NSW Education Standards Authority

2021 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

Total marks: 100

Section I – 20 marks (pages 2–14)

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

Section II – 80 marks (pages 17–36)

- Attempt Questions 21–35
- 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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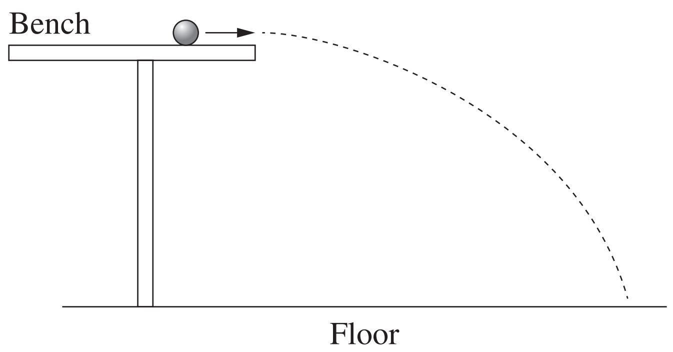
1 A marble is rolled off a horizontal bench and falls to the floor.



Rolling the marble at a slower speed would

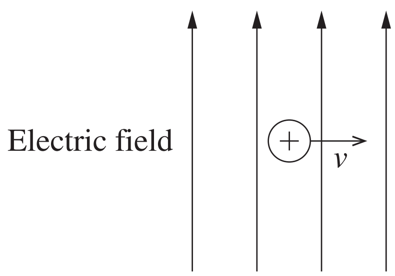
A. increase the range.

B. decrease the range.

C. increase the time of flight.

D. decrease the time of flight.

2 A positively charged particle is moving at velocity, v, in an electric field as shown.



What is the direction of the force acting on the particle due to the electric field?

A. Into the page

B. Out of the page

C. Up the page

D. Down the page

3 Which of the following is NOT a fundamental particle in the Standard Model of matter?

A. Electron

B. Gluon

C. Muon

D. Proton

4 An astronaut is travelling towards Earth in a spaceship at $0.8c$. At regular intervals, a radio pulse is sent from the spaceship to an observer on Earth.

Which quantity would the astronaut and the observer measure to be the same?

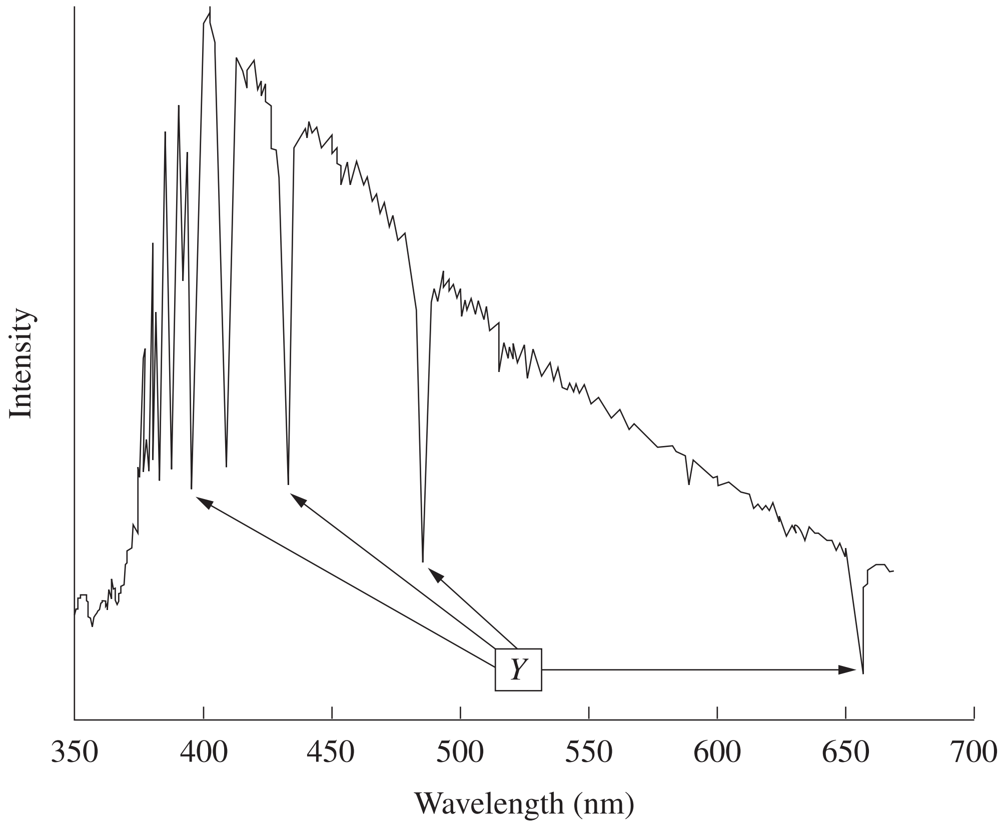
A. Length of the spaceship

B. Speed of the radio pulses

C. Momentum of the astronaut

D. Time interval between the radio pulses

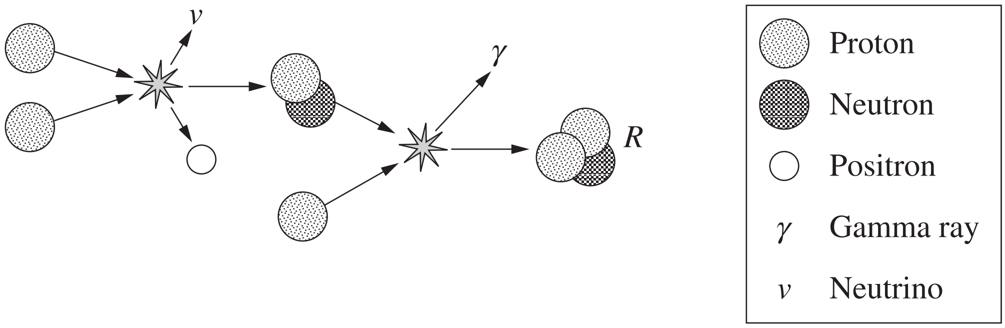
5 The spectrum of an object is shown.



Which row of the table correctly identifies the most likely source of the spectrum and the features labelled *Y*?

	Source of spectrum	*Features labelled Y*
A.	Star	Absorption lines
B.	Discharge tube	Absorption lines
C.	Star	Emission lines
D.	Discharge tube	Emission lines

6 The diagram shows part of a nuclear fusion process that occurs in stars.



What is the isotope labelled *R*?

A. H-2

B. He-2

C. H-3

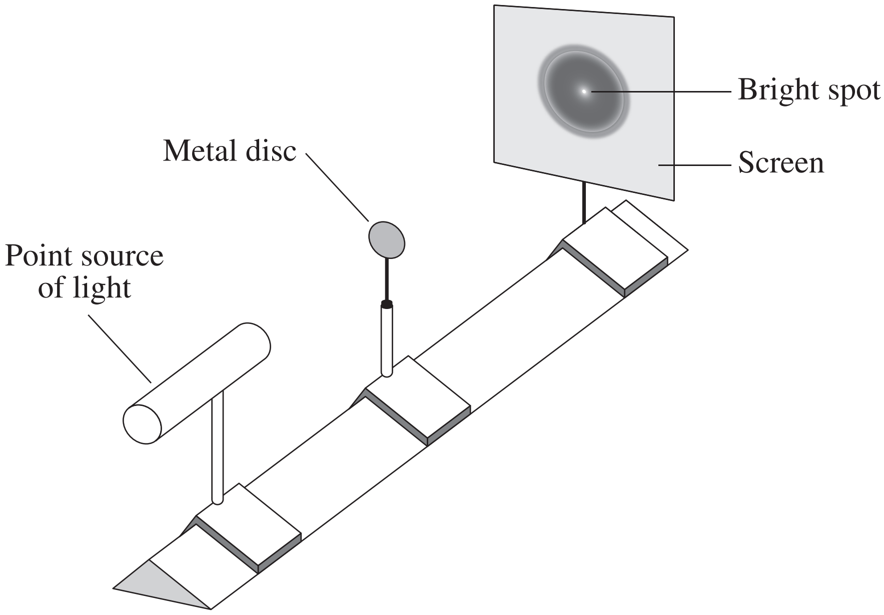
D. He-3

7 In a certain ideal transformer, the current in the secondary coil is four times as large as the current in the primary coil.

Which row of the table correctly identifies the type of transformer and the ratio of turns?

	Type of transformer	*Ratio of turns in primary coil to turns in secondary coil*
A.	Step up	4 : 1
B.	Step up	1 : 4
C.	Step down	4 : 1
D.	Step down	1 : 4

8 Light from a point source is incident upon a circular metal disc, forming a shadow on a screen as shown. A bright spot is observed in the centre of the shadow.



