Neap

Trial Examination 2024

HSC Year 12 Physics

General Instructions	• Reading time – 5 minutes • Working time – 3 hours • Write using black pen • Draw diagrams using pencil • Calculators approved by NESA may be used • A data sheet, formulae sheet, and Periodic Table are provided at the back of this paper
Total Marks: 100	**Section I – 20 marks (pages 2–9)** • Attempt Questions 1–20 • Allow about 35 minutes for this section **Section II – 80 marks (pages 11–32)** • Attempt Questions 21–34 • Allow about 2 hours and 25 minutes for this section

SECTION I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

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1 Which of the following statements about the speed of light is correct?

A. The speed of light in a vacuum is independent of the speed of the light source and the observer.

B. The speed of light in a vacuum decreases if the light source moves towards the observer.

C. The speed of light in a vacuum increases if the light source moves away from the observer.

D. The speed of light in a vacuum increases if the observer moves towards the light source.

2 The table shows data about three stars, *X*, *Y* and *Z*, in the Milky Way.

Star	*Spectral class*	*Distance from the Sun (parsecs)*	*Apparent magnitude*
X	M2	194	+0.51
Y	B5	25	+0.57
Z	A2	439	+1.34

Which of the following statements is correct?

A. Star *X* has the highest surface temperature.

B. Star *Y* has the highest surface temperature.

C. Stars *X* and *Y* have similar surface temperatures.

D. Star *Z* has the highest surface temperature.

3 During a game of paintball, player *X* shoots a paintball, which has a velocity of 80 m s^{-1}, horizontally from a height of 10 m towards player *Y*, who is positioned 25 m away.
What is the horizontal velocity of the paintball just before impact?

A. 8.0 m s^{-1}

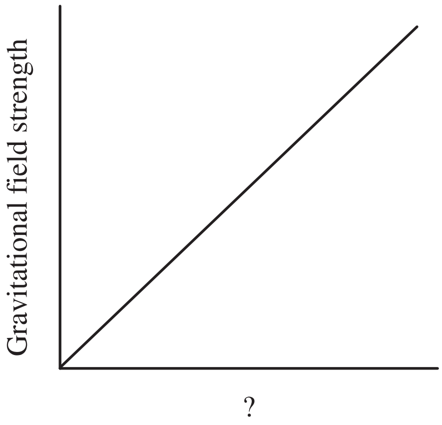
B. 8.2 m s^{-1}

C. 80 m s^{-1}

D. 800 m s^{-1}

 HSC_Y12Phys_QB_2024

4 A Physics student drew the graph shown.



Which of the following could be an appropriate title for the *x*-axis?

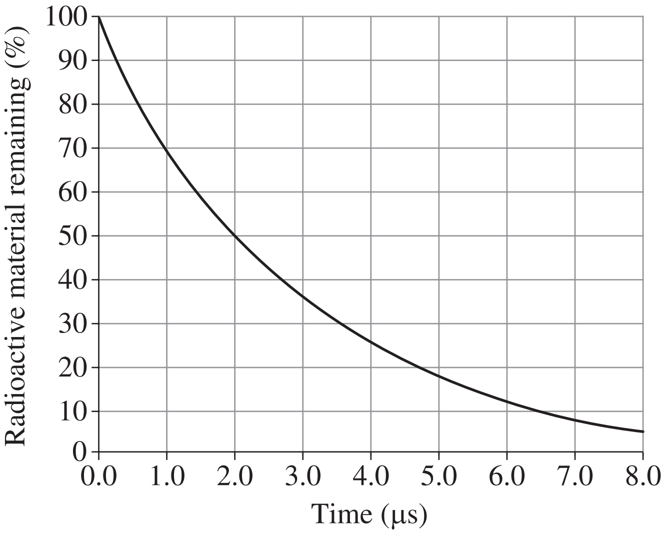
A. distance from the centre of the planet

B. inverse square of the distance from the surface of the planet

C. square of the distance from the centre of the planet

D. mass of the planet

5 The graph shows the amount of a particular radioactive material that remains over a period of time.



Based on the graph, what is the half-life of the radioactive material?

A. 2.0×10^{-6} s

B. 1.0 µs

C. 2.0×10^{-3} s

D. 2.0 s

6 Which of the following describes Einstein's mass–energy equivalence relationship most accurately?

A. Mass and energy are independent quantities.

B. The rest mass of an object is determined by its inertial frame of reference.

C. Mass and energy are identical.

D. Mass is a form of energy.

7 The gravitational force between two objects is F when the objects are separated by distance r. The distance between the objects is decreased by one third, and the mass of ONE of the objects is increased by a factor of 4.

What is the representative force (F_1) between the objects?

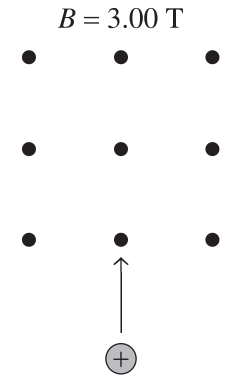
A. $F_1 = \frac{1}{36}F$

B. $F_1 = \frac{1}{3}F$

C. $F_1 = 12F$

D. $F_1 = 9F$

8 The diagram shows a proton being fired with a velocity of 1200 m s^{-1} into a uniform magnetic field of 3.00 T. The magnetic field is directed out of the page.



What is the acceleration of the proton as it enters the field?

A. 5.78×10^{-16} m s^{-2} to the right

B. 5.78×10^{-16} m s^{-2} to the left

C. 3.45×10^{11} m s^{-2} to the right

D. 3.45×10^{11} m s^{-2} to the left

9 A plutonium-239 isotope is struck by a neutron; it absorbs the neutron and undergoes nuclear fission according to the following equation.

$$ {}^{1}_{0}n + {}^{239}_{94}\mathrm{Pu} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{93}_{38}\mathrm{Sr} + 3\,{}^{1}_{0}n + \text{energy} $$

The combined mass of the plutonium-239 isotope's nucleus and the absorbed neutron is 3.99×10^{-25} kg. During the reaction, a mass of 3.07×10^{-28} kg is lost.

How much energy does the reaction release?

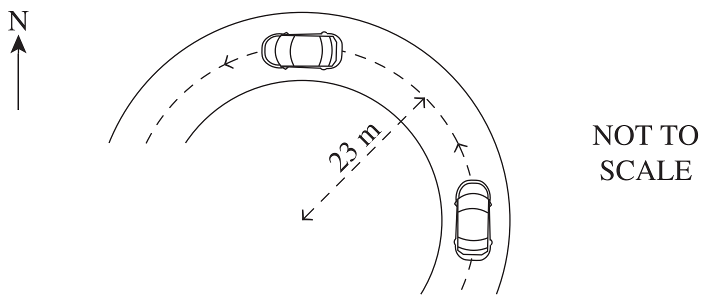
A. 4.42×10^{-30} eV

B. 3.99×10^{-25} eV

C. 2.76×10^{-11} eV

D. 1.72×10^{8} eV

10 An instructor at a driving school demonstrated driving around a bend in a vehicle of mass 2200 kg, as shown in the diagram.



The instructor was initially driving north at a speed of 10.5 m s^{-1} and then maintained a constant speed of 10.5 m s^{-1} as they continued around the bend.

The magnitude of the frictional force between the road and the car's wheels, under different conditions, is shown in the table.

Condition	*Frictional force (N)*
dry	9500
heavy rain	8000
chemical spill on road (oily residue)	6500

Based on this information, under which conditions would it be safe to drive around the bend?

A. none of the conditions

B. dry only

C. dry and heavy rain only

D. all of the conditions

11 If bismuth-211 undergoes ONE alpha decay, what daughter nuclide is produced?

A. $^{207}_{81}\mathrm{Tl}$

B. $^{207}_{85}\mathrm{Tl}$

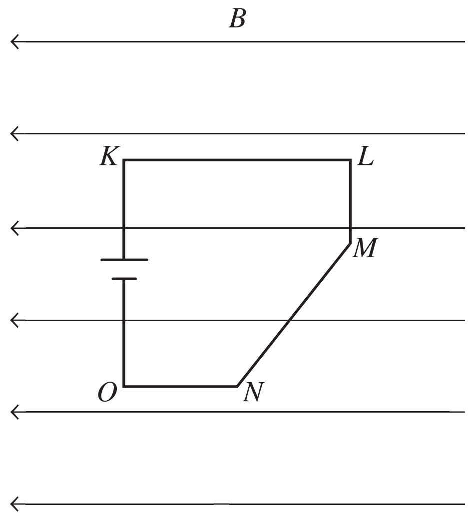
C. $^{215}_{85}\mathrm{At}$

D. $^{215}_{87}\mathrm{Fr}$

12 Which row of the table correctly compares the nucleosynthesis reactions that occur in main sequence stars?

	Proton–proton chain	*Carbon–nitrogen–oxygen (CNO) cycle*
A.	relatively slow and occurs in cooler main sequence stars	relatively fast and occurs in more massive, hotter main sequence stars
B.	relatively slow and occurs in more massive, hotter main sequence stars	relatively fast and occurs in cooler main sequence stars
C.	relatively fast and occurs in more massive, hotter main sequence stars	relatively slow and occurs in cooler main sequence stars
D.	relatively fast and occurs in cooler main sequence stars	relatively slow and occurs in more massive, hotter main sequence stars

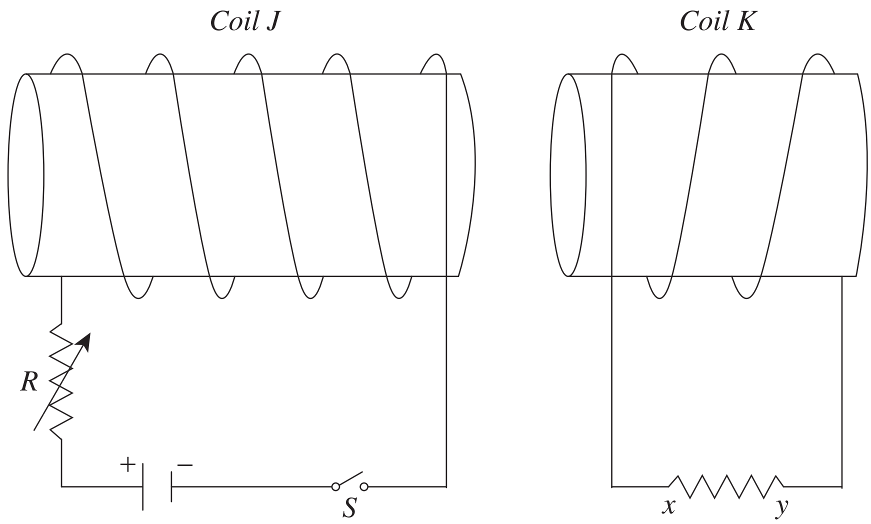
13 A current-carrying loop of wire, *KLMNO*, is placed in a uniform magnetic field that is directed to the left, as shown in the diagram.



Which row of the table describes the magnetic forces acting on sections *LM*, *MN* and *NO* of the loop?

	LM	*MN*	*NO*
A.	parallel out of the page	perpendicular into the page	perpendicular into the page
B.	perpendicular into the page	perpendicular out of the page	no magnetic force
C.	perpendicular into the page	perpendicular into the page	no magnetic force
D.	parallel into the page	parallel into the page	parallel into the page

14 The apparatus shown in the diagram is used in an experiment to demonstrate Lenz's law.



In the experiment, the following sequence of changes is made to the apparatus:

I Switch S is opened after having been closed for a short period of time.

II Coil K is brought closer to coil J and switch S is closed.

