NSW Education Standards Authority

Centre Number

Student Number

2025 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

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
- Write your Centre Number and Student Number at the top of this page

Total marks: 100

Section I – 20 marks (pages 2–11)

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

Section II – 80 marks (pages 13–36)

- Attempt Questions 21–36
- 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 did Maxwell contribute to the understanding of the nature of light?

A. Explanation of atomic emission spectra

B. Prediction of the speed of electromagnetic waves

C. Experimental support for the particle model of light

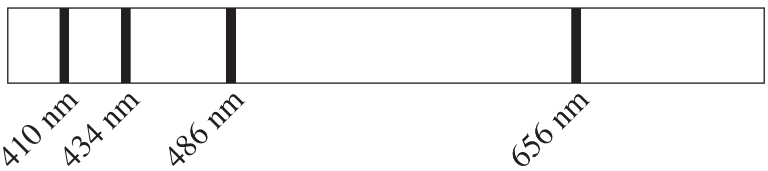
D. Experimental confirmation of light beyond the visible spectrum

2 An ideal transformer converts 240 V to 2200 V.

Which row in the table best describes the transformer?

	Type of transformer	*Number of turns in primary coil*	*Number of turns in secondary coil*
A.	Step up	120	1100
B.	Step up	1100	120
C.	Step down	120	1100
D.	Step down	1100	120

3 The diagram shows lines in the emission spectrum of hydrogen.



The production of this spectrum can be explained by applying the atomic model developed by which scientist?

A. Balmer

B. Bohr

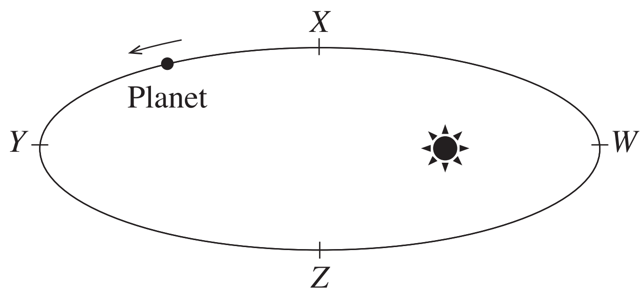
C. Planck

D. Rutherford

4 Which row in the table identifies the particle with the shortest de Broglie wavelength?

	Particle	*Velocity*
A.	Electron	$0.1c$
B.	Electron	$0.9c$
C.	Proton	$0.1c$
D.	Proton	$0.9c$

5 A planet orbits a star in an elliptical orbit as shown.



At which point in its orbit is the planet's kinetic energy increasing?

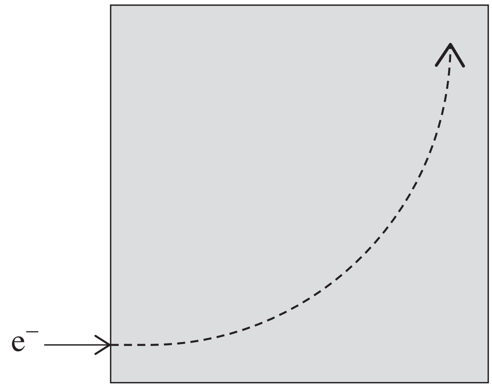
A. W

B. X

C. Y

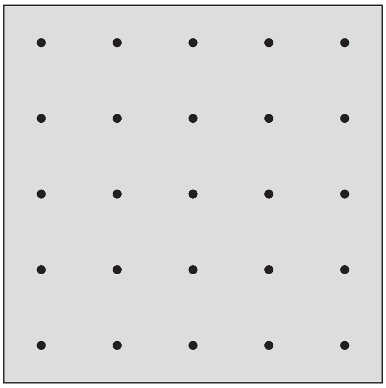
D. Z

6 In the diagram, an electron enters the shaded region where it is subjected to an external magnetic field that causes it to move in a circular arc, as indicated by the dotted line.

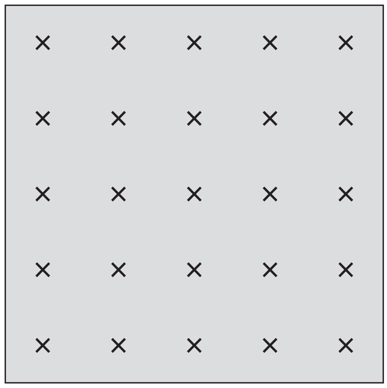


Which magnetic field could produce the motion of the electron shown?

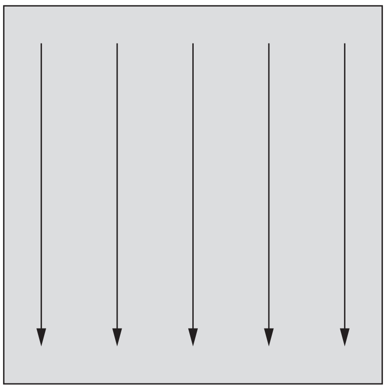
A.



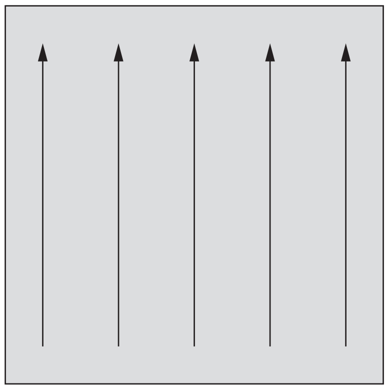
B.



C.



D.



7 A satellite in a circular orbit around Earth at an altitude of 500 km is moved to a new circular orbit at a higher altitude of 35 800 km.

Which statement correctly compares properties of the satellite in the higher orbit with its properties in the lower orbit?

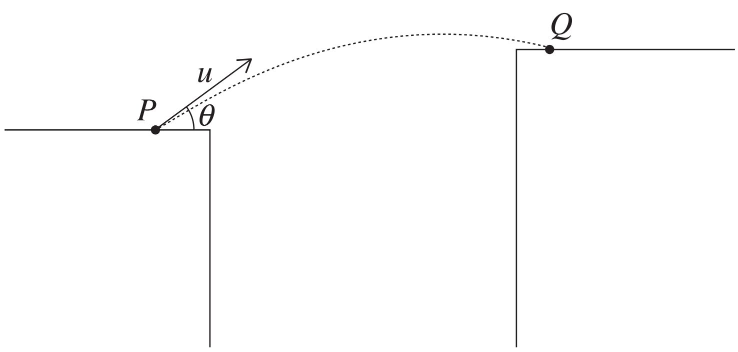
A. Its period is greater, and its acceleration is the same.

B. Its kinetic energy is less, and its acceleration is less.

C. Its orbital velocity is less, and its potential energy is positive.

D. Its escape velocity is greater, and the centripetal force is less.

8 A projectile is launched from point P, with speed u, at angle θ to the horizontal. It lands at point Q.

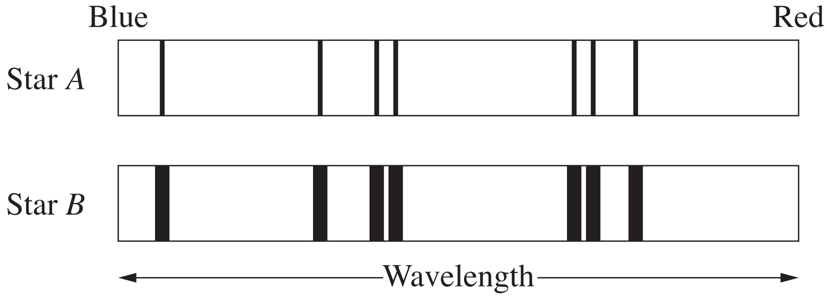


The time of flight of the projectile is t.

Which row in the table best describes the time to reach maximum height and the speed of the projectile at Q?

	Time to reach maximum height	*Speed of projectile at Q*
A.	$> \frac{t}{2}$	$< u$
B.	$> \frac{t}{2}$	$= u$
C.	$= \frac{t}{2}$	$= u$
D.	$= \frac{t}{2}$	$< u$

9 The diagram shows the absorption spectra of two different stars in the Milky Way galaxy.



Based on the information in the diagram, which of the following statements about the two stars is true?

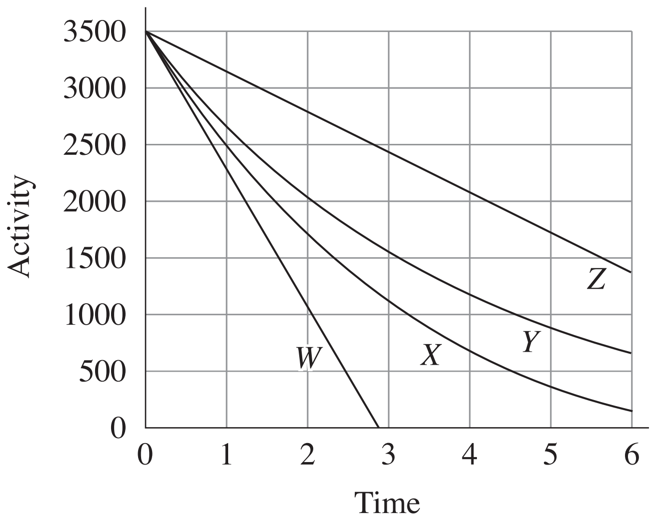
A. Star *A* has a lower density than Star *B*.

