2024 HSC Physics Examination

NSW Education Standards Authority

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Exam Overview

Year	2024
Total Marks	100
Section I	20 marks (Questions 1-20, Multiple Choice)
Section II	80 marks (Questions 21-33, Extended Response)

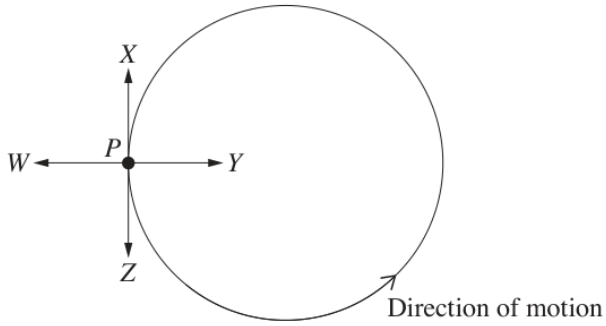
Section I: Multiple Choice

20 marks - Questions 1-20

Allow about 35 minutes for this section

Question 1

1 The diagram shows an object, P, undergoing uniform circular motion.



Which arrow shows the direction of the net force acting on P?

A. W

B. X

C. Y

D. Z

Figure 1: Q1

Question 2

2 Which of the following provides evidence for the model of light proposed by Huygens?

A. Emission spectra

B. Diffraction of light

C. Black body radiation

D. The photoelectric effect

Figure 2: Q2

Question 3

3 Which of the following is a fundamental particle in the Standard Model of matter?

A. Hadron

B. Neutron

C. Photon

D. Proton

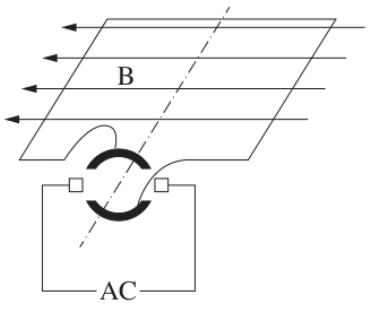
Figure 3: Q3

Question 4

4 A conducting coil is mounted on an axle and placed in a uniform magnetic field. The diagram shows different ways of connecting the coil to a power source.

Which setup allows the conducting coil to rotate continuously?

A.



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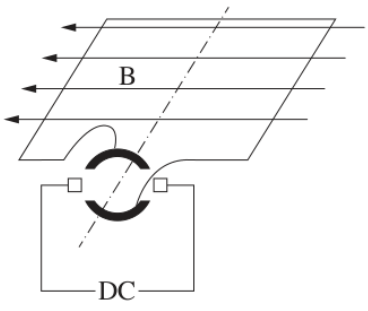

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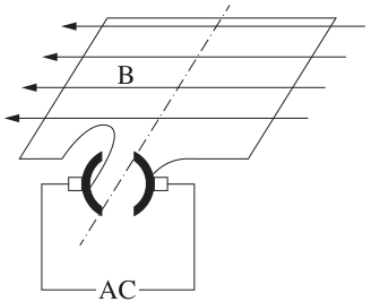

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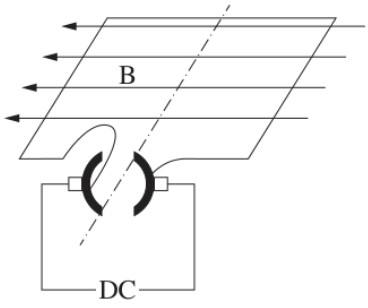
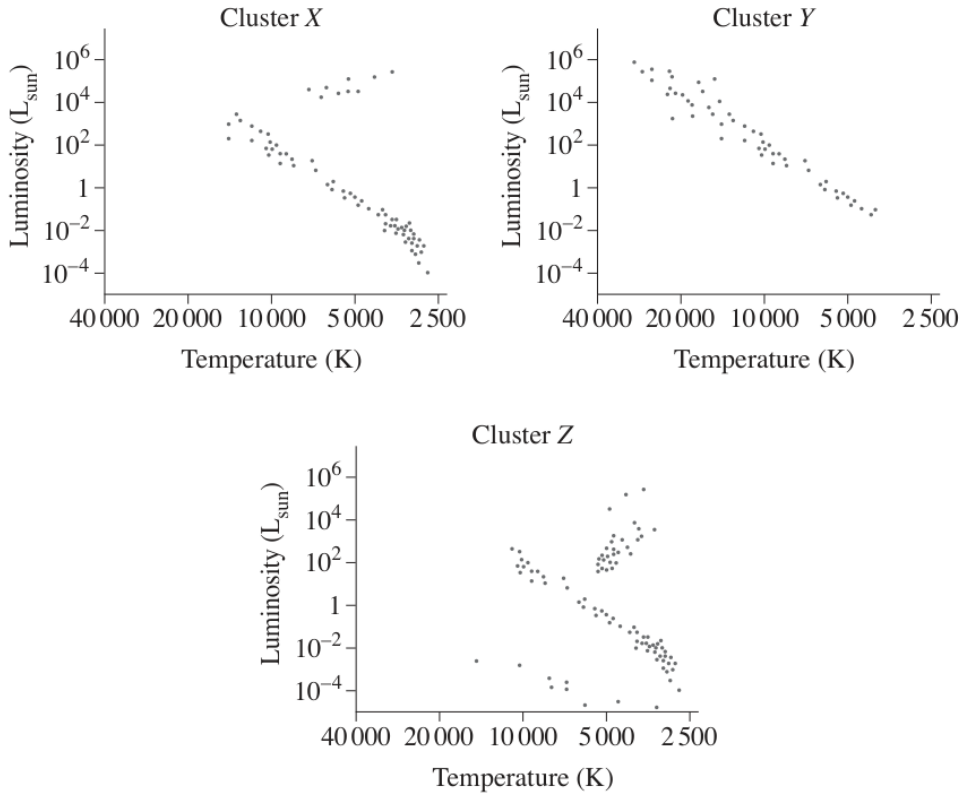


Figure 4: Q4

Question 5

5 A star cluster is a group of stars that form at the same time. Hertzsprung–Russell diagrams for three star clusters, *X*, *Y* and *Z* are shown.