III The resistance of R is decreased while switch S remains closed.

Which row of the table identifies the direction of the current in resistor xy after each change?

	I	*II*	*III*
A.	x to y	x to y	x to y
B.	x to y	y to x	y to x
C.	y to x	y to x	y to x
D.	y to x	x to y	y to x

15 The Moon is located 3.84×10^{8} m from Earth and has a mass of 7.35×10^{22} kg. Earth has a mass of 6.0×10^{24} kg.

If a 1.00 kg object is located midway between Earth and the Moon, what is the object's acceleration due to gravity?

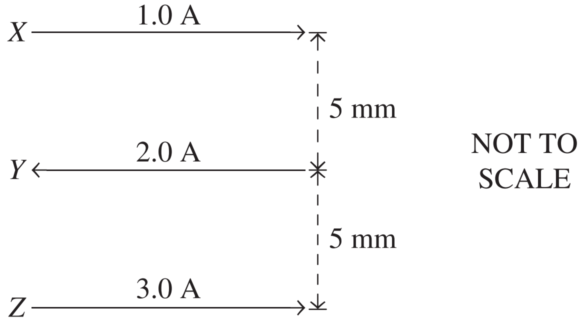
A. 1.07×10^{-2} m s^{-2} towards Earth

B. 1.07×10^{-2} m s^{-2} towards the Moon

C. 1.08×10^{-2} m s^{-2} towards Earth

D. 1.08×10^{-2} m s^{-2} towards the Moon

16 Three parallel current-carrying wires, X, Y and Z, are shown. The current in wire Y is flowing in the opposite direction to the currents in wires X and Z.



What is the magnitude of the net force acting on wire X?

A. 2×10^{-5} N m^{-1} up

B. 2×10^{-5} N m^{-1} down

C. 8×10^{-5} N m^{-1} up

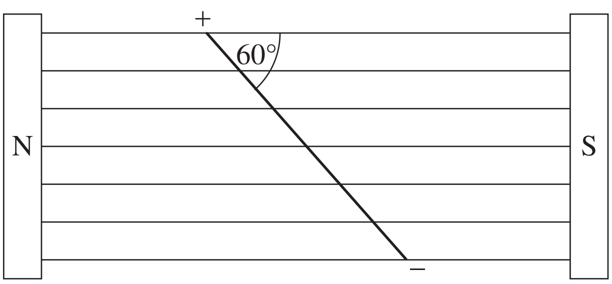
D. 8×10^{-5} N m^{-1} down

17 An observer on Earth claims to see an unidentified flying object (UFO). They estimate that the UFO has a length of 15.0 m and a width of 3.50 m, and is flying at a speed of 0.450 c.

What would the pilot of the UFO measure the UFO's length and width to be?

	Length (m)	*Width (m)*
A.	16.8	3.92
B.	13.4	3.50
C.	16.8	3.50
D.	13.4	3.92

18 A straight current-carrying conductor that has a length of 5.0 cm is suspended in a uniform magnetic field of 1.0 T at an angle of 60° to the field, as shown in the diagram.



If the current passing through the conductor is 2 A, what is the magnitude of the force acting on the conductor?

A. 0.087 N into the page

B. 0.087 N out of the page

C. 8.7 N into the page

D. 8.7 N out of the page

19 A satellite is currently in a low Earth orbit of 850 km and must be brought down to a lower orbit of 650 km.

In order to be stable in the lower orbit, the speed of the satellite would need to

A. increase by 105 m s^{-1}.

B. decrease by 105 m s^{-1}.

C. increase by 3115 m s^{-1}.

D. decrease by 3115 m s^{-1}.

20 A team of physicists are researching two planets, Endo and Exo, that orbit a distant star. The table shows some of the data that the team has gathered.

Planet	*Radius of orbit (m)*	*Orbital period (s)*
Endo	6.2×10^{8}	4.2×10^{4}
Exo	1.56×10^{9}	1.68×10^{5}

Based on the data in the table, which of the following statements is correct?

A. The acceleration due to gravity experienced by Endo is 2.5 times greater than the acceleration due to gravity experienced by Exo.

B. The acceleration due to gravity experienced by Exo is 2.5 times greater than the acceleration due to gravity experienced by Endo.

C. The acceleration due to gravity experienced by Endo is 6.3 times greater than the acceleration due to gravity experienced by Exo.

D. The acceleration due to gravity experienced by Exo is 6.3 times greater than the acceleration due to gravity experienced by Endo.

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HSC Year 12 Physics

Section II Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Instructions

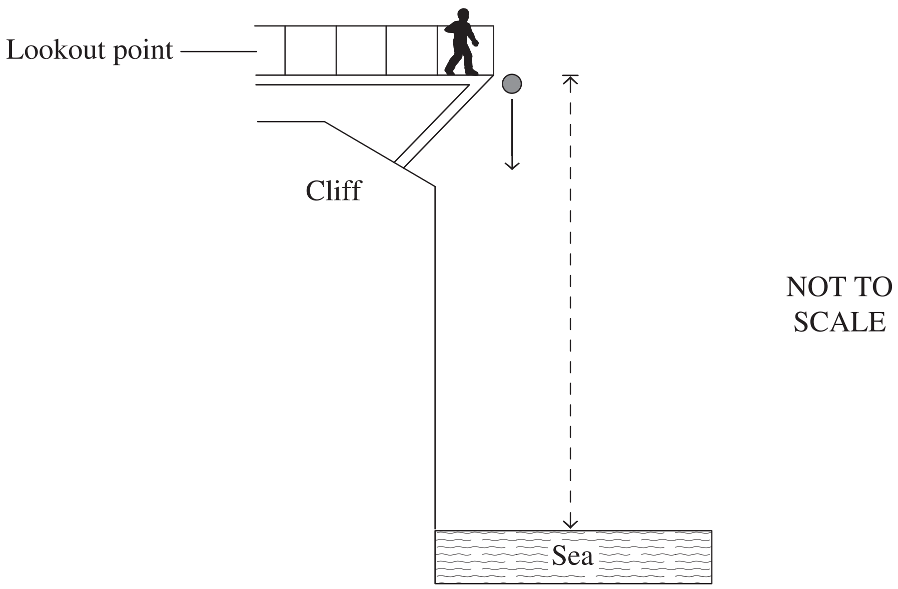
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (5 marks)

A popular tourist site has a lookout point at the top of a cliff overlooking the sea.

(a) A visitor accidentally rolls a ball off the lookout point, as shown in the diagram. It takes 3.5 seconds for the ball to land in the sea below. **2**



Calculate the vertical distance that the ball travels before it lands in the sea.

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(b) The tourist site also offers helicopter sightseeing tours. **3**

A passenger in one of the helicopters drops their phone while trying to take a photo of the scenery. When the phone is dropped, the helicopter is 200 m above the ground and travelling at a horizontal speed of 50.0 m s^{-1}.

Calculate the horizontal distance that the phone travels before it lands on the ground.

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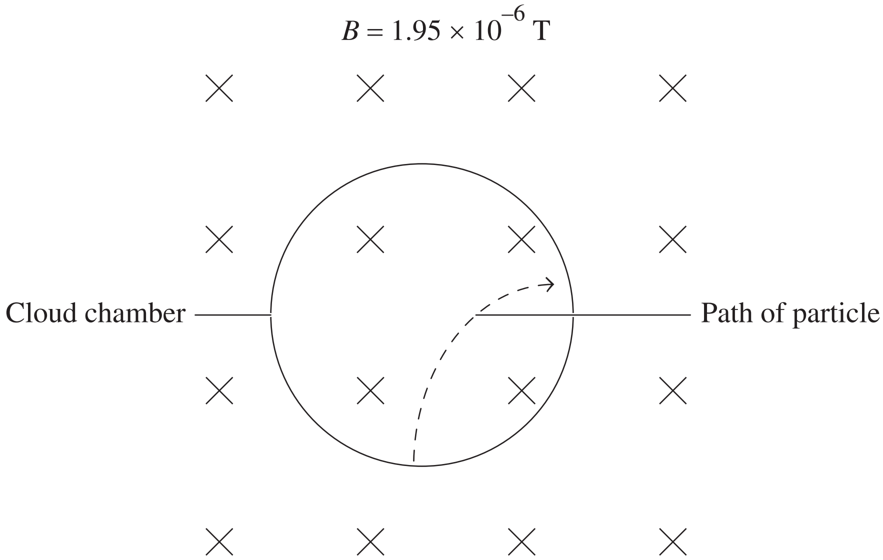
Question 22 (4 marks)

A particle in an accelerator reaches a velocity of 2.50×10^4 m s^{-1} before entering a Wilson cloud chamber. The cloud chamber is in a uniform magnetic field of 1.95×10^{-6} T. The path of the particle in the cloud chamber is illustrated in the diagram.



(a) State whether the particle is positively or negatively charged. **1**

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(b) The radius of the particle's path is 5.0 cm. **3**

Show that the mass-to-charge ratio of the particle is 2.6×10^{11} C kg^{-1}.

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Question 23 (8 marks)

A Physics student is provided with two pairs of sunglasses and two light sources. One pair of sunglasses and one light source are polarised.

(a) Explain how the student could identify which pair of sunglasses and which light source are polarised. **3**

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(b) Discuss how polarisation can be explained by comparing the particle model and wave models of light. **5**

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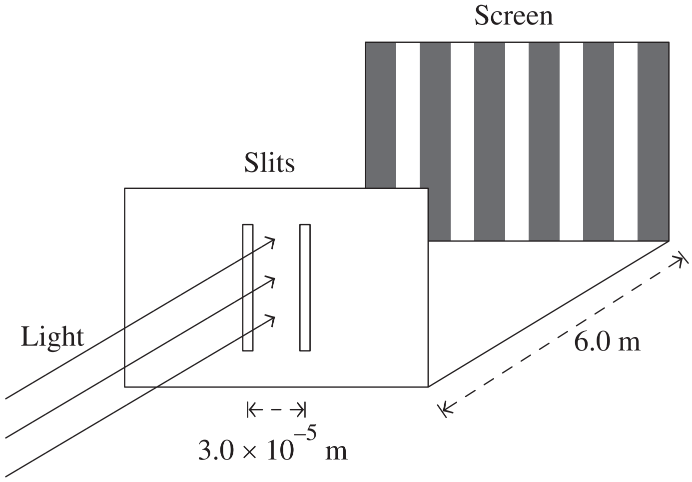
Question 24 (4 marks)

The diagram illustrates an experiment where light of wavelength 500 nm is incident upon a pair of slits that are 3.0×10^{-5} m apart. A pattern of maxima and minima is produced on a screen that is 6.0 m behind the slits.