B. Star *A* has a greater rotational velocity than Star *B*.

C. Star *A* has a greater translational velocity than Star *B*.

D. Star *A* and Star *B* have different chemical compositions.

10 The diagram shows four lines, *W*, *X*, *Y* and *Z*, depicting radioactivity varying with time.



Which of the four lines is consistent with a decay graph with the smallest decay constant (λ)?

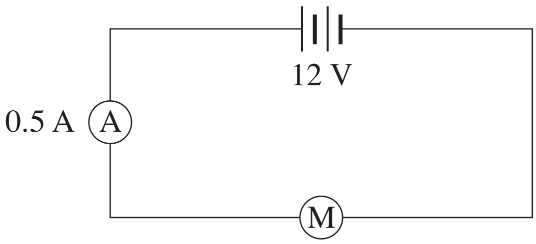
A. *W*

B. *X*

C. *Y*

D. *Z*

11 A DC motor connected to a 12 V supply is maintaining a constant rotational speed. An ammeter in the circuit reads 0.5 A.



Some material falls into the running motor, causing it to slow down.

What is the subsequent ammeter reading likely to be?

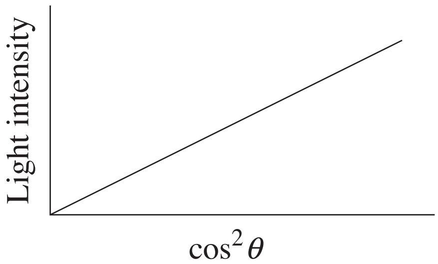
A. 0

B. Between 0 and 0.5 A

C. 0.5 A

D. Greater than 0.5 A

12 Which graph correctly represents Malus' Law?

A.


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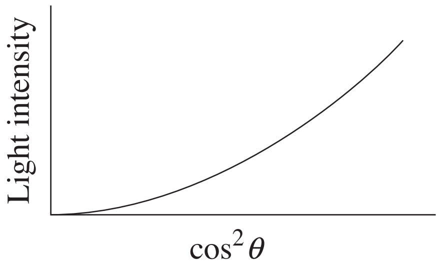
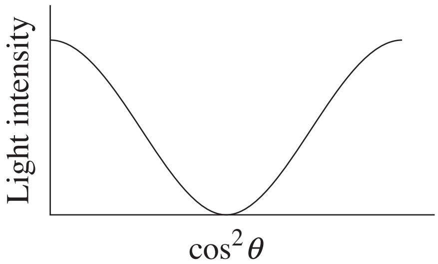
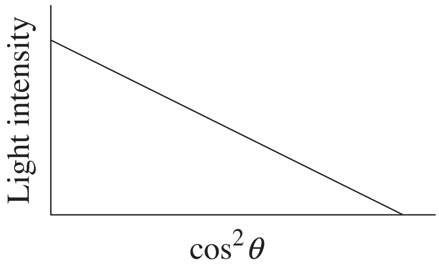
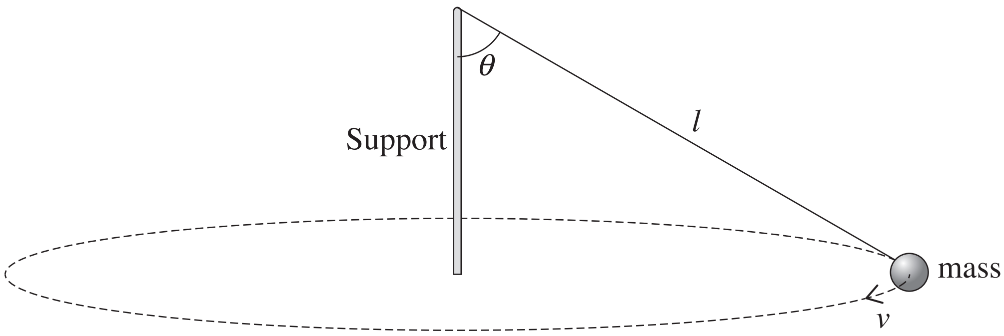


C.


D.


13 A mass is attached by a light, inextensible string of length l to a vertical rigid support.

The mass rotates with uniform speed, v, in a horizontal circle as shown.



What is the acceleration of the mass?

A. g

B. $\frac{v^2}{l}$

C. $\frac{v^2}{l\sin\theta}$

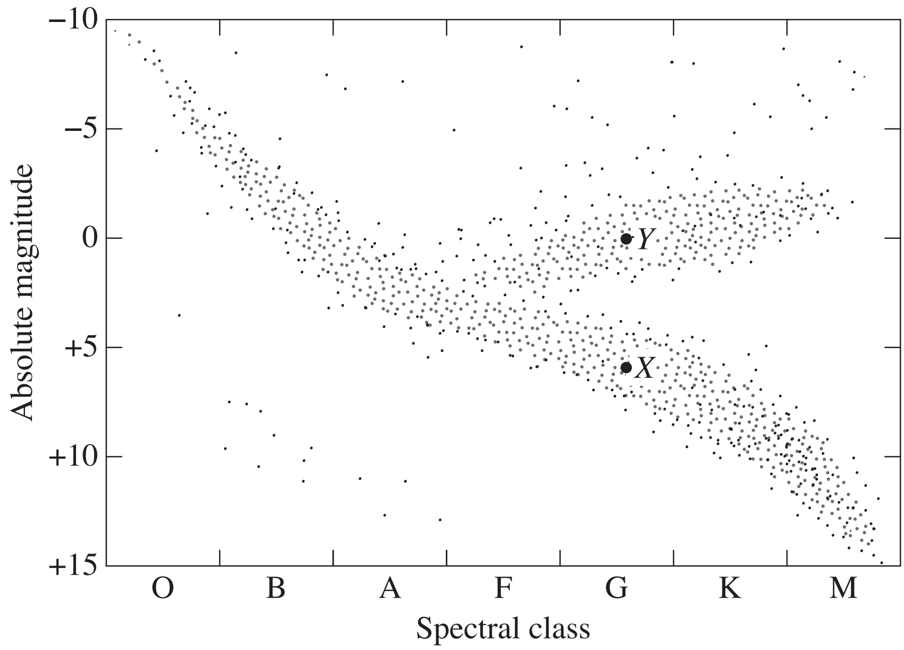
D. $\frac{v^2}{l\cos\theta}$

14 A proton having a velocity of $1 \times 10^6\ \mathrm{m\,s^{-1}}$ enters a uniform field with a trajectory that is initially perpendicular to the field.

Which row in the table correctly identifies the field, and its effect on the kinetic energy of the proton?

	Type of field	*Effect on kinetic energy*
A.	Electric	Decreases
B.	Electric	Increases
C.	Magnetic	Decreases
D.	Magnetic	Increases

15 Two stars, *X* and *Y*, are identified on the Hertzsprung–Russell diagram.



In what way are these two stars different?

A. *X* has a higher luminosity than *Y*.

B. *X* is a red star, and *Y* is a blue star.

C. *X* has a lower core temperature than *Y*.

D. *X* has a higher surface temperature than *Y*.

16 A neutron is absorbed by a nucleus, *X*.

The resulting nucleus undergoes alpha decay, producing lithium-7.

What is nucleus *X*?

A. Boron-10

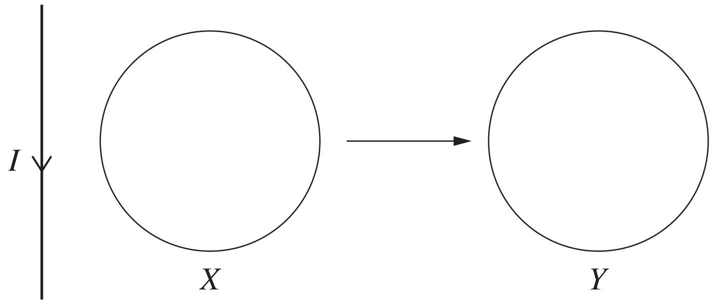
B. Boron-11

C. Lithium-6

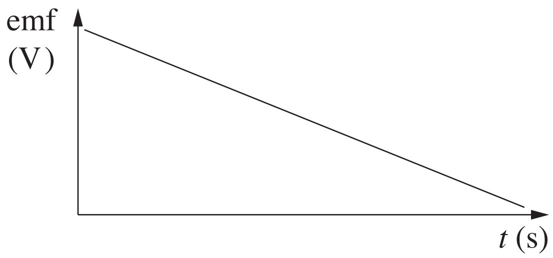
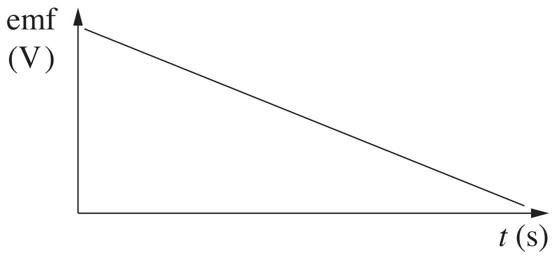
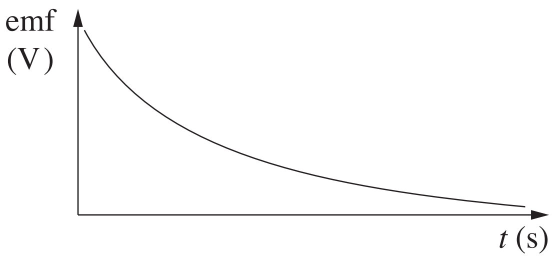
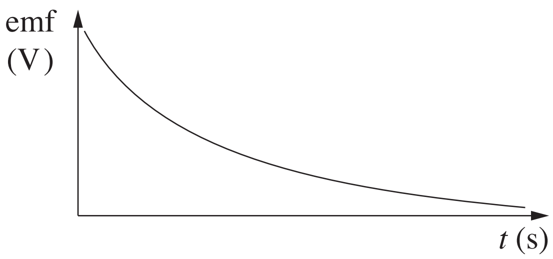
D. Lithium-10

17 A circular loop of wire is placed at position X, next to a straight current-carrying wire with the current direction shown.