Which row of the table correctly shows the three star clusters from youngest to oldest?

	Youngest ⟶		*Oldest*
A.	*Y*	*X*	*Z*
B.	*Y*	*Z*	*X*
C.	*Z*	*X*	*Y*
D.	*Z*	*Y*	*X*

Figure 5: Q5

Question 6

6 The photoelectric effect is mathematically modelled by the following relationship:

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

In this model, the symbol ϕ represents the amount of energy

A. supplied by a photon to an electron.

B. retained by an electron after being hit.

C. required to release an electron from a material.

D. left over after a collision of a photon with an electron.

Figure 6: Q6

Question 7

7 A pure sample of polonium-210 undergoes alpha emission to produce the stable isotope lead-206.

The half-life of polonium-210 is 138 days.

At the end of 276 days, what is the ratio of polonium-210 atoms to lead-206 atoms in the sample?

A. 1 : 4

B. 1 : 3

C. 1 : 2

D. 1 : 1

Figure 7: Q7

Question 8

8 An ideal transformer produces an output of 6 volts when an input of 240 volts is applied.

What change would be needed to produce an output of 12 volts, using the same input voltage?

A. Increase the number of turns on the primary coil

B. Decrease the number of turns on the primary coil

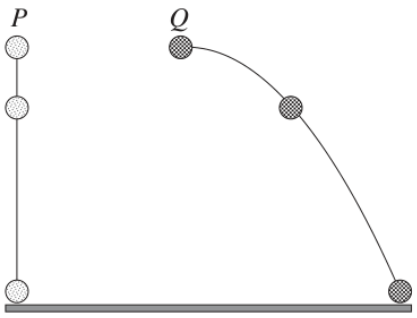
C. Increase the resistance connected to the secondary coil

D. Decrease the resistance connected to the secondary coil

Figure 8: Q8

Question 9

9 Object P is dropped from rest, and object Q is launched horizontally from the same height.



Which option correctly compares the projectile motion of P and Q?

A. The acceleration of P is less than the acceleration of Q.

B. The final velocity of Q is greater than the final velocity of P.

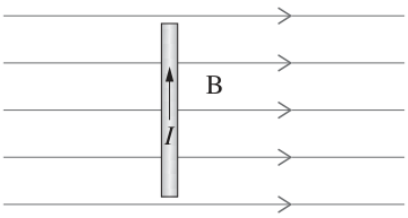
C. The time of flight of Q is greater than the time of flight of P.

D. The initial vertical velocity of P is less than the initial vertical velocity of Q.

Figure 9: Q9

Question 10

10 A rod carrying a current, I, placed in a uniform magnetic field as shown, experiences a force F.



How many degrees must the rod be rotated clockwise so that it experiences a force $\frac{F}{2}$?

A. 30°

B. 45°

C. 60°

D. 90°

Figure 10: Q10

Question 11

11 A satellite is in a circular orbit.

What is the relationship between its orbital velocity, v, and its orbital radius, r?

A. v is directly proportional to the square of r.

B. v is inversely proportional to the square of r.

C. v is directly proportional to the square root of r.

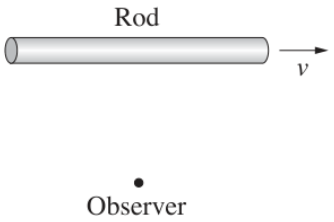
D. v is inversely proportional to the square root of r.

Figure 11: Q11

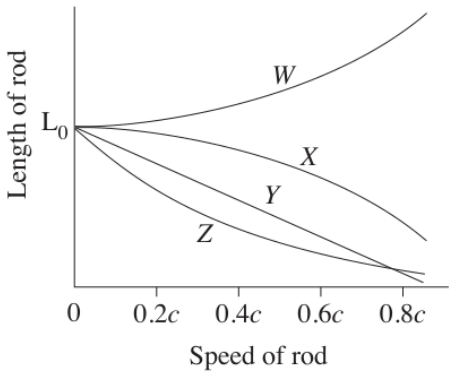
Question 12

12 A rod has a length, L_0, when measured in its own frame of reference.

The rod travels past a stationary observer at speed, v, as shown in the diagram.



Which option represents the relationship between the speed of the rod, v, and the length of the rod as measured by the stationary observer?



A. *W*

B. *X*

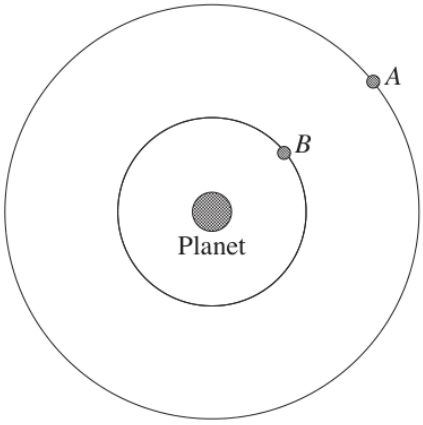
C. *Y*

D. *Z*

Figure 12: Q12

Question 13

13 The diagram shows two identical satellites, A and B, orbiting a planet.



Which row in the table correctly compares the potential energy, U, and kinetic energy, K, of the satellites?