(a) Calculate the distance between each of the maxima. **2**

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(b) Determine whether the experiment supports the particle or wave model of light. Explain your answer. **2**

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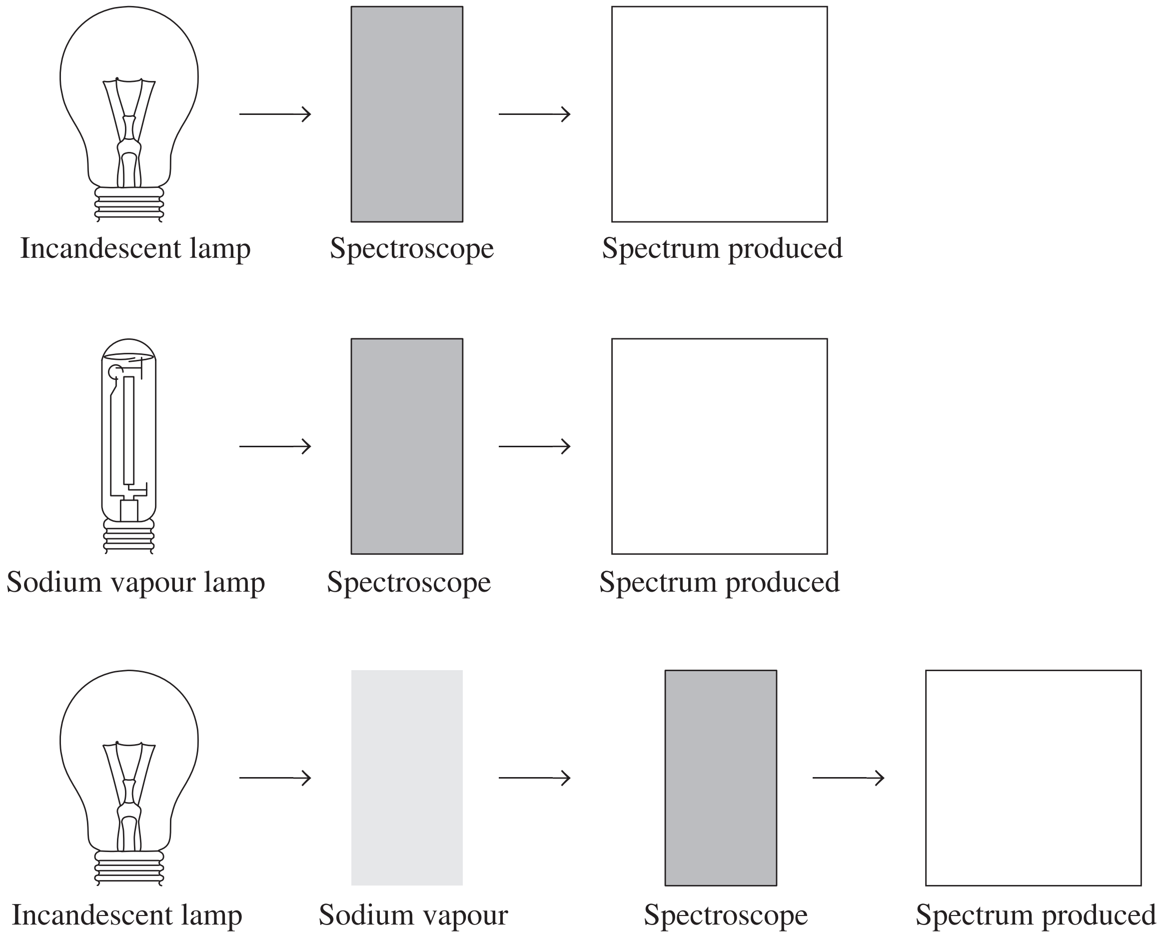
Question 25 (7 marks)

A Physics class is investigating the spectra produced by three light sources, as shown in the diagram. They determine that each light source will produce one of the following spectra.

- spectrum I: two yellow lines on a black background
- spectrum II: the full range of colours with two black lines
- spectrum III: the full range of colours



Question 25 continues on page 17

Question 25 (continued)

Complete the diagram on page 16 by identifying the spectrum (I, II or III) that each light source will produce, and explain whether each spectrum is a continuous, absorption or emission spectrum. **7**

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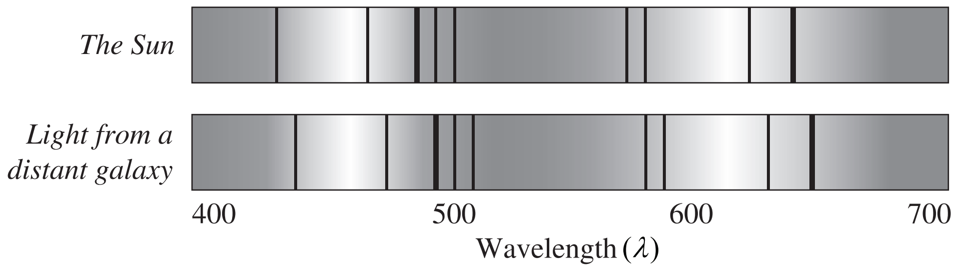
End of Question 25

Question 26 (4 marks)

The spectra of the Sun and the light from a distant galaxy are shown. **4**



Explain how the spectra support Hubble's law and the Big Bang theory.

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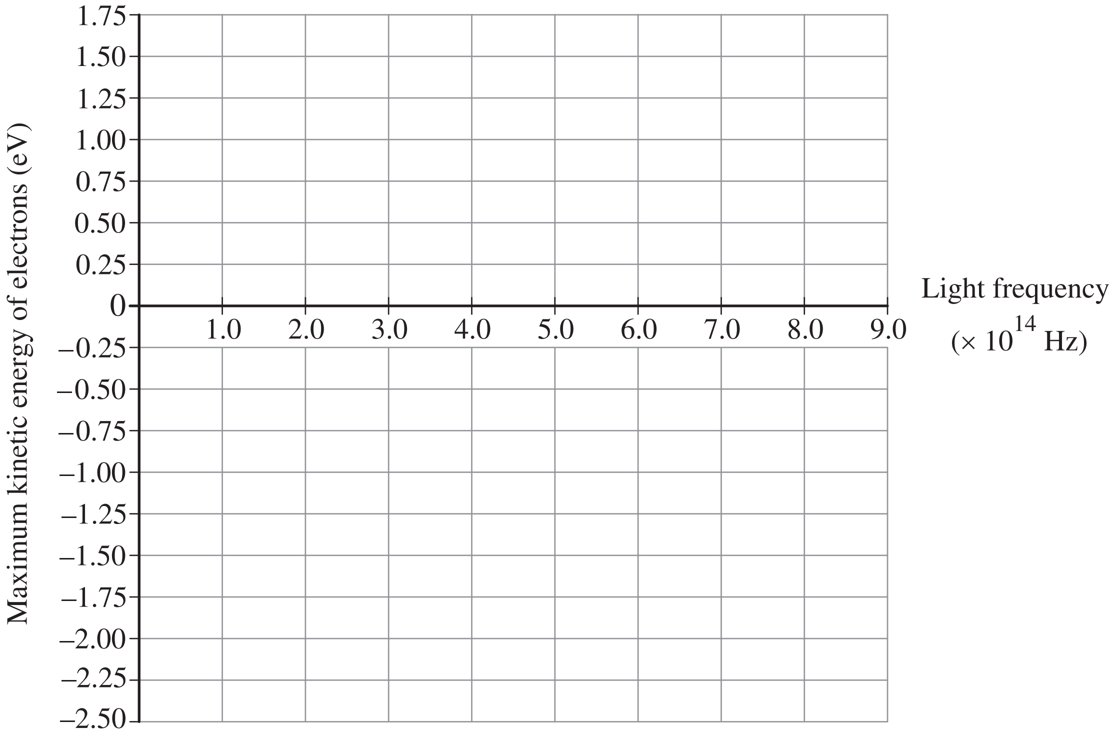
Question 27 (5 marks)

A team of physicists conducted an experiment to investigate the photoelectric effect. They directed light of different frequencies at the surface of a particular metal. The maximum kinetic energies of the electrons emitted by the metal were measured and the data was recorded in the table.

Light frequency (× 10^{14} Hz)	*Maximum kinetic energy of electrons (eV)*
5.6	0.01
6.0	0.18
6.5	0.41
7.1	0.70
7.9	0.97
8.8	1.31

(a) Plot the data on the axes provided and, using the plotted data: **3**

- determine the work function (ϕ) of the metal
- calculate a value for Planck's constant (h).



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Question 27 continues on page 20

Question 27 (continued)

(b) The team of physicists direct light of wavelength 420 nm at the metal. **2**

Using the values for ϕ and h from part (a) on page 19, determine whether the photoelectric effect will occur.

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End of Question 27

Question 28 (4 marks)

A thought experiment proposes the following question. **4**

> If I were sitting on a train that is travelling at the speed of light and I held a mirror up to my face, would I see my own reflection in the mirror?

There are two possible conclusions for this thought experiment.

- Conclusion I: Einstein would see his own reflection in the mirror.
- Conclusion II: Einstein would not see his own reflection in the mirror.

Discuss both possible conclusions for this thought experiment and determine which is correct.

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Question 29 (8 marks)

Analyse how the use of particle accelerators has provided evidence for the Standard Model of matter. **8**

Question 30 (6 marks)

A physicist conducted an experiment using a transformer. The results of the experiment are recorded in the table.

	Primary coil	*Secondary coil*
Voltage (V)	120	?
Current (mA)	3.0	30
Number of turns	?	5

(a) Assuming that the transformer was 100% efficient, determine the secondary voltage and the number of turns in the primary coil. **3**

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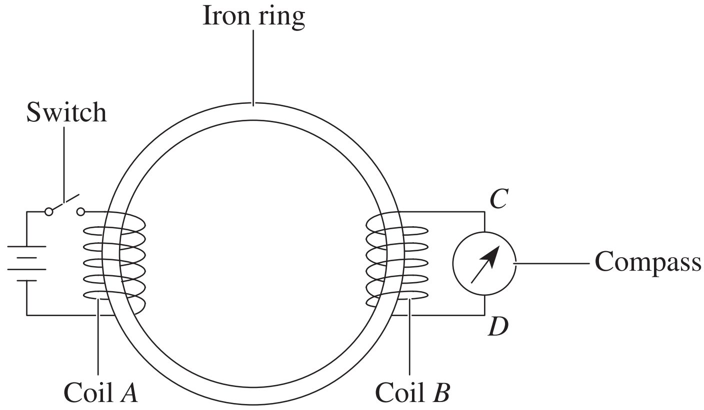
Question 30 continues on page 24

Question 30 (continued)

(b) Faraday's iron ring experiment used two coils and a soft iron ring, as shown in the diagram. **3**



A compass was placed above the wire *CD* to detect any changes in the magnetic field produced. Faraday observed that the compass needle did not deflect when the switch was left open or closed, but it did deflect momentarily when the switch was initially opened or closed.

Explain Faraday's observations.

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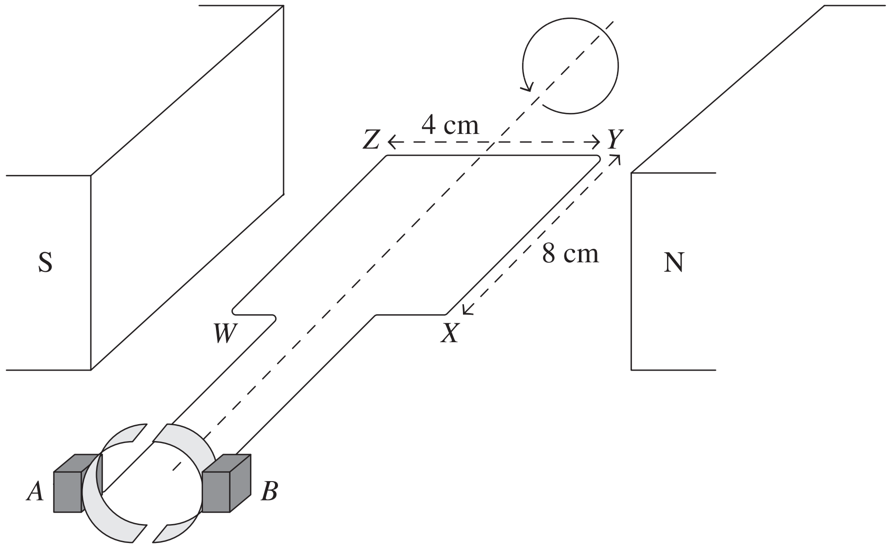
End of Question 30

Question 31 (7 marks)

A simple DC motor is shown in the diagram.



