. Here F is the electrostatic force between two point objects having charges Q and q at a distance r apart, while $\frac{1}{4\pi\varepsilon}$ is the constant of proportionality known as the Coulomb's constant with ε being the permittivity of the surrounding medium.

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	(c) Distinguish between the permittivity and the permittivity of free space ε_0. (d) Define the relative permittivity (dielectric constant) ε_r. (e) Use the coulomb as the unit of charge.
6.2.3 Electric field strength	Candidates should be able to: (a) Define electric field in terms of a region of space where the electric force acts. (b) Define the direction of the lines of force of an electrostatic field. (c) Use lines of force to describe electric fields qualitatively. (d) Draw the lines of force, including the direction, for a radial field, for a uniform field and for the field between two point charges of equal magnitude in vacuum. (e) Define the electric field strength at a point. (f) State and use the equation $E = \frac{F}{q}$, where E is the electric field strength, F is the force due to the electric field and q is the charge. (g) State and use the equation $E = \frac{Q}{4\pi\varepsilon r^2}$ for a point charge. (h) Solve problems involving the acceleration of a charged particle moving in a uniform electric field with the initial velocity being parallel to the lines of force.
6.2.4 Electric potential difference	Candidates should be able to: (a) Define electrostatic potential difference. (b) State and use the equation $W = qV$ where W is the work done and V is the potential difference. (c) State and use the equation $V = Ed$, where E is the electric field strength of a uniform electric field, V is the potential difference and d is the distance between the points. (d) State and use the equation $Vq = \Delta\text{K.E.}$ where $\Delta\text{K.E.}$ is the change in kinetic energy and V is the potential difference. (e) Define the electronvolt and use it as a unit of energy.
6.3 Capacitors	
6.3.1 Capacitance	Candidates should be able to: (a) Define the capacitance of a capacitor. (b) State and use the equation $Q = CV$ where V is the potential difference and C the capacitance. (c) Use farads as the unit of capacitance.

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6.3.2 The parallel plate capacitor	Candidates should be able to: (a) Sketch a well labelled diagram of the basic structure of a parallel plate capacitor. (b) List the factors on which the capacitance of a parallel plate capacitor depends and discuss how the capacitance will change when one of these factors is varied. (c) State and use the equation $C = \frac{\varepsilon A}{d} = \frac{\varepsilon_r \varepsilon_0 A}{d}$, where A is the area of overlap and d is the distance between the plates. (d) Derive and use the relation $\varepsilon_r = \frac{C}{C_0}$, where C is the capacitance for a general dielectric and C_0 is the capacitance when vacuum is the dielectric.
6.3.3 Charging and discharging of capacitors through resistors	Candidates should be able to: (a) Draw a diagram of a circuit that can be used to study the charging and the discharging of a capacitor using a two way switch and other components such as resistors, voltmeters and ammeters. (b) Draw graphs of charge stored, voltage and current against time obtained when charging and discharging a capacitor through a resistor. (c) Describe the change in charge stored on, voltage across and current through a capacitor when discharging the capacitor through a resistor as an exponential decay and relate it to radioactive decay.
6.3.4 Time constant	Candidates should be able to: (a) Define the time constant in terms of a decrease to approximately 37 % of the maximum value of the charge or voltage during discharge. (b) Use the graphs of charge stored in, voltage across and current through a capacitor against time for discharging a capacitor through a resistor in order to obtain the time constant. (c) State and use the equation $T = RC$, where T is the time constant. (d) Determine the charge in and voltage across a capacitor, as well as the corresponding current in the circuit, after a time period equal to an integral multiple of the time constant. (e) Sketch graphs of charge stored in and voltage across a capacitor against time when charging and discharging capacitors for different values of the time constant.