The bright spot is caused by a combination of

A. interference and refraction.

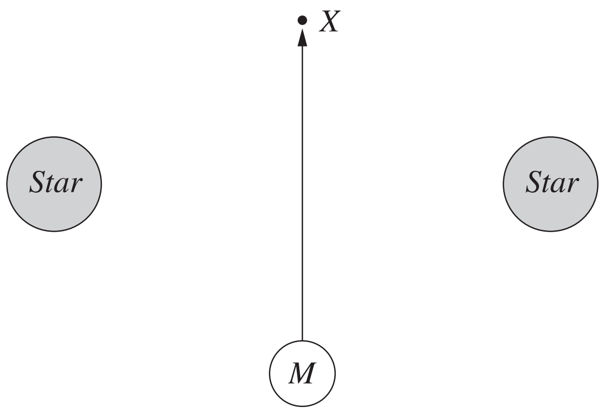
B. refraction and polarisation.

C. polarisation and diffraction.

D. diffraction and interference.

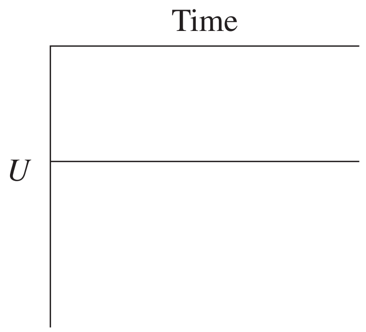
9 A mass, M, is positioned at an equal distance from two identical stars as shown.

The mass is then moved to position X.



Which graph best represents the gravitational potential energy, U, of the mass during this movement?

A.



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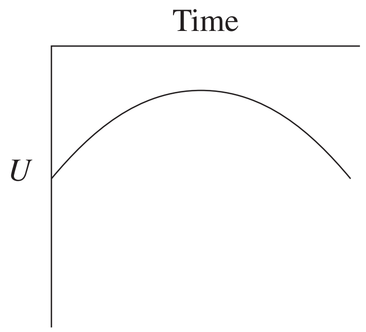
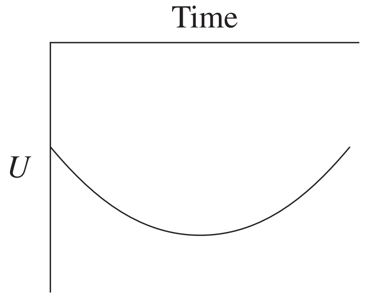


C.



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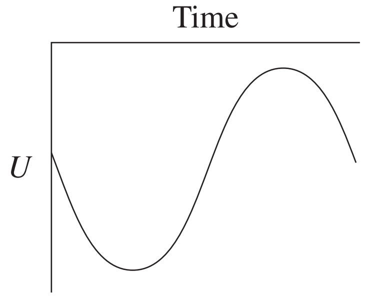
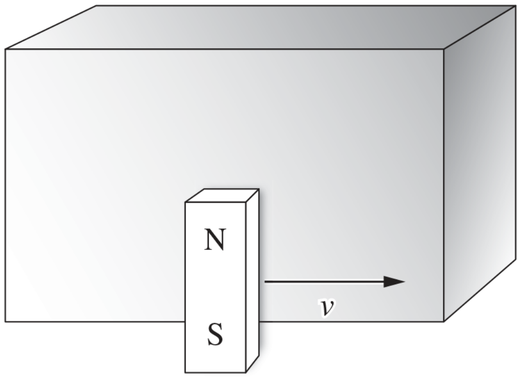


10 A strong magnet is moved past a copper block at a constant speed as shown.



What is the direction of the force acting on the copper block?

A. To the left

B. To the right

C. Into the page

D. Out of the page

11 What is the peak wavelength of electromagnetic radiation emitted by a person with a body temperature of 37°C (310 K)?

A. 9.3×10^{-6} m

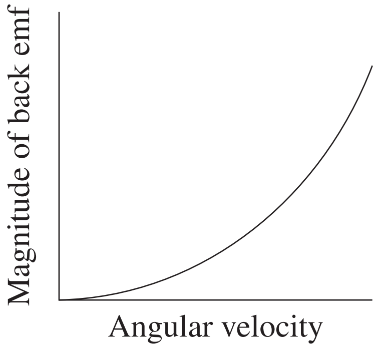
B. 7.8×10^{-5} m

C. 9.3×10^{-3} m

D. 7.8×10^{-2} m

12 Which graph shows the magnitude of back emf induced in a DC motor rotating continuously at different angular velocities?

A.



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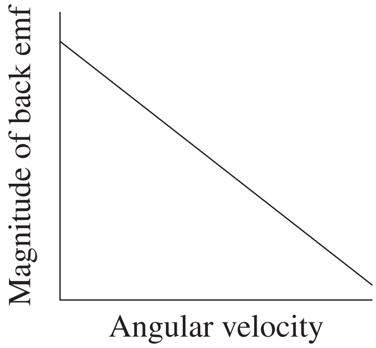

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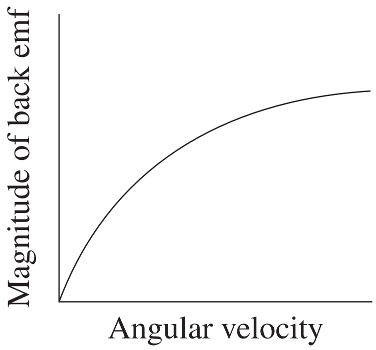
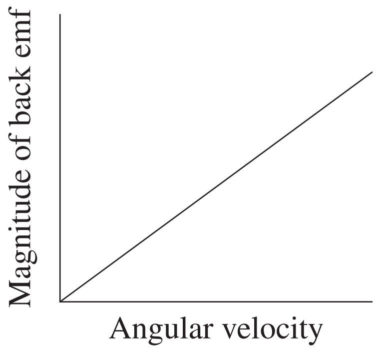
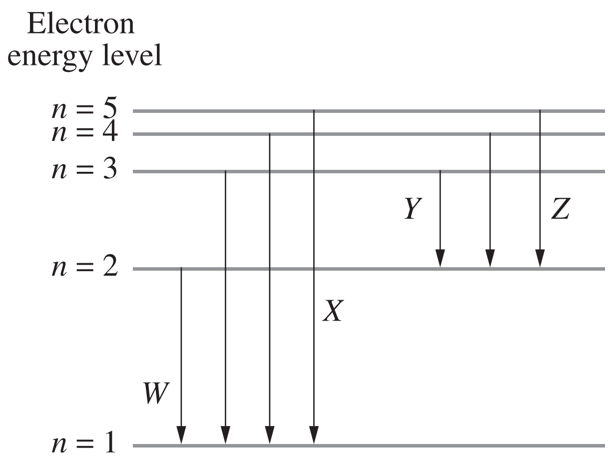


D.



13 The diagram shows electron transitions in a Bohr-model hydrogen atom.



Which transition would produce the shortest wavelength of light?

A. W

B. X

C. Y

D. Z

14 Which of the following statements correctly describes the gravitational interaction between the Earth and the Moon?

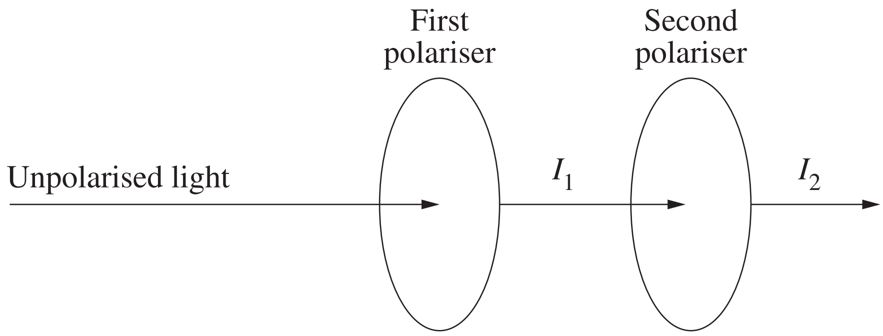
A. The Earth accelerates towards the Moon.

B. The net force acting on the Earth is zero.

C. The Moon and Earth experience equal and opposite accelerations.

D. The force acting on the Moon is smaller than the force acting on the Earth.

15 Unpolarised light is incident upon two consecutive polarisers as shown. The second polariser has a fixed transmission axis which cannot be rotated. I_1 is the intensity of light after the first polariser, and I_2 is the intensity of light after the second polariser.



How would I_1 and I_2 be affected if the transmission axis of the first polariser was rotated?