(a) On the diagram, label terminals *A* and *B* with their charges (+ or –). **1**

(b) One component of the motor ensures that the direction of the torque remains constant. **3**

With reference to the diagram, identify this component and explain why it is essential that the component maintains the direction of the torque.

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Question 31 continues on page 26

Question 31 (continued)

(c) The magnets produce a magnetic field of 0.65 T. The magnetic field is at right angles to side *XY*, and a current of 12 A flows through loop *WXYZ*. **3**

The loop rotates from the position shown in the diagram on page 25 (position I), to a position where the plane of the loop makes an angle of 60° from the horizontal (position II), and then to a position where the plane of the loop makes an angle of 90° from the horizontal (position III).

Determine the magnitude of the torque and the direction of rotation at positions I, II and III.

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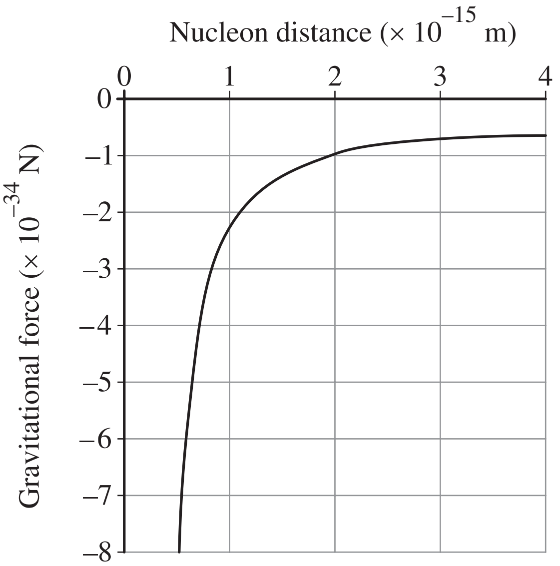
End of Question 31

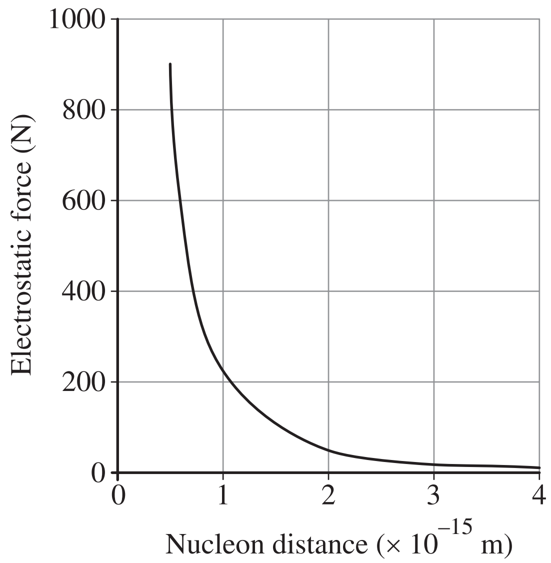
Question 32 (5 marks)

Graph 1 shows the relationship between gravitational force and nucleon distance, and graph 2 shows the relationship between electrostatic force and nucleon distance. **5**

Graph 1



Graph 2



Using the graphs and your knowledge of the fundamental forces, account for the stability of the nucleus.

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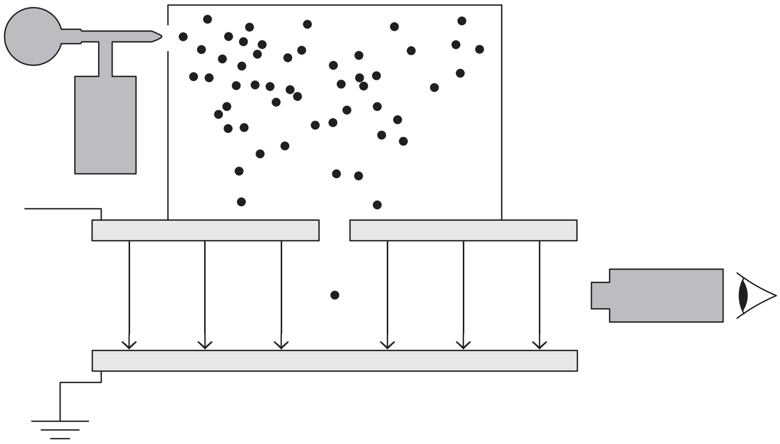
Question 33 (5 marks)

Outline how projectile motion could be modelled in a Physics classroom to show the relationship between launch angle and horizontal range. Assume that the projectile lands at the same height from which it was launched and support your answer with a graph. **5**

Question 34 (8 marks)

(a) The diagram shows a simplified representation of Millikan's oil drop experiment. **5**



Outline Millikan's experiment AND how it provided evidence relating to the electron.

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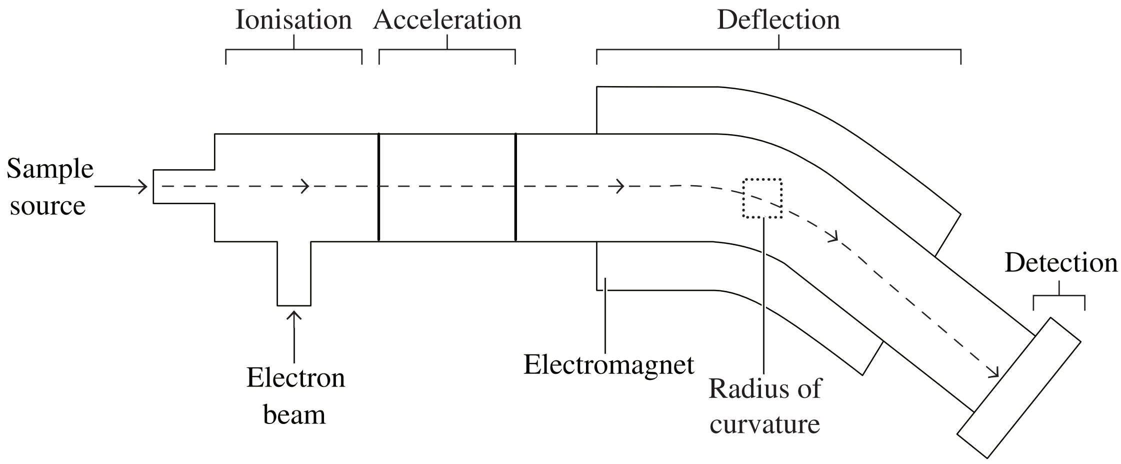
Question 34 continues on page 30

Question 34 (continued)

(b) Mass spectrometry is used to determine the mass of particles. A mass spectrometer projects a sample at a known velocity through an evacuated chamber. The sample is first bombarded with an electron beam, which causes particles in the sample to become positively charged ions with equal charges. The ions then enter a region of uniform magnetic field produced by an electromagnet that is perpendicular to the velocity of the ion. A simplified illustration of this process is shown. **3**



Explain how the magnetic field enables the masses of the ions to be determined.

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End of paper

Section II extra writing space

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Section II extra writing space

If you use this space, clearly indicate which question you are answering.

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 ms^{-1}
Earth's gravitational acceleration, g	9.8 ms^{-2}
Speed of light, c	3.00×10^{8} ms^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} $A^2\ s^4\ kg^{-1}\ m^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^{6} m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	4.18×10^{3} J kg^{-1} K^{-1}
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$s = ut + \frac{1}{2}at^2$

$v = u + at$

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

$\vec{F}_{\text{net}} = m\vec{a}$

$\Delta U = mg\Delta h$

$W = F_{\parallel}s = Fs\cos\theta$

$P = \frac{\Delta E}{\Delta t}$

$K = \frac{1}{2}mv^2$

$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$

$P = F_{\parallel}v = Fv\cos\theta$

$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$

$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$

$\omega = \frac{\Delta\theta}{t}$

$a_{\text{c}} = \frac{v^2}{r}$

$\tau = r_{\perp}F = rF\sin\theta$

$F_{\text{c}} = \frac{mv^2}{r}$

$v = \frac{2\pi r}{T}$

$F = \frac{GMm}{r^2}$

$U = -\frac{GMm}{r}$

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

Waves and thermodynamics

$v = f\lambda$

$f_{\text{beat}} = |f_2 - f_1|$

$f = \frac{1}{T}$

$f' = f\frac{(v_{\text{wave}} + v_{\text{observer}})}{(v_{\text{wave}} - v_{\text{source}})}$

$d\sin\theta = m\lambda$

$n_1\sin\theta_1 = n_2\sin\theta_2$

$n_x = \frac{c}{v_x}$

$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$

$I = I_{\text{max}}\cos^2\theta$

$I_1r_1^2 = I_2r_2^2$

$Q = mc\Delta T$

$\frac{Q}{t} = \frac{kA\Delta T}{d}$

FORMULAE SHEET (CONTINUED)

Electricity and magnetism

$$E = \frac{V}{d}$$

$$\vec{F} = q\vec{E}$$

$$V = \frac{\Delta U}{q}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$W = qV$$

$$I = \frac{q}{t}$$

$$W = qEd$$

$$V = IR$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$P = VI$$

$$B = \frac{\mu_0 NI}{L}$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$\Phi = B_{\parallel}A = BA\cos\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\frac{V_{\text{p}}}{V_{\text{s}}} = \frac{N_{\text{p}}}{N_{\text{s}}}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_{\text{p}}I_{\text{p}} = V_{\text{s}}I_{\text{s}}$$

Quantum, special relativity and nuclear

$$\lambda = \frac{h}{mv}$$

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$K_{\text{max}} = hf - \phi$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$\lambda_{\text{max}} = \frac{b}{T}$$

$$p_{\text{v}} = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$E = mc^2$$

$$E = hf$$

$$N_{\text{t}} = N_0 e^{-\lambda t}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

atomic number	79
symbol	**Au**
standard atomic weight	197.0
name	gold

1 **H** 1.008 hydrogen																	2 **He** 4.003 helium
3 **Li** 6.941 lithium	4 **Be** 9.012 beryllium											5 **B** 10.81 boron	6 **C** 12.01 carbon	7 **N** 14.01 nitrogen	8 **O** 16.00 oxygen	9 **F** 19.00 fluorine	10 **Ne** 20.18 neon
11 **Na** 22.99 sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 aluminium	14 **Si** 28.09 silicon	15 **P** 30.97 phosphorus	16 **S** 32.07 sulfur	17 **Cl** 35.45 chlorine	18 **Ar** 39.95 argon
19 **K** 39.10 potassium	20 **Ca** 40.08 calcium	21 **Sc** 44.96 scandium	22 **Ti** 47.87 titanium	23 **V** 50.94 vanadium	24 **Cr** 52.00 chromium	25 **Mn** 54.94 manganese	26 **Fe** 55.85 iron	27 **Co** 58.93 cobalt	28 **Ni** 58.69 nickel	29 **Cu** 63.55 copper	30 **Zn** 65.38 zinc	31 **Ga** 69.72 gallium	32 **Ge** 72.64 germanium	33 **As** 74.92 arsenic	34 **Se** 78.96 selenium	35 **Br** 79.90 bromine	36 **Kr** 83.80 krypton
37 **Rb** 85.47 rubidium	38 **Sr** 87.61 strontium	39 **Y** 88.91 yttrium	40 **Zr** 91.22 zirconium	41 **Nb** 92.91 niobium	42 **Mo** 95.96 molybdenum	43 **Tc** technetium	44 **Ru** 101.1 ruthenium	45 **Rh** 102.9 rhodium	46 **Pd** 106.4 palladium	47 **Ag** 107.9 silver	48 **Cd** 112.4 cadmium	49 **In** 114.8 indium	50 **Sn** 118.7 tin	51 **Sb** 121.8 antimony	52 **Te** 127.6 tellurium	53 **I** 126.9 iodine	54 **Xe** 131.3 xenon
55 **Cs** 132.9 caesium	56 **Ba** 137.3 barium	57–71 lanthanoids	72 **Hf** 178.5 hafnium	73 **Ta** 180.9 tantalum	74 **W** 183.9 tungsten	75 **Re** 186.2 rhenium	76 **Os** 190.2 osmium	77 **Ir** 192.2 iridium	78 **Pt** 195.1 platinum	79 **Au** 197.0 gold	80 **Hg** 200.6 mercury	81 **Tl** 204.4 thallium	82 **Pb** 207.2 lead	83 **Bi** 209.0 bismuth	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium	113 **Nh** nihonium	114 **Fl** flerovium	115 **Mc** moscovium	116 **Lv** livermorium	117 **Ts** tennessine	118 **Og** oganesson

