Sydney Boys High School

NESA Student Number:

Multiple Choice Answer Sheet

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

Start Here ➔

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

NESA Student Number:

Sydney Boys High School

Physics

August 2022
Trial Exam

General Instructions

- Reading time: 5 minutes
- Working time: 3 hours
- Write using black pen
- Draw diagrams using pencil
- SHOW ALL WORKING
- 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 student number in ALL of the boxes provided

Total marks: 100

Section I – Multiple Choice
- 20 marks
- Allow about 35 minutes for this section

Section II – Free Response
- 80 marks
- 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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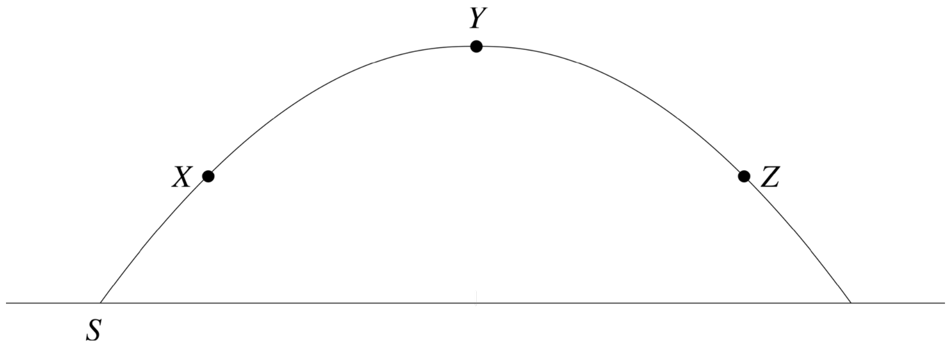
1. A ball is thrown from *S* at an angle to the horizontal as shown in the diagram below.



X, *Y*, and *Z* are different positions along the ball's trajectory.

Which of the following best represents the velocity and acceleration of the ball?

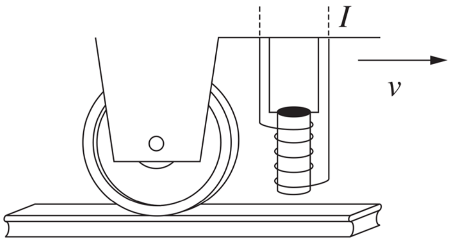
	Velocity			*Acceleration*		
	X	*Y*	*Z*	*X*	*Y*	*Z*
A.	↗	→	↘	↓	↓	↓
B.	↗	→	↘	↗	→	↘
C.	↑	zero	↓	↓	↓	↓
D.	↑	zero	↓	↗	→	↘

2. James Clerk Maxwell made significant contributions to physics.

Which of the following did Maxwell NOT contribute to our understanding of physics?

A. Unifying electricity and magnetism through equations
B. Predicting the existence of electromagnetic waves
C. Predicting the velocity of electromagnetic waves
D. Validating the existence of electromagnetic waves

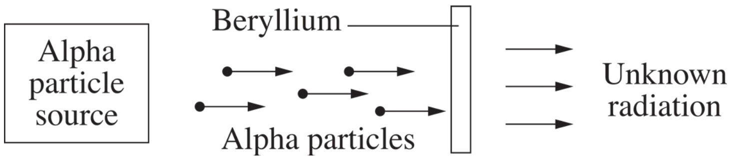
3. An electromagnet is attached to the bottom of a light train which is travelling from left to right, as shown.



When a large current is passed through the coils of the electromagnet, the train slows down as a direct result of the law of conservation of energy. In which of the following devices is the law of conservation of energy applied in the same way?

A. Induction motor
B. AC motor
C. Transformer
D. DC motor

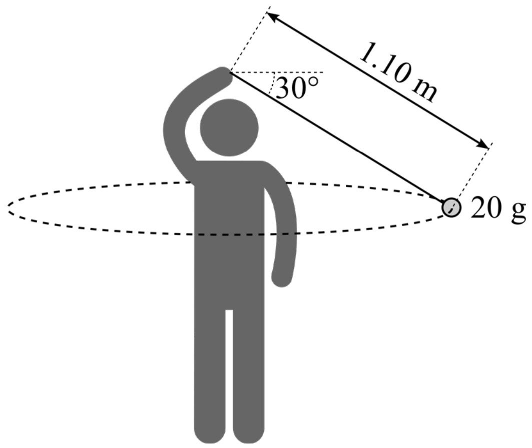
4. In an experiment, alpha particles were fired into a thin sheet of beryllium. Unknown radiation was detected.



Which of the results below provides the strongest evidence that the unknown radiation is not gamma radiation?

A. The unknown radiation could not be deflected by an electric field.
B. The unknown radiation had a very high penetrating power.
C. The unknown radiation caused protons to be ejected from a block of paraffin.
D. The unknown radiation could not produce the photoelectric effect.

5. A student swings a 20 g metal ball on the end of a 1.10 m length of string around his body at a constant angular velocity of 4π rad s^{-1}.

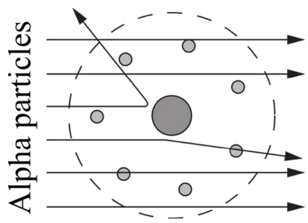


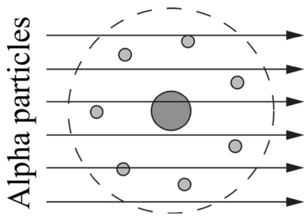
What is the magnitude of the centripetal force acting on the ball?

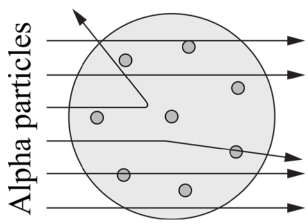
A. 2.9 N
B. 3.0 N
C. 3.3 N
D. 3.5 N

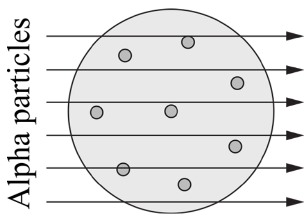
6. Geiger and Marsden carried out an experiment to investigate the structure of the atom.

Which diagram best represents the model corresponding to the results that they obtained?

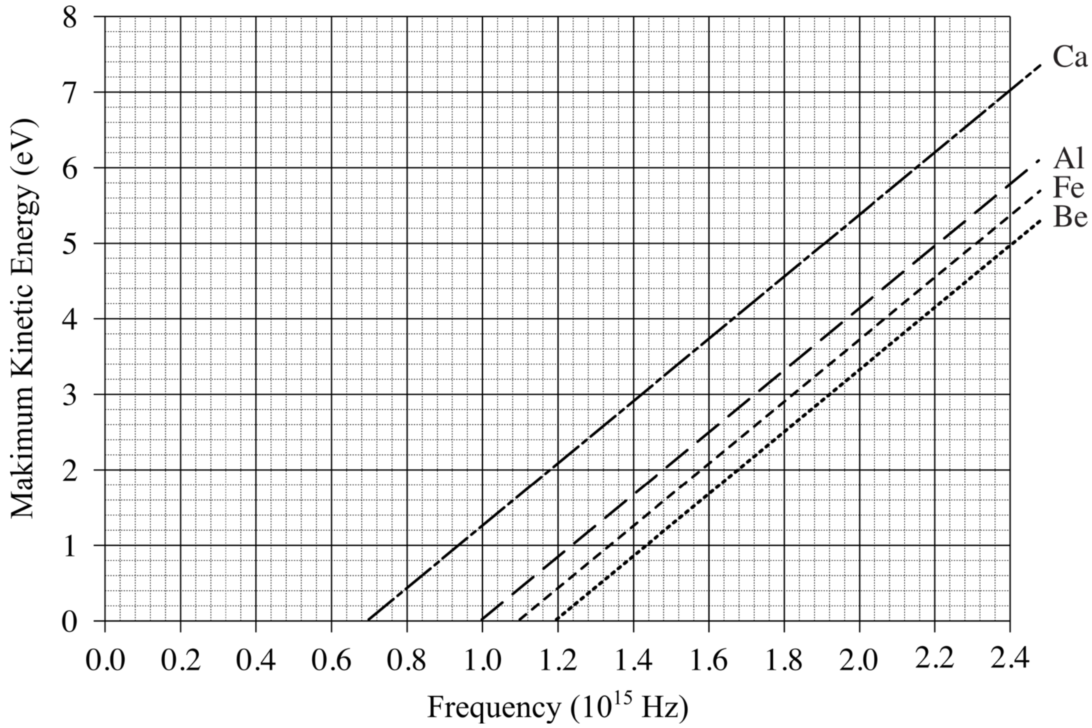
A.


B.


C.


D.


7. When electromagnetic radiation shines on metals, photoelectrons may be emitted. The maximum kinetic energy of emitted photoelectrons is plotted against radiation frequency for four metals as shown in the graph.

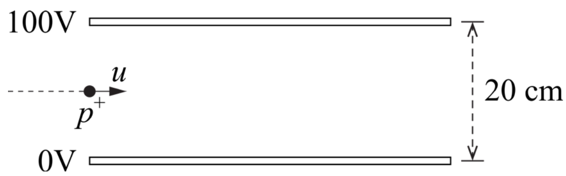


Electromagnetic radiation of wavelength 167 nm shines upon an unknown metal and the maximum kinetic energy of the photoelectrons is found to be 4.0×10^{-19} J.

Based on this information, what is the unknown metal?

A. Al
B. Be
C. Ca
D. Fe

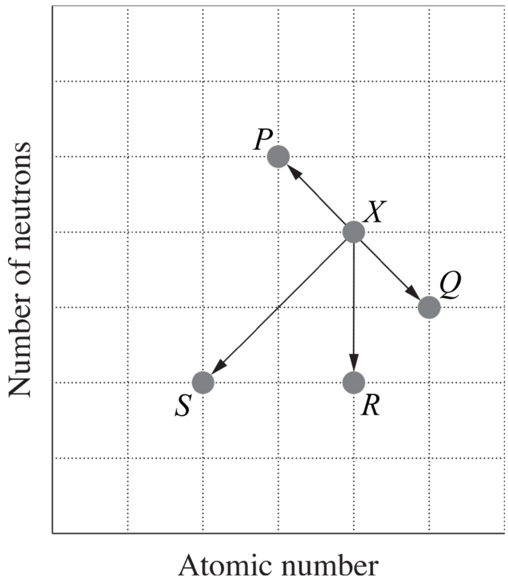
8. A proton, p+, enters an electric field between two parallel charged plates with an initial velocity of u m s^{-1}.



After two microseconds, the proton's velocity is in the direction 45° from the horizontal. What is the magnitude of the velocity at two microseconds?

A. u
B. $1.4u$
C. 1.35×10^5 m s^{-1}
D. 9.58×10^4 m s^{-1}

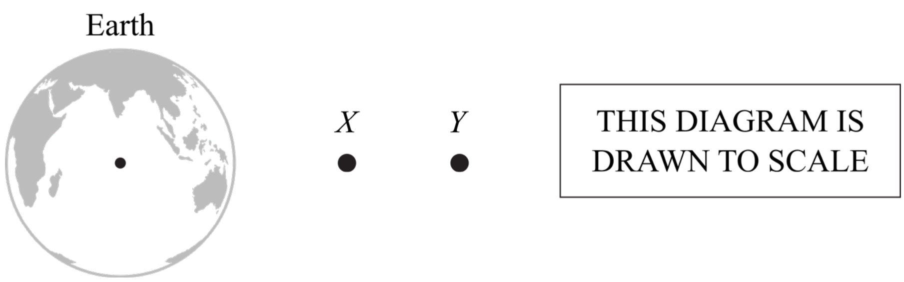
9. A radioisotope, X, undergoes β^- decay.



Which choice below represents the product of the decay?

A. P
B. Q
C. R
D. S

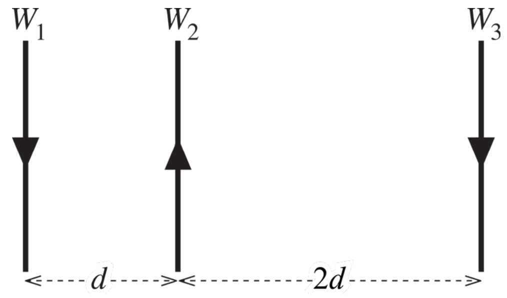
10. The gravitational potential energy of a mass positioned at X in the gravitational field of earth is U_x? and for the same mass positioned at Y is U_y. The diagram is drawn to scale.



What is the value of $\frac{U_x}{U_y}$?

A. 0.50
B. 0.67
C. 1.5
D. 2.0

11. Three identical wires W_1, W_2 and W_3 are positioned as shown. Each carries a current of the same magnitude in the direction indicated.



If the wire W_1, exerts a force on wire W_2 of F, then what is the magnitude and direction of the total, resultant force on W_2?