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6.4 Magnetic fields	
6.4.1 Magnetic field	Candidates should be able to: (a) Define magnetic field in terms of a region of space where the magnetic force acts. (b) Define the direction of the magnetic field lines. (c) Draw the magnetic field lines due to a bar magnet, a North and a South pole facing each other, a long straight current-carrying conductor, two long straight parallel conductors carrying equal currents and a solenoid. Where appropriate the magnetic polarity should be indicated. Use of mnemonics, such as the right hand grip rule, to indicate relative direction of quantities and magnetic polarity is expected. (d) Use standard symbols (such as $\otimes$ and $\times$) to indicate current and magnetic field lines direction relative to the plane in a two dimensional diagram.
6.4.2 Magnetic flux density, flux and flux linkage	Candidates should be able to: (a) Define magnetic flux density *B*, flux ϕ and flux linkage $N\phi$ where *N* is the number of turns. (b) Use the weber as the unit for magnetic flux. (c) Identify the magnetic flux density as a vector quantity.
6.4.3 Magnetic force on a current-carrying conductor	Candidates should be able to: (a) Relate the magnetic force on a current carrying conductor to the magnetic flux density. (b) State and use the equation $F = BIl\sin(\theta)$ where *F* is the force, *I* the current, *l* the length of the conductor and θ is the angle between the directions of the magnetic flux density and the current. (c) Use Fleming's left hand rule or any other equivalent rule. (d) Define the tesla and use it as the unit for the magnetic flux density.
6.4.4 Force on a charged particle moving through a magnetic field	Candidates should be able to: (a) Derive and use the equation $F = Bqv\sin(\theta)$ where *q* is the charge, *v* is the velocity and θ is the angle between *B* and *v*. (b) Relate the direction of the force to that of a charged particle in motion and the magnetic field. (c) Identify the magnetic force on a charged particle moving in a plane perpendicular to

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	that of a uniform magnetic field as a centripetal force. (d) Derive and use $mv = Bqr$ where *m* is the mass and *r* is the radius of the path.
6.5 Electromagnetic induction	
6.5.1 Magnetic flux and flux linkage	Candidates should be able to: (a) Describe a simple experimental setup using a solenoid and a magnet together with the corresponding procedure required to investigate how the rate of change of flux induces an electromotive force (e.m.f.) in a circuit, reporting the observations made. Only the qualitative analysis of the observations will be examined.
6.5.2 Faraday's and Lenz's laws of electromagnetic induction	Candidates should be able to: (a) State Faraday's and Lenz's laws of electromagnetic induction. (b) Relate Lenz's law to energy conservation. (c) State and use the equation $E = -\frac{d(N\phi)}{dt}$ where *N* is the number of turns, ϕ is the flux, the produce $N\phi$ is the flux linkage and *E* is the induced e.m.f. (d) State and use the equation $E = Blv$ where *l* is the length of the conductor inside the magnetic field and *v* the velocity. The quantities *B*, *l* and *v* are perpendicular to each other. (e) Describe qualitatively an experimental setup and procedure required to verify Lenz's law. (f) Identify instances where Lenz's law is necessary to explain the behaviour of a system. (g) Relate the directions of the magnetic field, current and the motion of the conductor in a simple generator. Use of Fleming's right hand rule is expected. (h) Determine the polarity at the ends of a conductor due to an induced e.m.f.
6.5.3 Simple alternating current generator	Candidates should be able to: (a) Sketch the basic structure of a simple generator consisting of a rectangular coil rotating in a uniform magnetic field and explain why an e.m.f. is induced. (b) Sketch the graphs of the output e.m.f. and current, relating the variation to those of oscillations.