Lanthanoids

57 **La** 138.9 lanthanum	58 **Ce** 140.1 cerium	59 **Pr** 140.9 praseodymium	60 **Nd** 144.2 neodymium	61 **Pm** promethium	62 **Sm** 150.4 samarium	63 **Eu** 152.0 europium	64 **Gd** 157.3 gadolinium	65 **Tb** 158.9 terbium	66 **Dy** 162.5 dysprosium	67 **Ho** 164.9 holmium	68 **Er** 167.3 erbium	69 **Tm** 168.9 thulium	70 **Yb** 173.1 ytterbium	71 **Lu** 175.0 lutetium

Actinoids

89 **Ac** actinium	90 **Th** 232.0 thorium	91 **Pa** 231.0 protactinium	92 **U** 238.0 uranium	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

Neap

Trial Examination 2024

HSC Year 12 Physics

Solutions and Marking Guidelines

SECTION I

Question 1 **A**

A is correct. The speed of light in a vacuum is an absolute constant; it is not dependent on the speed of the light source or the observer.

B, **C** and **D** are incorrect. These options do not adhere to Einstein's postulates, which state that the speed of light in a vacuum is constant and all inertial frames of reference are equivalent.

Mod 7 The Nature of Light (PH12–4, 12–7, 12–14)	Bands 2–3

Question 2 **B**

Using the spectral class classification system OBAFGKM – where O represents stars with the highest surface temperatures and M represents stars with the lowest surface temperatures – star Y (B5) has the highest surface temperature, followed by star Z (A2), and then star X (M2). The data relating to the stars' distances from the Sun and apparent magnitudes is not relevant to surface temperature.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–15)	Bands 2–3

Question 3 **C**

C is correct. When the paintball is shot horizontally, it has an initial horizontal component of velocity that is equal to its launch velocity. The horizontal component remains unchanged throughout the paintball's motion (V_x = constant = 80 m s^{-1}).

A is incorrect. This option may be reached by calculating $\frac{80}{10} = 8.0$.

B is incorrect. This option may be reached by calculating $\frac{80}{9.8} = 8.2$.

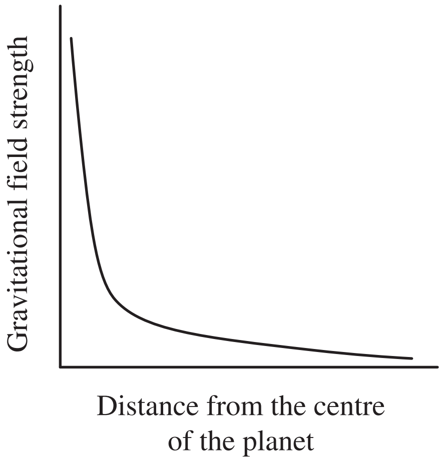
D is incorrect. This option may be reached by calculating $10 \times 80 = 800$.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–6, 12–12)	Bands 2–3

Question 4 **D**

D is correct. The graph of gravitational field strength versus mass of the planet would show that gravitational field strength increases at a steady rate as mass increases.

A is incorrect. The graph of gravitational field strength versus distance from the centre of the planet would show an inverse square relationship. There would be an initial steep decline in gravitational field strength that slows down, proportional to the distance from the centre of the planet, as shown in the graph.



B and **C** are incorrect. The title of the *x*-axis could be inverse square of the distance from the centre of the planet because gravitational field strength increases proportionally to the inverse square of the distance from the centre of the planet. Furthermore, Option **B** refers to the surface, rather than the centre, of the planet; and option **C** refers to the square, rather than the inverse square.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–7, 12–12) Bands 2–3

Question 5 **A**

A is correct. There are 1 000 000 μs in 1 s. Reading from the graph, 50% of the sample remains at approximately 2.0 μs. Therefore, the half-life of the sample in seconds is $\frac{2.0}{1\,000\,000} = 2.0 \times 10^{-6}$ s.

B is incorrect. This option may reached by misreading the graph and not converting the half-life to seconds.

C is incorrect. This option may be reached by calculating $\frac{2.0}{1000} = 2.0 \times 10^{-3}$ s.

D is incorrect. This option is a misinterpretation of the graph that assumes that the axis for time is already given in seconds.

Mod 8 From the Universe to the Atom (PH12–5, 12–15)
Working Scientifically Skills (PH12–6) Bands 2–3

Question 6 **D**

D is correct. According to Einstein's mass–energy equivalence relationship, $E = mc^2$, mass is a form of energy.

A and **C** are incorrect. Mass and energy are neither independent nor identical, as they are different forms of the same underlying quantity.

B is incorrect. An object's rest mass is the same for all inertial frames of reference.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–14)	Bands 3–4

Question 7 **D**

$$F = \frac{GMm}{r^2}$$

$$F \propto \frac{M}{r^2}$$

Given that the distance between the objects was decreased by one third, $r = 1 - \frac{1}{3} = \frac{2}{3}$.

Given that the mass of one of the objects was increased by a factor of 4:

$$\begin{aligned} F &= \frac{4}{\left(\frac{2}{3}\right)^2} \\ &= \frac{4}{\frac{4}{9}} \\ &= 9 \end{aligned}$$

Thus, $F_1 = 9F$.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–6, 12–12)	Bands 4–5

Question 8 **C**

C is correct and **D** is incorrect.

$$F = qvB$$
$$= 1.602 \times 10^{-19} \times 1200 \times 3.00$$
$$= 5.7672 \times 10^{-16} \text{ N to the right}$$

It can be determined that the direction is to the right as the proton enters the field because the particle has a positive charge and the magnetic field is out of the page. This is according to the right-hand grip rule.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}}{m}$$
$$= \frac{5.7672 \times 10^{-16}}{1.673 \times 10^{-27}}$$
$$= 3.45 \times 10^{11} \text{ m s}^{-2} \text{ to the right}$$

A and **B** are incorrect. These options do not calculate $\vec{F} = m\vec{a}$ or account for the mass of the proton.

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 3–4

Question 9 **D**

D is correct.

$$E = mc^2$$
$$= 3.07 \times 10^{-28} \times \left(3.00 \times 10^8\right)^2$$
$$= 2.763 \times 10^{-11} \text{ J}$$

$$\frac{2.763 \times 10^{-11}}{1.602 \times 10^{-19}} = 1.72 \times 10^8 \text{ eV}$$

A is incorrect. This option calculates $(2.763 \times 10^{-11}) \times (1.602 \times 10^{-19}) = 4.42 \times 10^{-30}$.

B is incorrect. This option calculates $(3.99 \times 10^{-25}) - (3.07 \times 10^{-28}) = 3.99 \times 10^{-25}$.

C is incorrect. This option calculates the energy in joules but uses the incorrect unit of measurement.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–15)	Bands 3–4

Question 10 **A**

$m = 2200$ kg

$v = 10.5 \text{ m s}^{-1}$

$r = 23$ m

$$F_c = \frac{mv^2}{r}$$
$$= \frac{2200 \times 10.5^2}{23}$$
$$= 10\,546 \text{ N}$$

The magnitude of the frictional force in all conditions is less than 10 546 N; therefore, it is not safe to drive around the bend under any of the conditions.

Mod 5 Advanced Mechanics (PH12–5, 12–6, 12–12)	Bands 4–5

Question 11 **A**

When bismuth-211 undergoes one alpha decay, its mass number decreases by 4, and its atomic number decreases by 2, which indicates the release of a helium nucleus. Therefore, the daughter nuclide produced has a mass number of 211 – 4 = 207 and an atomic number of 83 – 2 = 81. Reading from the periodic table, it can be determined that the daughter nuclide is $^{207}_{81}\text{Tl}$.

Mod 8 From the Universe to the Atom (PH12–6, 12–15)	Bands 2–3

Question 12 **A**

The proton–proton chain is a three-step process in which protons join to form a helium nucleus. It is a relatively slow process and occurs in cooler main sequence stars.

The carbon–nitrogen–oxygen (CNO) cycle is a six-step process in which protons fuse into a helium nucleus using carbon as a catalyst. It is a relatively fast process and occurs in more massive and, therefore, hotter main sequence stars.

Mod 8 From the Universe to the Atom (PH12–5, 12–15)	Bands 3–4

Question 13 **C**

Using the right-hand palm rule:

- The magnetic force acting on *LM* is perpendicular into the page because the current is moving down the page and the magnetic field (*B*) is to the left.
- The magnetic force acting on *MN* is perpendicular into the page because the current is moving down the page and *B* is to the left.
- There is no magnetic force acting on *NO* as it is parallel to *B*.

Mod 6 Electromagnetism (PH12–5, 12–13)	Bands 3–4

Question 14 **B**

The current in coil *J* flows clockwise when viewed from the left. According to Lenz's law, the induced current in coil *K* that flows through resistor *xy* opposes the change in flux through the coil.

After change I, in which switch *S* is opened and the current stops flowing, a current is induced in coil *K* that flows from *x* to *y*.

After change II, in which coil *K* is brought closer to coil *J* and switch *S* is closed, the current begins to flow through coil *J* again. The magnetic field around coil *J* interacts with the magnetic field induced around coil *K*. This induces a current in the direction that opposes the change. Therefore, the induced current flows from *y* to *x*.

After change III, in which the resistance of *R* is decreased while switch *S* remains closed, the magnetic fields interact in the same way as after change II. Therefore, the direction of the current does not change and flows from *y* to *x*.

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 4–5

Question 15 **A**

A is correct and **B** is incorrect.

Force acting on the object due to Earth:

$$mg = \frac{GMm}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{\left(\frac{1}{2} \times 3.84 \times 10^8\right)^2}$$

$$= 1.08 \ldots \times 10^{-2} \text{ m s}^{-2}$$

Force acting on the object due to the Moon:

$$mg = \frac{GMm}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times 7.35 \times 10^{22}}{\left(\frac{1}{2} \times 3.84 \times 10^8\right)^2}$$

$$= 1.32 \ldots \times 10^{-4} \text{ m s}^{-2}$$

The object's acceleration due to gravity:

$$g = \left(1.08 \ldots \times 10^{-2}\right) - \left(1.32 \ldots \times 10^{-4}\right)$$

$$= 1.07 \times 10^{-2} \text{ m s}^{-2} \text{ towards Earth}$$

C and **D** are incorrect. These options calculate the force acting on the object due to Earth.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–6, 12–12)	Bands 4–5

Question 16 A

A is correct and **B** is incorrect.