	Potential energy	*Kinetic energy*
A.	$U_A > U_B$	$K_A < K_B$
B.	$U_A < U_B$	$K_A > K_B$
C.	$U_A > U_B$	$K_A > K_B$
D.	$U_A < U_B$	$K_A < K_B$

Figure 13: Q13

Question 14

14 The velocity of a proton $\left({}_{1}^{1}\mathrm{H}\right)$ is twice the velocity of an alpha particle $\left({}_{2}^{4}\mathrm{He}\right)$. The proton has a de Broglie wavelength of λ.

What is the de Broglie wavelength of the alpha particle?

A. $\frac{\lambda}{8}$

B. $\frac{\lambda}{2}$

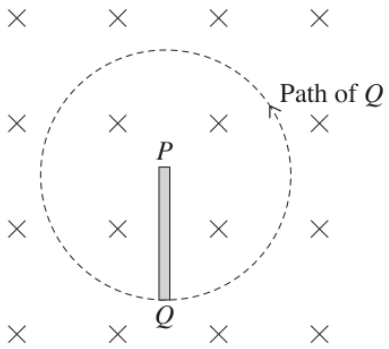
C. 2λ

D. 8λ

Figure 14: Q14

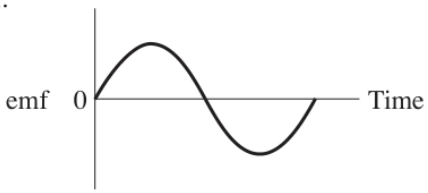
Question 15

15 A uniform magnetic field is directed into the page. A conductor PQ rotates about the end P at a constant rate.



Which graph shows the emf induced between the ends of the conductor, P and Q, as it rotates one revolution from the position shown?

A.



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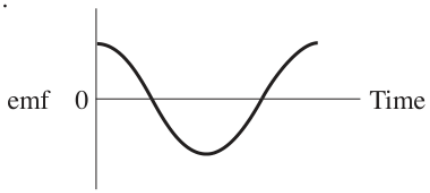

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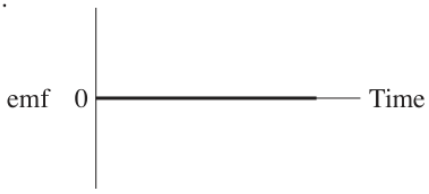


D.

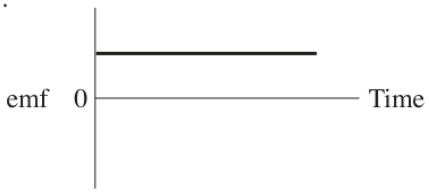
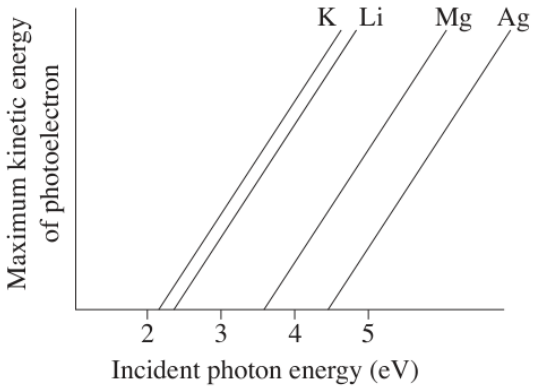


Figure 15: Q15

Question 16

16 The graph shows the relationship between the maximum kinetic energy of emitted photoelectrons and the incident photon energy for four different metal surfaces.



Light of frequency 7×10^{14} Hz is incident on the metals.

From which metals are photoelectrons emitted?