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6.6 Alternating current (a.c.)	
6.6.1 Peak and root mean square values for a sinusoidal alternating current	Candidates should be able to: (a) Define the peak and root mean square value of the voltage *V* and current *I* of a sinusoidal alternating current. (b) State and use the equations $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$ and $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$ where I_0 and V_0 are respectively the peak current and voltage while I_{rms} and V_{rms} are the corresponding rms current and voltage.
7. Vibrations and waves	
7.1 Simple harmonic motion	
7.1.1 Definitions and equations	Candidates should be able to: (a) Define periodic time, frequency amplitude, equilibrium (rest) position and restoring force. (b) Identify the resultant force acting on a particle performing simple harmonic motion as the restoring force. (c) State and use the equation**s** $T = \frac{1}{f}$ where T is the periodic time and *f* is the frequency. (d) Define simple harmonic motion. (e) State and use the equation $a = -\omega^2 x$ where *a* is the acceleration, *x* is the displacement from the equilibrium position and ω^2 is a positive constant that is related to the periodic time *T* through the equation, $\omega = \frac{2\pi}{T}$.
7.1.2 Acceleration-displacement graph	Candidates should be able to: (a) Sketch the acceleration-displacement graph. (b) Determine the value of the constant ω^2 from the acceleration-displacement graph.
7.1.3 Displacement-time, velocity-time and acceleration-time graphs	Candidates should be able to: (a) Sketch the corresponding displacement-time, velocity-time, and acceleration-time graphs. The initial conditions can be that at the initial time the system starts either from zero or from the maximum absolute value. (b) Determine the amplitude and periodic time from a given displacement-time graph.

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	(c) Determine the maximum velocity and periodic time from a given velocity-time graph. (d) Determine the maximum acceleration and periodic time from a given acceleration-time graph.
7.1.4 Phase	Candidates should be able to: (a) Explain what is meant by motion in-phase, anti-phase and out of phase. (b) Determine the phase difference between two simple harmonic oscillators and express it as a fraction of the cycle or of the periodic time. The phase difference can have any value between zero and one wavelength or one periodic time.
7.1.5 Free vibrations	Candidates should be able to: (a) Explain what is meant by free oscillations. (b) Define natural frequency or frequencies.
7.1.6 Forced vibrations and resonance	Candidates should be able to: (a) Explain what is meant by forced vibrations and forcing frequency. (b) Distinguish between the driver and the driven oscillating system. (c) Explain the terms resonance and resonant frequency. (d) Give examples where resonance is useful and others where it is undesirable.
7.2 Waves	
7.2.1 Progressive waves	Candidates should be able to: (a) Explain what is meant by a progressive wave. (b) Explain what is meant by a mechanical wave. (c) Define crest, trough, amplitude, periodic time, frequency and wavelength as applied to mechanical waves. (d) Relate the amplitude, frequency and periodic time of waves to those of the simple harmonic motion of particles in the medium. (e) State and use the equation $v = f\lambda$, where v is the speed of propagation, f is the frequency and λ is the wavelength.
7.2.2 Displacement-position and displacement-time graphs.	Candidates should be able to: (a) Sketch the displacement-position and displacement-time graphs for a progressive wave. (b) Determine the amplitude and the wavelength from a displacement-position graph. (c) Determine the amplitude and the periodic time from a displacement-time graph.

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	(d) Use the displacement-time and displacement-position graphs to determine the phase difference between two waves and express it as a fraction of the cycle, wavelength or periodic time.
7.2.3 Longitudinal and transverse progressive waves	Candidates should be able to: (a) Define longitudinal and transverse waves. (b) Give examples of transverse waves. (c) Give examples of longitudinal waves.
7.2.4 Electromagnetic waves	Candidates should be able to: (a) List the various regions of the electromagnetic spectrum giving a representative wavelength for each. (b) List the colours in the visible spectrum in increasing or decreasing wavelength order. (c) State the range of wavelengths of the visible spectrum (400 nm to 700 nm).
7.3 Superposition of waves	
7.3.1 The principle of superposition and the formation of stationary (standing) waves	Candidates should be able to: (a) State the principle of superposition of pulses and waves. (b) State the conditions for stationary waves. It should be assumed that the stationary waves are planar and complete cancellation occurs at the nodes. (c) Identify the formation of standing waves in a given system. Examinable situations will involve either two generators of waves or a generator of waves and reflector. Questions involving open ends will not be set. (d) Use displacement-position graphs to explain how nodes and antinodes are formed. (e) Define nodes and antinodes. (f) Identify nodes, antinodes and loops in a given standing wave. (g) Identify and calculate the wavelength in a stationary wave. (h) Distinguish between progressive and standing waves in terms of the amplitude, phase relationship, the propagation of the wave profile and energy as applied to a sinusoidal wave.
7.3.2 Standing waves on a string	Candidates should be able to: (a) Identify vibrating strings as a system that can resonate at various frequencies. (b) Describe qualitatively how a standing wave can be formed on a stretched string.