The loop is moved to position Y at a constant speed.



Which row in the table best describes the induced electromotive force (emf) in the loop as it moves from X to Y?

	Induced emf in loop	*Direction of induced emf in loop*
A.		Anticlockwise
B.		Clockwise
C.		Anticlockwise
D.		Clockwise

18 The escape velocity from the surface of a planet, which has no atmosphere, is v. A mass is launched at 45° to the planet's surface at v.

What will be the subsequent motion of the mass?

A. A circular orbit around the planet

B. An elliptical orbit around the planet

C. A parabolic trajectory, returning to land with velocity v

D. A trajectory reaching zero velocity at an infinite distance

19 A system consists of a sealed glass jar containing some oxygen and a small strip of magnesium.

The magnesium reacts with the oxygen to produce magnesium oxide as a product. Energy is released from the system in this reaction.

The mass of the system will

A. increase because oxygen is added to the magnesium.

B. decrease because energy is removed from the system.

C. increase because energy is added to the system by the reaction.

D. decrease because magnesium and oxygen are lost in the reaction.

20 Consider the possibility of an electron and a positron colliding in a particle accelerator to produce a proton and an antiproton, as shown in the equation below.

$$\text{electron} + \text{positron} \longrightarrow \text{proton} + \text{antiproton}$$

Which statement makes the correct conclusion about the possibility of such a reaction, and provides a plausible reason for this conclusion?

A. The reaction is impossible because electrons and positrons will combine to produce a single neutral particle.

B. The reaction is possible because the masses of the proton and antiproton are the result of their relativistic velocities.

C. The reaction is possible because the masses of the proton and antiproton come mainly from energy supplied by the accelerator.

D. The reaction is impossible because protons are much more massive than electrons and hence the reaction violates the law of conservation of mass.

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2025 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Physics

Section II Answer Booklet

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your Centre Number and Student Number at the top of this page
- 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 (3 marks)

A scientist has two unlabelled sources of radiation. One source emits alpha particles and the other emits beta particles. **3**

Outline TWO methods that could be used to determine which source is the alpha emitter, and which source is the beta emitter.

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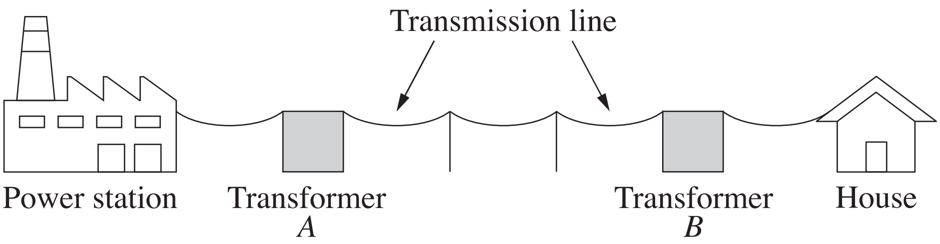
Question 22 (4 marks)

The diagram represents the parts of the AC system used to transfer energy from a power station to people's houses. **4**



Describe the energy transformations that take place in the transformers, and in the transmission line.

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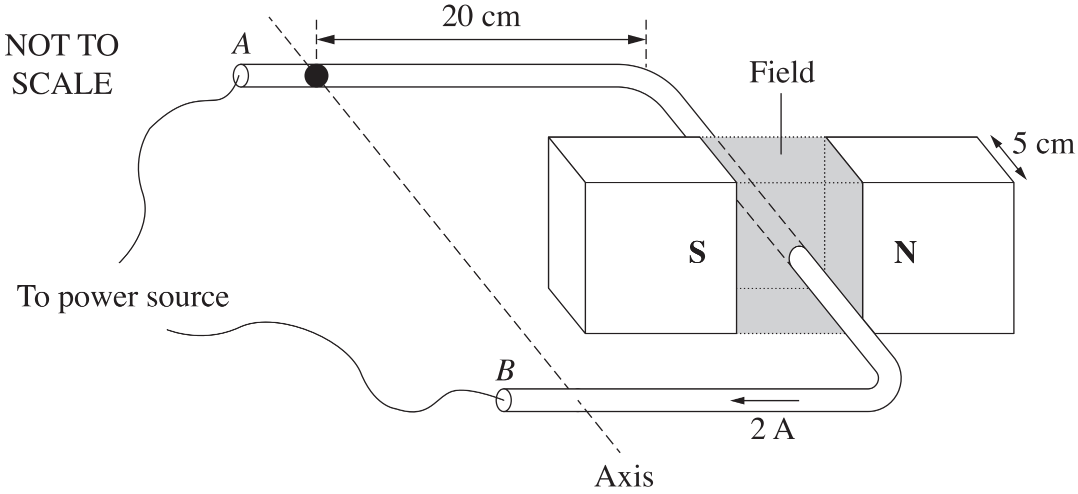
Question 23 (5 marks)

A wire loop is carrying a current of 2 A from A to B as shown. The length of wire within the magnetic field is 5 cm. The loop is free to pivot around the axis. The magnetic field is of magnitude 3×10^{-2} T and at right angles to the wire.



(a) Determine the torque produced on the wire loop due to the motor effect. **3**

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(b) Both the current and the magnetic field were changed, and the torque was observed to be in the same direction but twice the magnitude. **2**

What changes to the magnitude of BOTH the current and the magnetic field are required to produce this result?

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Question 24 (3 marks)

Two satellites, *A* and *B*, are in stable circular orbits around the Earth. The radius of satellite *A*'s orbit is three times that of satellite *B*'s orbit. Both satellites have the same kinetic energy. **3**

Show that the mass of *A* is three times the mass of *B*.

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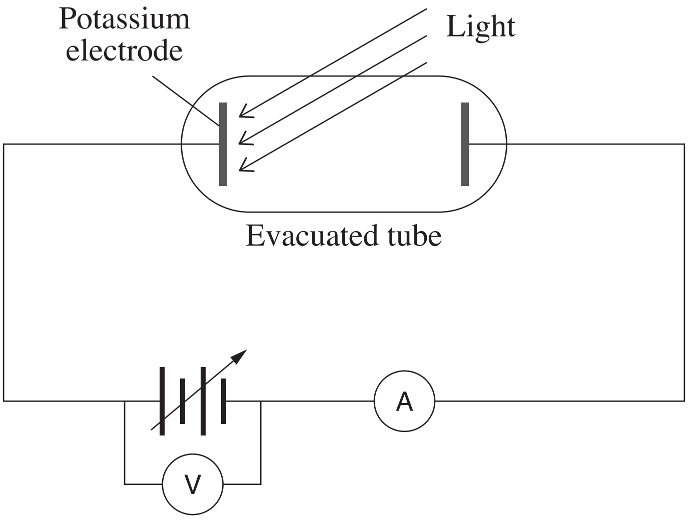
Question 25 (6 marks)

A student conducts an experiment to determine the work function of potassium.

The following diagram depicts the experimental setup used, where light of varying frequency is incident on a potassium electrode inside an evacuated tube.