A. K, Li only

B. Mg, Ag only

C. All of the metals

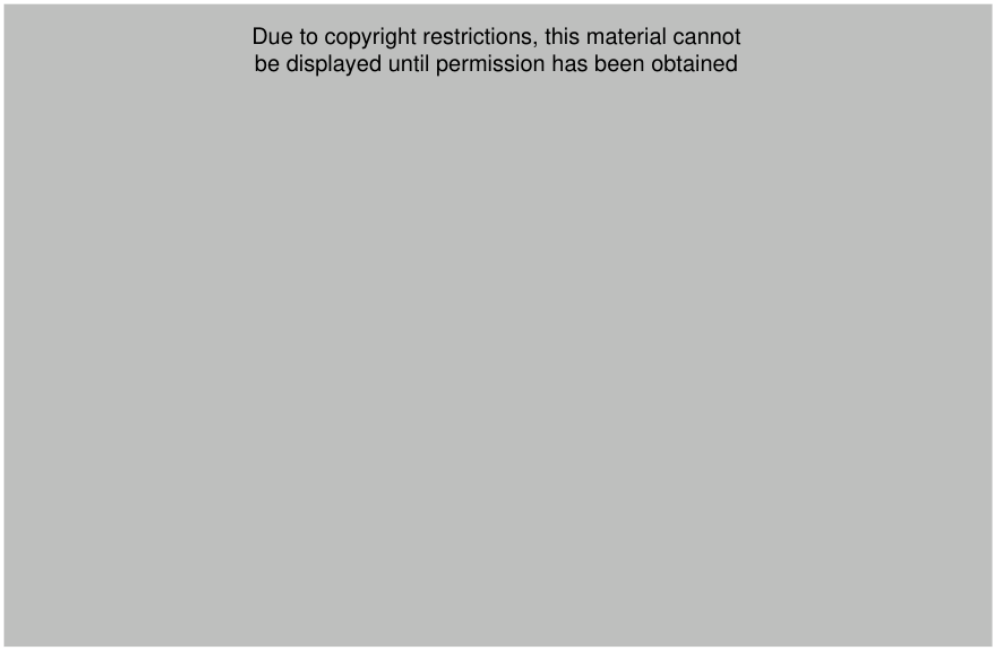
D. None of the metals

Figure 16: Q16

Question 17

17 The diagram shows a type of particle accelerator called a cyclotron.

Cyclotrons accelerate charged particles, following the path as shown.



An electric field acts on a charged particle as it moves through the gap between the dees. A strong magnetic field is also in place.

Once a charged particle has the required velocity, it exits the accelerator towards a target.

Which of the following is true about a charged particle in a cyclotron?

A. It increases speed while inside the dees.

B. It only accelerates while between the dees.

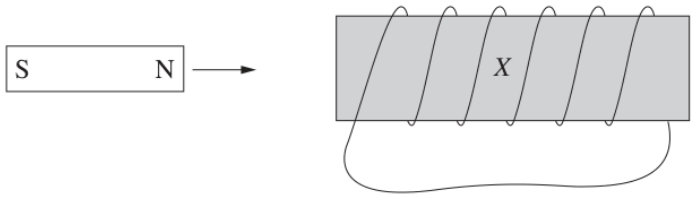
C. It undergoes acceleration inside and between the dees.

D. It slows down inside the dees and speeds up between the dees.

Figure 17: Q17

Question 18

18 The diagram shows a magnet moving towards a coil *X*.



This action causes a current to be induced in the coil.

Which situation will induce a current in coil *X* that is in the same direction as the current induced by the movement of the magnet?

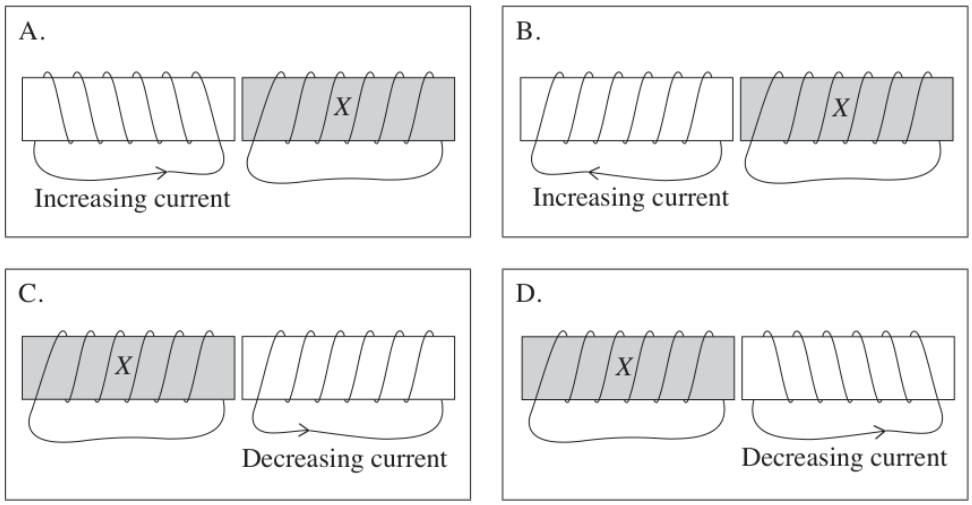


Figure 18: Q18

Question 19

19 In a vacuum chamber there is a uniform electric field and a uniform magnetic field.

A proton having a velocity, v, enters the chamber. Its velocity remains unchanged as it travels through the chamber.

A second proton having a velocity, $2v$, in the same direction as the first proton, then enters the chamber at the same point as the first proton.

In the chamber, the acceleration of the second proton

A. is zero.

B. is constant in magnitude and direction.

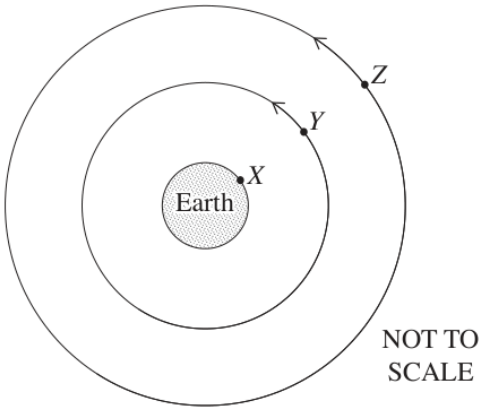
C. changes in both magnitude and direction.

D. is constant in magnitude, but not direction.

Figure 19: Q19

Question 20

20 Three identical atomic clocks are made so that they tick at precisely the same rate. One is kept in a laboratory, X, on Earth's equator. Another is placed on board a satellite, Y, in a circular orbit with a period of 12 hours. A third is placed in a satellite, Z, that is in a geostationary orbit. The satellites orbit Earth in the equatorial plane.



Assume that the satellites are inertial frames of reference and the clocks are affected ONLY by the predictions of special relativity.

Which statement correctly compares the rates at which the clocks tick, as determined by an observer at X, when the satellites are in the positions shown in the diagram?