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	(c) State and use the equations $f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ where f_n is the frequency of the n^{th} harmonic, L is the length of the string that is free to vibrate, T is the tension force in the string and μ is the mass per unit length of the string.
7.3.3 Diffraction of water waves at a gap	Candidates should be able to: (a) Describe an experiment to investigate the diffraction of water waves at a gap. This includes providing a diagram and observations made. (b) Explain and sketch how the diffraction pattern would change as the width of the gap and the wavelength are varied.
7.3.4 Interference of waves from two coherent point sources	Candidates should be able to: (a) Explain what is meant by two coherent sources. (b) Sketch the resulting wavefronts to describe qualitatively the regions of constructive and destructive interference of waves originating from two coherent point sources. (c) Explain what is meant by path difference and express the path difference as a multiple of the wavelength. (d) Determine the phase difference at a point taking into account the path difference. (e) State and use the conditions for constructive and destructive interference in terms of the phase difference. (f) Describe how the interference pattern arising from waves emitted from two point sources relates to the phase differences. (g) Describe qualitatively how the interference pattern would change if the source separation and the wavelength are changed.
7.3.5 Young's double-slit experiment using visible light	Candidates should be able to: (a) Define monochromatic light. (b) Sketch a diagram and use it to explain qualitatively how Young's double-slit experiment is carried out giving also the observation made. (c) Sketch the interference pattern (fringes) observed on a screen in Young's double slit experiment. (d) Identify the central (zeroth order) bright fringe and the n^{th} order bright (dark) fringes. (e) State the conditions for the interference pattern to be observable. (f) Explain why Young's double-slit experiment demonstrates that light is a wave.

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	(g) State how the pattern would change if the slit separation, wavelength and distance between the slits and the screen are changed. (h) State and use the equation $y = \frac{\lambda D}{d}$, where y is the fringe separation, λ is the wavelength, d is the slit separation and D is the distance between the double-slits and the screen.
7.4 Optics	
7.4.1 Light incident on a boundary and reflection	Candidates should be able to: (a) List the processes that can take place when light is incident on a boundary between two media - namely reflection, refraction (transmission) and absorption - and distinguish between them. (b) Define the terms transparent and opaque. (c) State the laws of reflection. (d) Draw the normal to a boundary and identify it in a given diagram. (e) Identify the angle of incidence and the angle of reflection. (f) Draw ray diagrams to show how light reflects by a plane boundary. The use of more than one reflecting surface placed in the path of the ray such as in periscopes can be examined. (g) Distinguish between real and virtual images. (h) Use geometric and trigonometric relations, together with the law of reflection to work out problems.
7.4.2 Refraction	Candidates should be able to: (a) Draw diagrams to show how the wavelength changes when the wave passes from one medium to another. (b) State the laws of refraction. This includes Snell's law. (c) Identify the angle of incidence and that of refraction. (d) Identify the angle of deviation and calculate it from the angle of incidence and that of refraction.
7.4.3 Refractive index	Candidates should be able to: (a) Define the refractive index of medium 2 with respect to medium 1 $\left({}_1n_2\right)$ and the absolute refractive index of a medium $\left(n_1\right)$. Only questions involving positive refractive indices will be examined. (b) Give an estimate of the absolute refractive index for air.