A. Both would change.

B. Only I_1 would change.

C. Only I_2 would change.

D. Neither would change.

16 The Sun has an energy output of 3.85×10^{28} W.

By how much does the Sun's mass decrease each minute?

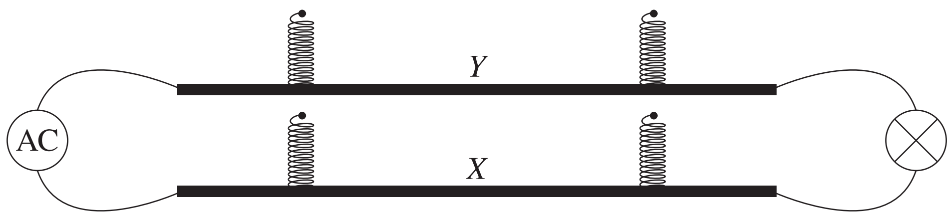
A. 4.28×10^{11} kg

B. 2.57×10^{13} kg

C. 1.28×10^{20} kg

D. 7.70×10^{21} kg

17 Two long, parallel conductors *X* and *Y* are connected to a light bulb and an AC power supply. The conductors are suspended horizontally from fixed points using sensitive spring balances. *X* is positioned directly below *Y*.



Which statement correctly compares the forces measured by the spring balances?

A. The forces measured on *X* and *Y* will always be equal.

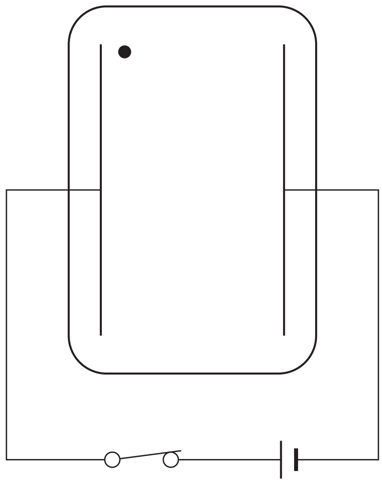
B. The force measured on *Y* will be greater than or equal to that on *X*.

C. The force measured on *X* will be greater than or equal to that on *Y*.

D. There will be a continuous reversal of which measured force is greater.

18 An evacuated chamber contains a pair of parallel plates connected to a power supply and a switch which is initially closed.

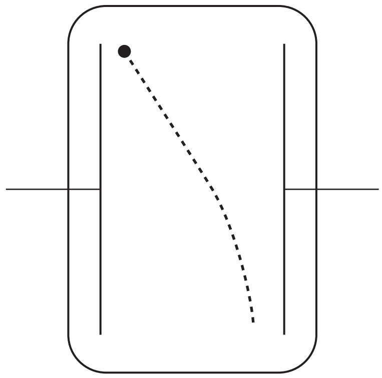
A positively charged mass (●) falls within the chamber, under the influence of gravity, from the position shown.



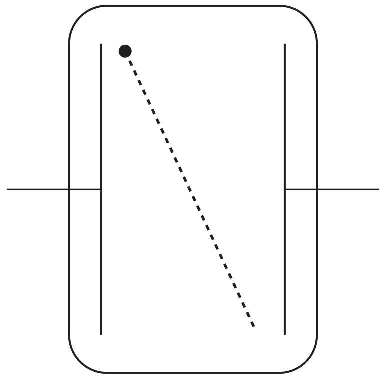
When the mass has fallen half the height of the chamber, the switch is opened.

Which of the following correctly shows the trajectory of the mass?

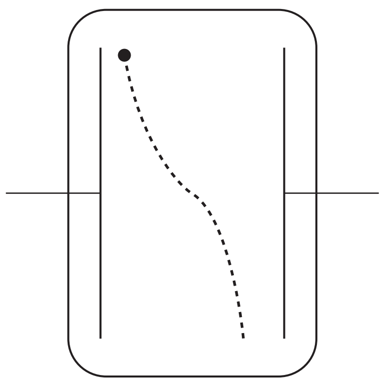
A.



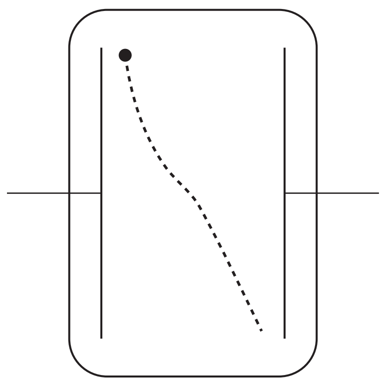
B.



C.

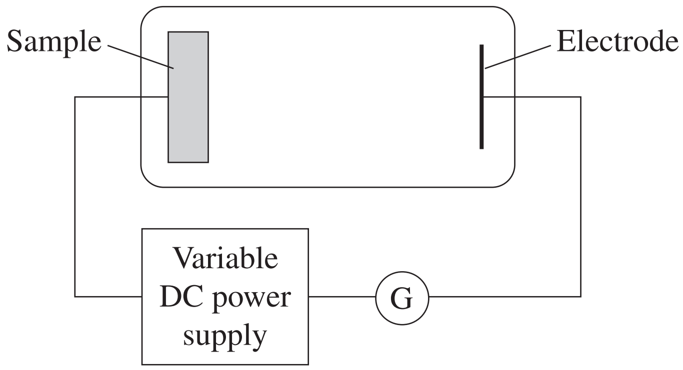


D.



19 Rh-106 is a metallic, beta-emitting radioisotope with a half-life of 30 seconds.

A sample of Rh-106 and an electrode are placed inside an evacuated chamber. They are connected to a galvanometer and a variable DC power supply.



A student measures the current, I, when the power supply is set to zero. They then measure the stopping voltage, V_s. The stopping voltage is the minimum voltage needed to prevent current flowing.

A few minutes later, these measurements are repeated.

How do the TWO sets of measurements compare?

A. Only I changes.

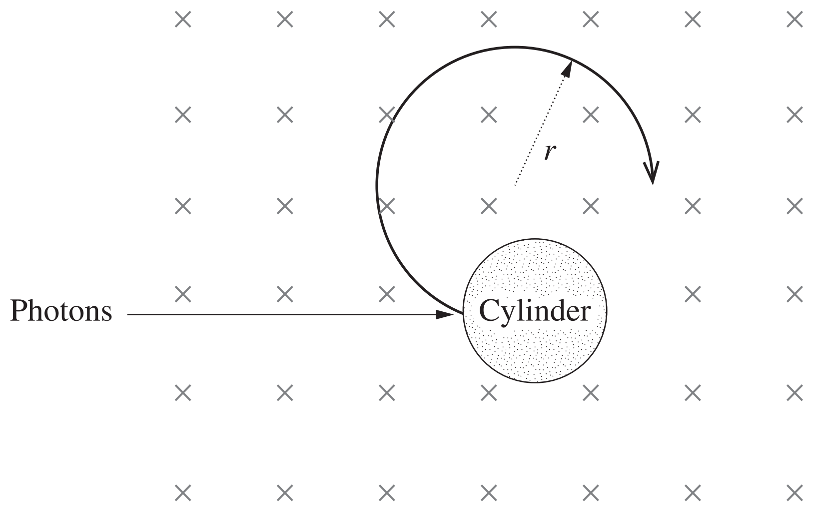
B. Only V_s changes.

C. Both I and V_s change.

D. Neither I nor V_s changes.

20 A metal cylinder is located in a uniform magnetic field. The work function of the metal is ϕ.

Photons having an energy of 2ϕ strike the side of the cylinder, liberating photoelectrons which travel perpendicular to the magnetic field in a circular path. The maximum radius of the path is r.



If the photon energy is doubled, what will the maximum radius of the path become?

A. $2r$

B. $3r$

C. $\sqrt{2}r$

D. $\sqrt{3}r$

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2021 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Physics

Section II Answer Booklet

Student Number

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

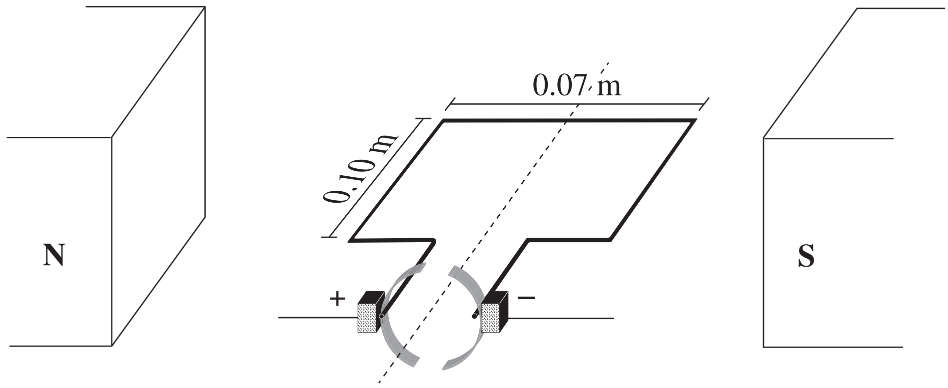
Instructions

- 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 (4 marks)

A DC motor is constructed from a single loop of wire with dimensions 0.10 m × 0.07 m. The magnetic field strength is 0.40 T and a current of 14 A flows through the loop.