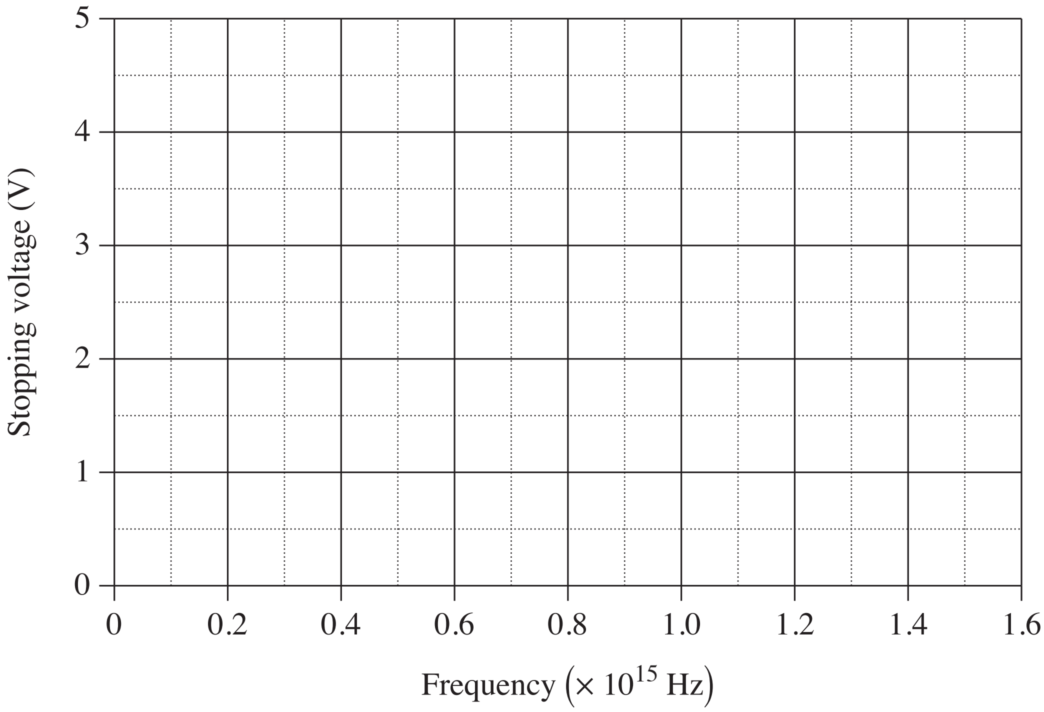
For each frequency of light tested, the voltage in the circuit is varied, and the minimum voltage (called the stopping voltage) required to bring the current in the circuit to zero is recorded.

Frequency of incident light $\left(\times 10^{15}\ \text{Hz}\right)$	*Stopping voltage* (V)
0.9	1.5
1.1	2.0
1.2	2.5
1.3	3.0
1.4	3.5
1.5	4.0

Question 25 continues on page 19

Question 25 (continued)

(a) Construct an appropriate graph using the data provided, and from this, determine the threshold frequency of potassium. **3**



Threshold frequency of potassium: .... Hz

(b) Using the particle model of light, explain the features shown in the experimental results. **3**

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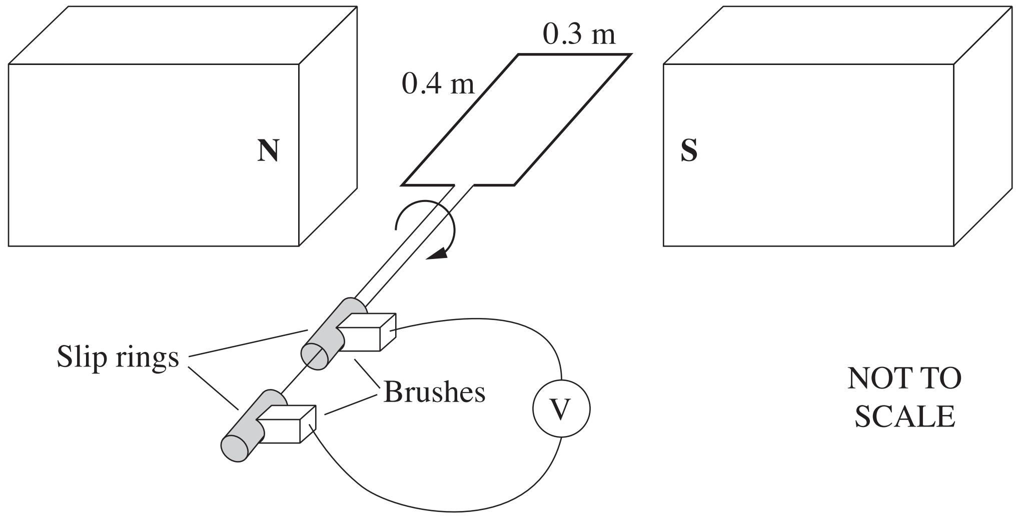
End of Question 25

Question 26 (5 marks)

The starting position of a simple AC generator is shown. It consists of a single rectangular loop of wire in a uniform magnetic field of 0.5 T. This loop is connected to two slip rings and the slip rings are connected via brushes to a voltmeter.



(a) The loop is rotated at a constant rate through an angle of 90 degrees from the starting position in the direction indicated, in 0.1 seconds. **2**

Calculate the magnitude of the average emf generated during this rotation.

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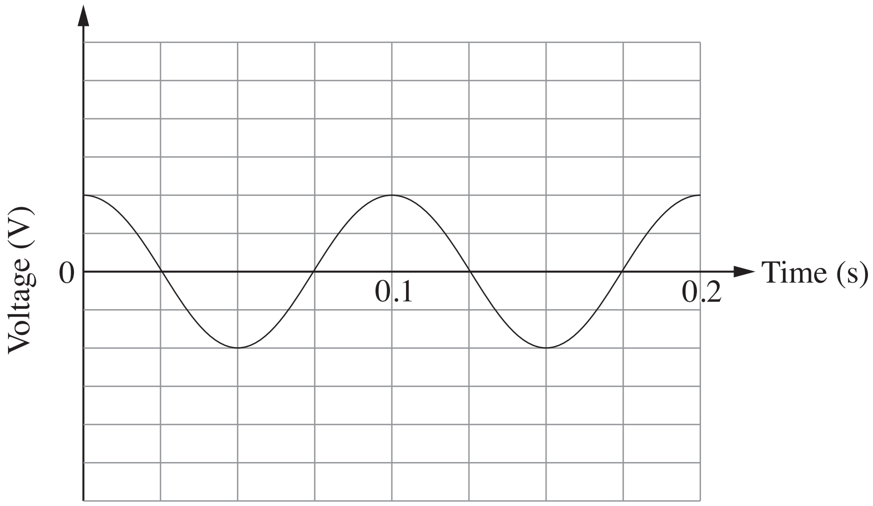
Question 26 continues on page 21

Question 26 (continued)

(b) The same coil was then rotated at 10 revolutions per second from the starting position. The voltage varies with time, as shown in the graph. **3**



On the same axes, sketch a graph that shows the variation of voltage with time if the rotational speed is 20 revolutions per second in the opposite direction, beginning at the original starting position.

Question 27 (3 marks)

Outline TWO ways in which Schrödinger's model of electron behaviour is different from electron behaviour in the atomic models of Rutherford and Bohr. **3**

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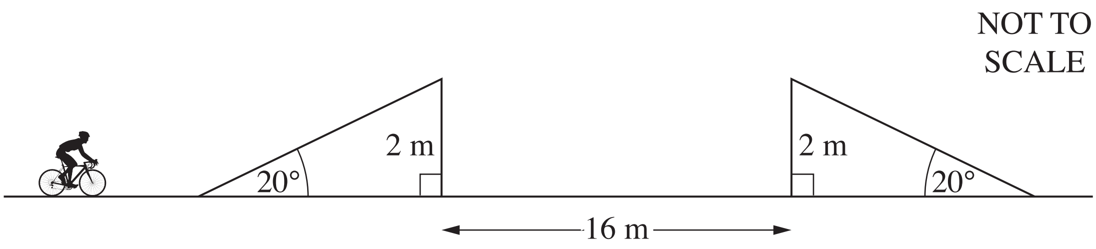
Question 28 (4 marks)

A bicycle rider jumps from one ramp to a second ramp separated by 16 m as shown. **4**
The ramps are inclined at 20° and are 2 m high.



What minimum speed is required for the rider to land on the second ramp?

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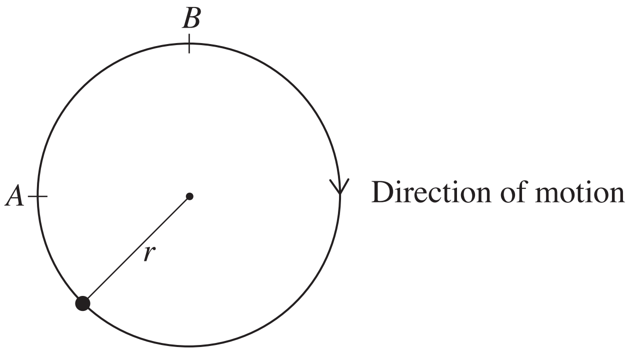
Question 29 (5 marks)

A mass moves around a vertical circular path of radius r, in Earth's gravitational field, without loss of mechanical energy. A string of length r maintains the circular motion of the mass.

When the mass is at its highest point B, the tension in the string is zero.



(a) Show that the speed of the mass at the highest point, B, is given by $v = \sqrt{rg}$. **2**

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(b) Compare the speed of the mass at point A to that at point B. Support your answer using appropriate mathematical relationships. **3**

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Question 30 (6 marks)

A beam of electrons travelling at 4×10^3 m s^{-1} exits an electron gun and is directed toward two narrow slits with a separation, d, of 1 μm. The resulting interference pattern is detected on a screen 50 cm from the slits.