	Magnitude	*Direction*
A.	zero	none
B.	½F	left
C.	F	right
D.	½F	right

12. The radioactive decay of thorium-232 is:

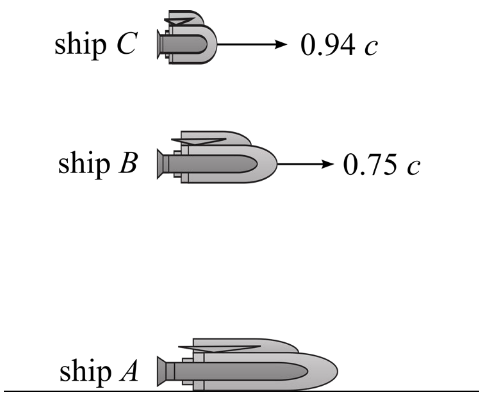
$$^{232}_{90}Th \longrightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$$

Using the information in the table below, what is the energy released as a result of this decay?

Nucleus or particle	*Mass* (u)
$^{232}_{90}Th$	232.038055
$^{228}_{88}Ra$	228.031070
$^{4}_{2}He$	4.001506

A. 5.10 MeV
B. 931.5 MeV
C. 3.73 GeV
D. 7.46 GeV

13. Three identical spaceships are near each other at a given time. An astronaut on ship *A*, sitting on a platform on earth, observes the lengths of the two other spaceships, ship *B* and ship *C*, as they pass by earth at 0.75 *c* and 0.94 *c*, respectively, as shown in the diagram below.



What would the astronauts on the two passing ships observe?

	Astronaut on ship B	*Astronaut on ship C*
A.	length of ship A > length of ship C	length of ship A > length of ship B
B.	length of ship A > length of ship C	length of ship A < length of ship B
C.	length of ship A < length of ship C	length of ship A > length of ship B
D.	length of ship A < length of ship C	length of ship A < length of ship B

14. The table contains information related to two moons orbiting mars.

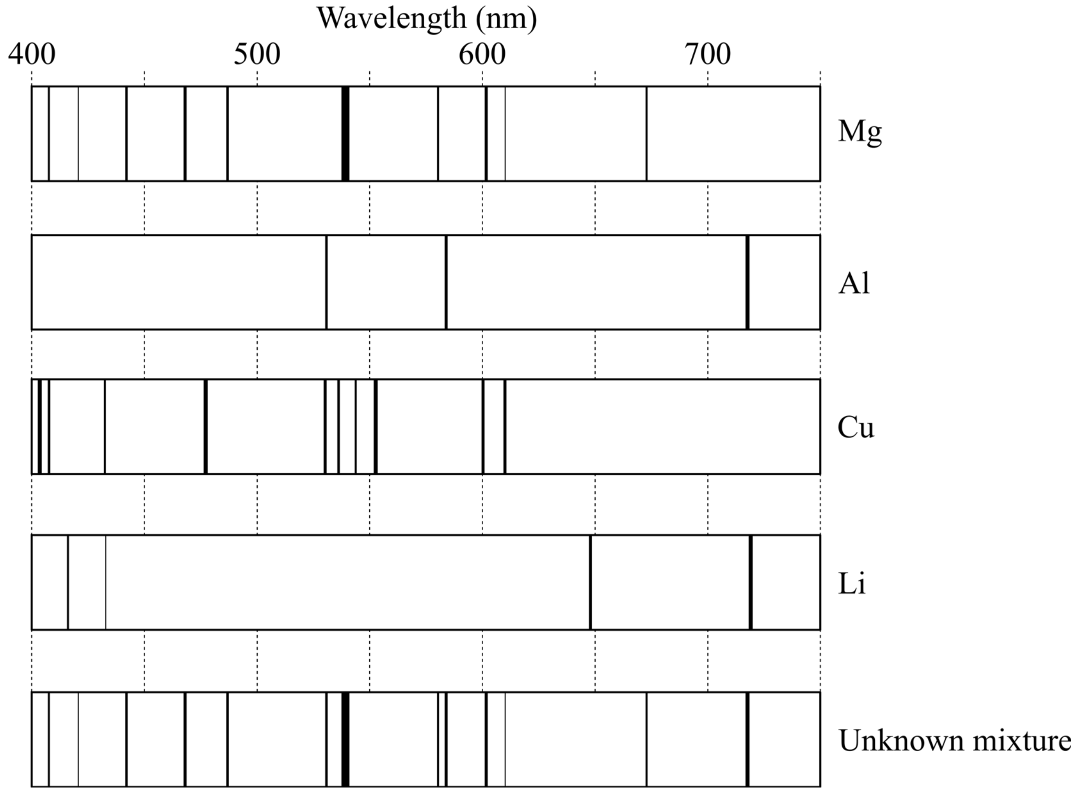
Moon	*Mass (kg)*	*Orbital radius (m)*	*Orbital velocity (km s^{-1})*
Deimos	1.476×10^{15}	2.35×10^{7}	1.35
Phobos	1.066×10^{16}	9.38×10^{6}	—

The orbital velocity of Phobos can be determined by using data selected from this table.

What is the orbital velocity of the moon Phobos?

A. 1.84 km s^{-1}
B. 2.14 km s^{-1}
C. 2.50 km s^{-1}
D. 5.37 km s^{-1}

15. The emission spectra from a selection of metals and an unknown mixture of metals is shown within the visible waveband in the figure below.



What metals are in the unknown mixture?

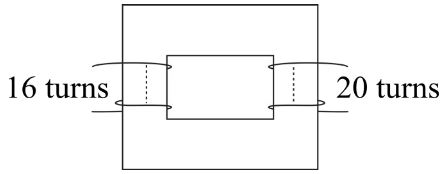
A. Lithium and copper
B. Aluminium and copper
C. Aluminium and magnesium
D. Lithium, Aluminium and magnesium

16. What is the wavelength, in metres, of a photon emitted from a hydrogen atom when an electron in the $n = 2$ level makes a transition to the $n = 1$ level?

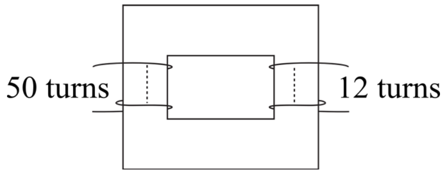
A. 1.09×10^{-18}
B. 1.22×10^{-7}
C. 8.23×10^{6}
D. 4.57×10^{14}

17. Which of the following ideal transformers could be used to convert an input voltage of 40 volts AC to an output voltage of 8 volts AC?

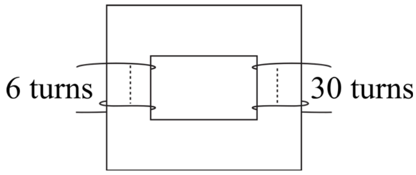
A.



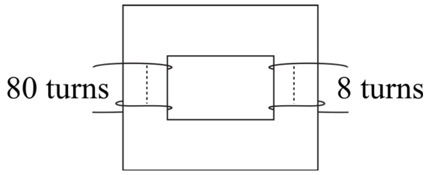
B.



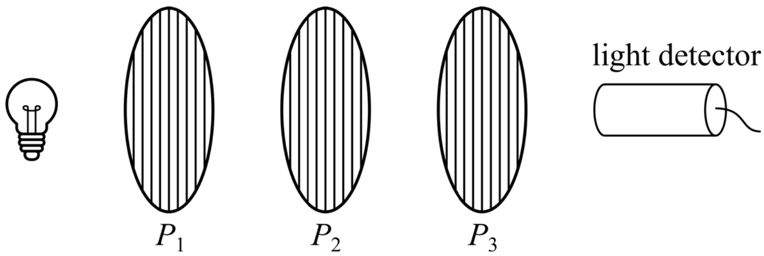
C.



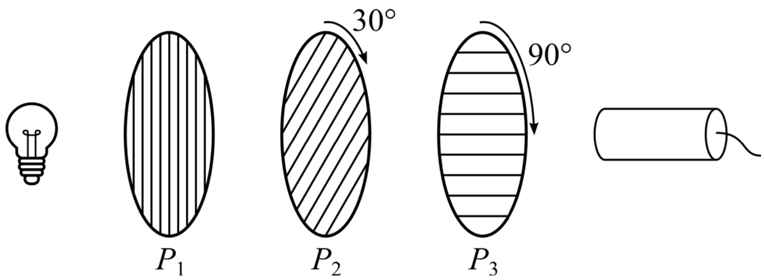
D.



18. Three polarisers, P_1, P_2 and P_3, were placed in between a light source and a light detector with their polarising axes aligned parallel, as shown in the diagram below. The light detector recorded a light intensity of I.



Polariser P_2 and P_3 were rotated clockwise, 30° and 90°, respectively. What light intensity did the light detector record?



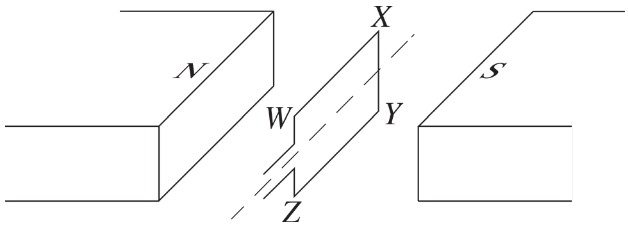
A. zero

B. $0.19I$

C. $0.50I$

D. I

19. The diagram shows some parts of a simple AC motor.



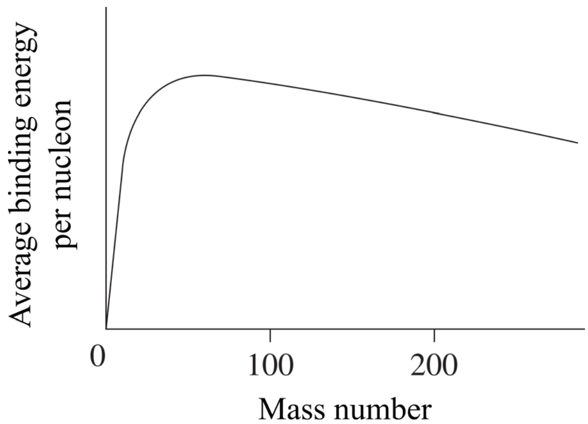
Which row of the table correctly describes the direction of force acting on side WX and the direction of torque this produces on the coil.

	Direction of force acting on WX	*Direction of torque produced on the coil by the force acting on WX*
A.	Remains constant	Remains constant
B.	Remains constant	Reverses every 180°
C.	Reverses every 180°	Remains constant
D.	Reverses every 180°	Reverses every 180°

20. In 1981, a German research team produced 5 atoms of the isotope bohrium-262 via the following nuclear reaction:

$$^{209}_{83}Bi + ^{54}_{24}Cr \longrightarrow ^{262}_{107}Bh + ^{1}_{0}n$$

Based on the graph below, which of the following choices best describes the nuclear process and energetics of this reaction?



	Nuclear reaction is:	*Energy is:*
A.	fission	released
B.	fission	absorbed
C.	fusion	released
D.	fusion	absorbed

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NESA Student Number:

Sydney Boys High School 2022 Trial

Physics

Section II Answer Booklet 1

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

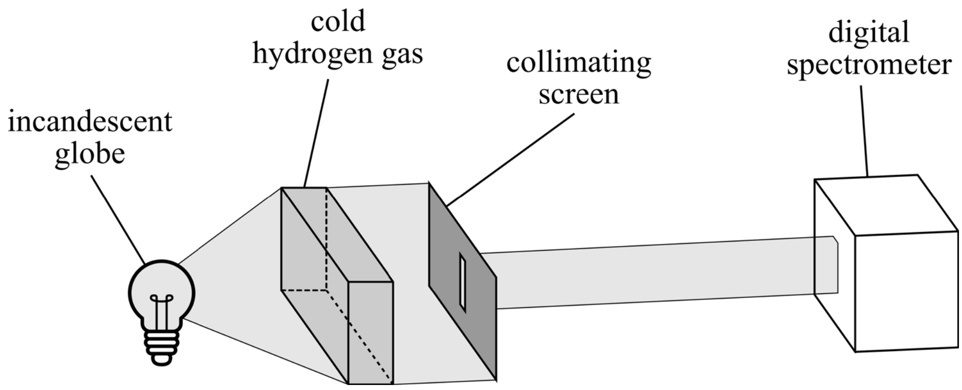
Instructions

- Write your 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.