A. The clock at Y ticks faster than either the clock at X or the clock at Z.

B. The clock at Y ticks slower than either the clock at X or the clock at Z.

C. The clocks tick at different rates, with X being the fastest and Y being the slowest.

D. The clocks tick at different rates, with Z being the slowest and X being the fastest.

Figure 20: Q20

Section II: Extended Response

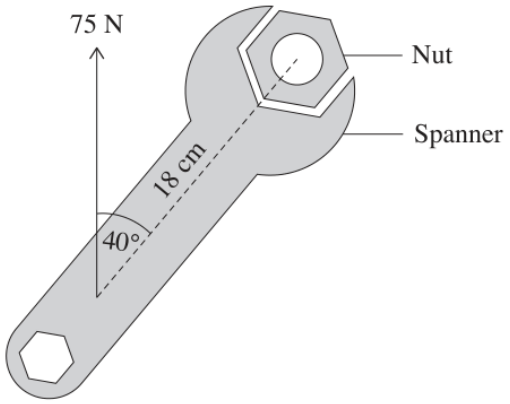
80 marks - Questions 21-33

Allow about 2 hours and 25 minutes for this section

Question 21 (6 marks)

Question 21 (6 marks)

To tighten a nut, a force of 75 N is applied to a spanner at an angle, as shown.



(a) Calculate the magnitude of the torque produced by the applied force. **2**

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(b) Explain TWO ways in which torque can be increased in a simple DC motor. **4**

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Figure 21: Q21

Part (a)

(a) Calculate the magnitude of the torque produced by the applied force. **2**

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Figure 22: Q21a

Part (b)

(b) Explain TWO ways in which torque can be increased in a simple DC motor. **4**

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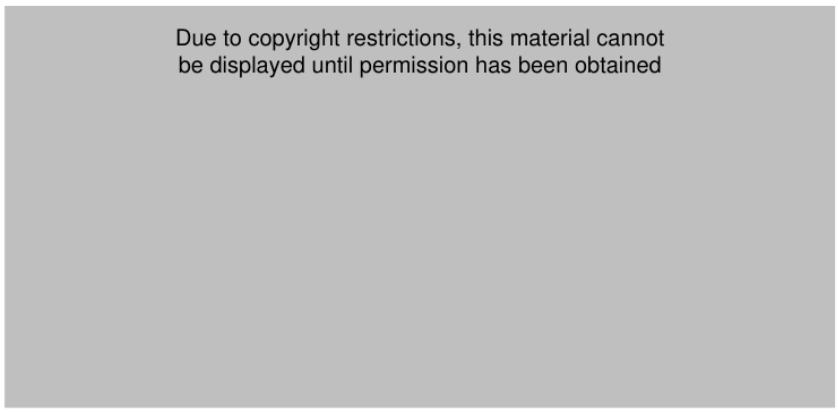
Figure 23: Q21b

Question 22 (5 marks)

Question 22 (5 marks)

The following graph, based on the data gathered by Hubble, shows the relationship between the recessional velocity of galaxies and their distance from Earth.



(a) Describe the significance of the graph to our understanding of the universe. **2**

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(b) How were the recessional velocities of galaxies determined? **3**

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Figure 24: Q22

Part (a)

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(a) Describe the significance of the graph to our understanding of the universe. **2**

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Figure 25: Q22a

Part (b)

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(b) How were the recessional velocities of galaxies determined? **3**

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Figure 26: Q22b

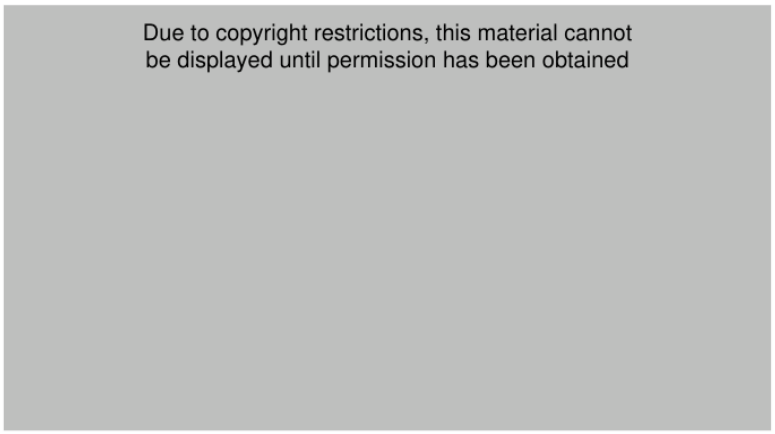
Question 23 (9 marks)

Question 23 (9 marks)

Development of models of the atom has resulted from both experimental investigations and hypotheses based on theoretical considerations.

(a) A key piece of experimental evidence supporting the nuclear model of the atom was a discovery by Chadwick in 1932.

An aspect of the experimental design is shown.



(i) What was the role of paraffin in Chadwick's experiment? **2**

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(ii) How did Chadwick's experiment change the model of the atom? **3**

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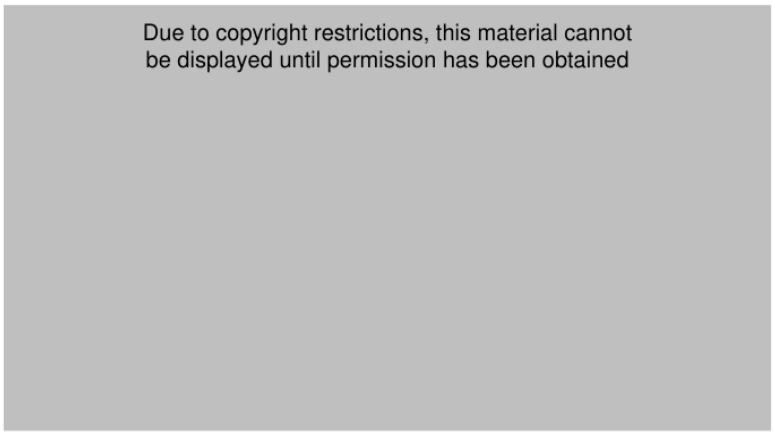
Question 23 continues on page 21

Figure 27: Q23

Part (a)

(a) A key piece of experimental evidence supporting the nuclear model of the atom was a discovery by Chadwick in 1932.