(a) Show that the wavelength of the electrons in this experiment is 182 nm. **2**

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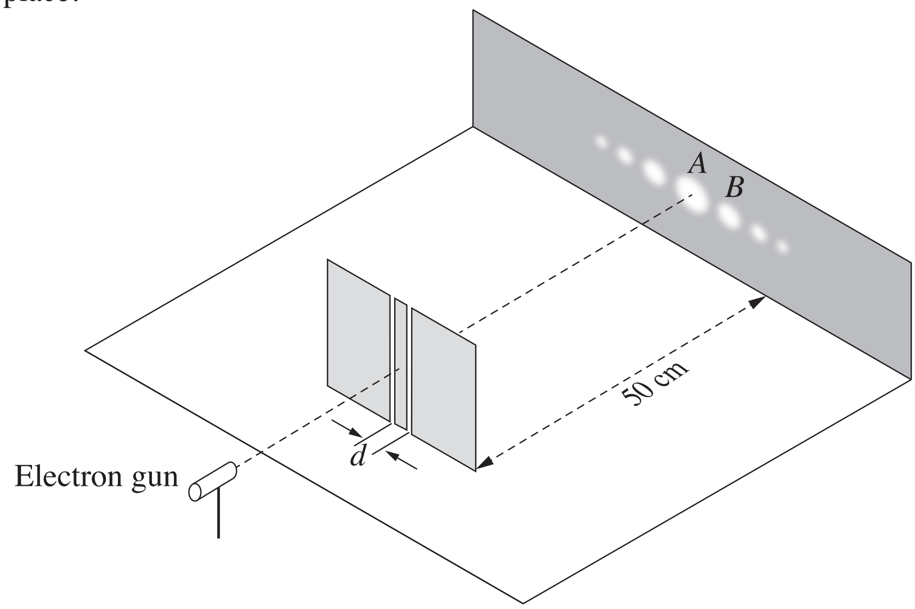
(b) An interference fringe occurs on the screen where constructive interference takes place. **2**



Determine the distance between the central interference fringe A and the centre of the next bright fringe B.

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(c) Determine the potential difference acting in the electron gun to accelerate the electrons in the beam from rest to 4×10^3 m s^{-1}. **2**

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Question 31 (5 marks)

Experiments have been carried out by scientists to investigate cathode rays. **5**

Assess the contribution of the results of these experiments in developing an understanding of the existence and properties of electrons.

Question 32 (8 marks)

Analyse the consequences of the theory of special relativity in relation to length, time and motion. Support your answer with reference to experimental evidence. **8**

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Question 33 (6 marks)

Analyse the role of experimental evidence and theoretical ideas in developing the Standard Model of matter. **6**

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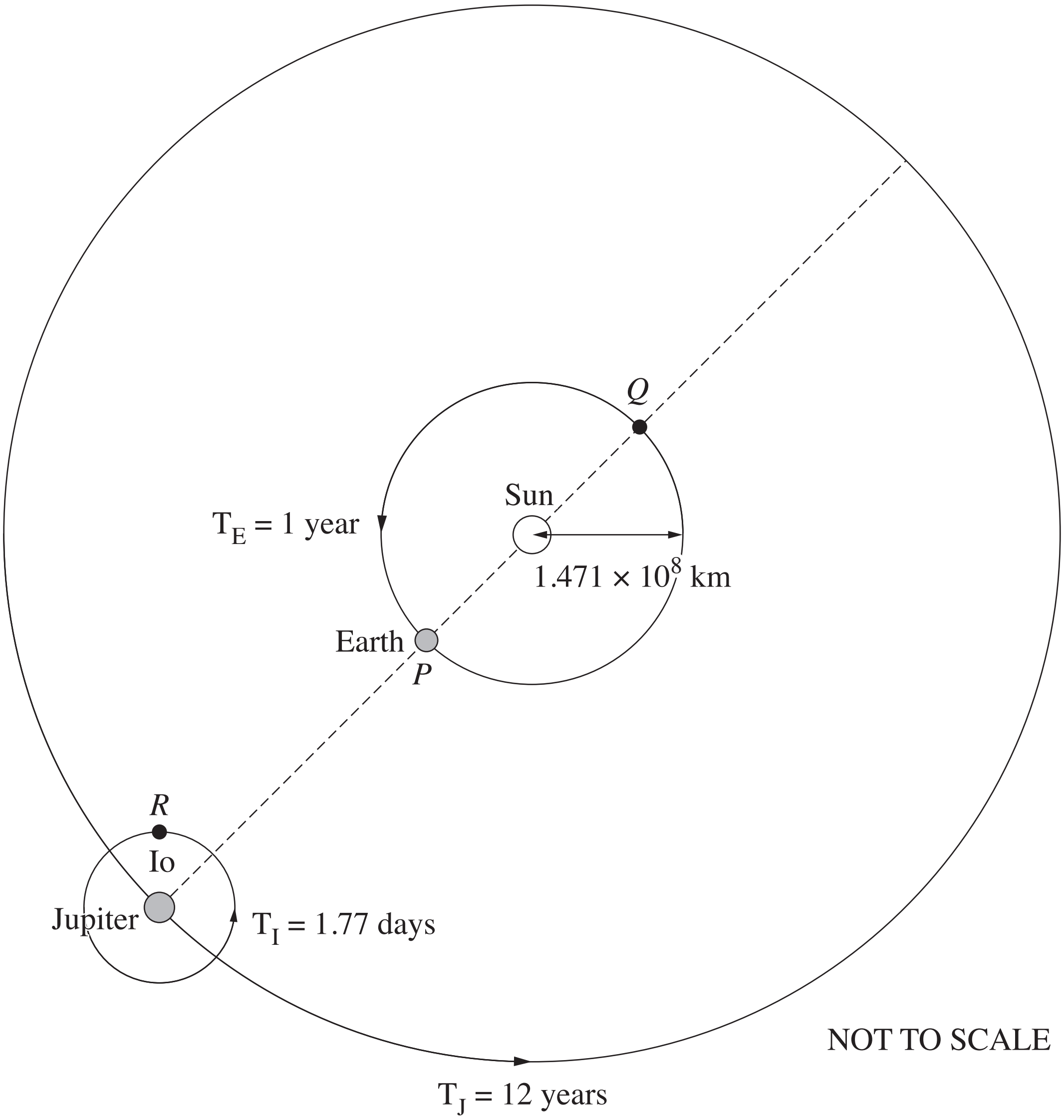
Question 34 (5 marks)

The diagram shows a model of the orbits of Earth, Jupiter and Io, including their orbital direction and periods of orbit. In this model, it is assumed that the orbits of Earth, Jupiter and Io are circular.



A method to determine the speed of light using this model is described below.

When Earth was at position *P*, the orbital period of Io was measured, and the time that Io was at position *R* was recorded.

Six months later, Io had orbited Jupiter 103 times, and Earth had reached position *Q*. The orbital period of Io was used to predict when it would be at position *R*. Assume that Jupiter has not moved significantly in its orbit around the Sun.

The time for Io to reach position *R* was measured to be 1.000×10^3 seconds later than predicted, due to the time it takes light to cross the diameter of Earth's orbit from *P* to *Q*.

Question 34 continues on page 29

Question 34 (continued)

(a) Use the measurements provided in the model to calculate the speed of light. **2**

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(b) Consider a modification to this model in which the Earth's orbit is elliptical. **3**

Explain how this modification will affect the determination of the speed of light.

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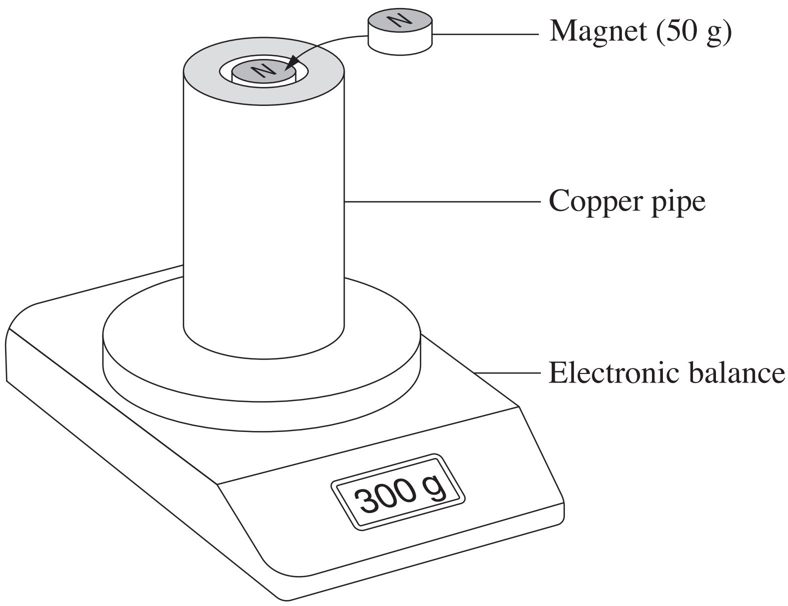
End of Question 34

Question 35 (4 marks)

A hollow copper pipe is placed upright on an electronic balance, which shows a reading of 300 g. A 50 g magnet is suspended inside the pipe and subsequently released. **4**



It was observed that the readings on the balance began to increase after the magnet began to fall, and that the reading reached a constant maximum of 350 g before the magnet reached the bottom of the tube.

