CHERRYBROOK TECHNOLOGY HIGH SCHOOL

2025

TRIAL HSC EXAMINATION

AP4

NESA Number:

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen, draw diagrams and graphs in pencil.
- Show all working
- NESA approved calculators may be used
- A data sheet, formulae sheet and Periodic Table are provided
- Write your NESA number in the space provided on all parts of the exam and on any extra writing booklets.

Total marks – 100

Section I – 20 marks

- Attempt Questions 1-20 on the MC answer grid provided.
- Allow about 35 minutes for this part

Section II – 80 marks

- Attempt Questions 21-41 in the spaces provided
- Allow about 2 hours and 25 minutes for this part

Section I - 20 marks

Part A

Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet provided for Questions 1-20

1. A spaceship is travelling at 0.9*c* when an astronaut aboard is instructed to clean the ship. Mission control is watching from Earth and sees exactly 30 minutes of cleaning time.

How long did the astronaut clean for from the astronaut's frame of reference?

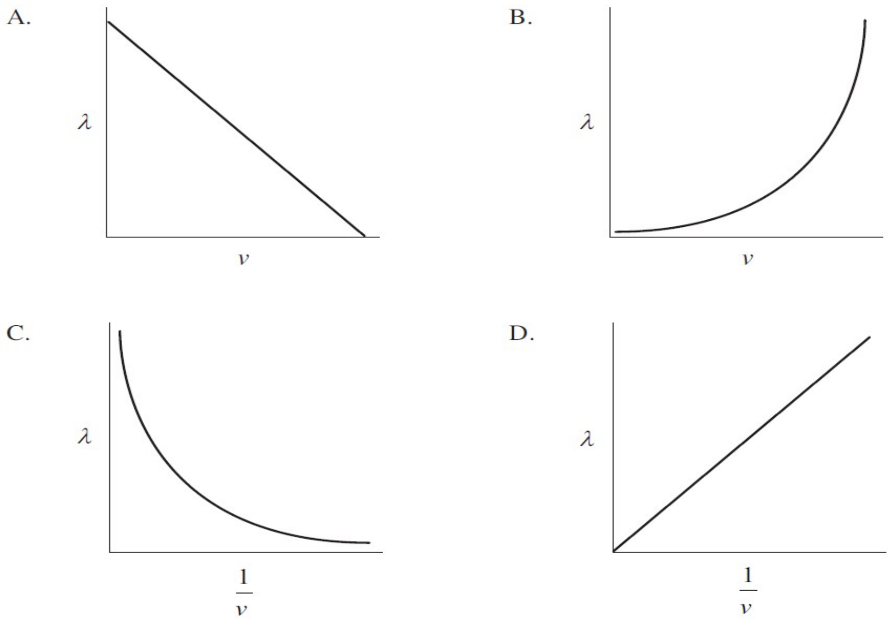
A. 9 minutes

B. 69 minutes

C. 13 minutes

D. 95 minutes

2. Which of the following graphs represents the relationship between the de Broglie wavelength, λ, and the speed, *v* ?



3. Which of the following particles is a hadron as well as being a baryon?

A. pion

B. neutron

C. tau neutrino

D. muon

4. Which of the following evidence suggests protons and neutrons are not fundamental particles?

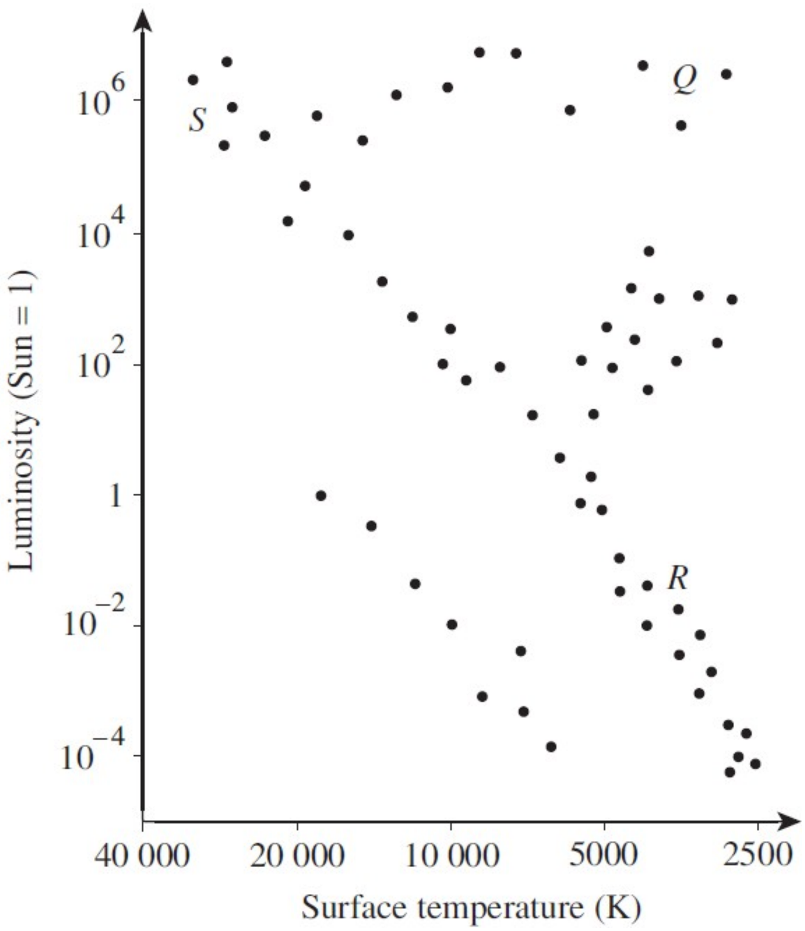
A. Protons have a mass of 1.67×10^{-27} kg.