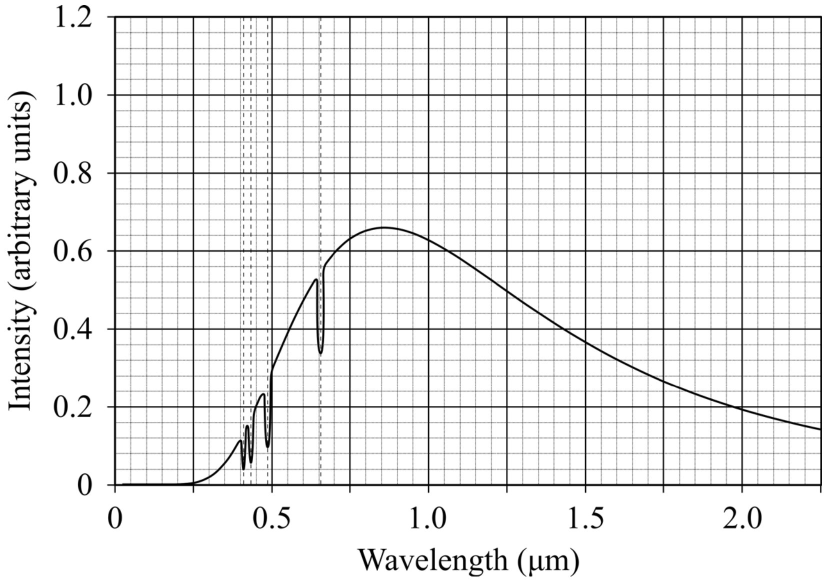
Please turn over

Question 21 (7 marks)

The light from an incandescent bulb passes through a transparent container of cold hydrogen gas before passing though a collimating slit, as shown in the diagram below.



The collimated light is incident on a digital spectrometer that measures the spectral intensity curve, which is shown on the graph below.



Question 21 continues on page 15

Question 21 (continued)

(a) Explain the absorption dips in the curve in terms of the Bohr model of the atom, with reference to the law of conservation of energy. **2**

(b) Calculate the temperature of the incandescent globe. **2**

(c) On the same graph, sketch the curve expected if the experiment is repeated with another incandescent globe radiating at a higher temperature. Assume the absorption dips are approximately the same height. **3**

End of Question 21

Question 22 (6 marks)

Thomas Young described an experiment where light was passed through two slits and the subsequent result was projected on to a screen. The diagram below shows the results predicted by two different models.

Prediction X

Prediction Y

(a) Identify an assumption of EACH model that determines the results on the screen. **2**

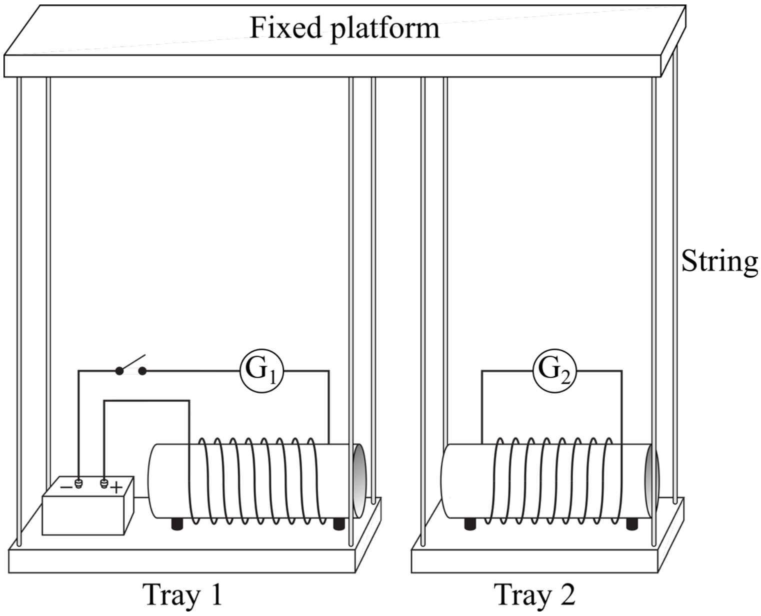
(b) How did Young's results help lead to the reconceptualisation of the model of light? **4**

Question 23 (4 marks)

Use the work of TWO scientists to explain how the combination of their experiments led to a better understanding of the electron? **4**

Question 24 (9 marks)

Two solenoids are mounted on trays as shown. Each tray is suspended by identical strings of negligible mass to a fixed platform, such that each tray can swing freely. Each solenoid is connected to a galvanometer, and the solenoid on tray 1 is also connected to an open switch and a battery. The total mass of tray 1 is twice that of tray 2. **9**



Explain what would be observed when the switch on tray 1 is closed. In your answer, refer to the current in each galvanometer and the movement of the trays until they reach their maximum displacement.

Question 24 continues on page 19

Question 24 (continued)

End of Question 24

Question 25 (7 marks)

A scientist was studying the radioactive decay of beryllium-11. His results are shown in the table below.

Time (s)	*Mass of beryllium-11 (g)*	$\ln(N_t/N_0)$
2	32.6	0
7	21.8	−0.25
13	16.1	−0.55
20	11.4	−0.90
24	9.3	−1.10

(a) Plot the results for *time* and $\ln(N_t/N_0)$ on the grid below. **5**

Question 25 continues on page 21

Question 25 (continued)

(b) Use your graph to determine the decay constant of beryllium-11. **2**

End of Question 25

Question 26 (4 marks)

(a) Outline a practical investigation to observe the emission spectra of gas discharge tubes. **2**

(b) Identify ONE potential hazard associated with performing gas discharge tube investigations, and outline ONE safe work practice which addresses this hazard. **2**

Question 27 (5 marks)

(a) Using de Broglie's hypothesis, calculate the wavelength of the electron in the first stationary state if its speed is 2.188×10^{6} m s^{-1}. **2**

(b) Describe how de Broglie's hypothesis extended the work of Bohr in explaining the stability of electron orbits in the hydrogen atom. **3**

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NESA Student Number:

Sydney Boys High School 2022 Trial

Physics

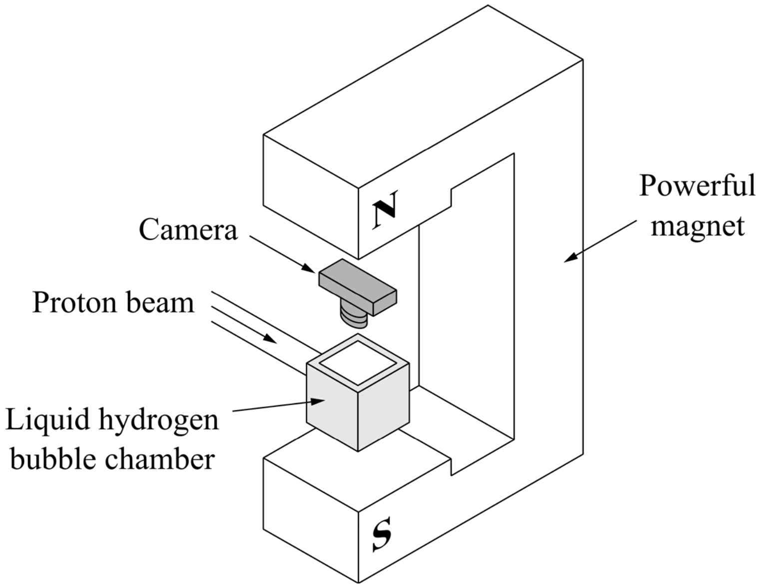
Section II Answer Booklet 2

Please turn over

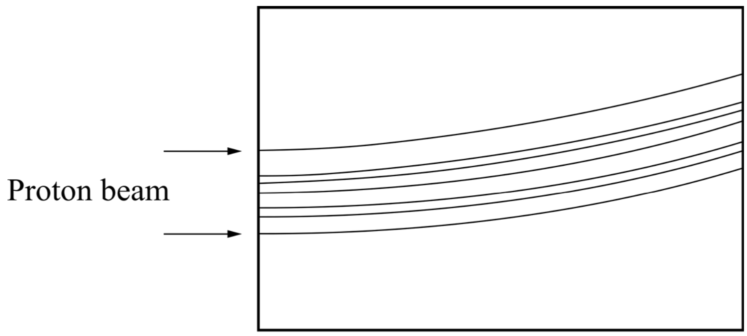
Question 28 (7 marks)

Bubble chambers are used in conjunction with particle accelerators to photographically record the tracks of fast-moving charged particles. An intense magnetic field is applied at right angles to the path of the particles to deflect them according to their charge and momentum.

The diagram shows a beam of protons travelling horizontally and entering a liquid hydrogen bubble chamber in a vertical magnetic field of 25.0 mT.



Examination of the photograph taken by the camera, as sketched below, shows that the protons were deflected along a circular path of radius 0.280 metres.



Proton tracks in bubble chamber

Question 28 continues on page 27

Question 28 (continued)

(a) Derive an expression for the velocity of a proton from the forces it experiences in this experiment. **2**

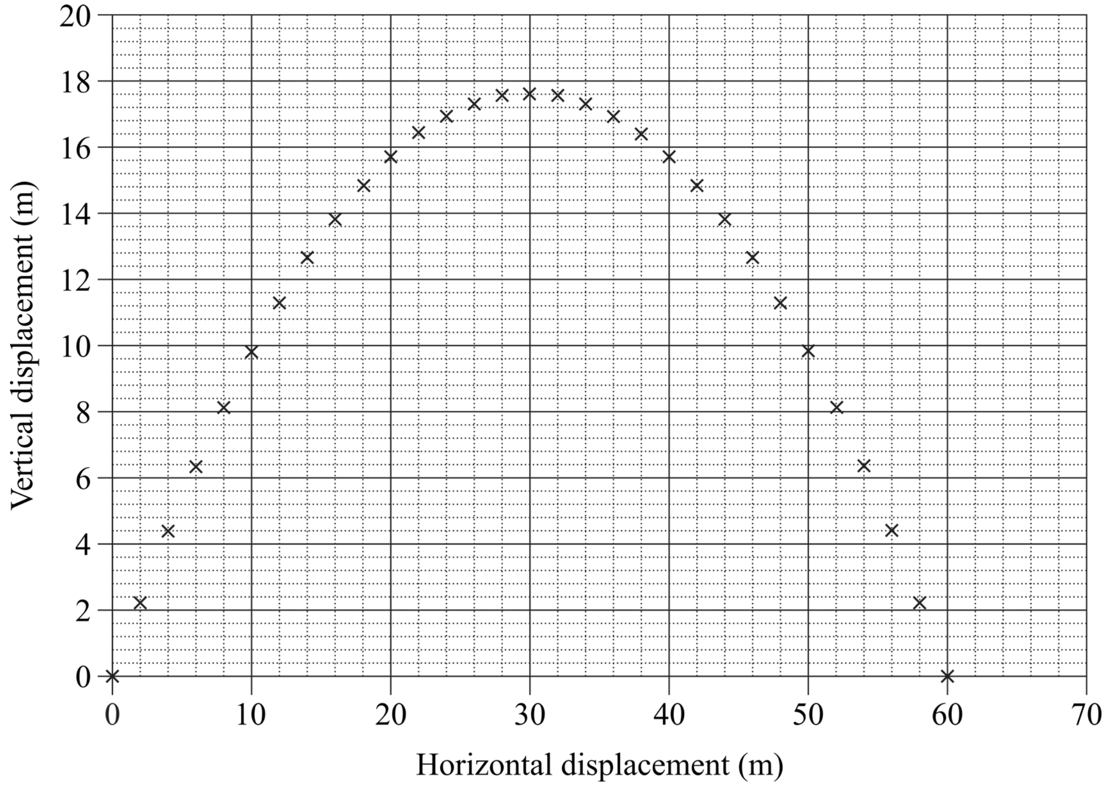
(b) Calculate the velocity of a proton in the bubble chamber. **2**

(c) Outline TWO limitations of applying special relativity to the analysis of the motion of the protons in this experiment. **3**

End of Question 28

Question 29 (4 marks)

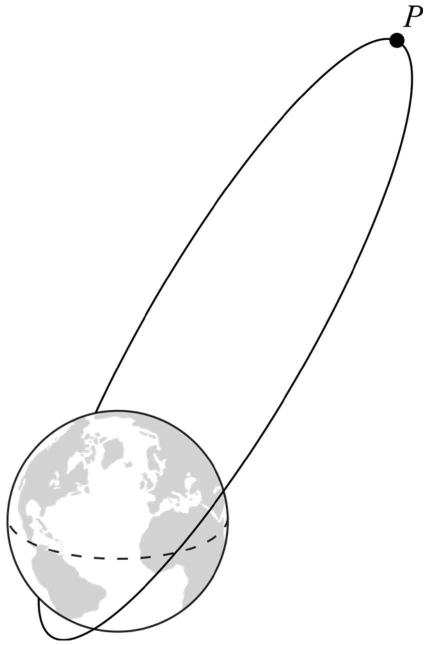
The graph shows the vertical displacement of a projectile throughout its trajectory on earth. **4**



Calculate the initial velocity of the projectile.

Question 30 (3 marks)

A Molniya orbit is an inclined, highly elliptical orbit with a period of 12 hours, designed to provide communications and remote sensing coverage over high latitudes.