Explain these observations.

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Question 36 (8 marks)

A satellite with velocity v, is in a geostationary orbit as shown in Figure 1. **8**

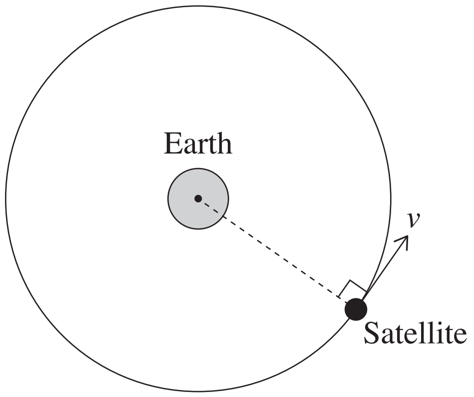

Figure 1

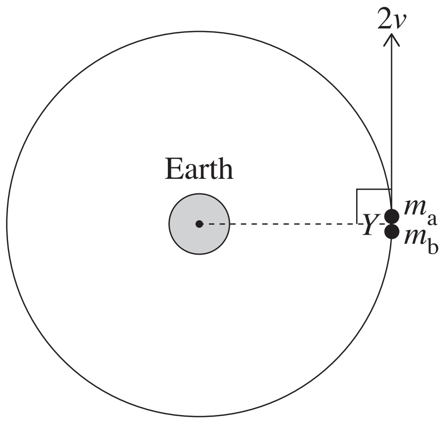

Figure 2

At point Y, the satellite explodes and splits into two pieces m_a and m_b, of identical mass. As a result of the explosion, the velocity of one piece, m_a, changes from v to $2v$ as shown in Figure 2.

Analyse the subsequent motion of BOTH m_a and m_b after the explosion. Include reference to relevant conservation laws and formulae in your answer.

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Question 36 continues on page 32

Question 36 (continued)

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Physics

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 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7} \text{ N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
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)	$1.097 \times 10^{7} \text{ m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5 \text{ MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3} \text{ kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$$v = u + at$$

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

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

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

$$\Delta U = mg\Delta h$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

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

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

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

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

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

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

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 N I}{L}$$

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

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

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

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

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

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

$$V = IR$$

$$P = VI$$

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

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

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

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

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

Quantum, special relativity and nuclear

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

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

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

$$E = mc^2$$

$$E = hf$$

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

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

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

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

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

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

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.

2025 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

Question	Answer
1	B
2	A
3	B
4	D
5	D
6	A
7	B
8	A
9	A
10	C
11	D
12	A
13	C
14	B
15	C
16	A
17	C
18	D
19	B
20	C

Section II

Question 21

Criteria	Marks
• Outlines TWO methods and subsequent observations that could be used to identify each source as either alpha or beta emitters	3
• Outlines a method that could be used to distinguish the sources OR • Identifies TWO methods that could be used to identify each source	2
• Provides some relevant information	1

Sample answer:

Pass the radiation through a thin material to a detector. Observe any changes in counts. The beta source count will be reduced by an amount less than the alpha source count.

Pass each type of radiation through a magnetic field and observe any differences in deflection and observe deflection in opposite directions.

Answers could include:

- Magnetic field
- Electric field
- Cloud chamber

Question 22

Criteria	Marks
• Describes energy transformations in the transformers and in the transmission line	4
• Describes an energy transformation in the transformer or transmission line AND identifies another energy transformation	3
• Describes an energy transformation that occurs OR • Identifies energy transformations	2
• Provides some relevant information	1

Sample answer:

The energy output of both transformer *A* and transformer *B* is less than the energy input. These transformers produce heat energy in their cores due to resistive losses, magnetic effects and mechanical vibrations.

In the transmission line, heat energy is produced due to the resistance of the wires.

Question 23 (a)

Criteria	Marks
• Determines the torque produced on the wire loop by the motor effect	3
• Determines the magnitude of the torque produced OR • Determines the magnitude of the force produced	2
• An appropriate step is performed	1

Sample answer:

$$\begin{aligned} F &= BIL \\ &= 3 \times 10^{-2} \times 2 \times 0.05 \\ &= 0.003 \text{ N} \end{aligned}$$

$$\begin{aligned} \tau &= Fd \\ &= 0.003 \times 0.2 \\ &= 6 \times 10^{-4} \text{ Nm clockwise viewed from the side } B \end{aligned}$$

Question 23 (b)

Criteria	Marks
• States BOTH changes required to produce the results	2
• States ONE change required to produce the result	1

Sample answer:

The magnetic field was quadrupled and the current was halved.

Question 24

Criteria	Marks
• Shows all relevant steps to determine the mass ratio	3
• Makes progress towards determining mass ratio	2
• Provides some relevant information	1

Sample answer:

$$F_C = F_G$$

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

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

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$

$$\therefore \quad \frac{GMm_A}{2r_A} = \frac{GMm_B}{2r_B}$$

Or $\dfrac{m_A}{r_A} = \dfrac{m_B}{r_B} \quad \Rightarrow \quad \dfrac{m_A}{m_B} = \dfrac{r_A}{r_B}$

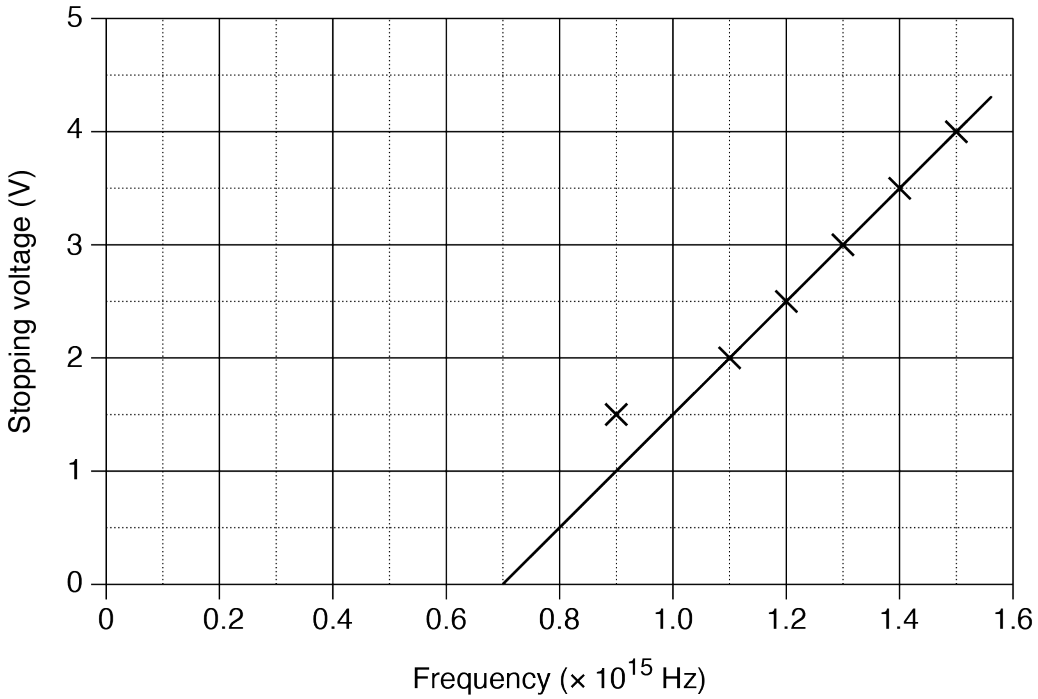
Substitute $r_A = 3r_B$ $\quad \dfrac{3r_B}{r_B} = \dfrac{m_A}{m_B} = 3$

$$\therefore \quad m_A = 3m_B$$

Question 25 (a)

Criteria	Marks
• Correctly plots all data • Draws appropriate line of best fit to determine the threshold frequency	3
• Correctly plots data and determines an x-intercept OR • Correctly plots data and draws an appropriate line of best fit	2
• Correctly plots some data OR • Draws a line of best fit	1

Sample answer:



Threshold frequency of potassium: 0.7×10^{15} Hz or 7×10^{14} Hz

Question 25 (b)

Criteria	Marks
• Shows how the features shown in the experiment are explained by the particle model of light	3
• Relates a feature shown to an aspect of the particle model of light	2
• Provides some relevant information	1

Sample answer:

The photon model of light explains the trend by stating that light consists of discrete packets of energy called photons. The energy of a photon is directly proportional to its frequency ($E = hf$). When photons strike the metal, they transfer energy to electrons. If the photon energy exceeds the work function of the metal, the threshold frequency is exceeded and electrons are ejected with kinetic energy proportional to the excess energy ($KE = hf - \phi$).

As the frequency of light increases, the photon energy increases, resulting in higher kinetic energy for the ejected electrons. This is observed as a higher stopping voltage, which is required to halt the more energetic electrons.