B. Neutrons have a zero net charge.

C. Neutrons do not have their own magnetic field.

D. Protons and neutrons can undergo beta decay.

5. A Hertzsprung–Russell diagram is shown. Three regions, Q, R and S, are labelled.



Which row identifies the correct regions?

	Region where the p-p chain is dominant in cores	*Region where stars have the greatest size*
A.	*R*	*Q*
B.	*R*	*S*
C.	*S*	*Q*
D.	*S*	*S*

6. Which form of electromagnetic radiation has the highest energy per photon?

A. X-rays

B. Ultraviolet

C. Infrared

D. Microwaves

7. Which of the following observations could not be explained by Rutherford's atomic model?

A. Some alpha particles were deflected at large angles.

B. Atoms emit discrete spectral lines.

C. Atoms are mostly empty space.

D. Most alpha particles passed through the gold foil.

8. In an electromagnetic wave travelling through a vacuum, the electric field and magnetic fields are:

A. Parallel to each other but perpendicular to the direction of wave travel.

B. At 120 degrees to each other and at 120 degrees to the speed of light.

C. Perpendicular to each other and to the direction of wave travel.

D. Randomly aligned but always oscillating.

9. What is the energy of a gamma ray photon produced from a single positron–electron annihilation?

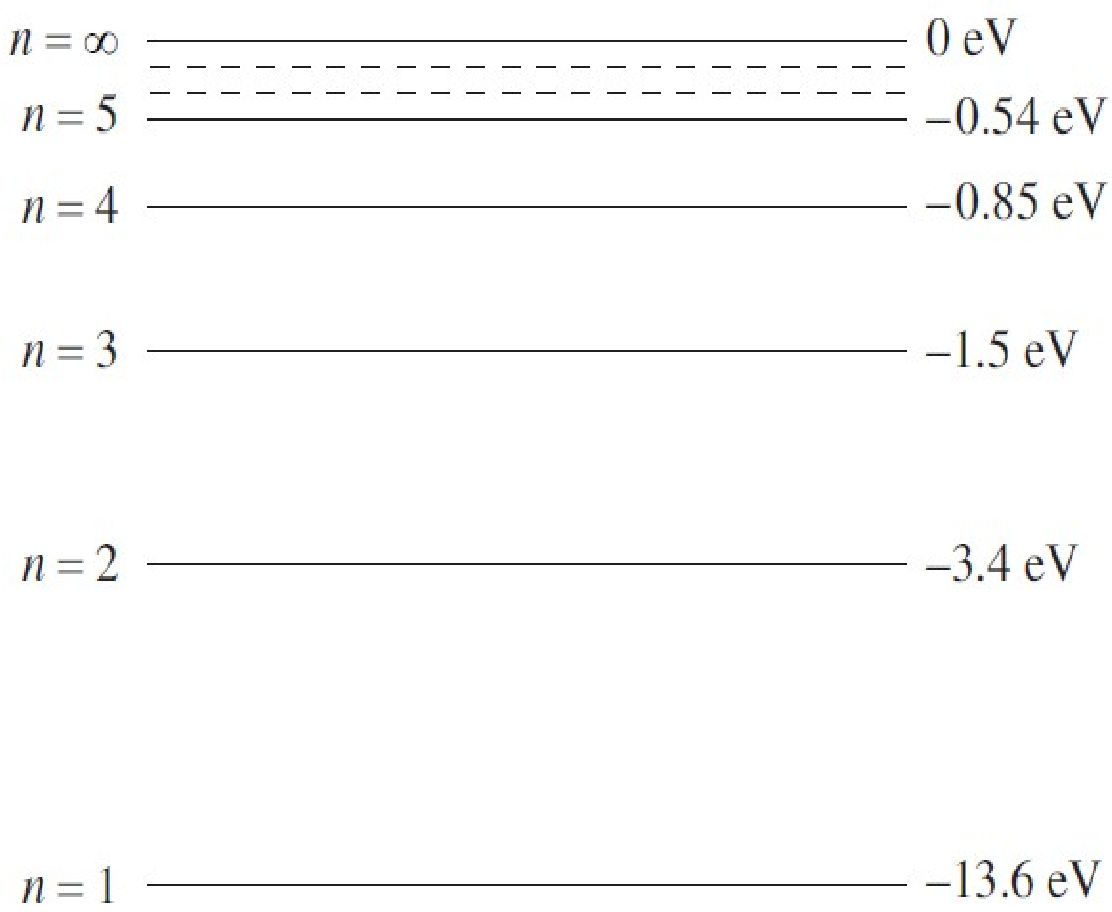
A. 0.5 eV

B. 1.0 eV

C. 0.5 MeV

D. 1.0 MeV

10. The electron energy level diagram for a hydrogen atom is shown below.



Which of the following statements is correct?