(a) Calculate the magnitude of the maximum torque produced by the motor. **2**

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(b) Describe how the magnitude of the torque changes as the loop moves through half a rotation from the position shown. **2**

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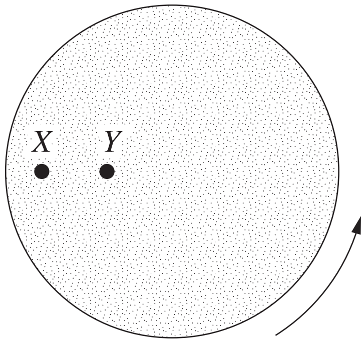
Question 22 (3 marks)

A horizontal disc rotates at a constant rate as shown. Two points on the disc, X and Y, are labelled. X is twice as far away from the centre of the disc as Y. **3**



Compare the angular and instantaneous velocities of X with those of Y.

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Question 23 (4 marks)

Describe how Millikan and Thomson each used fields to determine properties of the electron. **4**

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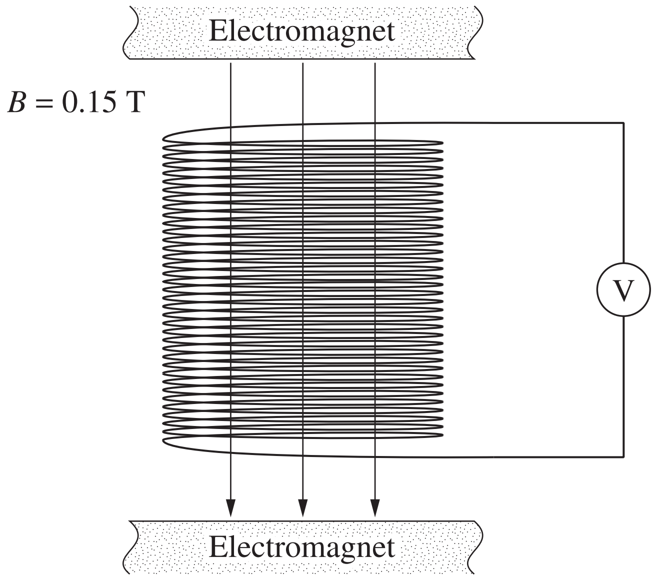
Question 24 (3 marks)

A stationary coil of 35 turns and cross-sectional area of 0.02 m^2 is placed between two electromagnets, and connected to a voltmeter as shown. The electromagnets produce a uniform magnetic field of 0.15 T through the coil. **3**



The magnitude of the magnetic field is then reduced to zero at a constant rate over a period of 0.4 s.

Calculate the magnitude of the emf induced in the coil.

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Question 25 (5 marks)

A satellite is launched from the surface of Mars into an orbit that keeps it directly above a position on the surface of Mars.

Mass of Mars = 6.39×10^{23} kg

Length of Martian day = 24 hours and 40 minutes

(a) Identify TWO energy changes as the satellite moves from the surface of Mars into orbit. **2**

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(b) Calculate the orbital radius of the satellite. **3**

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Question 26 (6 marks)

A student performs an experiment to measure Planck's constant, h, using a device that emits specific frequencies of light when specific voltages are applied.

The voltage, V, needed to produce each frequency, f, is given by

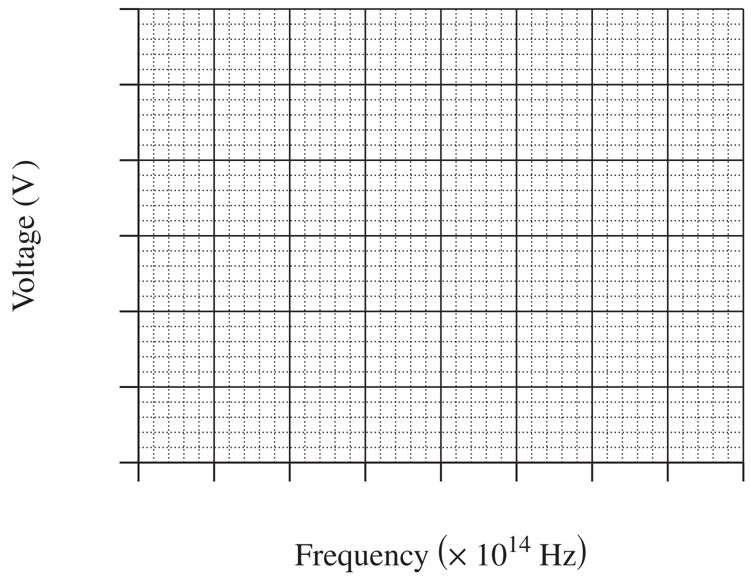
$$V = \frac{hf}{q_e}$$

where q_e is the charge on an electron.

Data from the experiment is shown.

Data point	*Frequency* $(\times 10^{14}$ Hz$)$	*Voltage* (V)
1	3.5	1.3
2	4.8	1.7
3	5.3	1.9
4	7.0	2.6

(a) Graph this data on the axes provided. Include a line of best fit. **3**



Question 26 continues on page 23

Question 26 (continued)

(b) The student proposes using data point 1 to calculate a value for Planck's constant. **3**

Justify a better method to calculate Planck's constant from the experimental data provided.

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End of Question 26

Please turn over

Question 27 (6 marks)

A student is considering how to levitate a thin metal rod in a strong magnetic field of 1.2 T. The current flowing through the rod will be 2.3 A.

(a) Use a labelled diagram to show a suitable orientation of the current and the magnetic field to achieve this outcome. Include relevant forces in your diagram. **3**

(b) Explain why the maximum mass per unit length of the rod cannot exceed 0.282 kg m^{-1}. Support your answer with a calculation. **3**

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Question 28 (5 marks)

A spaceship travels to a distant star at a constant speed, v. When it arrives, 15 years have passed on Earth but 9.4 years have passed for an astronaut on the spaceship.

(a) What is the distance to the star as measured by an observer on Earth? **3**

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(b) Outline how special relativity imposes a limitation on the maximum velocity of the spaceship. **2**

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Question 29 (5 marks)

Bohr, de Broglie and Schrödinger EACH proposed a model for the structure of the atom. **5**

How does the nature of the electron proposed in each of the three models differ?

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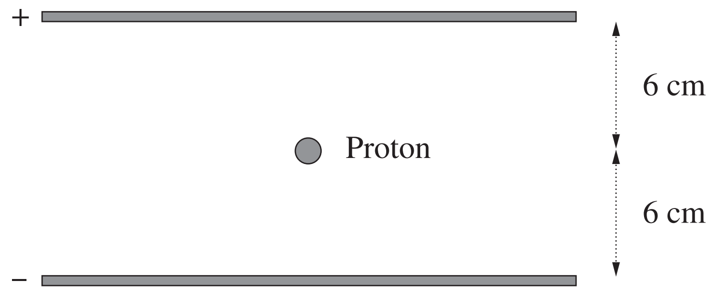
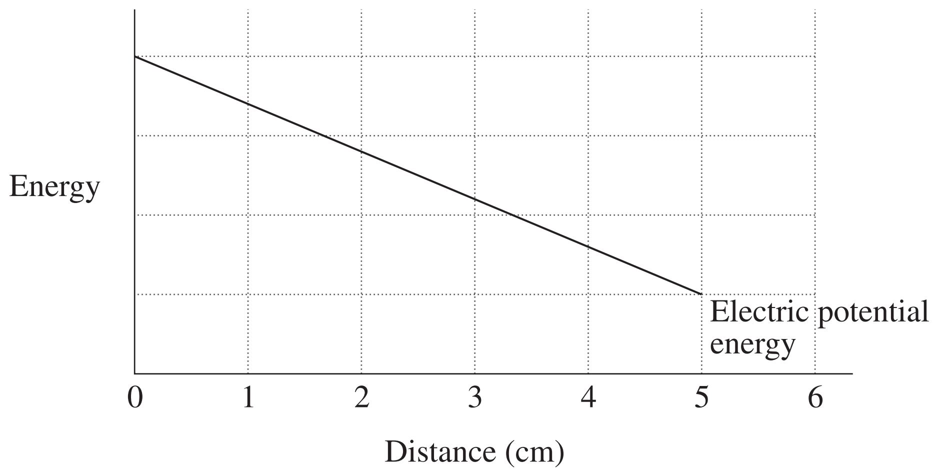
Question 30 (5 marks)

In an experiment, a proton accelerates from rest between parallel charged plates. The spacing of the plates is 12 cm and the proton is initially positioned at an equal distance from both plates, as shown. Ignore the effect of gravity.