Account for the changes in velocity of the satellite as it completes one orbit from position *P*. **3**

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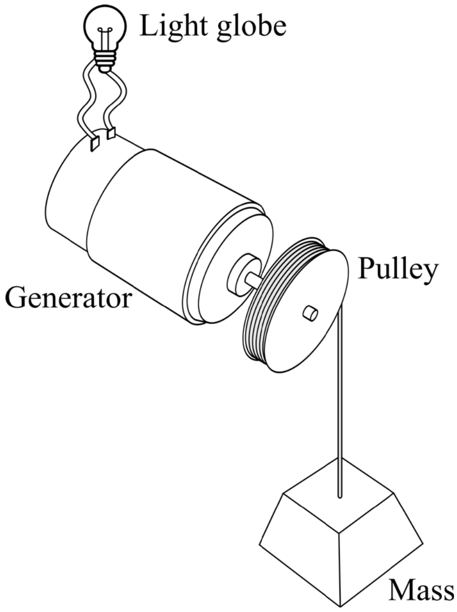
Question 31 (7 marks)

The *g-lite* was designed to provide light to remote locations that do not have access to electricity. It uses a lowering mass to drive a generator to illuminate a light globe. **7**



Explain the factors that affect the maximum brightness of the light globe. Use mathematical models to support your answer.

Question 31 continues on page 31

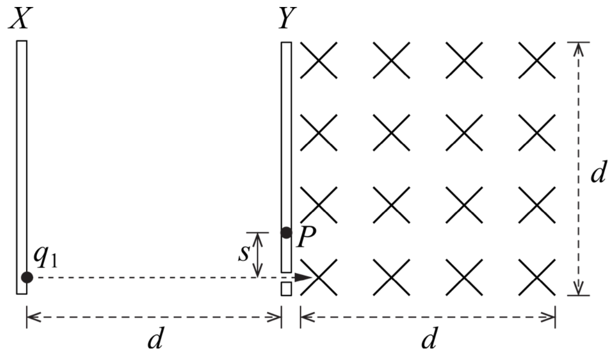
Question 31 (continued)

End of Question 31

Question 32 (6 marks)

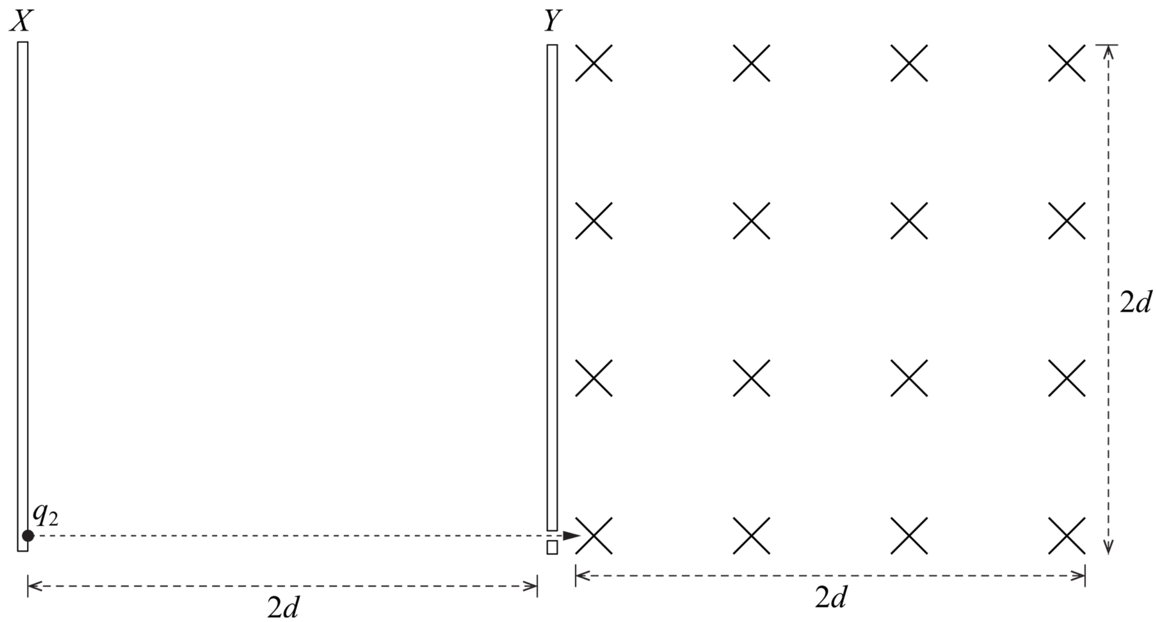
A charged particle, q_1, is accelerated from rest between oppositely charged plates X and Y, before entering a uniform magnetic field, as shown in the diagram below.

The particle strikes plate Y at point P, a vertical distance s from its entry point into the magnetic field. Ignore the effect of gravity.



The experiment is repeated with an apparatus that is twice the size, as shown in the diagram below. The voltage between the plates and the magnetic flux are the same.

An identical particle, q_2, is accelerated from rest between the oppositely charged plates, before entering the uniform magnetic field.



Question 32 continues on page 33

Question 32 (continued)

(a) Compare the work done on q_1 and q_2. Justify your answer. **3**

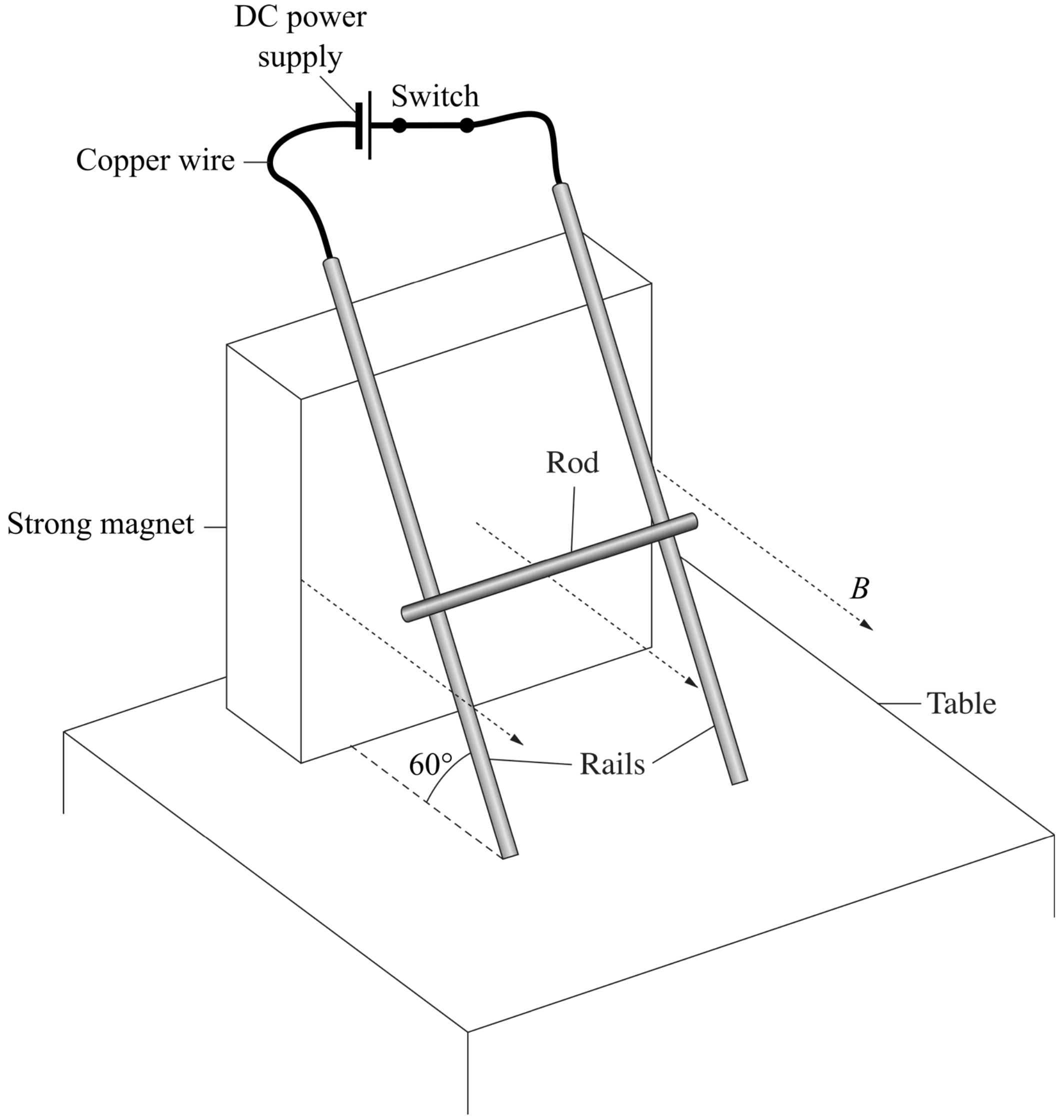
(b) Compare the vertical distances travelled by q_1 and q_2 in the magnetic field. **3**

End of Question 32

Question 33 (8 marks)

A 500 g metal rod is allowed to slide along a pair of parallel metal rails, 30 cm apart and tilted at 60° to the horizontal. The rods are connected to a DC power supply and switch, which results in a current of 2.8 A passing through the rod.

The apparatus is in a uniform magnetic field of 2.5 T which is outward, perpendicular to the strong magnet.



(a) What is the force, including its direction, acting on the rod solely due to the magnetic field? **2**

....

....

....

....

Question 33 continues on page 35

(b) Calculate the initial acceleration of the rod along the rails. **3**

(c) The experiment is repeated with the switch open. **3**

Explain why the acceleration of the rod is different with the switch open.

End of Question 33

Question 34 (3 marks)

A spaceship travels to a distant star at a constant speed, v. When it arrives, 17.6 years have passed on Earth but 9.2 years have passed for an astronaut on the spaceship. **3**

What is the distance to the star, as measured by an observer on Earth?

End of paper

Sydney Boys High School

NESA Student Number:

Multiple Choice Answer Sheet

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

A ⊗ B ⊗ ← **correct** C ○ D ○

Start Here ➔

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

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.

---

1. The velocity is tangent to the trajectory, and the acceleration (due to gravity) is always down.

2. Hertz validated the existence of electromagnetic waves (producing radio waves with the induction coil).

3. In the train application, the relative motion between the electromagnet and the rails induces eddy currents in the rail (due to Lenz's Law) so as to reduce relative motion between the electromagnet and the rails (thereby slowing the train down). An induction motor works the same way, except to use the relative motion between the rotating magnetic field and the axle, so as to speed up the axle and reduce relative motion between the two.

4. Neither neutrons nor gamma radiation will be deflected by a magnetic field, and both types of radiation have high penetrating powers and eject protons from paraffin. However, neutrons will not produce the photoelectric effect, whilst gamma radiation will (it will definitely have an energy greater than the work function of a metal).

5. The centripetal force is the net force resulting in circular motion, not the tension in the string:

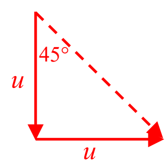
$$F_C = \frac{mv^2}{r} = \frac{m(\omega r)^2}{r} = m\omega^2 r = m\omega^2 l \cos\theta = 0.02 \times (4\pi)^2 \times 1.1 \times \cos 30 = 3.0 \text{ N}$$

6. Geiger and Marsden produced the results that Rutherford used to develop his model nuclear of the atom. The small number of large-angle deflections indicated a central positive nucleus surrounded by negative electrons.

7. From Planck, $c = f\lambda \quad \Rightarrow \quad f = \frac{c}{\lambda} = \frac{3.00\times10^{8}}{167\times10^{-9}} = 1.80 \times 10^{15}$ Hz

Given that $K_{\max\,(eV)} = \frac{K_{\max\,(J)}}{|q_e|} = \frac{4.0\times10^{-19}}{1.602\times10^{-19}} = 2.50$ eV, reading from the graph $(1.80 \times 10^{15}\ \text{Hz}, 2.50\ \text{eV})$ corresponds to Be.

8. The field strength is irrelevant for this question. From the vector diagram shown to the right, for the velocity to be 45° to the horizontal, then the vertical component must also be u m s^{-1}. This means that the net velocity has a magnitude of $\sqrt{2}u = 1.4u$ m s^{-1}.



9. β⁻ decay involves $p^+ \longrightarrow n^0 + e^-$, so the nuclide loses 1 proton and gains 1 neutron. Thus, the number of protons (atomic number) goes down by 1 and the number of neutrons goes up by 1.

10. From the scale diagram, $r_X = 2.8$ cm and $r_Y = 4.2$ cm. Therefore:

$U = -\frac{GMm}{r}, U \propto -\frac{1}{r}$. Therefore, $\frac{U_X}{U_Y} = \frac{-\frac{1}{r_X}}{-\frac{1}{r_Y}} = \frac{r_Y}{r_X} = \frac{4.2}{2.8} = 1.5$

11. From $\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$, given that $l, I_1$and I_2 are the same, $F \propto \frac{1}{r}$. From the question, $F_{1,2} = F$ to the right (repelled by W_1). From the diagram, $F_{3,2} = \frac{1}{2}F_{1,2} = \frac{1}{2}F$ to the left (repelled by W_3). Therefore, net force is $F_{net} = F_{1,2} - F_{3,2} = F - \frac{1}{2}F = \frac{1}{2}F$ to the right.