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	(c) State and use the equation ${}_1n_2 = \frac{v_1}{v_2}$ where v_1 is the speed in medium 1 and v_2 is the speed in medium 2 to solve problems. (d) Discuss how the wavelength of monochromatic light depends on the medium. (e) Derive and use the equation ${}_1n_2 = \frac{\lambda_1}{\lambda_2}$ where λ is the wavelength. (f) State and use the equation $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$, where n_1 and n_2 are respectively the refractive indices of medium 1 and 2 while θ_1 and θ_2 are respectively the angles the rays make with the normal in medium 1 and medium 2. (g) Combine the laws of refraction and reflection with geometric and trigonometric relations to solve problems. (h) State and use the equation $n = \frac{\text{Real depth}}{\text{Apparent depth}}$.
7.4.4 Total internal reflection	Candidates should be able to: (a) Use diagrams to illustrate what happens at a boundary between media to light rays originally travelling in the optically denser medium as the angle of incidence is increased from zero. (b) Define the critical angle. (c) State the conditions for total internal reflection. (d) Derive and use the equation $\sin(c) = \frac{n_2}{n_1}$, where *c* is the critical angle and n_1 is the refractive index of the optically denser medium while n_2 is that of the optically rarer medium. (e) Discuss how right angle prisms can be used to deflect light by $90°$. (f) Name a naturally occurring phenomenon that depends on total internal reflection.
7.4.5 Dispersion	Candidates should be able to: (a) Define dispersion. (b) Draw diagrams indicating how light consisting of multiple wavelengths/frequencies is dispersed as it passes through a dispersive medium such as a prism.

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7.4.6 Refraction of light by a single thin lens	Candidates should be able to: (a) Use ray diagrams to illustrate the following: principal axis, principal focus, optical centre, focal plane and focal length. (b) Draw ray diagrams to show how an image is formed by a given single converging lens for different object distances. (c) Use either the real-is-positive or the Cartesian sign convention to solve problems. (d) State the lens equation and use it to solve problems involving a single thin converging lens. (e) Define linear magnification. (f) State and use the equations for magnification to solve problems involving a single thin converging lens. (g) Describe a rough method for determining the focal length of a thin converging lens. (h) Describe in detail an experiment to determine the focal length of a thin converging lens using a graphical method. This includes providing a diagram, the procedure, adequate precautions, the measurements made as well as the calculations.
8. Nuclear, atomic and quantum theory	
8.1 Nuclear Physics	
8.1.1 Rutherford's alpha scattering experiment	Candidates should be able to: (a) Describe in detail the alpha scattering experiment. This includes providing a basic diagram, procedure used, precautions taken and observations made. (b) Discuss how the conclusions derived from the observations made in the alpha scattering experiment lead to a nuclear model of the atom. (c) Define nucleon.
8.1.2 The nucleus	Candidates should be able to: (a) List the following properties of electrons, protons and neutrons: the approximate ratio of their masses relative to that of a nucleon and express their charges in terms of the electronic charge e. (b) Define the terms: proton (or atomic) number Z, neutron number N and nucleon (or mass) number A. (c) State and use the equation $A = Z + N$. (d) Define element and isotope. (e) Represent an element with given chemical symbol or using letter(s) together with the nucleon and proton number. These should be

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	set in the general form ${}^{A}_{Z}\mathrm{X}$ where X is the symbol for the element. (f) Identify the notation “isotope name”-*A* as giving the isotope name together with the nucleon (mass) number.
8.1.3 Radioactive decay	Candidates should be able to: (a) Define the terms radioactive decay, activity, decay constant and half-life. (b) Identify $\frac{dN}{dt}$, where N is the number of radioactive nuclei in a sample and t is time, as the decay rate. (c) Use the Becquerel as the unit of activity. (d) State the law of radioactive decay. (e) State and use the equation $\frac{dN}{dt}=-\lambda N$ or $A=\lambda N$ where λ is the radioactive decay constant and A is the activity. (f) State and use the equation $T_{\frac{1}{2}}=\frac{0.693}{\lambda}$ where $T_{\frac{1}{2}}$ is the half-life. (g) Identify the sources of background radiation.
8.1.4 Radioactive dating	Candidates should be able to: (a) Use the half-life to determine the age of a sample. (b) Explain that the uncertainty in the age of a sample depends on the randomness of radioactive decay.
8.1.5 Modes of radioactive decay	Candidates should be able to: (a) Explain what alpha (α) particles, beta particles (β^-) and gamma (γ) radiation are and compare their physical properties. (b) Describe the alpha, beta (β^-) and gamma decay processes. (c) Write down nuclear equations to represent alpha and beta (β^-) decay.
8.1.6 Nuclear energy	Candidates should be able to: (a) Define the atomic mass unit. (b) Convert a mass expressed in kilograms into atomic mass units and vice versa. (c) Define the mole and Avogadro’s number. (d) Use Avogadro’s number to convert between the number of moles and the number of atoms. (e) Express the quantity of substance in terms of its mass or the number of moles. (f) Define the term mass defect.