An aspect of the experimental design is shown.



(i) What was the role of paraffin in Chadwick's experiment? **2**

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(ii) How did Chadwick's experiment change the model of the atom? **3**

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Question 23 continues on page 21

Figure 28: Q23a

(i)

(i) What was the role of paraffin in Chadwick's experiment? **2**

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Figure 29: Q23a_i

(ii)

(ii) How did Chadwick's experiment change the model of the atom? **3**

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Question 23 continues on page 21

– 20 –

Figure 30: Q23a_ii

Part (b)

(b) Explain how de Broglie's hypothesis regarding the nature of electrons addressed limitations in the Bohr–Rutherford model of the atom. **4**

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End of Question 23

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Figure 31: Q23b

Question 24 (8 marks)

Question 24 (8 marks)

An absorption spectrum resulting from the passage of visible light from a star's surface through its hydrogen atmosphere is shown. Absorption lines are labelled *W* to *Z* in the diagram.

(a) Determine the surface temperature of the star. **2**

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(b) Absorption line *W* originates from an electron transition between the second and sixth energy levels. Use $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ to calculate the frequency of light absorbed to produce absorption line *W*. **3**

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Question 24 continues on page 23

Figure 32: Q24

Part (a)

(a) Determine the surface temperature of the star. **2**

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Figure 33: Q24a

Part (b)

(b) Absorption line W originates from an electron transition between the second and sixth energy levels. Use $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ to calculate the frequency of light absorbed to produce absorption line W. **3**

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Question 24 continues on page 23

Figure 34: Q24b

Part (c)

(c) Explain the physical processes that produce an absorption spectrum. **3**

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End of Question 24

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Figure 35: Q24c

Question 25 (6 marks)

Question 25 (6 marks)

The mathematical model below shows the relationship between the orbital radius of a satellite and its period.

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

(a) By considering gravitational force, show how this model can be derived. **2**

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Question 25 continues on page 25

Figure 36: Q25

Part (a)

(a) By considering gravitational force, show how this model can be derived. **2**

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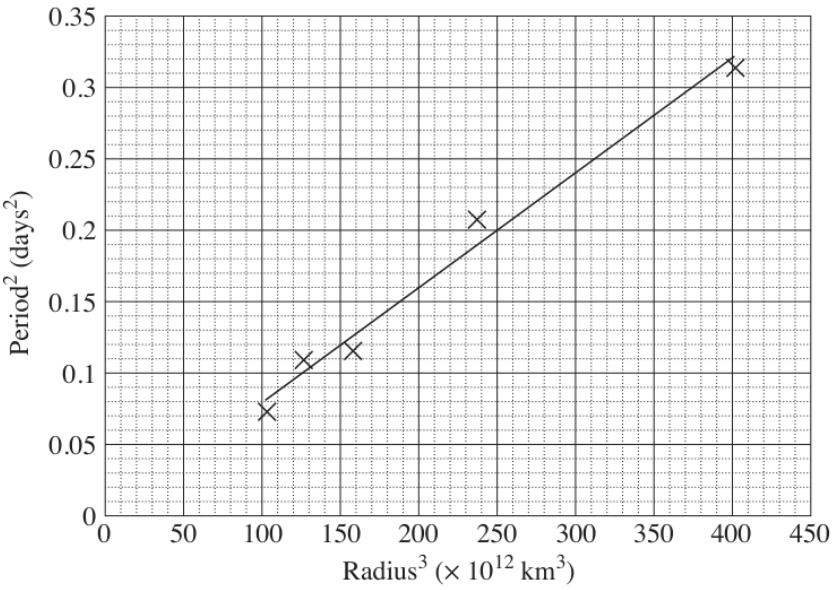
Question 25 continues on page 25

Figure 37: Q25a

Part (b)

(b) A planet with five moons is discovered. The following graph is produced from observations of the orbital radius of the moons and their orbital periods, measured in Earth days. **4**



Use the graph to calculate the mass of the planet.

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End of Question 25

Figure 38: Q25b

Question 26 (3 marks)

Question 26 (3 marks)

Muons are unstable particles produced when cosmic rays strike atoms high in the atmosphere. The muons travel downward, perpendicular to Earth's surface, at almost the speed of light. **3**

Classical physics predicts that these muons will decay before they have time to reach Earth's surface.

Explain qualitatively why these muons can reach Earth's surface, regardless of whether their motion is considered from either the muon's frame of reference or the Earth's frame of reference.

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Figure 39: Q26

Question 27 (7 marks)

Question 27 (7 marks)

The simplified model below shows the reactants and products of a proton–antiproton reaction which produces three particles called pions, each having a different charge.

$$p + \bar{p} \longrightarrow \pi^+ + \pi^0 + \pi^-$$

There are no other products in this process, which involves only the rearrangement of quarks. No electromagnetic radiation is produced. Assume that the initial kinetic energy of the proton and antiproton is negligible.