Magnitude of the force acting on wire *X* due to current I_Y (2.0 A):

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$
$$= \frac{4\pi \times 10^{-7}}{2\pi}\frac{1.0 \times 2.0}{5 \times 10^{-3}}$$
$$= 8 \times 10^{-5}\ \text{N m}^{-1}\ \text{up}$$

Magnitude of the force acting on wire *X* due to current I_Z (3.0 A):

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$
$$= \frac{4\pi \times 10^{-7}}{2\pi}\frac{1.0 \times 3.0}{10 \times 10^{-3}}$$
$$= 6 \times 10^{-5}\ \text{N m}^{-1}\ \text{down}$$

Magnitude of the net force acting on wire *X*:

$$F_{\text{net}} = \left(8 \times 10^{-5}\right) - \left(6 \times 10^{-5}\right)$$
$$= 2 \times 10^{-5}\ \text{N m}^{-1}\ \text{up}$$

The directions are determined by the right-hand grip rule.

C is incorrect. This option calculates the magnitude of the force acting on wire *X* due to the current in wire *Y* only.

D is incorrect. This option calculates the magnitude of the force acting on wire *X* due to the current in wire *Y* only and does not take into account that the current in wire *Y* is in the opposite direction to the current in wire *X*.

Mod 6 Electromagnetism (PH12–5, 12–13) Working Scientifically Skills (PH12–6)	Bands 4–5

Question 17 C

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$
$$15.0 = l_0\sqrt{\left(1 - \frac{(0.450c)^2}{c^2}\right)}$$
$$l_0 = \frac{15.0}{\sqrt{1 - 0.2025}}$$
$$= 16.8\ \text{m}$$

The pilot would measure the length of the UFO to be 16.8 m. They would measure the width of the UFO to be 3.50 m, the same measurement as the observer on Earth, because only the dimension that is parallel to the velocity, in this case the length of the UFO, is contracted.

Mod 7 The Nature of Light (PH12–4, 12–14)	Bands 5–6

Question 18 **B**

B is correct and **A** is incorrect.

$$F = lIB\sin\theta$$
$$= 0.050\times 2\times 1.0\times \sin(60°)$$
$$= 0.087 \text{ N}$$

According to the right-hand palm rule, since the magnetic field is left to right, the force is out of the page.

C and **D** are incorrect. These options do not convert the length to metres before calculating the force.

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 4–5

Question 19 **A**

A is correct and **B** is incorrect. The speed of the satellite would need to increase in the lower orbit.

$$v_{\text{at 850 km orbit}} = \sqrt{\frac{GM}{r}}$$
$$= \sqrt{\frac{(6.67\times 10^{-11})\times(6.0\times 10^{24})}{(6.371\times 10^{6})+(0.85\times 10^{6})}}$$
$$= \sqrt{\frac{4.002\times 10^{14}}{7.221\times 10^{6}}}$$
$$= 7444.57\ldots \text{ m s}^{-1}$$

$$v_{\text{at 650 km orbit}} = \sqrt{\frac{GM}{r}}$$
$$= \sqrt{\frac{(6.67\times 10^{-11})\times(6.0\times 10^{24})}{(6.371\times 10^{6})+(0.65\times 10^{6})}}$$
$$= \sqrt{\frac{4.002\times 10^{14}}{7.021\times 10^{6}}}$$
$$= 7549.86\ldots \text{ m s}^{-1}$$

Change in speed:

$$\Delta v = 7549.86\ldots - 7444.57\ldots$$
$$= 105 \text{ m s}^{-1}$$

C and **D** are incorrect. These options do not include Earth’s radius in the calculations.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–6, 12–12)	Bands 5–6

Question 20 **C**

C is correct and **D** is incorrect. Both Exo and Endo experience acceleration due to gravity according to $g = \frac{GM}{r^2}$. Exo is approximately 2.5 times further away from the star than Endo is $\left(\frac{1.56 \times 10^9}{6.2 \times 10^8} = 2.5\right)$ and so will experience a lower acceleration due to gravity than Endo. In accordance with the inverse square relationship $\left(g \propto \frac{1}{r^2}\right)$, Endo will experience an acceleration due to gravity that is approximately $\frac{1}{2.5^2}$, or 6.3, times greater than the acceleration due to gravity experienced by Exo.

A and **B** are incorrect. These options do not use the inverse square relationship to calculate the acceleration due to gravity.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–6, 12–12)	Bands 5–6

SECTION II

Question 21

(a) $u = 0$

$a = 9.8 \text{ m s}^{-2}$

$t = 3.5 \text{ s}$

$s = ?$

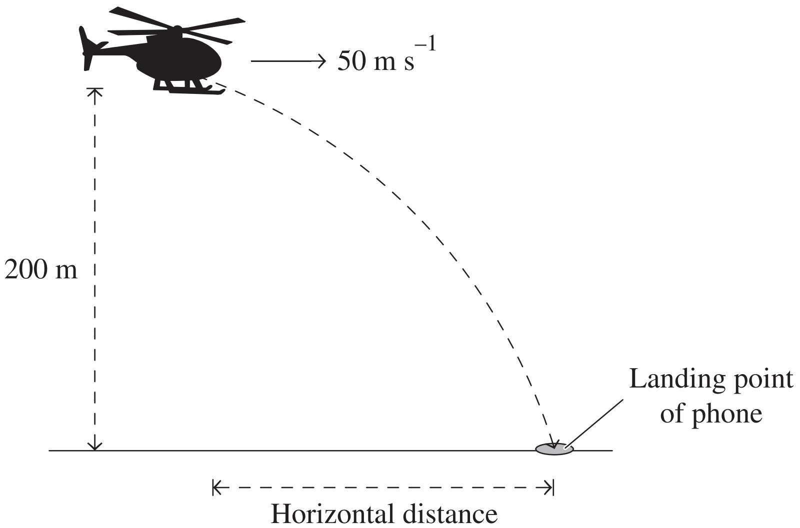
$$s = ut + \frac{1}{2}at^2$$

$$= 0 + \frac{1}{2} \times 9.8 \times 3.5^2$$

$$= 60 \text{ m}$$

Mod 5 Advanced Mechanics (PH12–6, 12–12)	Bands 2–3
• Provides the correct solution using the required variables AND the correct formula	2
• Provides some relevant working	1

(b) The scenario can be illustrated as follows.



$a_y = 9.8 \text{ m s}^{-2}$

$a_x = 0 \text{ m s}^{-1}$

$u = 50 \text{ m}^{-1}$

The angle of projection is 0° because the phone was dropped from the helicopter. Therefore:

$$u_x = u\cos\theta$$
$$= 50\cos(0)$$
$$= 50 \text{ m s}^{-1}$$

$$u_y = u\sin\theta$$
$$= 50\sin(0)$$
$$= 0 \text{ m s}^{-1}$$

(continues on next page)

(continued)

Calculating the phone's time of flight gives:

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$-200 = 0 + \frac{1}{2}(-9.8) \times t^2$$

$$t^2 = \frac{-200}{-4.9}$$

$$t = \sqrt{40.81\ldots}$$

$$= 6.38\ldots \text{ seconds}$$

Therefore, calculating the horizontal distance that the phone travels gives:

$$s_x = u_x t$$

$$= 50.0 \times 6.38\ldots$$

$$= 319 \text{ m}$$

Note: Responses are not required to include diagrams to obtain full marks.

Mod 5 Advanced Mechanics (PH12–6, 12–12)	Bands 3–4
• Provides the correct solution.	3
• Calculates the phone's time of flight	2
• Provides some relevant working	1

Question 22

(a) negatively charged *(as B is into the page and the particle arcs to the right)*

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 2–3
• States that the particle is negatively charged.	1

(b)
$$\frac{mv^2}{r} = qvB$$
$$r = \frac{mv}{qB}$$
$$\frac{q}{m} = \frac{v}{rB}$$
$$= \frac{2.50 \times 10^4}{0.050 \times 1.95 \times 10^{-6}}$$
$$= 2.6 \times 10^{11}\ \text{C kg}^{-1}$$

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 4–5
• Substitutes into the relevant formula correctly	3
• Attempts to substitute into the relevant formula	2
• Identifies the relevant formula.	1

Question 23

(a) When the polarised sunglasses are placed in front of the polarised light source, the sunglasses will cause the light to dim. The student could place one of the pairs of sunglasses in front of one of the light sources, then rotate the pair of sunglasses through different angles until they have been rotated 90°. The student should repeat this process for each pair of sunglasses with each light source.

Mod 7 The Nature of Light (PH12–2, 12–7, 12–14)	Bands 3–4
• Outlines a simple procedure. AND • Explains the expected results.	3
• Outlines a simple procedure	2
• Provides some relevant information	1

(b) If light passes through one polariser and then passes through a second polariser that is perpendicular to the first, then none of the light that passes through the first polariser will pass through the second. This cannot be explained by Newton's particle model of light because it describes light as a stream of particles, which should pass through both polarisers. It is also not possible to explain polarisation with Huygens' longitudinal wave model. Longitudinal waves cannot be polarised because the direction of oscillation of a longitudinal wave is parallel, not perpendicular, to the direction of propagation.

Polarisation supports the transverse wave model of light. According to this model, light waves are electromagnetic waves, which have an electric field and a magnetic field that oscillate perpendicular to each other. This means that the electric and magnetic fields can pass through or be blocked by a polariser depending on its polarisation axis.

Mod 7 The Nature of Light (PH12–7, 12–14)	Bands 5–6
• Outlines polarisation. AND • Explains that polarisation cannot be explained by the particle model of light. AND • Explains that polarisation cannot be explained by the longitudinal wave model of light. AND • Outlines electromagnetic waves. AND • Explains how polarisation supports the transverse wave model of light.	5
• Any FOUR of the above points	4
• Any THREE of the above points	3
• Any TWO of the above points	2
• Provides some relevant information	1

Question 24

(a)

$$d\sin\theta = m\lambda$$

$$3.0\times10^{-5}\times\sin\theta = 1\times\left(500\times10^{-9}\right)$$

$$\sin\theta = \frac{500\times10^{-9}}{3.0\times10^{-5}}$$

$$\theta = 0.95\,...^\circ$$

$$\tan(0.95\,...^\circ) = \frac{x}{6.0}$$

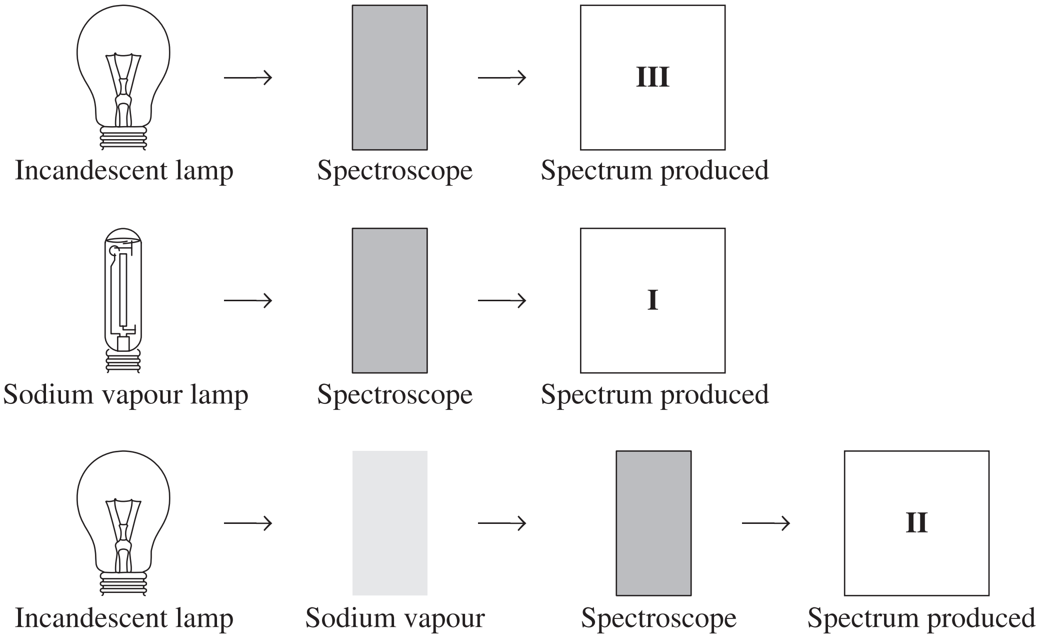
$$x = 0.10\text{ m}$$

Mod 7 The Nature of Light (PH12–2, 12–4)	Bands 5–6
• Calculates the distance between each of the maxima	2
• Calculates the angle	1

(b) The experiment supports the wave model of light because the light wave diffracts as it passes through the slits. This is seen in the diffraction pattern on the screen; the maxima are due to constructive interference of the diffracted light, and the minima are due to destructive interference.