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	(g) State and use the equation $E = mc^2$, where E is the energy, m is the mass and c is the speed of light. (h) Convert between mass and energy using appropriate conversion factors.
8.1.7 Fission and fusion as sources of energy	Candidates should be able to: (a) Explain the terms nuclear fusion and nuclear fission. (b) Write down nuclear equations representing fission and fusion reactions given sufficient information. (c) Describe the fission of uranium. (d) Discuss the pros and cons of using nuclear energy with particular reference to carbon free energy. (e) Calculate the energy released during given fusion and fission reactions.
8.2 Quantum theory	
8.2.1 Atomic energy levels	Candidates should be able to: (a) Explain that an accelerating electron emits electromagnetic waves making Rutherford atomic model unstable. (b) Explain how the energy level diagram of an atom relates to the emission and absorption spectrum of a vapour made up of isolated atoms of the particular element. (c) Sketch suitable energy level diagrams for atoms from a given set of data. (d) Define ground state, excited state, ionization and ionization energy. (e) Explain why the energy levels are assigned a negative energy value. (f) State the conditions for an electron to transition between the energy levels of an atom. (g) State and use the equation $\Delta E = hf$, where ΔE is the change in energy (or the difference between energy levels).
9. Data analysis	
9.1 Graphs	Candidates should be able to: (a) Sketch and identify plots corresponding to simple equations including the following: $y = kx + c$, $y = kx$, $y = kx^2$, $y = \frac{k}{x}$, and $y = \frac{k}{x^2}$. Here x and y are general variables while k and c are constants. (b) Identify the rate of change of y with respect to x as the gradient of the tangent to a curve

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	and use $\frac{dy}{dx}$ to represent it. The use of calculus will not be examined. (c) Use the scale of the axes to determine the coordinates of a point on a curve. (d) Determine the gradient at a point on a curve. (e) Determine or estimate the area between a curve and an axis. Use of calculus will not be examined. (f) Identify the area between a curve and an axis with a physical quantity when this has physical significance.
9.2 Data manipulation and plotting of graphs	Candidates should be able to: (a) Translate information between numerical data, algebraic equations, word statements and graphical representations. (b) Round off calculated values to an appropriate number of significant figures that will depend on the precision of the given data. (c) Select and plot two variables from experimental or other data, choosing suitable scales and range. This means that the graph needs not start from the origin. (d) Use the range and the number of boxes to determine a convenient scale. The scale should be easy to use, such as 1, 2 and 5. In addition the plotted points should be spread over more than half the range of each axis. (e) Use scale factors of the form 10^n where *n* is an integer and/or SI prefixes to simplify the scale of an axis. (f) Label the axis of a graph using the appropriate notation. The appropriate notation is of the form $V\ /\ 10^{-3}\ \mathrm{V}$, $V\ /\ \mathrm{mV}$ or $\mathrm{Voltage\ /\ millivolts}$. The forms $V\ (\mathrm{V})$ and $V\ /\ \times 10^{-3}\ \mathrm{V}$ will not be accepted. (g) Draw the line that best fits the plotted set of data points. The sum of the vertical distances of the data points above the line should be equal to that of the data points below the line. In addition the vertical distances should be minimal.
9.3 Straight line graphs and data analysis	Candidates should be able to: (a) Distinguish between linear and proportional relations. (b) Derive an equation for a relation between variable terms which are proportional by adding the appropriate constant of proportionality and vice versa. (c) Explain why straight lines are generally preferred when analysing data.

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	(d) Determine the gradient of a straight line graph. (e) Determine the *y*-intercept of a straight line from the point of intersection with the line $x = 0$ and by using the straight line equation together with two points on the straight line. (f) Set a given equation in a straight line format identifying the *x* and *y* variables as well as the gradient and the intercept.

General note

The candidate should be able to identify analogies of physical phenomena across the syllabus.