(a) The electrical potential energy of the proton is recorded in the following graph for the first 5 cm of its motion. **2**

On the graph, sketch the corresponding kinetic energy of the proton over the same distance.



(b) The experiment is repeated using an electron in the place of the proton. **3**

Explain how the motion of the electron would differ from that of the proton.

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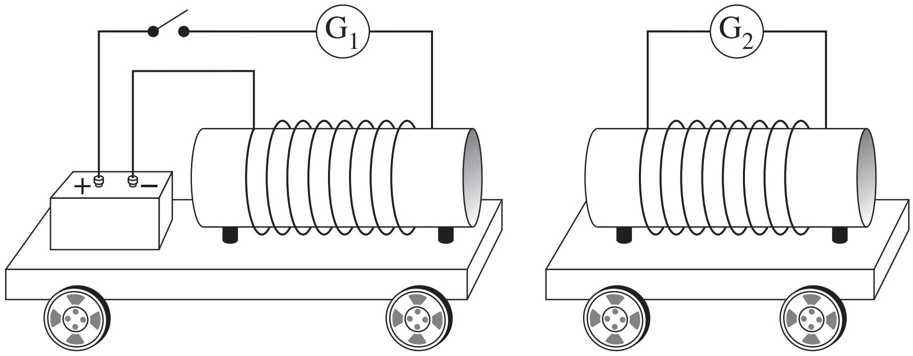
Question 31 (7 marks)

Two identical solenoids are mounted on carts as shown. Each solenoid is connected to a galvanometer, and the solenoid on cart 1 is also connected to an open switch and a battery. The total mass of cart 1 is twice that of cart 2. **7**



Cart 1 Cart 2

Explain what would be observed when the switch on cart 1 is closed. In your answer, refer to the current in each galvanometer and the initial movement of the carts.

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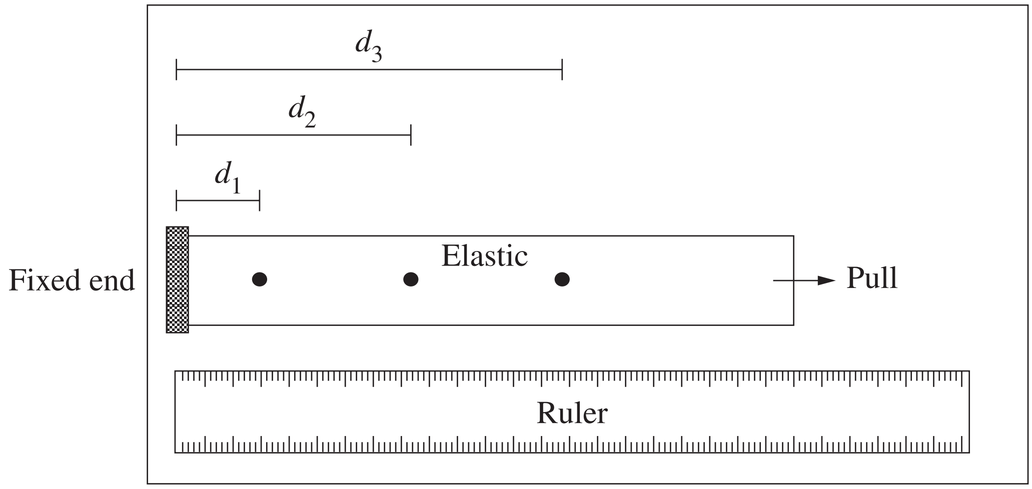
Question 32 (5 marks)

Two students perform an investigation with a piece of elastic laid out straight on a table. The elastic is fixed at one end and has three markings at regular intervals. The distances from each marking to the fixed end, d_1, d_2 and d_3, are measured as shown. **5**



Top view of table

A student pulls the elastic to extend it, and the new values of d_1, d_2 and d_3 are measured. The student observes that each value has doubled.

How well do the observations from this investigation model the evidence that led to Hubble's discovery of the expansion of the universe? Justify your answer.

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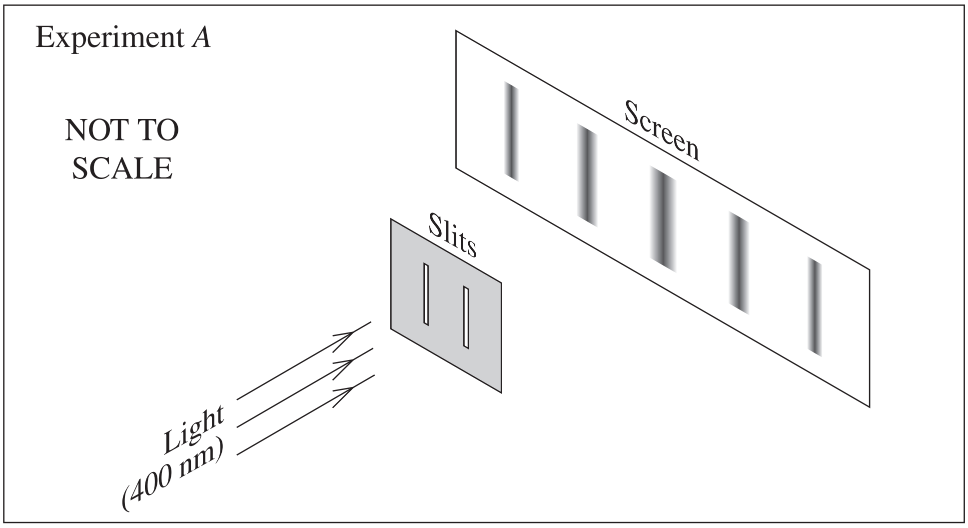
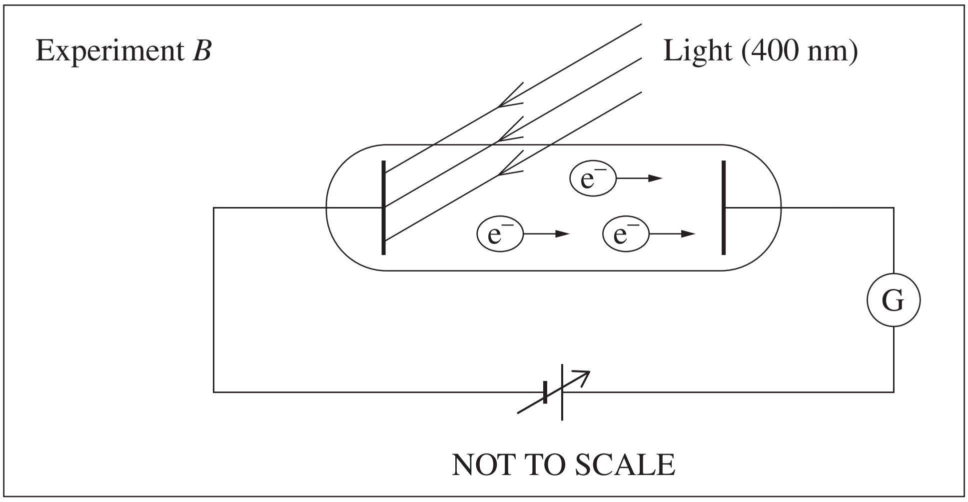
Question 33 (9 marks)

Two experiments are performed with identical light sources having a wavelength of 400 nm. **9**

In experiment *A*, the light is incident on a pair of narrow slits 5.0×10^{-5} m apart, producing a pattern on a screen located 3.0 m behind the slits.



In experiment *B*, the light is incident on different metal samples inside an evacuated tube as shown. The kinetic energy of any emitted photoelectrons can be measured.



Some results from experiment *B* are shown.