Question 26 (a)

Criteria	Marks
• Calculates the magnitude of the average emf during the rotation	2
• Provides one correct step in the calculation	1

Sample answer:

$$\phi = BA \text{ and } \varepsilon = \frac{\Delta\phi}{\Delta t}$$

$$\therefore \varepsilon = \frac{\Delta(BA)}{\Delta t} = \frac{B\Delta A}{\Delta t}$$

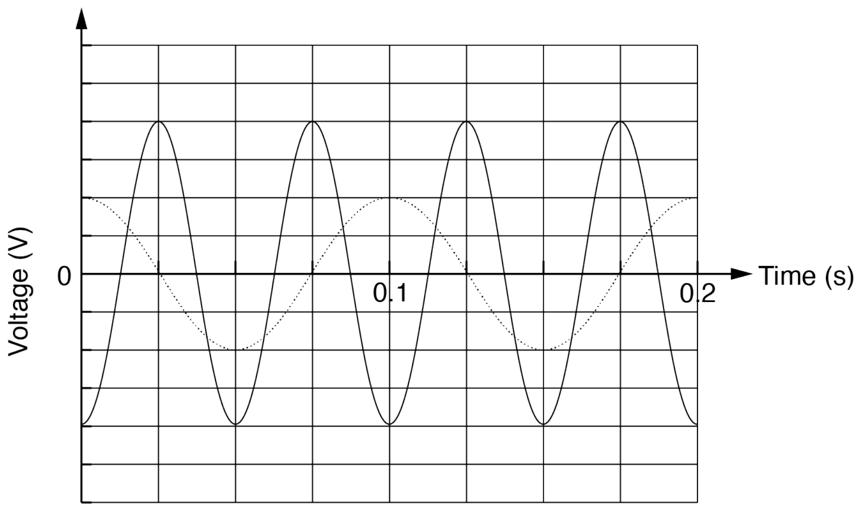
$$\varepsilon = \frac{0.5 \times 0.4 \times 0.3}{0.1}$$

$$\varepsilon = 0.6 \text{ V}$$

Question 26 (b)

Criteria	Marks
• Sketches an appropriate graph of how the voltage varies with time	3
• Sketches some relevant aspects of the graph	2
• Provides some relevant information	1

Sample answer:



Question 27

Criteria	Marks
• Outlines TWO ways in which Schrödinger's model differs from those of Rutherford and Bohr	3
• Outlines ONE way in which Schrödinger's model differs from those of Rutherford and Bohr OR • Outlines TWO features of Schrödinger's model	2
• Provides some relevant information	1

Sample answer:

In contrast to Bohr's idea of fixed orbits, Schrödinger described orbitals as probabilities of electrons as being in particular locations.

Unlike Rutherford's model in which electrons were imagined as particles orbiting the nucleus, Schrödinger described the electrons as waves, based on the work of de Broglie.

Question 28

Criteria	Marks
• Calculates the minimum speed required for the rider to land on the second ramp	4
• Provides substantial working to calculate the minimum speed	3
• Makes progress towards determining the minimum speed	2
• Provides some relevant information	1

Sample answer:

To calculate u:

In the horizontal direction, $s_x = u_x t$ with $u_x = u\cos(\theta)$, so $t = \dfrac{s_x}{u\cos(\theta)}$

In the vertical direction, $0 = u_y t + \frac{1}{2} a_y t^2$ with $u_y = u\sin(\theta)$, so $u = \dfrac{-a_y t}{2\sin(\theta)}$

Substituting into the equation for u gives, $u^2 = \dfrac{-a_y s_x}{2\cos(\theta)\sin(\theta)}$ or $u = \sqrt{\dfrac{-a_y s_x}{2\cos(\theta)\sin(\theta)}}$

For $a_y = -9.8$, $s_x = 16$ and $\theta = 20$

$u = 15.6 \text{ m s}^{-1}$

Question 29 (a)

Criteria	Marks
• Shows steps required to derive the equation	2
• Shows a relevant step	1

Sample answer:

At the top of the circle, $\dfrac{mv^2}{r} = mg$

so, with simplification

$v = \sqrt{rg}$

Question 29 (b)

Criteria	Marks
• Compares the speed of the mass at each point, using the law of conservation of energy • Uses appropriate mathematical relationships	3
• Compares the speed of the mass, using the law of conservation of energy	2
• Provides some relevant information	1

Sample answer:

The speed of the ball at point A will be greater than v from part (a).

Total mechanical energy = E_k + GPE

At point B:

Total mechanical energy $= \frac{1}{2} \times m \times gr + mg(2r)$ = total mechanical energy at A

At A the gravitational potential energy = mgr and thus $\frac{1}{2} \times m \times gr + 2mgr = mgr + E_{kA}$

Simplifying gives $E_{kA} = 1.5mgr = \frac{1}{2} mv_A^2$

And finally $v_A = \sqrt{3gr} = \sqrt{3}v_B$

Question 30 (a)

Criteria	Marks
• Shows the wavelength is equal to 182 nm	2
• Substitutes one correct value into the appropriate equation	1

Sample answer:

$\lambda = \frac{h}{mv}$ with the mass of an electron 9.109×10^{-31} kg

$$\lambda = \frac{6.626 \times 10^{-34}}{9.109 \times 10^{-31} \times 4 \times 10^{3}}$$

$\lambda = 1.82 \times 10^{-7}$ m

$\lambda = 182$ nm

Question 30 (b)

Criteria	Marks
• Calculates the required distance	2
• Makes one correct substitution into an appropriate formula	1

Sample answer:

Distance between the central bright spot and the centre of the next interference fringe = $\frac{\lambda \text{ mL}}{d}$ (m = 1)

$$\text{Distance} = \frac{182 \times 10^{-9} \times 1 \times 0.5}{1 \times 10^{-6}}$$

$$\begin{aligned}\text{Distance} &= 0.091 \text{ m} \\ &= 9.1 \text{ cm}\end{aligned}$$

Question 30 (c)

Criteria	Marks
• Calculates the required potential difference	2
• Makes one correct substitution into an appropriate formula	1

Sample answer:

Using the work-energy relationship, $qV = \frac{1}{2}mv^2$

$$V = \frac{mv^2}{2q} = \frac{9.109 \times 10^{-31} \times (4 \times 10^3)^2}{2 \times 1.602 \times 10^{-19}} = 4.5 \times 10^{-5} \text{ V}$$

Question 31

Criteria	Marks
• Provides a comprehensive assessment of the experimental results • Relates the results to both existence and properties of electrons	5
• Provides a sound assessment of the experimental results • Relates the results to the properties and/or existence of electrons	4
• Outlines an experiment and/or results • Relates experimental results to the existence and/or properties of electrons	3
• Outlines a relevant experiment or result OR • Relates an experimental result to the existence or property of electrons	2
• Provides some relevant information	1

Sample answer:

Experimental results and their interpretation have played an essential role in developing and understanding of both the existence and properties of electrons.

It was demonstrated that cathode rays could be deflected by an electric field in a manner consistent with negatively charged particles. This experiment also allowed the deduction that the cathode rays were not electromagnetic waves because the latter would not be deflected by an electric field.

The combined effect of changing the magnitudes of electric and magnetic fields through which the electrons passed was measured and from this the charge-to-mass ratio of the electron was calculated.

Answers could include:

By using electrodes made of different materials, Thomson was able to deduce that the cathode rays' properties were independent of the source of the electrons and hence that they were a constituent of atoms themselves rather than being a product of the cathode ray.

Cathode rays were passed through thin metal foils and the analysis of this behaviour allowed scientists (Lenard/Hertz) to deduce that the electrons had mass.

Crookes' observation that cathode rays travelled in straight lines and cast sharp shadows from which he deduced that the rays were particles and not waves (which would have shown diffraction effects).

Question 32

Criteria	Marks
• Provides a comprehensive analysis of the consequences of special relativity on time, length and motion • Refers to applicable experimental evidence	8
• Provides a thorough analysis of the consequences of special relativity on time, length and motion • Refers to applicable experimental evidence	6–7
• Provides analysis of the consequences of special relativity on time and/or length and/or motion • Refers to some relevant experimental evidence	4–5
• Makes some reference to special relativity and/or related experimental evidence	2–3
• Provides some relevant information	1

Sample answer:

The two postulates of special relativity are: the speed of light in a vacuum is an absolute constant, and all inertial frames of reference are equivalent.

The consequences of these postulates are time dilation, length contraction and relativistic momentum dilation. Time dilation means that the measured time between events increases as the speed of an observer increases. Length contraction means that the length of an object decreases as the speed of an observer increases, and relativistic momentum dilation means that objects (with mass) cannot travel at c as it takes increasing amounts of energy to accelerate objects as they approach the speed of light.

Length contraction and time dilation can both be seen in observations of muons at Earth's surface. The short half-life of muons suggests that there should be very few of them that arrive at Earth's surface from their point of origin high in Earth's atmosphere, but the muon flux is greater than suggested by half-life and distance travelled alone. However, when the distance travelled is considered from the muon's frame of reference, it is length-contracted according to $l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$, giving an effective shorter distance for them to travel. From the perspective of an observer on Earth's surface, the time taken for them to decay is dilated, giving an effective greater amount of time for them to travel before decaying.

The effects of relativistic momentum can be seen in particle accelerators in terms of the increasing amounts of energy to required to accelerate the particles as they approach the speed of light – it is though the objects are much more massive than they are.