Mod 7 The Nature of Light (PH12–2, 12–4, 12–7, 12–14)	Bands 5–6
• States that the experiment supports the wave model of light. AND • Explains why the experiment supports the wave model of light with reference to diffraction	2
• States that the experiment supports the wave model of light	1

Question 25



The first incandescent lamp will produce spectrum III, which is a continuous spectrum, as its heated filament produces all wavelengths of light. As light is produced by an electric current passing through a conductor with a high resistance and melting point, the collision between the electrons and the conductor produces heat and light.

The sodium vapour lamp will produce spectrum I, which is an emission spectrum. The two yellow lines on the black background correspond to photons of light that are released when the energy levels of the excited electrons in the sodium vapour decrease.

The second incandescent lamp will produce spectrum II, which is an absorption spectrum. The lamp produces all wavelengths of light. Some of these wavelengths will be absorbed by the sodium vapour and others will pass through. The wavelengths that are absorbed will appear as black lines on a coloured background.

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(continued)

Mod 7 The Nature of Light (PH12–4, 12–7, 12–14)	Bands 5–6
• Identifies which spectrum (I, II or III) will be produced by each of the THREE light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by each of the THREE light sources. AND • Provides a detailed explanation for ALL THREE identified spectrum types	7
• Identifies which spectrum (I, II or III) will be produced by each of the THREE light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by each of the THREE light sources. AND • Provides a detailed explanation for TWO of the identified spectrum types	6
• Identifies which spectrum (I, II or III) will be produced by each of the THREE light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by any TWO light sources. AND • Provides a detailed explanation for TWO of the identified spectrum types	5
• Identifies which spectrum (I, II or III) will be produced by each of the THREE light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by any TWO light sources. AND • Provides a detailed explanation for ONE of the identified spectrum types.	4
• Identifies which spectrum (I, II or III) will be produced by any TWO light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by any TWO light sources.	3
• Identifies which spectrum (I, II or III) will be produced by any TWO light sources. AND • Identifies which type of spectrum (continuous, absorption or emission) will be produced by any ONE light source	2
• Provides some relevant information	1

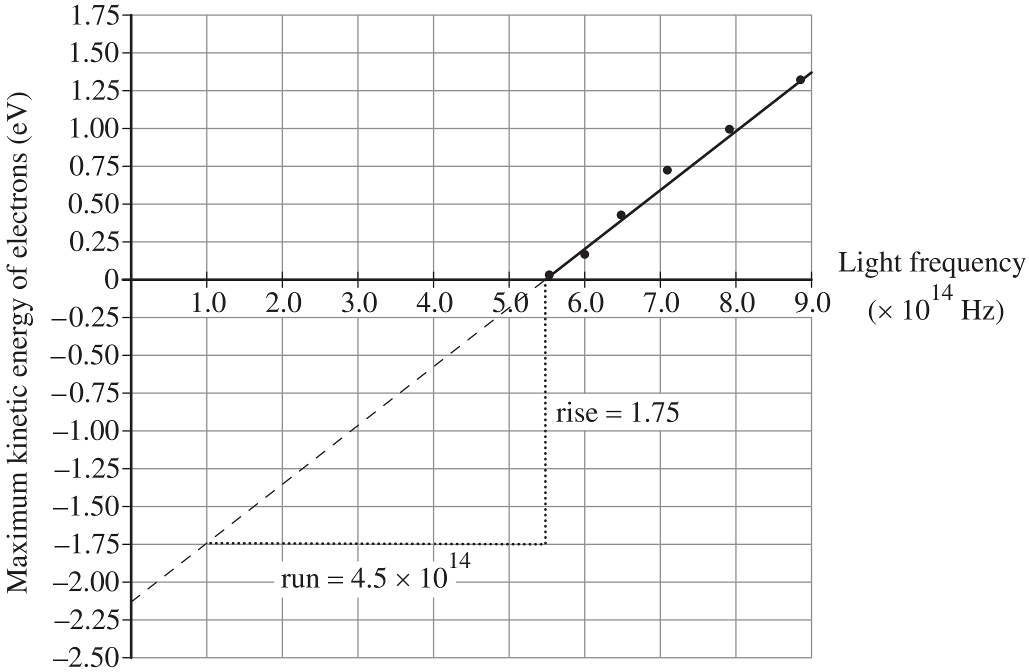
Question 26

Hubble's law states that the further a galaxy is from Earth's galaxy, the faster it is moving away from Earth. Hubble plotted velocity against distance and obtained a linear graph, indicating that the universe is expanding. This can be seen in the red shift of the spectra. Comparing the spectrum of the Sun to the spectrum of light from a distant galaxy shows that the Sun and light from the distant galaxy have the same spectral lines; however, in the spectrum of light from the distant galaxy, these lines have shifted towards the red end. This indicates a longer wavelength and thus a greater distance from Earth, thereby providing evidence that the universe is expanding. This subsequently supports the Big Bang theory, which proposes that all matter and energy in the universe was originally contained to a single extremely hot and dense point before rapidly expanding.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–7, 12–15)	Bands 4–5
• States Hubble's law. AND • Identifies the red shift in the spectra. AND • Explains how the spectra support Hubble's law. AND • Explains how the spectra support the Big Bang theory	4
• Any THREE of the above points	3
• Any TWO of the above points	2
• Provides some relevant information	1

Question 27

(a)



$\phi = 2.13$ eV *(based on extrapolation of the line of best fit and identifying the y-intercept)*

$$h = \frac{\text{rise}}{\text{run}}$$

$$= \frac{0-(-1.75)}{\left(5.5\times10^{14}-1.0\times10^{14}\right)}$$

$$= \frac{1.75}{4.5\times10^{14}}$$

$$= 3.9\times10^{-15}\text{ eV s}$$

Note: For the work function, ϕ, accept responses in the range 2.10–2.30 eV. For Planck's constant, h, accept responses in the range 3.5–4.5 × 10^{-15} eV s.

Mod 7 The Nature of Light (PH12–4, 12–7, 12–14)	Bands 2–3
• Plots all data points AND draws a line of best fit. AND • Determines ϕ of the metal by extrapolating the line. AND • Calculates h by calculating the gradient of the line	3
• Any TWO of the above points	2
• Any ONE of the above points	1

(b) $K_{\text{max}} = \dfrac{hc}{\lambda} - \phi$

$$= \frac{3.9 \times 10^{-15} \times 3.00 \times 10^{8}}{4.20 \times 10^{-7}} - 2.13$$

$$= 0.66 \text{ eV}$$

Thus, as there is energy remaining from the photon after the electron has escaped the metal, the photoelectric effect will occur.

Note: Consequential on answer to ***Question 27(a).***

Mod 7 The Nature of Light (PH12–4, 12–7, 12–14)	Bands 4–5

- Calculates the maximum kinetic energy of the electrons emitted.
  AND
- Determines that the photoelectric effect will occur. 2

- Calculates the maximum kinetic energy of the electrons emitted 1

Question 28

For conclusion I to be true, light from Einstein's face would be travelling at the speed of light (c) relative to the train. A stationary observer outside the train would see the light travelling at twice the speed of light, $2c$. Seeing his reflection does not violate the principle of relativity, as the speed of light is constant in all inertial frames of reference. Therefore, conclusion I is correct.

For conclusion II to be true, light from Einstein's face would not be travelling at the speed of light (c) and so would never reach the mirror. Therefore, he would not see his reflection. This conclusion violates the principle of relativity and so is incorrect.

Mod 7 The Nature of Light (PH12–4, 12–7, 12–14)	Bands 5–6

- Discusses conclusion I AND conclusion II in detail.
  AND
- States that conclusion I is correct 4

- Discusses conclusion I AND conclusion II.
  AND
- States that conclusion I is correct 3

- Discusses conclusion I OR conclusion II.
  AND
- States conclusion I is correct 2

- Discusses conclusion I OR conclusion II with limited detail.
  OR
- States that conclusion I is correct 1

Question 29

The fundamental particles of the Standard Model of matter are quarks, leptons, bosons and the Higgs boson. Experiments using particle accelerators have provided evidence for the existence of these particles and three of the fundamental forces; weak nuclear force, strong nuclear force and electromagnetism. Particle accelerators allow particles to collide at great speeds that produce large amounts of energy. This causes the particles to break down which makes it possible to determine their composition.

In the Bohr model of the atom, the fundamental particles are protons, neutrons and electrons. However, particle accelerators have led to the discovery that protons and neutrons are not fundamental particles, as they can be broken down into quarks. The Standard Model identifies six types of quarks: up, down, charm, strange, top and bottom. Experiments using particle accelerators to observe electron–proton collisions have led to the discovery that protons comprise two up quarks and one down quark; and neutrons comprise one up quark and two down quarks.

The Standard Model also identifies six leptons: electron, muon, tau, electron neutrino, muon neutrino and tau neutrino. An experiment using a particle accelerator that enabled electron–positron collisions led to the discovery of the tau lepton, which subsequently implied the existence of the tau neutrino lepton. Further research involving particle acceleration has also provided evidence of neutrinos.

Furthermore, particle accelerators such as the Large Hadron Collider (LHC) have been key to confirming the existence of bosons (including photons, gluons, W bosons, Z bosons and the Higgs boson). In the Standard Model, bosons are force carriers, which hold together matter particles. The photon carries the electromagnetic force, the gluon carries the strong nuclear force, and the W and Z bosons carry the weak nuclear force. The use of particle accelerators has increased understanding of these fundamental forces.