12. $m_{defect} = m_{reactants} - m_{products} = 232.038055 - (228.031070 + 4.001506)$
$= 0.005479u = 9.101 \times 10^{-30}$ kg
$E = mc^2 = 9.101 \times 10^{-30} \times (3.00 \times 10^8)^2$
$= 8.19 \times 10^{-13}$ J $= 5.10 \times 10^6$ eV $= 5.10$ MeV

13. An astronaut on *ship B* will see *ship A* moving backwards at 0.75 *c* and *ship C* moving forwards at 0.19 *c*. Therefore, *ship A* is moving faster with respect to *ship B* and will appear shorter than *ship C*.
An astronaut on *ship C* will see *ship A* moving backwards at 0.94 *c* and *ship B* moving backwards at 0.19 *c* and. Therefore, *ship A* is moving faster with respect to *ship C* and will appear shorter than *ship B*.

14. Combining Kepler's Law, $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$, and orbital velocity, $v = \frac{2\pi r}{T}$, gives:

$$\frac{r^3}{\left(\frac{2\pi r}{v}\right)^2} = \frac{rv^2}{4\pi^2} = \frac{GM}{4\pi^2} \quad \Rightarrow \quad rv^2 = GM$$

Given that GM is constant for objects orbiting the same body,

$$r_P v_P^2 = r_D v_D^2 \quad \Rightarrow \quad v_P = v_D\sqrt{\frac{r_D}{r_P}} = 1.35 \times \sqrt{\frac{2.35 \times 10^7}{9.38 \times 10^6}} = 2.14 \text{ km s}^{-1}$$

15. Use distinctive, unique wavelengths, such as 540 nm (Mg), 720 nm (Al), 553 nm (Cu) or 648 nm (Li). The unknown mixture has 540 nm (Mg) and 720 nm (Al), but not 553 nm (Cu) nor 648 nm (Li).

16. From Rydberg formula, $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097 \times 10^7 \times \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 8.23 \times 10^6 \text{ m}^{-1}$
Therefore, $\lambda = \frac{1}{8.23\times 10^6} = 1.22 \times 10^{-7}$ m

17. $\frac{V_P}{V_S} = \frac{N_P}{N_S} \quad \Rightarrow \quad \frac{N_P}{N_S} = \frac{40}{8} = 5$
The only transformer with a coil ratio of 5 has 30 turns on the right and 6 turns on the left.

18. From Malus' Law, $I = I_{max}\cos^2\theta$:
$P_1 \rightarrow P_2$: $I_2 = I\cos^2 30 = 0.75I$
$P_2 \rightarrow P_3$: $I_3 = I_2\cos^2\theta = 0.75I\cos^2(90 - 30) = 0.19I$

19. From an AC current, the direction of the force on *WX* will reverse every 180°. A motor requires torque in a continuous direction in order to turn, so torque on the coil must always be in the same direction.

20. Two nuclei are combining to make a larger nucleus, which describes fusion (the emitted neutron is not considered another nucleus).
The move from $^{209}_{83}Bi$ and $^{54}_{24}Cr$ to $^{262}_{107}Bh$ is moving down the right-hand side of the binding energy per nucleon curve, meaning that the average binding energy per nucleon is decreasing and the product is less stable that the reactants. Therefore, the reaction is endothermic (energy must go into the reaction in order for it to proceed).

NESA Student Number:

Sydney Boys High School 2022 Trial

Physics

Section II Answer Booklets

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

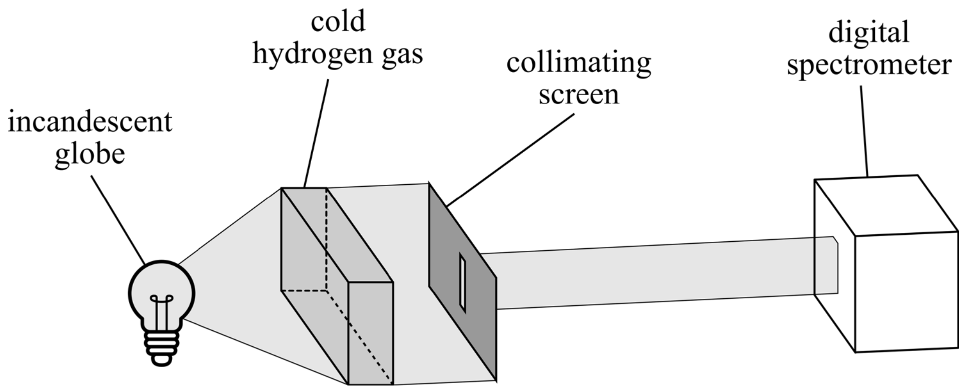
Instructions

- Write your 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.

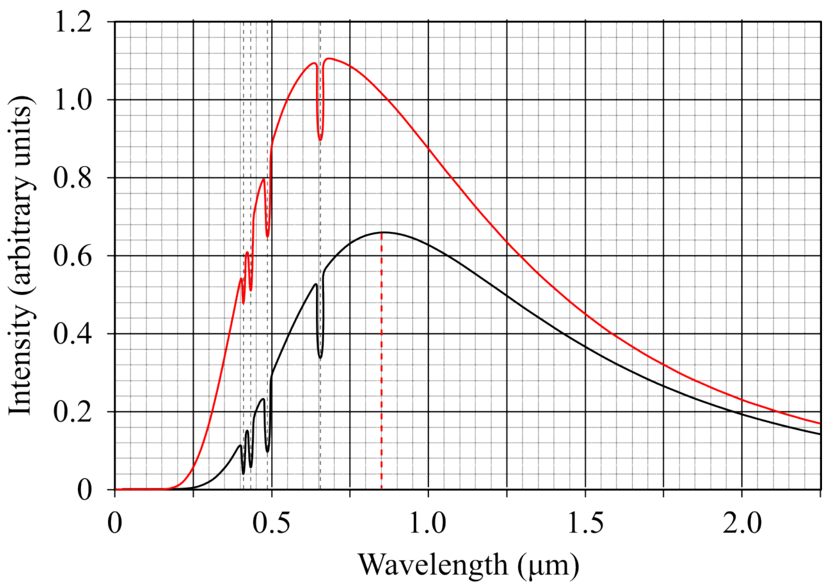
Please turn over

Question 21 (7 marks)

The light from an incandescent bulb passes through a transparent container of cold hydrogen gas before passing though a collimating slit, as shown in the diagram below.



The collimated light is incident on a digital spectrometer that measures the spectral intensity curve, which is shown on the graph below.

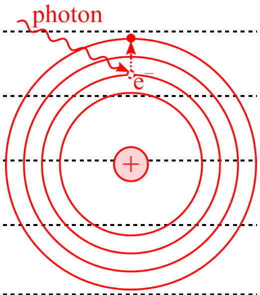


Question 21 continues on page 7

Question 21 (continued)

(a) Explain the absorption dips in the curve in terms of the Bohr model of the atom, with reference to the law of conservation of energy. **2**

The absorption dips are due to electrons moving from the second electron orbit (corresponding to the Balmer series) to a higher electron orbit, with a higher energy. This increase in electron energy requires an input of energy into the electron, via the absorption of a photon. In this way, the total energy of the photon and electron in the lower orbit before absorption is equal to the energy of the electron in the higher orbit, according to the law of conservation of energy:



$$\sum E_i = \sum E_f$$

$$E_{photon} + E_{i(electron)} = E_{f(electron)}$$

✓ identifies electron transition to higher orbit
✓ relates increase in energy to photon energy (*must* refer to LOCOE)

note: a number of students explained in terms of emission lines, which are irrelevant to this question

(b) Calculate the temperature of the incandescent globe. **2**

From Wein's displacement law:

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

From the spectrum, $\lambda_{max} = 0.85 \times 10^{-6}$ m:

$$T = \frac{b}{\lambda_{max}} = \frac{2.898 \times 10^{-3}}{0.85 \times 10^{-6}} = 3409 = 3400 \text{ K}$$

✓ uses correct equation
✓ correct value (±100 K) & units

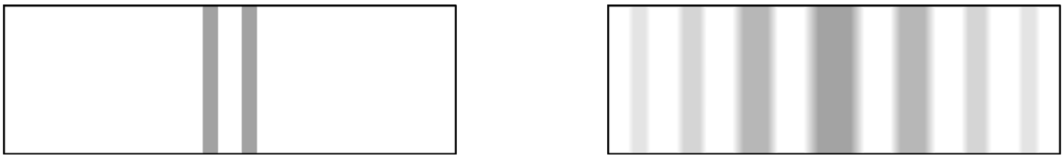
(c) On the same graph, sketch the curve expected if the experiment is repeated with another incandescent globe radiating at a higher temperature. Assume the absorption dips are approximately the same height. **3**

✓ curve has higher intensity across spectrum
✓ curve has shorter peak wavelength
✓ absorption dips have same wavelengths

End of Question 21

Question 22 (6 marks)

Thomas Young described an experiment where light was passed through two slits and the subsequent result was projected on to a screen. The diagram below shows the results predicted by two different models.



Prediction X *Prediction Y*

(a) Identify an assumption of EACH model that determines the results on the screen. **2**

Prediction X corresponds to the assumption that light is a particle/corpuscle in nature.

Prediction Y corresponds to the assumption that light is wave in nature.

✓ identifies particle and wave models OR correctly identifies one model
✓ correctly identifies both models

(b) How did Young's results help lead to the reconceptualisation of the model of light? **4**

At the time of Young's experiment, Newton's corpuscular model was the accepted model for light. Young's experiment involved passing a fine beam of light through two small slits, close together. This produced an interference pattern, consisting of alternating bright and dark regions (such as that shown in *Prediction Y*). Interference is strictly a wave phenomenon (particles cannot interfere), meaning that the production of an interfereence pattern by the light indicated that light was wavelike in nature. This challenged Newton's particle model of light, paving the way for Huygens' wave model to be accepted in the intervening years.

✓ identifies initially accepted particle model of light
✓ describes Young's results
✓ identifies new wave model of light
✓ relates Young's results to wave model

notes: * "reconceptualisation" refers to a change – you need to show how initial model is changed to the new model
* Young's results did *not* lead to wave-particle duality model
* avoid using the word "prove" (or its derivatives) – it is a *very* strong word in science (hard to use correctly)

Question 23 (4 marks)

Use the work of TWO scientists to explain how the combination of their experiments led to a better understanding of the electron? **4**

JJ THOMSON performed his charge-to-mass experiment by passing cathode rays through perpendicular electric and magnetic fields. By carefully controlling the electric and magnetic fields, and measuring the corresponding deflections of the cathode rays, he was able to demonstrate that the cathode rays had a fixed charge-to-mass ratio, regardless of the cathode metal used. Thus, he confirmed that cathode rays behaved like negatively charged particles, thereby discovering the electron.

GP THOMSON (JJ Thomson's son) fired a beam of electrons at thin films of aluminium and gold. On the other side of the gold foil was a photographic plate. The results showed clear diffraction rings of the electrons, allowing the crystal dimensions to be measured. These electron diffraction patterns were compared to those from x-rays, showing a remarkable similarity, and agreeing with the measured crystal dimensions. In this way, GP Thomson confirmed de Broglie's hypothesis that electrons could behave like waves.

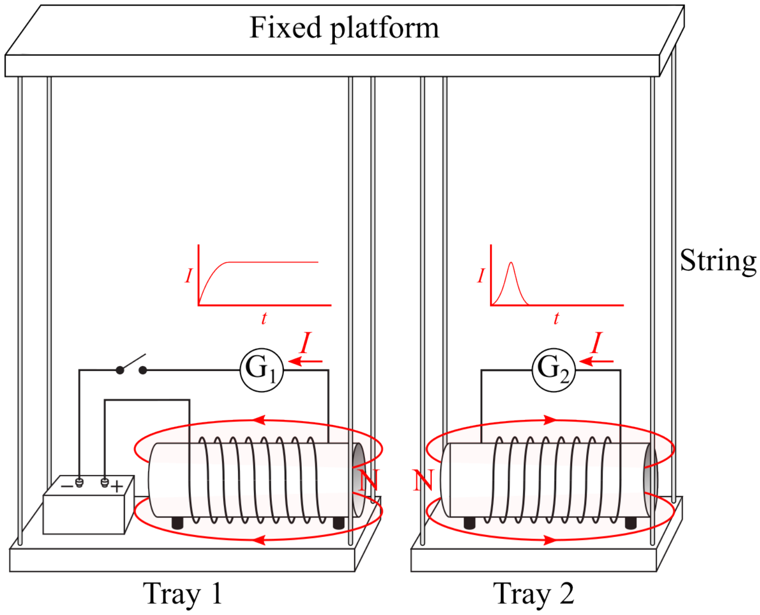
Thus, the work of JJ and GP Thomson combine to give a comprehensive model of the electron that includes the wave-particle duality of electrons.