Question 33

Criteria	Marks
• Provides a detailed analysis of how experimental evidence and theoretical ideas contributed to the development of the Standard Model of matter	6
• Provides an analysis of how experimental evidence and theoretical ideas contributed to the development of the Standard Model of matter	5
• Describes experiment(s) and idea(s) relating to fundamental particles and/or forces AND links these to the Standard Model of matter	3–4
• Outlines experiments and/or ideas relating to fundamental particles or forces	2
• Provides some relevant information	1

Sample answer:

Experiments and theoretical ideas have both been critical in the development of the Standard Model of matter.

Particle accelerators have been used to verify key ideas about fundamental particles and the structure of matter. Particle accelerators allow for small wavelength ‘matter probes’ at high energies, giving high resolution for probing the structure of matter.

Examples of particle accelerator use in the development of the Standard Model include:
- Verification of the electroweak theory, which says that the electromagnetic and weak nuclear forces are a result of the same interaction.
- The discovery of a Higgs Boson, many decades after it was first proposed as necessary in explaining the mass of particles.
- Verification of the existence of quarks by showing the protons and neutrons have internal structure.

Earlier experiments used simpler equipment such as the cloud chamber which was used to discover antimatter following its earlier theoretical prediction.

Many experiments have verified earlier theoretical ideas, and these confirmations have then in turn allowed the proposal of further ideas, which have in turn later been verified by experiments.

Question 34 (a)

Criteria	Marks
• Calculates the speed using relevant calculations and the provided measurements	2
• Makes a valid step in the calculation	1

Sample answer:

$$\begin{aligned} d &= 2 \times 1.471 \times 10^{11} \\ &= 2.942 \times 10^{11}\ \text{m} \end{aligned}$$

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{2.942 \times 10^{11}}{1 \times 10^{3}} \\ &= 2.942 \times 10^{8}\ \text{m s}^{-1} \end{aligned}$$

Question 34 (b)

Criteria	Marks
• Relates an effect to the calculation of the speed of light	3
• Describes the effect of the ellipticity on the distance OR • Relates a change in distance to the corresponding change in light travel time	2
• Provides some relevant information	1

Sample answer:

If light travels along the long axis of the ellipse, then the distance travelled by the light across Earth's orbit is greater than 2.942×10^{8} m. The effect of this would be to increase the calculated speed of light.

Answers could include:

Reduced speed of light due to measurement of distance along the short axis of the ellipse.

Question 35

Criteria	Marks
• Relates the measurements on the balance to the motion of the magnet and its interactions with the pipe	4
• Relates a measurement on the balance to the motion of the magnet and aspects of its interactions with the pipe	3
• Describes some aspects of the motion of the magnet and relates this to a measurement on the balance OR • Describes the motion of the magnet and/or interactions with the pipe	2
• Provides some relevant information	1

Sample answer:

The reading on the scale has two phases.

1. The magnet accelerates to a maximum speed. This results in an increasing change in magnetic flux causing the creation of an increasing electromagnetic force that opposes the constant gravitational force acting on the magnet. The force on the magnet due to this interaction produces an equal and opposite force on the pipe, which results in an increase in the downward force on the scale.
2. The magnet reaches a constant speed when the upward electromagnetic force is equal and opposite to the weight force of the magnet. The force of the magnet on the pipe will be equal to the weight of the magnet. The reading on the scale will then be the weight of the pipe and magnet, shown in grams.

Question 36

Criteria	Marks
• Comprehensively analyses the motion of both pieces with reference to relevant conservation laws and formulae	8
• Analyses features of the motion of both pieces with reference to relevant conservation laws and formulae	6–7
• Describes a feature of the motion of each piece OR describes features of the motion of one piece • Applies a conservation law and a relevant formula	4–5
• Describes a feature of the motion of a piece • Identifies a relevant conservation law and/or refers to a relevant equation	2–3
• Provides some relevant information	1

Sample answer:

By the law of conservation of momentum, the momentum changes of m_a and m_b resulting from the force produced by the explosion must be equal but opposite.

Since they are of equal mass, the velocity change of both pieces, must be the same, but in opposite directions. Since the velocity of m_a increases by v in the direction in which it was travelling, the velocity of m_b, is also v, but in the opposite direction to which it was travelling.

Hence, relative to the Earth, the velocity of m_b must become zero at that instant.

The orbital velocity of the satellite prior to the explosion is given by

$$v_{\text{orbital}} = \sqrt{\frac{GM}{r}}$$

Hence the instantaneous velocity of m_a as a result of the explosion is double the orbital velocity before the explosion

because $2v = 2\sqrt{\frac{GM}{r}}$ > the escape velocity $v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$ the velocity of m_a after the explosion is greater than the escape velocity.

After the explosion, the pieces m_a will continue travel away from Earth at a decreasing velocity, however because its initial velocity exceeds the escape velocity from the explosion point, it will never stop or return to Earth. Its total energy (kinetic + potential) remains constant and will always be positive.

Consequently, m_b will begin to accelerate, from an initial velocity of zero, towards the centre of Earth. Its acceleration is initially less than 9.8 m s^{-2} because it is not at Earth's surface.

As the force due to gravity on m_b increases, its acceleration increases and so its velocity towards the centre of Earth increases at an increasing rate until it reaches Earth's atmosphere.

Consistent with the law of conservation of energy, until m_b reaches Earth's atmosphere, the sum of its kinetic and potential energy must remain constant and equal to its initial potential energy at the instant after the explosion.

2025 HSC Physics
Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 7 Electromagnetic Spectrum	PH12-14
2	1	Mod 6 Electromagnetic Induction	PH12-5, PH12-13
3	1	Mod 8 Quantum Mechanical Nature of the Atom	PH12-15
4	1	Mod 8 Quantum Mechanical Nature of the Atom	PH12-15
5	1	Mod 5 Motion in Gravitational Fields	PH12-12
6	1	Mod 6 Charged Particles, Conductors and Electric and Magnetic Fields	PH12-4, PH12-13
7	1	Mod 5 Motion in Gravitational Fields	PH12-12
8	1	Mod 5 Projectile Motion	PH12-4, PH12-12
9	1	Mod 7 Electromagnetic Spectrum	PH12-5, PH12-14
10	1	Mod 8 Properties of the Nucleus	PH12-5, PH12-15
11	1	Mod 6 Applications of the Motor Effect	PH12-5, PH12-13
12	1	Mod 7 Light: Wave Model	PH12-5, PH12-14
13	1	Mod 5 Circular Motion	PH12-6, PH12-12
14	1	Mod 6 Charged Particles, Conductors and Electric and Magnetic Fields	PH12-4, PH12-13
15	1	Mod 8 Origins of the Elements	PH12-5, PH12-15
16	1	Mod 8 Properties of the Nucleus	PH12-5, PH12-15
17	1	Mod 6 Electromagnetic Induction	PH12-6, PH12-13
18	1	Mod 5 Motion in Gravitational Fields	PH12-6, PH12-12
19	1	Mod 7 Light and Special Relativity	PH12-6, PH12-14
20	1	Mod 8 Deep inside the Atom	PH12-15

Section II

Question	Marks	Content	Syllabus outcomes
21	3	Mod 8 Properties of the Nucleus	PH12-6, PH12-15
22	4	Mod 6 Electromagnetic Induction	PH12-7, PH12-13
23 (a)	3	Mod 6 The Motor Effect	PH12-5, PH12-13
23 (b)	2	Mod 6 The Motor Effect	PH12-5, PH12-13
24	3	Mod 5 Motion in Gravitational Fields	PH12-6, PH12-12
25 (a)	3	Mod 7 Light: Quantum Model	PH12-4, PH12-12
25 (b)	3	Mod 7 Light: Quantum Model	PH12-7, PH12-12
26 (a)	2	Mod 6 Electromagnetic Induction	PH12-5, PH12-13
26 (b)	3	Mod 6 Electromagnetic Induction	PH12-4, PH12-13
27	3	Mod 8 Quantum Mechanical Model of the Atom	PH12-15
28	4	Mod 5 Projectile Motion	PH12-6, PH12-12

Question	Marks	Content	Syllabus outcomes
29 (a)	2	Mod 5 Circular Motion	PH12-7, PH12-12
29 (b)	3	Mod 5 Circular Motion	PH12-7, PH12-12
30 (a)	2	Mod 8 Quantum Mechanical Model of the Atom	PH12-7, PH12-15
30 (b)	2	Mod 7 Light: Wave Model	PH12-4, PH12-14
30 (c)	2	Mod 6 Charged Particles, Conductors and Electric and Magnetic Fields	PH12-4, PH12-13
31	5	Mod 8 Structure of the Atom	PH12-7, PH12-15
32	8	Mod 7 Light and Special Relativity	PH12-7, PH12-14
33	6	Mod 8 Deep inside the Atom	PH12-7, PH12-15
34 (a)	2	Mod 7 Electromagnetic Spectrum	PH12-4, PH12-14
34 (b)	3	Mod 7 Electromagnetic Spectrum	PH12-7, PH12-14
35	4	Mod 6 Applications of the Motor Effect	PH12-5, PH12-13
36	8	Mod 5 Motion in Gravitational Fields	PH12-5, PH12-7, PH12-12