Protons consist of two up quarks (u) and a down quark (d). Antiprotons consist of two up antiquarks ($\bar{u}$) and a down antiquark ($\bar{d}$). Each of the pions consists of two quarks.

The following tables provide information about hadrons and quarks.

Table 1: Hadron information

Particle	*Rest mass* (MeV/c^2)	*Charge*
proton (p)	940	+1
antiproton ($\bar{p}$)	940	−1
neutral pion (π^0)	140	zero
positive pion (π^+)	140	+1
negative pion (π^-)	140	−1

Table 2: Quark charges

Particle	*Charge*
down quark (d)	$-\frac{1}{3}$
up quark (u)	$+\frac{2}{3}$
down antiquark ($\bar{d}$)	$+\frac{1}{3}$
up antiquark ($\bar{u}$)	$-\frac{2}{3}$

Question 27 continues on page 29

Figure 40: Q27

Part (a)

(a) Identify the quarks present in the π^-, π^+ and the π^0 particles. **2**

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Figure 41: Q27a

Part (b)

(b) The energy released in the reaction is shared equally between the pions. **2**

Calculate the energy released per pion in this reaction.

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Figure 42: Q27b

Part (c)

(c) Calculation of the pions' velocities using classical physics predicts that each pion has a velocity, relative to the point at which the proton–antiproton reaction occurred, which exceeds 3×10^8 m s^{-1}. **3**

Explain the problem with this prediction and how it can be resolved.

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End of Question 27

Figure 43: Q27c

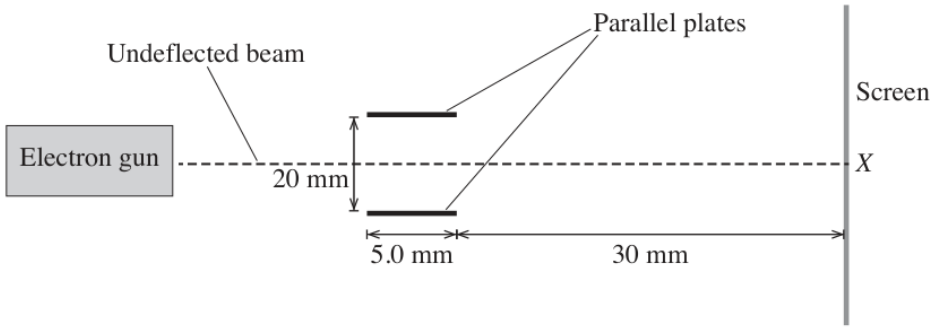
Question 28 (7 marks)

Question 28 (7 marks)

An electron gun fires a beam of electrons at 2.0×10^6 m s^{-1} through a pair of parallel charged plates towards a screen that is 30 mm from the end of the plates as shown.

There is a uniform electric field between the plates of 1.5×10^4 N C^{-1}. The plates are 5.0 mm wide and 20 mm apart. The electron beam enters mid-way between the plates. *X* marks the spot on the screen where an undeflected beam would strike.

Ignore gravitational effects on the electron beam.



NOT TO SCALE

(a) Show that the acceleration of an electron between the parallel plates is 2.6×10^{15} m s^{-2}. **2**

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(b) Show that the vertical displacement of the electron beam at the end of the parallel plates is approximately 8.1 mm. **2**

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Question 28 continues on page 31

Figure 44: Q28

Part (a)

(a) Show that the acceleration of an electron between the parallel plates is $2.6 \times 10^{15}\ \text{m s}^{-2}$. **2**

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Figure 45: Q28a

Part (b)

(b) Show that the vertical displacement of the electron beam at the end of the parallel plates is approximately 8.1 mm. **2**

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Question 28 continues on page 31

Figure 46: Q28b

Part (c)

(c) How far from point X will the electron beam strike the screen? **3**

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End of Question 28

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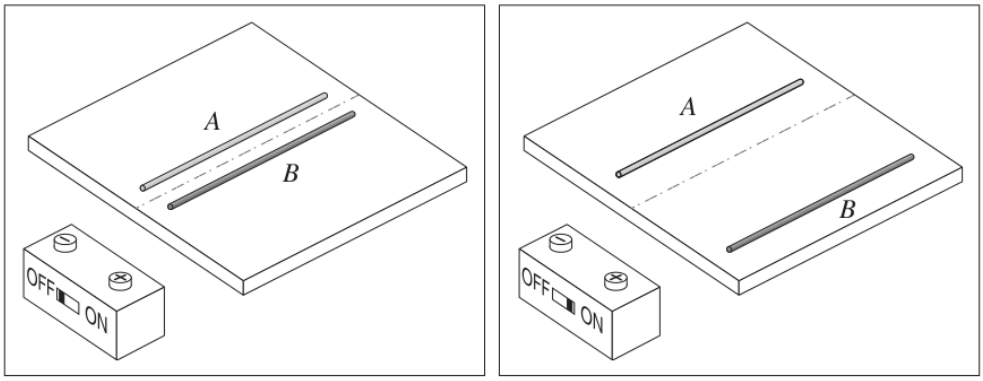
Figure 47: Q28c

Question 29 (6 marks)

Question 29 (6 marks)

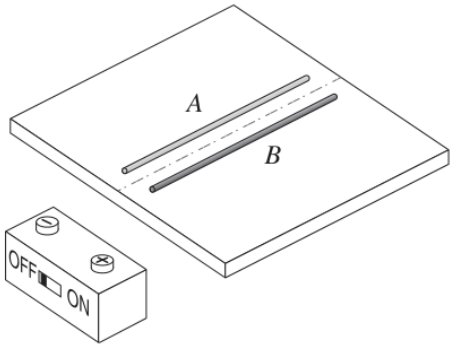
Two horizontal metal rods, *A* and *B*, of different materials are resting on a frictionless table. Initially they are at rest in position 1.