✓ identifies TWO relevant scientists
✓ outlines experiment of ONE scientist
✓ outlines experiments of TWO scientists
✓ relates experiments to properties/nature of the electron

notes:
* only the first TWO scientists mentioned were considered
* you <u>must</u> relate the work of each scientist to the *properties* or *nature* of the electron, not just the experimental variable
* other scientists include Millikan (charge of an electron), Bohr (behaviour of electrons in atoms), de Broglie (matter-wave hypothesis), Schrödinger (wavefunction)
* Millikan determined the *charge* of the electron (not its mass), and his value was not 1.602×10^{-19} C – it was actually smaller, at 1.592×10^{-19} C
* Geiger-Marsden didn't developed understanding of electrons – only that they weren't in the nucleus
* Planck & Einstein developed understanding of nature of light, not electrons

Question 24 (9 marks)

Two solenoids are mounted on trays as shown. Each tray is suspended by strings of negligible mass to a fixed platorm, such that each tray can swing freely. Each solenoid is connected to a galvanometer, and the solenoid on tray 1 is also connected to an open switch and a battery. The total mass of tray 1 is twice that of tray 2. **9**



Explain what would be observed when the switch on tray 1 is closed. In your answer, refer to the current in each galvanometer and the movement of the trays until they reach their maximum displacement.

When the switch is closed, a constant current will pass through solenoid 1 on tray 1, passing through galvanometer G_1 to the left (as indicated on the diagram above). This will lead to a continuous reading on G_1. As a result of this continuous current, solenoid 1 will be surrounded by a constant external magnetic field, starting from the right-hand side and continuing around to the left-hand side (corresponding to a north pole on the right hand side, as indicated above).

The initial increase in the current in solenoid 1 will lead to an increase in the magnetic field around solenoid 1, such that the solenoid 2 on tray 2 will experience an increasing magnetic flux to the right. This change in flux will lead to an emf (according to Faraday's Law, $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$), and this emf will produce a current in the closed circuit that will act to oppose the change in flux (according to Lenz's Law). Thus, the opposing flux will directed to the left through solenoid 2, resulting in a north pole on its left-hand side (as indicated above). This magnetic field is associated with a current that travels through galvanometer G_2 to the left (as

Question 24 continues on page 11

indicated on the diagram above). Given that the emf in the solenoid 2 is only induced when the magnetic field around solenoid 1 is changing, the current through solenoid 2 is brief, such that the needle on G_2 only flicks briefly.

Since closing the switch will produce a continuous north pole of the right-hand side of tray 1 and a temporary north pole on the left-hand side of tray 2, there will be a brief repulsive force between the two solenoids. This will push the two trays apart, exerting equal but opposite forces on the two trays (according to Newton's 3rd Law). As a result, they swing away from each other. Given that tray 1 is twice the mass of tray 2, it will experience half the acceleration of tray 1 (according to Newton's 2nd Law, $F = ma$).

In addition, from the conservation of momentum, the total momentum of the system is zero, and, intially, $p_1 = p_2 \quad \Rightarrow \quad m_1 v_1 = m_2 v_2 \quad \Rightarrow \quad \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{1}{2}$

Therefore, tray 2 will initially move with twice the velocity of tray 1. In addition, tray 2 moves off with a greater velocity, and it will swing out further than tray 1, gaining more vertical height above the rest position.

✓ provides some relevant information (note: never leave an answer blank)
✓ identifies continuous current to the left in G_1
✓ identifies correct field/pole(s) on solenoid 1
✓ correctly applies Lenz's Law between solenoids
✓ identifies correct current in G_2 for magnetic field of solenoid 2
✓ applies Faraday's law to temporary current in G_2
✓ relates facing poles to repulsion
✓ quantitatively applies LOCOM/Newton's 2nd to initial motion
✓ relates initial motion to swing height/distance

notes: * if you annotate/draw information on the diagram, it will *only* be considered for marking if you refer to it in your answer
* the direction a galvanometer needle moves does not indicate the direction of the current through the wires to the galvanometer (it depends on how it is connected)
* the question specifically asks for "current in each galvanometer", so describing the direction of current through the solenoid does not count

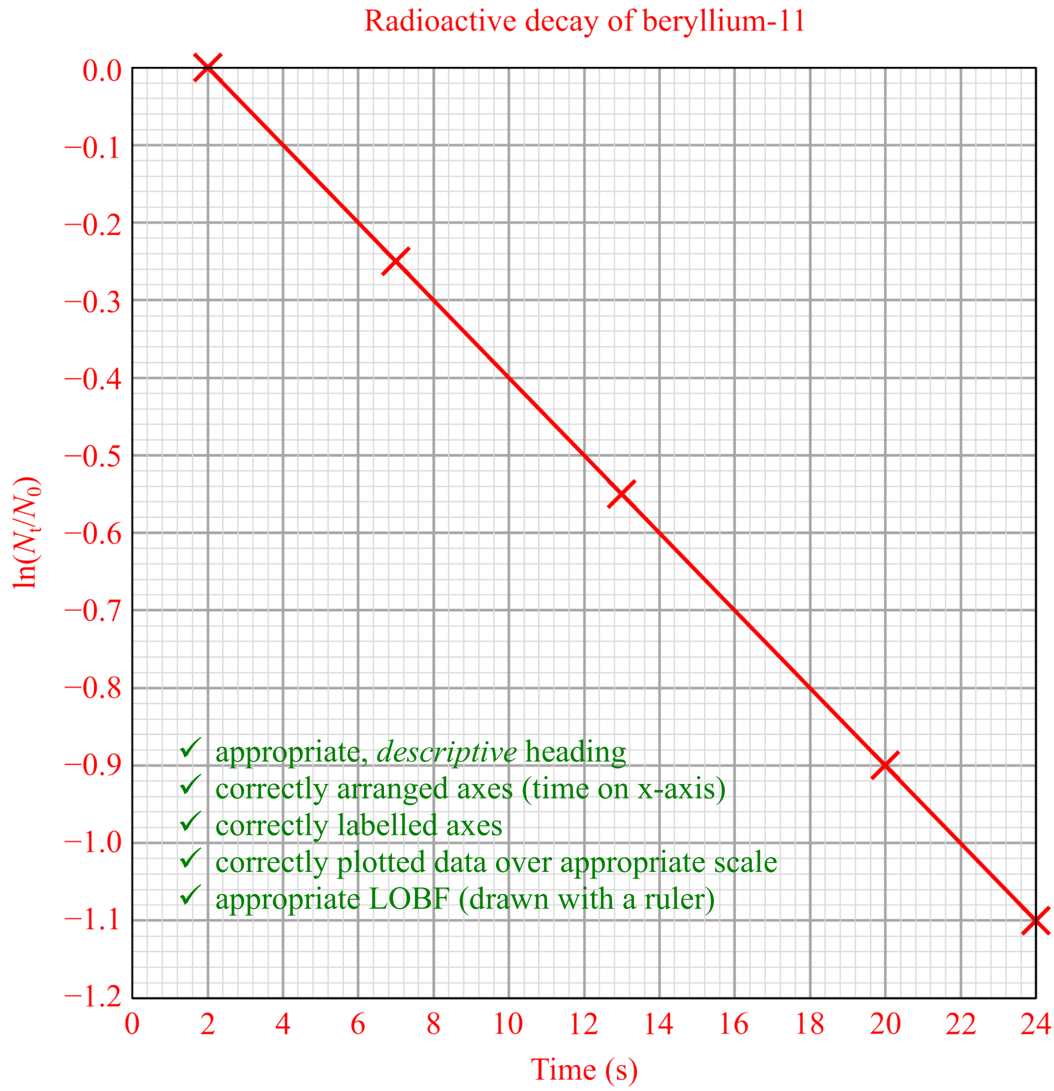
End of Question 24

Question 25 (7 marks)

A scientist was studying the radioactive decay of beryllium-11. His results are shown in the table below.

Time (s)	*Mass of beryllium-11 (g)*	$\ln(N_t/N_0)$
2	32.6	0
7	21.8	−0.25
13	16.1	−0.55
20	11.4	−0.90
24	9.3	−1.10

(a) Plot the results for *time* and $ln(N_t/N_0)$ on the grid below. **5**



note: a heading must provide context for the graph, so that a reader understands what the results are all about

Question 25 continues on page 13

(b) Use your graph to determine the decay constant of beryllium-11. **2**

From the graph:

$$gradient = \frac{rise}{run} = \frac{\ln\frac{N_0}{N_t}}{t} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{-1-(-0.1)}{22-4} = -0.050$$

From radioactive decay, $N_t = N_0 e^{-\lambda t}$

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

$$\ln\frac{N_t}{N_0} = -\lambda t$$

$$\lambda = -\frac{\ln\frac{N_0}{N_t}}{t} = -gradient = -(-0.050) = 0.050\ \mathrm{s^{-1}}$$

✓ uses appropriate calculation
✓ correct value (±0.001) & units

End of Question 25

Question 26 (4 marks)

(a) Outline a practical investigation to observe the emission spectra of gas discharge tubes. **2**

In order to observe the emission spectra of gas discharge tubes:

1. fasten a gas discharge tube to a retort stand, using a bosshead and clamp

2. connect the input of an induction coil to a power supply

3. connect the output of the induction coil to the gas discharge tube

4. turn on the power supply

5. observe the gas discharge tube using a hand-held spectroscope

✓ outlines appropriate investigation
✓ identifies all equipment used

notes: * you must include how to *produce* the spectrum (it needs a high voltage) and how to *observe* the spectrum
* gas discharge tubes are not dangerously bright (you should have seen one in class), nor hot

(b) Identify ONE potential hazard associated with performing gas discharge tube investigations, and outline ONE safe work practice which addresses this hazard. **2**

Hazards include:

* electrocution (high voltage)

* x-rays (sparking)

Safety measures include:

* using a tapping key/avoid touching metal parts during use

* reducing time of exposure/use for short times

✓ identifies an appropriate hazard
✓ outlines an appropriate safety measure

note: "*being careful*" or "*take care*" are not valid safety measures (they are *basic* scientific protocols)

Question 27 (5 marks)

(a) Using de Broglie's hypothesis, calculate the wavelength of the electron in the first stationary state if its speed is 2.188×10^6 m s^{-1}. **2**

From de Broglie's hypothesis:

$$\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}}{9.109\times10^{-31}\times2.188\times10^6} = 3.325\times10^{-10}\text{ m} = 0.3325\text{ nm}$$

✓ uses appropriate equation(s)
✓ correct value, units & sig figs

note: use of relativity is not necessary since effects are below degree of significant figures ($v = 0.00729c$, $\gamma = 1.0000266$), but using relativity gives:

$$\lambda = \frac{h}{\frac{m_e v}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}} = \frac{6.626\times10^{-34}}{\frac{9.109\times10^{-31}\times2.188\times10^6}{\sqrt{\left(1-\frac{(2.188\times10^6)^2}{(3.00\times10^8)^2}\right)}}} = 3.324\times10^{-10}\text{ m (difference due to rounding)}$$

(b) Describe how de Broglie's hypothesis extended the work of Bohr in explaining the stability of electron orbits in the hydrogen atom. **3**

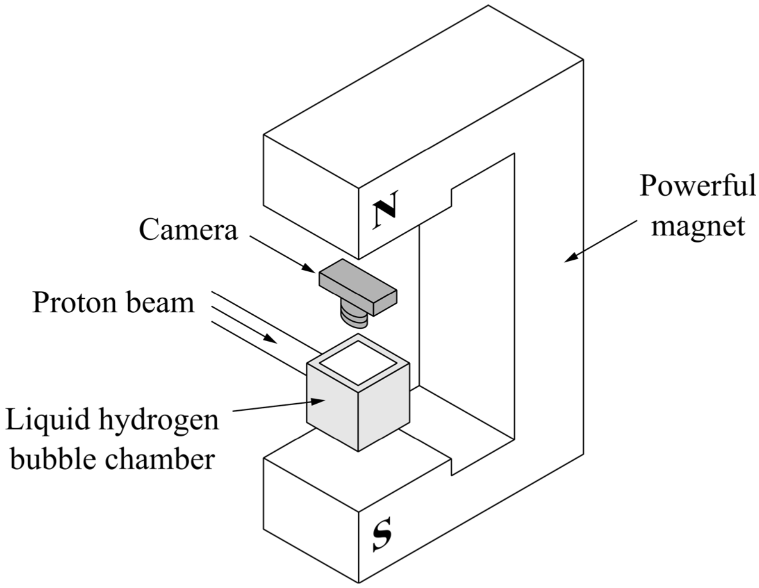
Bohr proposed that electrons orbit the nucleus is quantised, stable "stationary states". However, he did not provide a reason for the orbiting electrons' stability. Louis de Broglie hypothesised that moving particles have an associated matter-wave. Thus, an orbiting electron would move with this wavelike nature such that it forms a standing wave over the orbit. This would require the length of the circumference to be an integer number of wavelengths of the electron's matter-wave, according to $2\pi r_n = n\lambda_n$. This requirement results in Bohr's quantised stationary states and prevents the emission of EMR, except to move between these stationary states.