Metal sample	*Work function* (J)	*Photoelectrons observed?*
Nickel	8.25×10^{-19}	No
Calcium	4.60×10^{-19}	Yes

Question 33 continues on page 31

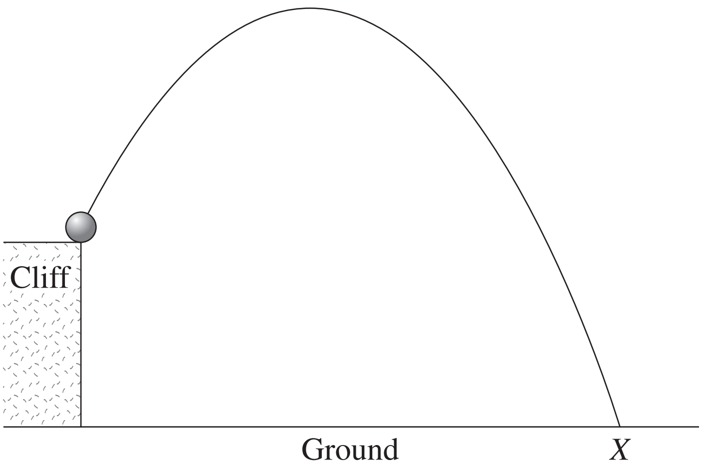
Question 33 (continued)

How do the results from Experiment *A* and Experiment *B* support TWO different models of light? In your answer, include a quantitative analysis of each experiment.

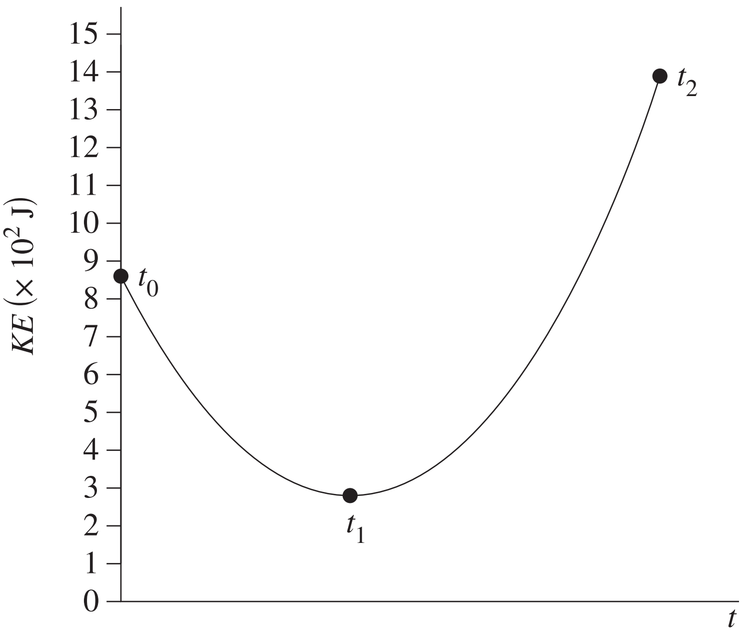
End of Question 33

Question 34 (7 marks)

A 3.0 kg mass is launched from the edge of a cliff.



The kinetic energy of the mass is graphed from the moment it is launched until it hits the ground at X. The kinetic energy of the mass is provided for times t_0, t_1 and t_2.



Time (t)	*KE* (J)
t_0	864
t_1	284
t_2	1393

Question 34 continues on page 33

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Question 34 (continued)

(a) Account for the relative values of kinetic energy at t_0, t_1 and t_2. **4**

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(b) The horizontal component of the velocity of the mass during its flight is $13.76\ \mathrm{m\,s^{-1}}$. **3**

Calculate the time of flight of the mass.

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End of Question 34

Please turn over

Question 35 (6 marks)

A spacecraft is powered by a radioisotope generator. Pu-238 in the generator undergoes alpha decay, releasing energy. The decay is shown with the mass of each species in atomic mass units, *u*.

$$\begin{array}{ccccc} {}^{238}\text{Pu} & \longrightarrow & {}^{234}\text{U} & + & \alpha \\ 238.0495u & & 234.0409u & & 4.0026u \end{array}$$

(a) Show that the energy released by one decay is 9.0×10^{-13} J. **3**

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(b) At launch, the generator contains 9.0×10^{24} atoms of Pu-238. The half-life of Pu-238 is 87.7 years. **3**

Calculate the total energy produced by the generator during the first ten years after launch.

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End of paper

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Section II extra writing space

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

Section II extra writing space

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

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	$340\ \mathrm{m\,s^{-1}}$
Earth's gravitational acceleration, g	$9.8\ \mathrm{m\,s^{-2}}$
Speed of light, c	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12}\ \mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}\ \mathrm{N\,A^{-2}}$
Universal gravitational constant, G	$6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$
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)	$1.097 \times 10^{7}\ \mathrm{m^{-1}}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5\ \mathrm{MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3}\ \mathrm{kg\,m^{-3}}$
Specific heat capacity of water	$4.18 \times 10^{3}\ \mathrm{J\,kg^{-1}\,K^{-1}}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

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

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

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

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

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

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

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

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

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

$$v = u + at$$

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

$$Q = mc\Delta T$$

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

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

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

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

$$I_1r_1^2 = I_2r_2^2$$

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

Electricity and magnetism

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

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

$W = qV$

$W = qEd$

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

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

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

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

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

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

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

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

$V = IR$

$P = VI$

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

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

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

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

$V_p I_p = V_s I_s$

Quantum, special relativity and nuclear

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

$K_{max} = hf - \phi$

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

$E = mc^2$

$E = hf$

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

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

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

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

$N_t = N_0 e^{-\lambda t}$

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

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.

2021 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21 (a)

Criteria	Marks
• Correctly calculates the magnitude of the maximum torque	2
• Provides some relevant information	1

Sample answer:

$\tau = nIAB\sin\theta = 1 \times 14 \times 0.1 \times 0.07 \times 0.40 \times \sin(90^{o})$

$\tau = 0.04\ Nm$

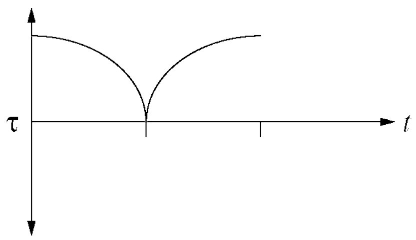
Question 21 (b)

Criteria	Marks
• Correctly describes changes in magnitude of torque throughout one half-rotation	2
• Provides some relevant information	1

Sample answer:

The torque begins at a maximum and decreases to zero at 90º from the initial position. The torque then increases to a maximum at 180º from the initial position.

Answers could include:



Question 22

Criteria	Marks
• Correctly compares angular and instantaneous velocities of *X* and *Y*	3
• Correctly compares instantaneous velocities OR • Correctly compares angular velocities, and magnitude or direction of instantaneous velocities	2
• Provides some relevant information	1

Sample answer:

The angular velocities of *X* and *Y* are equal. The instantaneous velocity of *X* is twice that of *Y*. The directions of instantaneous velocities for *X* and *Y* are the same.

Question 23

Criteria	Marks
• Provides a thorough description of the use of fields by Thomson and Millikan to determine properties of the electron	4
• Provides some description of the use of fields by Thomson and Millikan to determine properties of the electron OR • Provides a thorough description of the use of fields by either Thomson or Millikan to determine properties of the electron	3
• Shows some understanding of the use of fields by Thomson and/or Millikan to study the electron	2
• Provides some relevant information	1

Sample answer:

Thomson used electric and magnetic fields to balance forces on electrons, allowing him to calculate the charge to mass ratio of electrons. Millikan used electric and gravitational fields to levitate charged droplets, allowing him to determine the charge on the electron.

Question 24

Criteria	Marks
• Correctly calculates the magnitude of the induced emf	3
• Provides some working for calculating the magnitude of the emf	2
• Provides some relevant information	1

Sample answer:

$$\Phi = \Delta B_{\parallel} A = 0.15 \times 0.02 = 0.003\ Wb$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -35\frac{(0 - 0.003)}{0.4} = 0.3\ V$$

Question 25 (a)

Criteria	Marks
• Identifies two changes in energy of satellite	2
• Provides some relevant information	1

Sample answer:

The gravitational potential energy and kinetic energy of the satellite both increase as it moves into orbit.