Both rods are then connected to a battery using wires. After the switch is turned on, currents of different magnitude flow in each rod. The rods move to position 2 after time, *t*. In position 2, *B* has a larger displacement than *A* from position 1. The masses of the wires are negligible.



Position 1 Position 2

(a) Position 1 is reproduced below. Draw wires to show how the battery must be connected to the ends of the two rods in order for the magnitude of the current in each rod to be different, and for position 2 to be reached. No components, other than the wires, are required. **2**

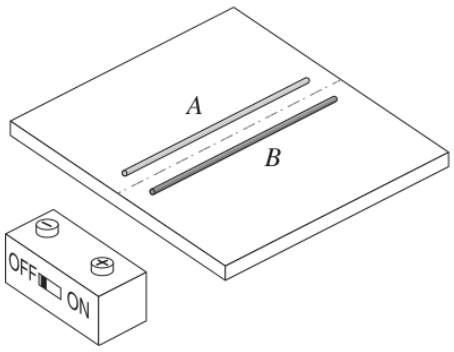


Question 29 continues on page 33

Figure 48: Q29

Part (a)

(a) Position 1 is reproduced below. Draw wires to show how the battery must be connected to the ends of the two rods in order for the magnitude of the current in each rod to be different, and for position 2 to be reached. No components, other than the wires, are required. **2**



Question 29 continues on page 33

Figure 49: Q29a

Part (b)

(b) When the switch is turned on, the current in rod *A* is greater than the current in rod *B*. **4**

Consider this statement.

> Position 2 results from the larger current in rod *A*, causing a larger force to act on rod *B*.

Evaluate this statement with reference to relevant physics principles.

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End of Question 29

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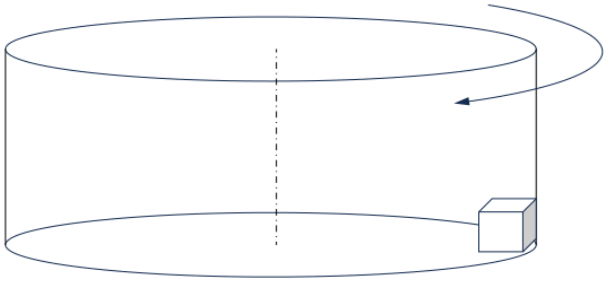
Figure 50: Q29b

Question 30 (4 marks)

Question 30 (4 marks)

An object sits on the floor of a hollow cylinder rotating around an axis, as shown. The cylinder's rotation causes the object to undergo uniform circular motion. **4**



Explain the effect on all of the forces acting on the object if the period of the cylinder's rotation is halved. Ignore the effects of friction.

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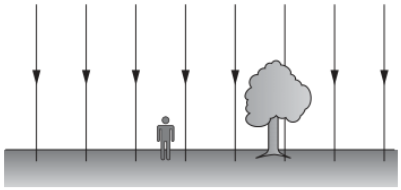
Figure 51: Q30

Question 31 (4 marks)

Question 31 (4 marks)

In a thought experiment, a projectile is launched vertically from Earth's surface. Its initial velocity is less than the escape velocity. **4**

The behaviour of the projectile can be analysed by using two different models, Model *A* and Model *B* as shown.

Model A	*Model B*
	
Earth's gravitational field is uniform	Earth's gravitational field is radial

The effects of Earth's atmosphere and Earth's rotational and orbital motions can be ignored.

Compare the maximum height reached by the projectile, using each model. In your answer, describe the energy changes of the projectile.

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Figure 52: Q31

Question 32 (8 marks)

Question 32 (8 marks)

Many scientists have performed experiments to explore the interaction of light and matter. **8**

Analyse how evidence from at least THREE such experiments has contributed to our understanding of physics.

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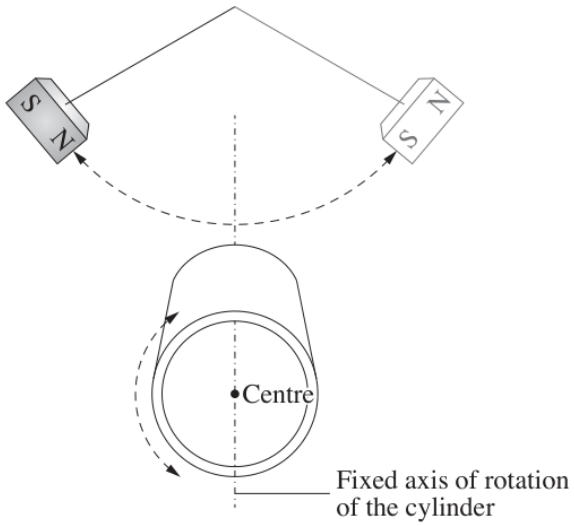
Figure 53: Q32

Question 33 (7 marks)

Question 33 (7 marks)

A magnet is swinging as a pendulum. Close below it is an aluminium (non-ferromagnetic) can. The can is free to spin around a fixed axis as shown. **7**



Analyse the motion and energy transformations of both the can and the magnet.

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Figure 54: Q33