✓ describe de Broglie's hypothesis
✓ identify Bohr's "stationary states"
✓ relate de Broglie's hypothesis to Bohr's "stationary states"

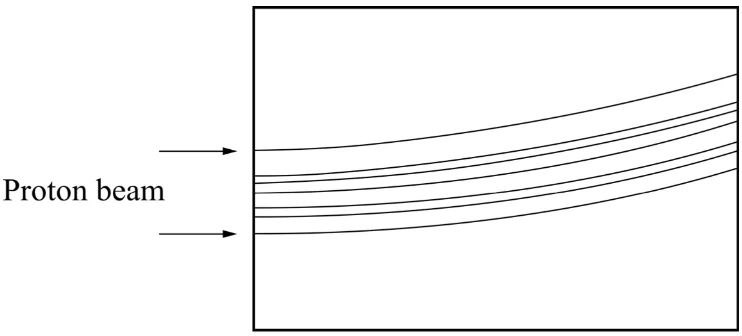
Question 28 (7 marks)

Bubble chambers are used in conjunction with particle accelerators to photographically record the tracks of fast-moving charged particles. An intense magnetic field is applied at right angles to the path of the particles to deflect them according to their charge and momentum.

The diagram shows a beam of protons travelling horizontally and entering a liquid hydrogen bubble chamber in a vertical magnetic field of 25.0 mT.



Examination of the photograph taken by the camera, as sketched below, shows that the protons were deflected along a circular path of radius 0.280 metres.



Proton tracks in bubble chamber

Question 29 continues on page 17

Question 29 (continued)

(a) Derive an expression for the velocity of a proton from the forces it experiences in this experiment. **2**

$F_C = F_B$

$\frac{mv^2}{r} = qvB, \quad \Rightarrow \quad v = \frac{qBr}{m}$

✓ identifies an appropriate equation
✓ derives correct expression

(b) Calculate the velocity of a proton in the bubble chamber. **2**

From (a):

$v = \frac{qBr}{m} = \frac{1.602\times10^{-19}\times25.0\times10^{-3}\times0.280}{1.673\times10^{-27}} = 670293 = 6.70 \times 10^5 \text{ m s}^{-1}$

✓ some correct working
✓ correct value & units with correct sig figs

(c) Outline TWO limitations of applying special relativity to the analysis of the motion of the protons in this experiment. **3**

6.70×10^6 m s^{-1} corresponds to 0.0022 c, with a Lorentz factor of:

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-0.0022^2}} = 1.00000242$

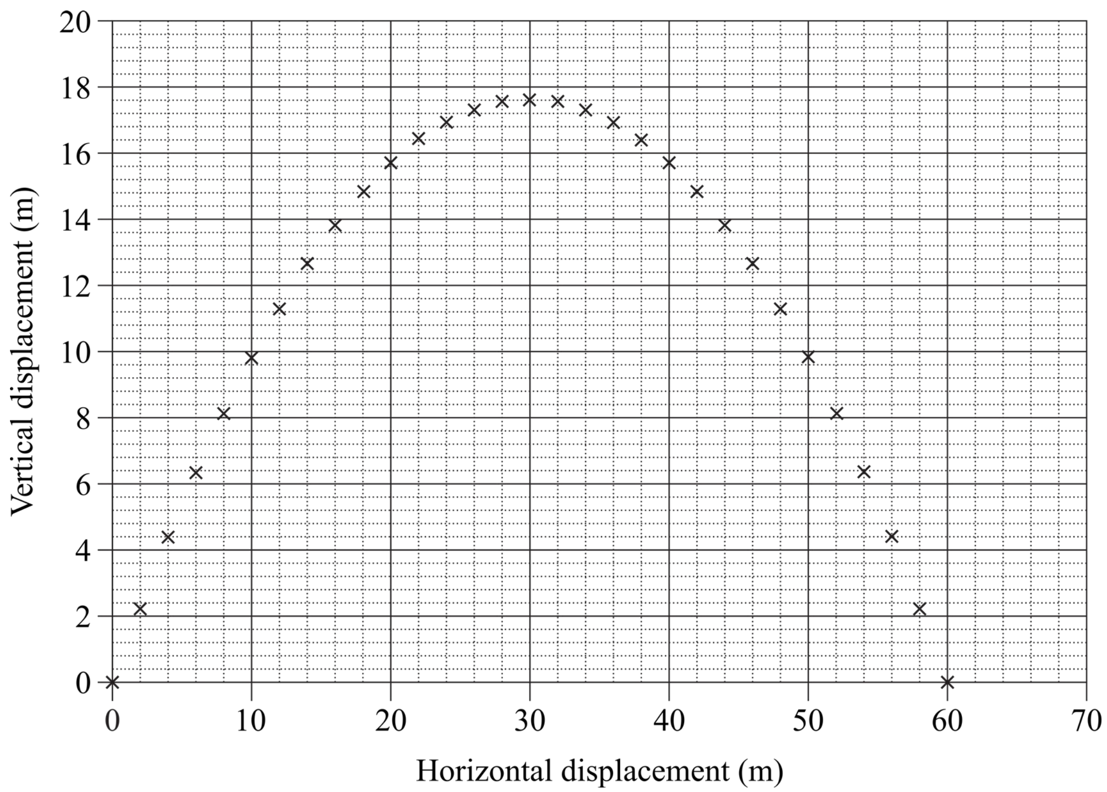
This means that the proton is going far too slow to apply special relativity. In addition, the proton is undergoing centripetal acceleration, meaning that it is not an inertial frame of reference, and is, therefore, not an appropriate frame of reference to apply special relativity.

✓ identifies ONE limitation
✓ outlines ONE limitation
✓ outlines TWO limitations

End of Question 29

Question 29 (4 marks)

The graph shows the vertical displacement of a projectile throughout its trajectory on earth. **4**



Calculate the initial velocity of the projectile.

From the graph, $v_y = 0$ at $s_y = 17.6$ m. Falling from maximum height gives:

$v_y^2 = u_y^2 + 2a_y s_y$

$\Rightarrow v_y = \sqrt{u_y^2 + 2a_y s_y} = \sqrt{0^2 + 2 \times -9.8 \times -17.6} = 18.57 \text{ m s}^{-1}$

From the symmetry of the parabolic projectie motion trajectory, $v_y = -u_y$, and:

$v_y = u_y + a_y t$

$\Rightarrow t = \frac{v_y - u_y}{a_y} = \frac{-u_y - u_y}{a_y} = \frac{-2u_y}{a_y} = \frac{-2 \times 18.57}{-9.8} = 3.79 \text{ s}$

Therefore:

$u_x = \frac{s_x}{t} = \frac{60.0}{3.790} = 15.83 \text{ m s}^{-1}$

✓ provides some relevant information
✓ uses appropriate equation(s) to get an (incorrect) answer
✓ correct speed & units
✓ correct direction

This gives:

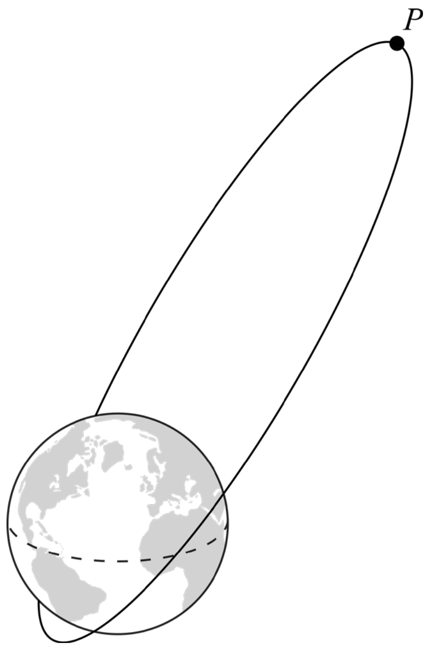
$u = \sqrt{u_x^2 + u_y^2} = \sqrt{15.83^2 + 18.57^2} = 24.40 \text{ m s}^1$

$\theta = \tan^{-1} \frac{u_y}{u_x} = \tan^{-1} \frac{18.57}{1.583} = 49.6°$

The launch velocity is 24 m s^{-1} at 50° above the horizontal.

Question 30 (3 marks)

A Molniya orbit is an inclined, highly elliptical orbit with a period of 12 hours, designed to provide communications and remote sensing coverage over high latitudes.



Account for the changes in velocity of the satellite as it completes one orbit from position *P*. **3**

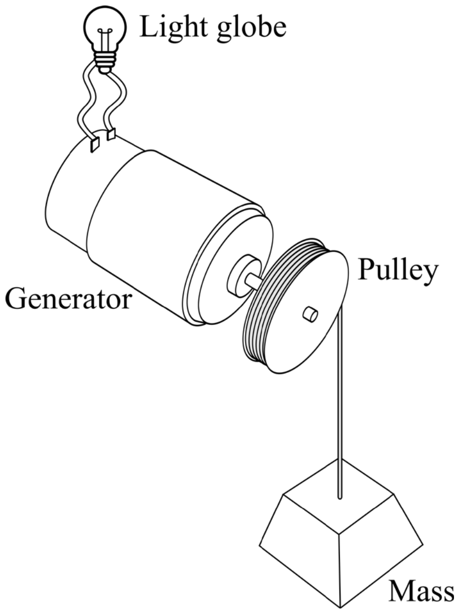
The total energy of the satellite is due to its gravitational potential energy and kinetic energy, according to $E = U + K$. As the satellite moves from P towards Earth, the gravitational potential energy decreases $\left(\text{from } U = -\frac{GMm}{r^2}\right)$. Therefore, according to the law of conservation of energy, the kinetic energy must increase, thereby increasing the speed of the satellite. As the satellite passes the perihelion and returns towards P, kinetic energy is transformed back into gravitational potential energy, thereby decreasing the speed of the satellite. In addition, the gravitational force always acts at an angle to the velocity of the satellite, causing it to change direction over the course of its orbit. Since both the speed and the direction are continuously changing, the satellite experiences a constantly changing velocity.

✓ provides some relevant information
✓ provides a reason for a change in velocity
✓ accounts for changes in velocity

note: This is not a Kepler's law question, what is the physics behind Kepler's law?? It's the Law of Conservation of Energy!!

Question 31 (7 marks)

The *g-lite* was designed to provide light to remote locations that do not have access to electricity. It uses a lowering mass to drive a generator to illuminate a light globe. **7**



Explain the factors that affect the maximum brightness of the light globe. Use mathematical models to support your answer.

In order to get maximum brightness in the bulb, it must have the EMF (voltage) provided to the bulb increased. There are 2 components to the apparatus supplying the voltage; the generator and the input of kinetic energy that turns the generator.

Factors affecting the physical turning system:

* *The mass of the Mass*: A greater mass will lead to a greater force on the pulley, according to $F_g = mg$. This will increase the maximum brightness of the light globe.

* *The radius of the pulley*: A larger radius will result in a larger torque on the generator, according to $\tau = rF$, thereby increasing the maximum brightness of the light globe. However, a larger radius will also increase the circumference, according to $C = 2\pi r$ so that it increases the distance needed to be travelled by the mass in order to complete 1 rotation.

* *Friction in the pulley/axle*: Greater friction in the pulley or axle of the generator will decrease the rate of rotation of the generator, thereby decreasing the maximum brightness possible.

Question 32 continues on page 21

Question 32 (continued)

* *Design of the generator*: According to $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -N\frac{\Delta(BA)}{\Delta t}$:

− Stronger magnets will produce a stronger magnetic field (increasing B)

− Larger area coils will result in larger changes in flux (increasing A)

− More coils will increasing the flux linkage (increasing N)

These changes will all increase the induced emf, increasing the maximum brightness of the light globe.

* *Diameter of the coil wire*: A larger diameter of the coil wire will decrease the electrical resistance of the wire, thereby increasing the current (according to Ohm's Law, $V = \varepsilon = IR$) and increasing the maximum brightness of the light globe.

* *Diameter of the connecting wires*: A larger diameter of the wire connecting the globe to the generator will, similarly, increase the maximum brightness of the light globe.