Question 25 (b)

Criteria	Marks
• Correctly calculates the orbital radius	3
• Provides some working for calculating the orbital radius	2
• Provides some relevant information	1

Sample answer:

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

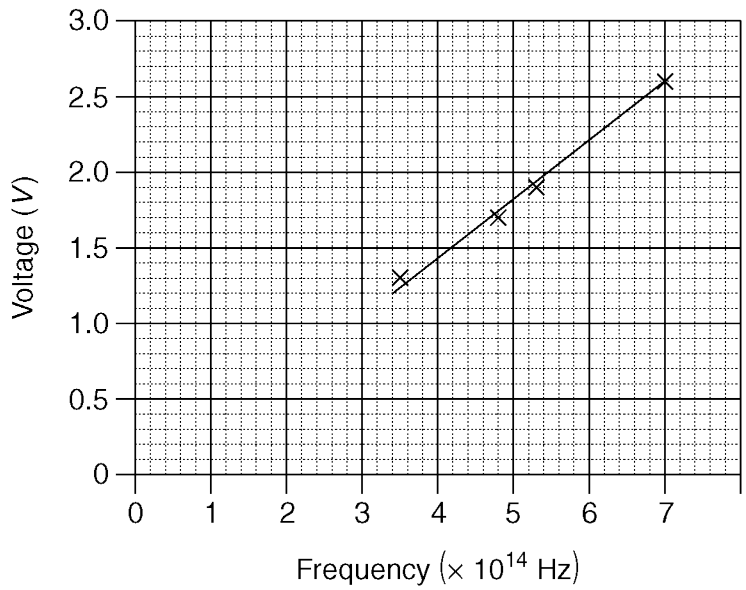
$$\frac{r^3}{\left(\left(24 + \frac{40}{60}\right) \times 60 \times 60\right)^2} = \frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{4\pi^2}$$

$$r = 2.0 \times 10^7 \text{ m}$$

Question 26 (a)

Criteria	Marks
• Uses appropriate scale • Correctly plots data points • Draws line of best fit	3
• Correctly plots some data points using an appropriate scale OR • Correctly plots all data points OR • Correctly plots some data points and draws a line of best fit OR • Provides a substantially correct graph	2
• Correctly plots some data points OR • Provides an appropriate scale OR • Draws a line of best fit	1

Sample answer:



Question 26 (b)

Criteria	Marks
• Proposes a better method to calculate *h* and justifies the method	3
• Proposes a better method to calculate *h* OR • Proposes some improvement with a reason	2
• Provides some relevant information	1

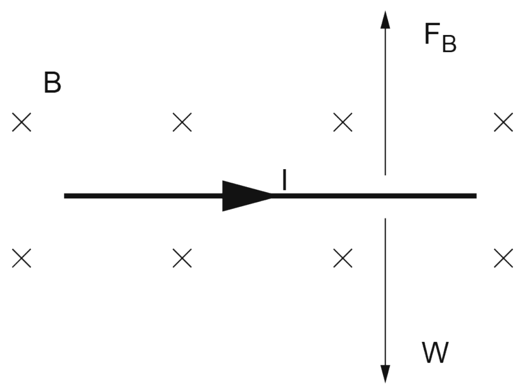
Sample answer:

The gradient of the line of best fit could be calculated from the graph, and substituted into the equation to calculate *h*. This takes more data points into account, increasing the accuracy.

Question 27 (a)

Criteria	Marks
• Proposes a suitable orientation of *B* and *I* and supports answer with a diagram showing labelled forces	3
• Proposes a suitable orientation of *B* and *I* OR • Uses a diagram showing labelled opposing forces to propose an orientation of *B* and *I*	2
• Provides some relevant information	1

Sample answer:



Answers could include:

Any appropriate orientation of *B* and *I*.

Question 27 (b)

Criteria	Marks
• Calculates mass per unit length • Explains why that is the maximum possible value	3
• Calculates mass per unit length OR • Provides some working to calculate mass per unit length and identifies that it is the maximum possible value	2
• Provides some relevant information	1

Sample answer:

$$W = F_B$$

$$mg = lIB\sin\theta$$

$$\frac{m}{l} = \frac{IB\sin\theta}{g} = \frac{2.3 \times 1.2 \times \sin 90^\circ}{9.8} = 0.28\ \text{kgm}^{-1}$$

Once mass per unit length exceeds this amount, the force due to the magnetic field cannot suspend the rod against its weight.

Question 28 (a)

Criteria	Marks
• Calculates distance to star as seen by observer on Earth	3
• Provides some working to calculate distance to star	2
• Provides some relevant information	1

Sample answer:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$15 = \frac{9.4}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$v = 0.779c$$

$$s = ut = 0.779 \times 15 = 12\,ly$$

Question 28 (b)

Criteria	Marks
• Outlines how special relativity imposes a limitation on the maximum velocity of the spaceship	2
• Provides some relevant information	1

Sample answer:

Relativistic momentum would approach infinity as v approaches c. This means that an infinite force would be required to accelerate it further, limiting the velocity.

Question 29

Criteria	Marks
• Shows a comprehensive understanding of how the nature of the electron differs between the THREE models	5
• Outlines the nature of the electron in each model showing a sound understanding of the differences	4
• Outlines the nature of the electron in TWO models OR • Identifies a feature of the electron in each of the THREE models showing some understanding of the differences	3
• Identifies features of the electron in the model(s)	2
• Provides some relevant information	1

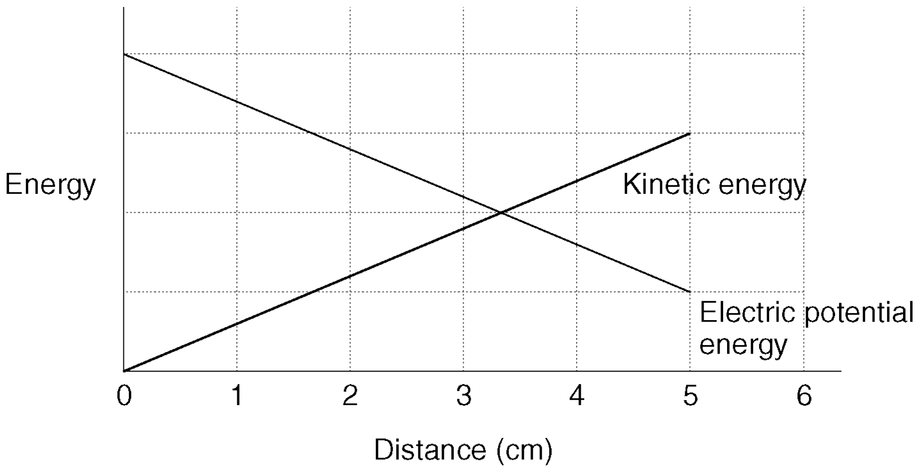
Sample answer:

Bohr proposed that the electron was a negatively charged particle which orbits the nucleus at quantised energy levels. De Broglie’s model subsequently proposed that the electron instead had a dual wave/particle nature, and existed in stable standing waves around the nucleus. In contrast, Schrödinger’s model described the electron as having a wave nature with properties that could be predicted by his wave equation.

Question 30 (a)

Criteria	Marks
• Correctly sketches the *KE* of the proton	2
• Provides some relevant information	1

Sample answer:



Question 30 (b)

Criteria	Marks
• Provides a relevant explanation of how the motion of the electron would differ from that of the proton	3
• Describes ways in which the motion of the electron would differ from that of the proton OR • Outlines ONE way in which the motion of the electron would differ from that of the proton and provides some explanation	2
• Provides some relevant information	1

Sample answer:

The electron will move in the opposite direction to the proton. The electron would experience an equal force to the proton but in the opposite direction, as its charge has the same magnitude but opposite sign.

Because the mass of the electron is significantly smaller, it would experience a much higher acceleration.

Answers could include:

References to other relevant features of motion such as time.

Question 31

Criteria	Marks
• Provides details of the current in each galvanometer and initial movement of each cart • Provides a comprehensive explanation of the observation when the switch is closed	7
• Provides details of the current in each galvanometer and initial movement of each cart • Provides an explanation of current and movement of carts	6
• Provides some details of the current and initial movement • Provides some explanation	4–5
• Provides some details of the current and/or initial movement OR • Provides some explanation	2–3
• Provides some relevant information	1

Sample answer:

When the switch is closed, a constant direct current will be observed on G_1. This current will create a magnetic field in the solenoid with a south pole facing cart 2. As this field is generated, the solenoid on cart 2 experiences a momentary change in magnetic flux, inducing an emf and a current in the solenoid. By Lenz's law, the direction of this current opposes the original change in flux, forming a south pole facing cart 1, and causing a momentary deflection of G_2 in the opposite direction to the current in G_1.

The equal and opposite magnetic repulsion of the south poles causes the carts to move away from each other. To conserve momentum, cart 1 will have half the initial velocity of cart 2 since its mass is double that of cart 2.

Answers could include:

Reference to Faraday's law, the conservation of energy or Newton's law.

Question 32

Criteria	Marks
• Justifies how well the observations model Hubble's evidence	5
• Provides some justification for how well the observations model Hubble's evidence	4
• Relates aspects of the investigation to the expansion of the universe	2–3
• Provides some relevant information	1

Sample answer:

As the elastic is stretched, each marking moves by an amount proportional to its distance from the fixed end. This successfully models Hubble's observation that more distant galaxies are receding from Earth at greater rates, proportional to their distance from Earth.