Over time, the technology of particle accelerators has improved, enabling the ongoing identification and analysis of many components of the Standard Model.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–7, 12–15)	Bands 5–6

- Explains the Standard Model of matter.
  AND
- Explains how particle accelerators work.
  AND
- Analyses how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Analyses how particle accelerators have provided evidence of the fundamental forces of the Standard Model 8

- Outlines the Standard Model of matter.
  AND
- Outlines how particle accelerators work.
  AND
- Analyses how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Analyses how particle accelerators have provided evidence of the fundamental forces of the Standard Model 7

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(continued)

- Outlines the Standard Model of matter.
  AND
- Outlines how particle accelerators work.
  AND
- Outlines how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Outlines how particle accelerators have provided evidence of the fundamental forces of the Standard Model 6

- Outlines the Standard Model of matter OR how particle accelerators work.
  AND
- Outlines how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Outlines how particle accelerators have provided evidence of the fundamental forces of the Standard Model. 5

- Outlines how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Outlines how particle accelerators have provided evidence of the fundamental forces of the Standard Model 4

- Identifies how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  AND
- Identifies how particle accelerators have provided evidence of the fundamental forces of the Standard Model. 3

- Identifies how particle accelerators have provided evidence of the fundamental particles of the Standard Model.
  OR
- Identifies how particle accelerators have provided evidence of the fundamental forces of the Standard Model 2

- Provides some relevant information 1

Question 30

(a) $V_p I_p = V_s I_s$

$$V_s = \frac{V_p I_p}{I_s}$$

$$= \frac{120 \times 3.0}{30}$$

$$= 12 \text{ V}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$N_p = \frac{V_p N_s}{V_s}$$

$$= \frac{120 \times 5}{12}$$

$$= 50 \text{ turns}$$

Mod 6 Electromagnetism (PH12–4, 12–5, 12–13) Working Scientifically Skills (PH12–6)	Bands 3–4
• Calculates V_s. AND • Determines N_p	3
• Calculates V_s. OR • Determines N_p using ratios	2
• Provides some relevant working	1

(b) *For example:*

Faraday's law states that a change in magnetic flux will induce an electromotive force (emf), which will in turn induce a current.

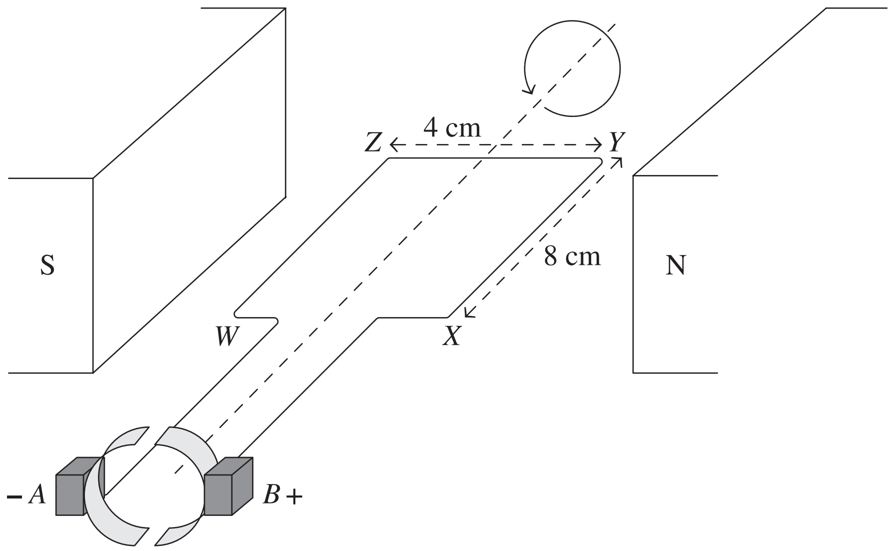
When the switch is left open, there is no magnetic field; when it is left closed, there is a constant magnetic field. Therefore, coil *B* does not experience a change in flux, so the compass needle does not deflect.

When the switch is initially opened or closed, the magnetic field produced by coil *A* rapidly changes, causing coil *B* to experience a change in magnetic flux. This induces a current in coil *B*, which in turn causes the compass needle to deflect.

Mod 6 Electromagnetism (PH12–4, 12–5, 12–7, 12–13) Working Scientifically Skills (PH12–6)	Bands 5–6
• Explains what happens in coil *B* when the switch is initially opened or closed. AND • Explains why the needle deflects when the switch is initially opened or closed. AND • Explains what happens in coil *B* when the switch is left open or closed	3
• Outlines what happens in coil *B* when the switch is initially opened or closed. AND • Outlines what happens in coil *B* when the switch is left open or closed	2
• Provides some relevant information	1

Question 31

(a)



Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 2–3
• Labels terminal *A* as negative and terminal *B* as positive	1

(b) The commutator (split-ring) reverses the direction of the current every half rotation. If the current is not reversed every half rotation, the forces on *WZ* and *XY* will remain in a constant direction, resulting in a torque that reverses.

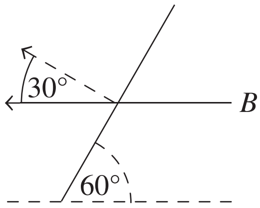
Mod 6 Electromagnetism (PH12–4, 12–5, 12–13)	Bands 3–4
• Identifies the commutator. AND • Explains how the commutator maintains the constant torque. AND • Refers to the diagram.	3
• Identifies the commutator. AND • Explains how the commutator maintains the constant torque	2
• Identifies the commutator. OR • Provides some relevant information	1

(c) Position shown in the diagram (position I):

$$\tau = nIAB\sin\theta$$
$$= 1 \times 12 \times 0.080 \times 0.040 \times 0.65 \times \sin(90°)$$
$$= 0.025 \text{ N m anticlockwise}$$

Position where the plane of the loop makes an angle of 60° from the horizontal (position II):

View from front

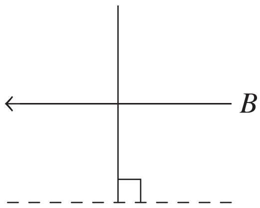


$\therefore \sin(30°)$

$$\tau = 1 \times 12 \times 0.080 \times 0.040 \times 0.65 \times \sin(30°)$$
$$= 0.012 \text{ N m anticlockwise}$$

Position where the plane of the loop makes an angle of 90° from the horizontal (position III):

View from front



$\therefore \sin(0°)$

$$\tau = 1 \times 12 \times 0.080 \times 0.040 \times \sin(0°)$$
$$= 0 \text{ N m anticlockwise}$$

Note: Responses are not required to include diagrams to obtain full marks.

Mod 6 Electromagnetism (PH 12–4, 12–5, 12–13)	Bands 4–5

• Determines the magnitude of the torque in all THREE positions. AND • Determines the direction of rotation in all THREE positions	3
• Determines the magnitude of the torque in TWO positions. AND • Determines the direction of rotation in TWO positions	2
• Provides some relevant working	1

Question 32

The average distance between two nucleons is approximately 1×10^{-15} m. Thus, as can be seen in Graph 1 and Graph 2, the magnitude of the gravitational force between two nucleons is approximately -2.2×10^{-34} N, and the magnitude of the electrostatic force between two protons is approximately 230 N. The magnitude of the electrostatic force, which is repulsive, is greater than the magnitude of the gravitational force, which is attractive, by a factor of approximately 10^{36}. Given that the magnitude of the electrostatic force is significantly greater than that of the gravitational force, it would be expected that protons would repel each other, thus rendering the nucleus unstable. However, due to the strong nuclear force, atoms are stable. The strong nuclear force exists between nucleons and involves the exchange of π-mesons. At the average distance between nucleons, the strong nuclear force is a strong, attractive force that overcomes the repulsion caused by the electrostatic force, thus accounting for the stability of the nucleus. The addition of neutrons creates a greater strong nuclear force with no increase in the electrostatic force; hence, a higher number of neutrons is required for larger nuclei to remain stable.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–15)	Bands 4–6
• Refers to data from BOTH graphs. AND • Compares the gravitational AND electrostatic force between nucleons. AND • Identifies that the difference between the magnitudes of the gravitational force and electrostatic force should make the atom unstable. AND • Describes the strong nuclear force. AND • Explains how the strong nuclear force overcomes electrostatic repulsion	5
• Refers to data from ONE graph. AND • Compares the gravitational AND electrostatic force between nucleons. AND • Describes the strong nuclear force. AND • Explains how the strong nuclear force overcomes electrostatic repulsion	4
• Compares the gravitational AND electrostatic force between nucleons. AND • Describes the strong nuclear force. AND • Explains how the strong nuclear force overcomes electrostatic repulsion	3
• Describes the gravitational AND electrostatic force between nucleons. AND • Describes the strong nuclear force.	2
• Provides some relevant information	1

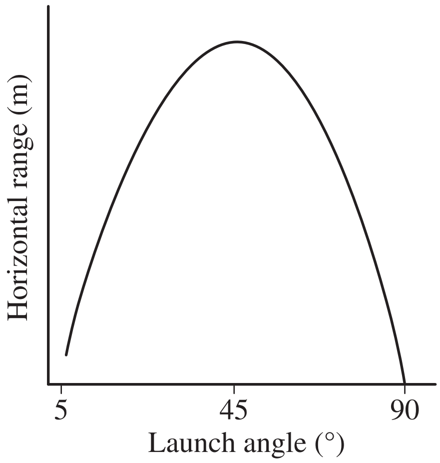
Question 33

For example:

Projectile motion can be modelled using simulations. By analysing the primary data from a simulation, the relationship between the launch angle (independent variable) and the horizontal range (dependent variable) can be investigated.

A simulation can be used to conduct a number of trials where the launch angle of a projectile is changed and the resultant horizontal ranges are recorded. For example, launch angles could be increased by increments of 5°, in the range of 5°–90°.

The data can then be plotted on a graph, as shown. The graph shows that as the launch angle increases from 5° to 45°, the horizontal range increases; then, as the launch angle increases from 45° to 90°, the horizontal range decreases. Thus, the relationship is parabolic.



Note: Accept other appropriate models.

Mod 5 Advanced Mechanics (PH12–4, 12–5, 12–7, 12–12)	Bands 4–5

Criteria	Marks
• Identifies ONE appropriate method of modelling projectile motion. AND • Outlines the suggested model. AND • Identifies the primary data obtained. AND • Discusses the relationship between launch angle and horizontal range. AND • Sketches an appropriate graph	5
• Any FOUR of the above points	4
• Any THREE of the above points	3
• Any TWO of the above points	2
• Provides some relevant information	1

Question 34

(a) In Millikan's experiment, oil droplets were charged using X-rays and then suspended in an electric field produced by two metal electrodes. The field strength was varied to create an upward electric force that balanced the downward gravitational force, allowing the charged oil droplets to become suspended. This showed that the charged oil droplets were interacting with the electric field. The magnitude of the electric field, the magnitude of gravity and the masses of the oil droplets were known. Millikan used these values to calculate the charges of the oil droplets, according to the following formula.

$$F_E = F_g$$

$$qE = mg$$

$$q = \frac{mg}{E}$$

In Millikan's formula, q was consistently calculated as an integer multiple of approximately 1.602×10^{-19} C. Hence, Millikan concluded that the lowest common denominator of the recorded charges was equal to the minimum possible charge, and thus the charge of an electron.

Mod 8 From the Universe to the Atom (PH12–5, 12–6, 12–7, 12–15)	Bands 4–5

Criteria	Marks
• Outlines the experiment in detail. AND • Explains how the experiment determined the charge of the electron	5
• Outlines the experiment. AND • Explains how the experiment determined the charge of the electron	4
• Outlines the experiment. AND • States that the experiment determined the charge of the electron	3
• Describes the experiment with limited detail. AND • States that the experiment determined the charge of an electron	2
• Provides some relevant information	1

(b) As the positively charged ions enter the uniform magnetic field, a magnetic force acts on the ions. This causes the ions to undergo uniform circular motion, according to the formula $F_c = \frac{mv^2}{r}$.

The ions deflect in a circular path, accelerating at a rate that is inversely proportional to their masses (centripetal acceleration). As the ions have the same charge and velocity, their radii of curvature will be proportional to their masses. By measuring these radii, the masses of the ions can be determined.

Mod 5 Advanced Mechanics (PH12–7) Mod 6 Electromagnetism (PH12–4, 12–5)	Bands 5–6
• Explains how the magnetic force results in circular motion. AND • Explains that the centripetal acceleration of the ions is inversely proportional to their masses. AND • Explains how the ions' radii of curvature can be used to determine their masses	3
• Any TWO of the above points	2
• Provides some relevant information	1