Criteria	**Mark**
• provides a comprehensive explanation of the relevant factors for both components. • supports the answer with mathematical models	7
• provides explanations of relevant factors for both components • supports the answer with at least one mathematical model	6
• describes some relevant factors and provides some explanation for both components • refers to at least one mathematical model	5
• outlines relevant factors and/or mathematical models	3–4
• outlines a relevant factor OR • identifies relevant factors and/or features of a mathematical mode	2
• provides some relevant information	1

2 parts to answer: the turning system and the generator

turning system
✓ factor
✓ mathematical model
✓ how increases voltage/power

generator
✓ factors (minimum 2)
✓ mathematical model
✓ how increases voltage/power

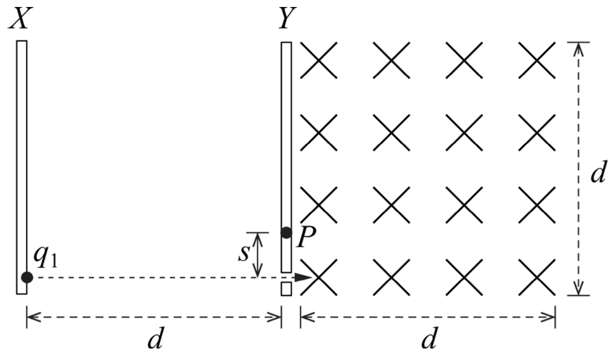
note: $\tau = BIA\cos\theta$ is for motors, not generators

✓ succinct information with no incorrect statements. must discuss both components well.

Question 32 (6 marks)

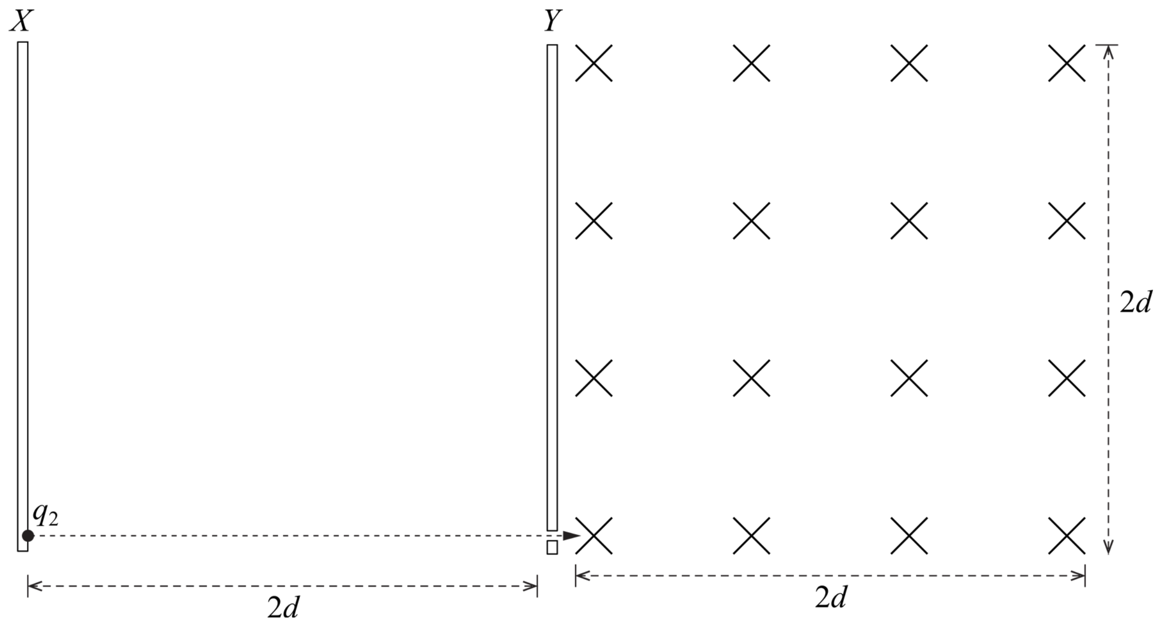
A charged particle, q_1, is accelerated from rest between oppositely charged plates X and Y, before entering a uniform magnetic field, as shown in the diagram below.

The particle strikes plate Y at point P, a vertical distance s from its entry point into the magnetic field. Ignore the effect of gravity.



The experiment is repeated with an apparatus that is twice the size, as shown in the diagram below. The voltage between the plates and the magnetic flux are the same.

An identical particle, q_2, is accelerated from rest between the oppositely charged plates, before entering the uniform magnetic field.



32 continues on page 23

32 (continued)

(a) Compare the work done on q_1 and q_2. Justify your answer. **3**

The work done on q_1 and q_2 are the same.

The charges are both accelerated by the electric field between the electric plates. From $W_E = qV$, both the magnitudes of the charges and the voltages are the same, making the total work done the same.

The charges both follow circular paths in the magnetic field, due to the magnetic force acting perpendicular to the velocity at all times. From $W = F_{\parallel}s$, the work done during circular motion will be the same. That is $W_B = 0$.

✓ provides some correct relevant information
✓ correct comparison within E or B
✓ valid justification within E and B

(b) Compare the vertical distances travelled by q_1 and q_2 in the magnetic field. **3**

As stated in (a), the work done by the electric field is the same for both q_1 and q_2. Therefore, the speeds of the charges entering the magnetic fields are the same, according to

$W_E = \Delta K_{p^+} \quad \Rightarrow \quad qV = \frac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{\frac{2qV}{m}}$ (given that the particles are identical and the voltages are the same).

The radius of the circular path is given by:

$F_C = F_B \quad \Rightarrow \quad \frac{mv^2}{r} = qvB \quad \Rightarrow \quad r = \frac{mv}{qB} \quad \Rightarrow \quad r \propto \frac{1}{B}$ (given that the particles are identical and the speeds are the same).

From the diagram above, $\Phi = BA \quad \Rightarrow \quad B = \frac{\Phi}{\mathrm{A}} = \frac{\Phi}{\mathrm{d}^2}$, meaning that the magnetic field strength is inversely proportional to the square of the magnetic field dimensions. As a result, $B_2 = \frac{1}{4}B_1$.

Since $r \propto \frac{1}{B}$ and $B \propto \frac{1}{\mathrm{d}^2}$, then $r \propto d^2$. Thus, $r_2 = 4r_1$, making $s_2 = 4s_1$.

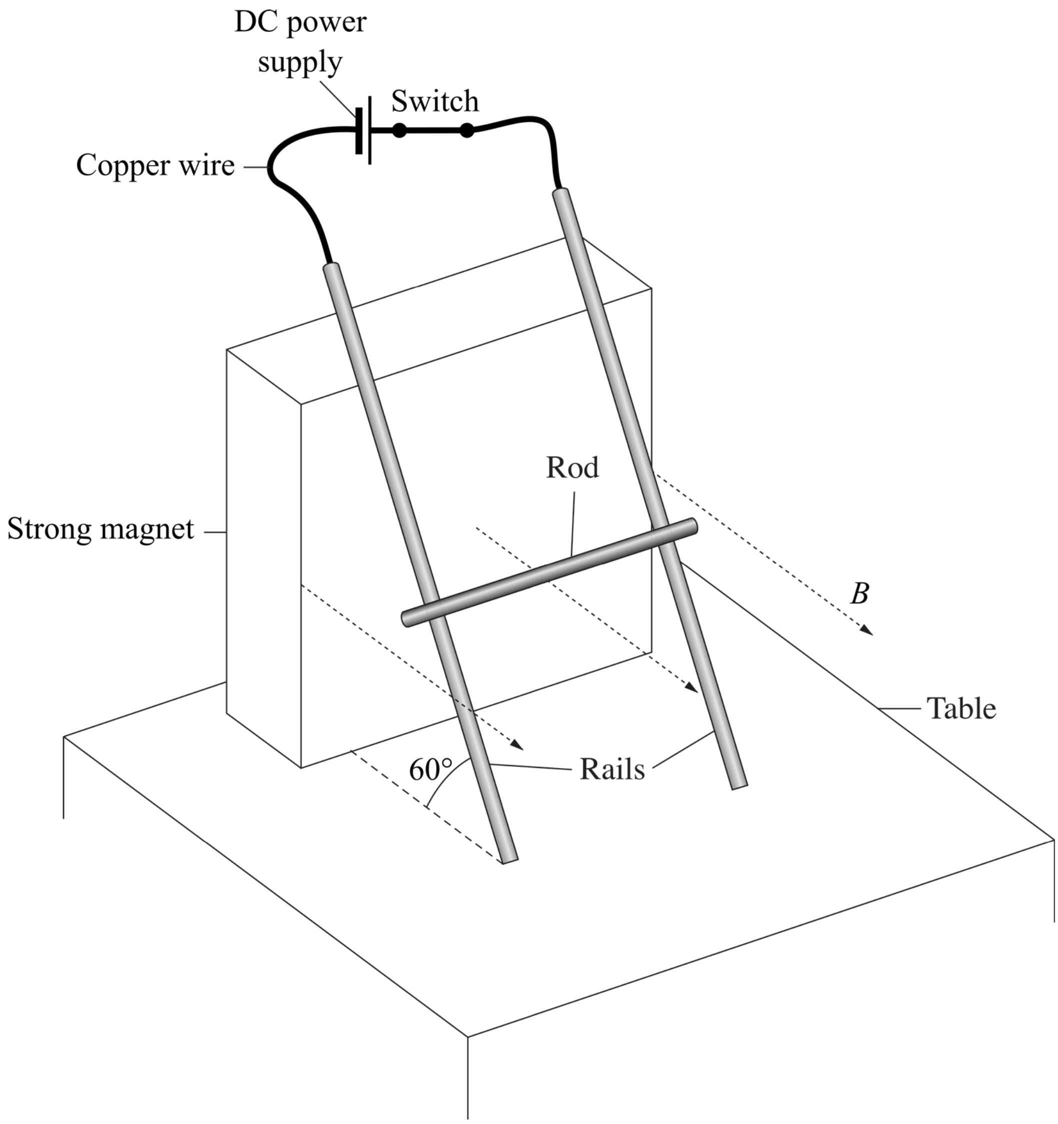
✓ provides some relevant information
✓ correctly compares B_1 & B_2
✓ correctly compares s_1 and s_2

End of Question 33

Question 33 (8 marks)

A 500 g metal rod is allowed to slide along a pair of parallel metal rails, 30 cm apart and tilted at 60° to the horizontal. The rods are connected to a DC power supply and switch, which results in a current of 2.8 A passing through the rod.

The apparatus is in a uniform magnetic field of 2.5 T which is outward, perpendicular to the strong magnet.



(a) What is the force, including its direction, acting on the rod solely due to the magnetic field? **2**

$F_B = lIB\sin\theta = 0.3 \times 2.8 \times 2.5 \times \sin 90 = 2.1$ N

From the right hand palm rule, the force is 2.1 N upwards.

✓ uses correct equation
✓ correct value & direction

note: direction is not up the rails, it's straight up the page

33 continues on page 25

Question 33 (continued)

(b) Calculate the initial acceleration of the rod along the rails. **3**

$F_g = mg = 0.5 \times 9.8 = 4.9$ N downwards.

Therefore, the net vertical force is $F_{vert} = F_g - F_B = 4.9 - 2.1 = 2.8$ N downwards.

Since the rails are not vertical, $F_{net} = F_{vert} \sin\theta = 2.8 \times \sin 60 = 2.4$ N.

From Newton's 2nd Law:

$F = ma \quad \Rightarrow \quad a = \frac{F_{net}}{m} = \frac{2.4}{0.5} = 4.8$ m s^{-2} down the rails

✓ calculates F_g
✓ calculates F_{net}
✓ correctly applies Newton's 2nd Law

(c) The experiment is repeated with the switch open. **3**

Explain why the acceleration of the rod is different with the switch open.

When the switch is opened, there will no longer be current flowing through the rod, and the magnetic force acting on the rod will be zero. Thus, the acceleration of the rod will solely be due to its weight. As a result, the acceleration will be greater than with the switch closed:

$F = ma \quad \Rightarrow \quad a = \frac{F_{net}}{m} = \frac{4.9 \times \sin 60}{0.5} = 8.5$ m s^{-2} down the rails.

✓ provides some relevant information
✓ relates no current to no magnetic force
✓ describes increased acceleration down (cannot say it's 9.8)

End of Question 33

Question 34 (3 marks)

A spaceship travels to a distant star at a constant speed, *v*. When it arrives, 17.6 years have passed on Earth but 9.2 years have passed for an astronaut on the spaceship. **3**

What is the distance to the star, as measured by an observer on Earth?

Due to time dilation, the longer time is the moving time, making $t_0 = 9.2$ years and $t_v = 17.6$ years:

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

$$v = \sqrt{1-\left(\frac{t_0}{t_v}\right)^2}\, c = \sqrt{1-\left(\frac{9.2}{17.6}\right)^2}\, c = 0.8524\, c$$

From Earth's frame of reference, $t = 17.6$ years, giving a distance of:

$$v = \frac{s}{t} \quad \Rightarrow \quad s = vt = 0.8524c \times 17.6y = 15.0\, ly$$

✓ uses an appropriate equation
✓ calculates speed of spaceship
✓ correctly relates speed to distance

note: no carry on for third mark

End of paper