However, a limitation of the investigation is that it can only model expansion in one dimension whereas Hubble's evidence showed that the universe is expanding in three dimensions.

Answers could include:

Other benefits or limitations of the model, such as:

- The investigation only examines a change in position of the markings, while Hubble measured speed of galaxies.
- As the elastic stretches, the markings themselves will stretch. Hubble did not find that the galaxies were spreading out.

Question 33

Criteria	Marks
• Provides comprehensive quantitative analysis of each experiment • Shows a comprehensive understanding of how results from the experiments support two different models of light	9
• Provides quantitative analysis of each experiment • Shows a thorough understanding of how results from the experiments support two different models of light	8
• Provides aspects of quantitative analysis of each experiment • Relates the experiments to two different models of light	6–7
• Provides aspects of analysis of experiment(s) • Provides information about relevant models of light	4–5
• Provides information about relevant model(s) of light AND/OR • Includes quantitative information	2–3
• Provides some relevant information	1

Sample answer:

In Experiment *A*, a pattern of bright and dark regions will be observed on the screen. The spacing between adjacent regions can be calculated:

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

$$5 \times 10^{-5}\sin\theta = 1 \times 400 \times 10^{-9}$$

$$\theta = 0.46^{\circ}$$

$$s = 3 \times \tan 0.46 = 0.024 \text{ m}$$

The pattern is explained by the wave model where light waves from the slits arrive at the screen causing bright regions at points of constructive interference and dark regions at points of destructive interference. This supports the wave model of light.

In Experiment *B*, photoelectrons are emitted from calcium but not nickel. The particle model of light can be used to calculate the photon energy of incident light:

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{400 \times 10^{-9}} = 7.50 \times 10^{14}\,Hz$$

$$E = hf = 6.626 \times 10^{-34} \times 7.50 \times 10^{14} = 4.97 \times 10^{-19}\,J$$

This energy is higher than the work function of calcium but not nickel, explaining why one photon has enough energy to liberate a photo electron from the calcium sample, supporting the particle model of light. The particle model can be further applied to calculate the kinetic energy of photoelectrons emitted from the calcium sample.

$$K_{max} = hf - \phi = 4.97 \times 10^{-19} - 4.60 \times 10^{-19} = 3.70 \times 10^{-20}\,J$$

Question 34 (a)

Criteria	Marks
• Accounts for the relative values of *KE* at t_0, t_1 and t_2	4
• Accounts for some of the relative values of *KE*	3
• Shows some understanding of the changes in *KE*	2
• Provides some relevant information	1

Sample answer:

After the mass is launched at t_0, downwards gravitational acceleration reduces the vertical velocity of the mass until it is zero, at time t_1. The *KE* is a minimum here but is not zero since the horizontal component of its velocity is unaffected by gravity. After t_1, the kinetic energy of the mass increases again as the vertical component of motion increases under the influence of gravity until it strikes the ground at t_2. The kinetic energy at t_2 is greater than the value at t_0 as the mass has lower GPE than at t_0.

Question 34 (b)

Criteria	Marks
• Correctly calculates time of flight	3
• Shows some working to calculate time of flight	2
• Provides some relevant information	1

Sample answer:

At t_0 find u_y $\quad KE = \frac{1}{2}mv^2 \quad v^2 = 2\frac{(864)}{3} = 576$

so $v = 24$

Using Pythagoras, $\quad 24^2 = u_y{}^2 + 13.76^2 \quad$ so $u_y = 19.66\ \text{ms}^{-1}$

At t_2 find v_y $\quad KE = \frac{1}{2}mv^2 \quad v^2 = 2\frac{(1393)}{3} = 928.7$

so $v = 30.47$

Using Pythagoras, $\quad 30.47^2 = v_y{}^2 + 13.76^2 \quad$ so $v_y = 27.19\ \text{ms}^{-1}$

To calculate time of flight $\quad v_y = u_y + a_g t \quad$ so $\quad t = \frac{(v_y - u_y)}{a_g}$

$= \frac{27.19 - (-19.66)}{9.8}$

$= 4.8\ \text{s}$

Answers could include:

Calculations using $\Delta u = mg\Delta h$.

Question 35 (a)

Criteria	Marks
• Correctly calculates the energy released in one decay	3
• Shows some working to determine energy release	2
• Provides some relevant information	1

Sample answer:

$$\Delta m = (234.0409 + 4.0026) - 238.0495 = -0.006u$$

$$\Delta m = 0.006 \times 1.661 \times 10^{-27} = 9.966 \times 10^{-30} \text{ kg}$$

$$E = mc^2 = 9.966 \times 10^{-30} \times (3 \times 10^8)^2 = 9.0 \times 10^{-13} J$$

Question 35 (b)

Criteria	Marks
• Correctly calculates the energy produced during the ten years	3
• Shows some working to determine the energy produced during the ten years	2
• Provides some relevant information	1

Sample answer:

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{87.7} = 0.0079y^{-1}$$

$$N_t = N_0 e^{-\lambda t} = 9 \times 10^{24} \times e^{-0.0079 \times 10} = 8.316 \times 10^{24}$$

$$\Delta N = 9 \times 10^{24} - 8.316 \times 10^{24} = 6.84 \times 10^{23}$$

$$E = 6.84 \times 10^{24} \times 9.0 \times 10^{-13} = 6.2 \times 10^{11} J$$

2021 HSC Physics Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 5: Projectile Motion	PH12-12, PH11/12-5
2	1	Mod 6: Charged particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-4
3	1	Mod 8: Deep inside the Atom	PH12-15
4	1	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
5	1	Mod 7: Electromagnetic Spectrum Mod 8: Origins of the Elements	PH12-14, PH12-15, PH11/12-5
6	1	Mod 8: Origins of the Elements	PH12-15, PH11/12-5
7	1	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-5
8	1	Mod 7: Light: Wave Model	PH12-14, PH11/12-5
9	1	Mod 5: Motion in Gravitational Fields	PH12-12, PH11/12-5
10	1	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-6
11	1	Mod 7: Light: Quantum Model	PH12-14, PH11/12-5
12	1	Mod 5: Circular Motion Mod 6: Application of the Motor Effect	PH12-12, PH12-13, PH11/12-5
13	1	Mod 8: Quantum Mechanical Nature of the Atom	PH12-15, PH11/12-5
14	1	Mod 5: Motion on Gravitational Fields	PH12-12, PH11/12-7
15	1	Mod 7: Light: Wave Model	PH12-14, PH11/12-6
16	1	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
17	1	Mod 6: The Motor Effect	PH12-13, PH11/12-6
18	1	Mod 5: Projectile Motion Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-12, PH12-13, PH11/12-6
19	1	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-6
20	1	Mod 5: Circular Motion Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields Mod 7: Light: Quantum Model	PH12-12, PH12-13, PH12-14, PH11/12-6

Section II

Question	Marks	Content	Syllabus outcomes
21 (a)	2	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-4
21 (b)	2	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-7
22	3	Mod 5: Circular Motion	PH12-12, PH11/12-5
23	4	Mod 8: Structure of the Atom	PH12-15, PH11/12-7
24	3	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-4
25 (a)	2	Mod 5: Motion in Gravitational Fields	PH12-12
25 (b)	3	Mod 5: Motion in Gravitational Fields	PH12-12, PH11/12-4
26 (a)	3	Mod 7: Light: Quantum Model	PH12-14, PH11/12-4

Question	Marks	Content	Syllabus outcomes
26 (b)	3	Mod 7: Light: Quantum Model	PH12-14, PH11/12-5
27 (a)	3	Mod 5: Motion in Gravitational Fields Mod 6: The Motor Effect	PH12-12, PH12-13, PH11/12-6
27 (b)	3	Mod 5: Motion in Gravitational Fields Mod 6: The Motor Effect	PH12-12, PH12-13, PH11/12-4
28 (a)	3	Mod 7: Light and Special Relativity	PH12-14, PH11/12-4
28 (b)	2	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
29	5	Mod 8: Quantum Mechanical Nature of the Atom	PH12-15, PH11/12-7
30 (a)	2	Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-5
30 (b)	3	Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-6
31	7	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-6
32	5	Mod 8: Origins of the Elements	PH12-15, PH11/12-6
33	9	Mod 7: Light: Wave Model Mod 7: Light: Quantum Model	PH12-14, PH11/12-7, PH11/12-4
34 (a)	4	Mod 5: Projectile Motion	PH12-12, PH11/12-5
34 (b)	3	Mod 5: Projectile Motion	PH12-12, PH11/12-4
35 (a)	3	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-4
35 (b)	3	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-4, PH11/12-5