A. An electron that transitions from n = 2 to n = 5 produces a photon with 2.86 eV of energy.

B. The Balmer series is the name given to spectral emission lines that result from electron transitions from higher levels down to n = 1.

C. An electron that transitions from n = 4 to n = 2 produces a photon with a wavelength that is longer than the wavelength of a photon produced from an electron that transitions from n = 2 to n = 1.

D. The energy required to ionise a hydrogen atom when its electron is in the ground state is four times greater than the energy required to transition an electron from n = 1 to n = 2.

11. A satellite is moved from a geostationary orbit to a higher orbit.

Which statement about the orbit change is correct?

A. During the move the gravitational potential energy decreases.

B. The change in gravitational potential energy is independent of the mass of the satellite.

C. The work done is the difference between the gravitational potential energy of the higher orbit and that of the geostationary orbit.

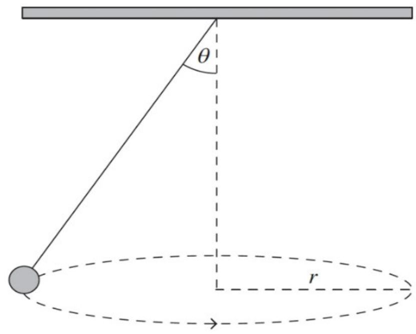
D. The sum of gravitational potential energy and kinetic energy is conserved.

12. Two planets, A and B, orbit the same star. Planet A's average orbital distance is six times larger than the average orbital distance of planet B.

What is the relationship between the orbital periods, T, of the planets?

A. $T_A = 3\ T_B$
B. $T_A = 15\ T_B$
C. $T_A = 36\ T_B$
D. $T_A = 216\ T_B$

13. A ball that is attached to a ceiling with a thin string is undergoing uniform circular motion, as shown in the diagram.



Which of the following is the correct expression for calculating θ?

A. $\tan^{-1}\left(\frac{v^2}{rg}\right)$

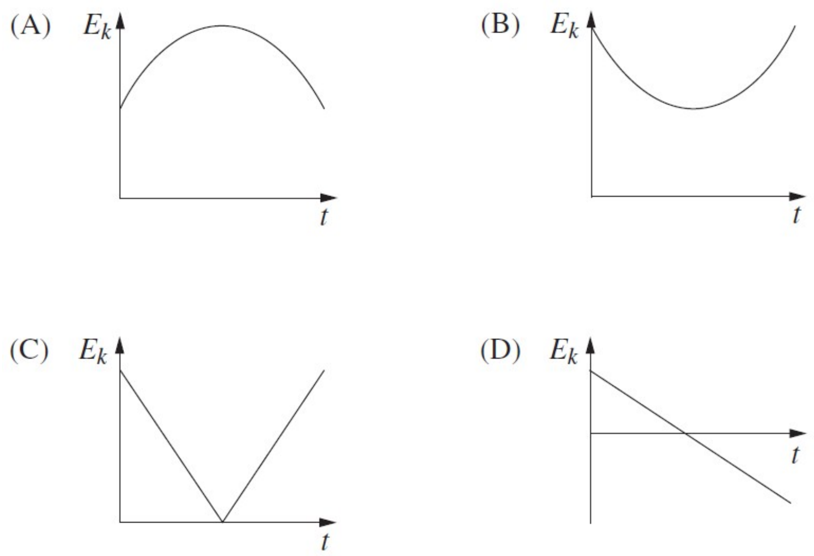
B. $\sin^{-1}\left(\frac{mg}{T}\right)$

C. $\sin^{-1}\left(\frac{m^2v^2g}{r}\right)$

D. $\tan^{-1}\left(\frac{mv^2}{rg}\right)$

14. A ball was thrown upward at an angle of 45°. It landed at the same height as thrown. Which graph best represents the kinetic energy of the ball during its time of flight?

Which graph best represents the kinetic energy of the ball during its time of flight?



15. Which of the following correctly describes the cause of electromagnetic induction?

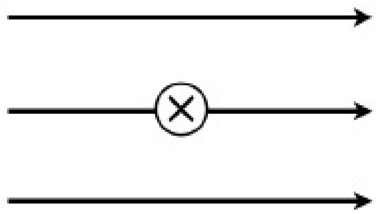
A. A changing electric field produces a changing magnetic field.

B. A magnetic field induces a current when it changes relative to a conductor.

C. A static magnetic field creates a static current.

D. Electric charges moving at constant velocity produce an induced current.

16. A straight wire carries a current into the page in a uniform magnetic field directed to the right as shown below.



What is the direction of the force on the wire?

A. Into the page.

B. Out of the page.

C. Up towards the top of the page.

D. Down towards the bottom of the page.

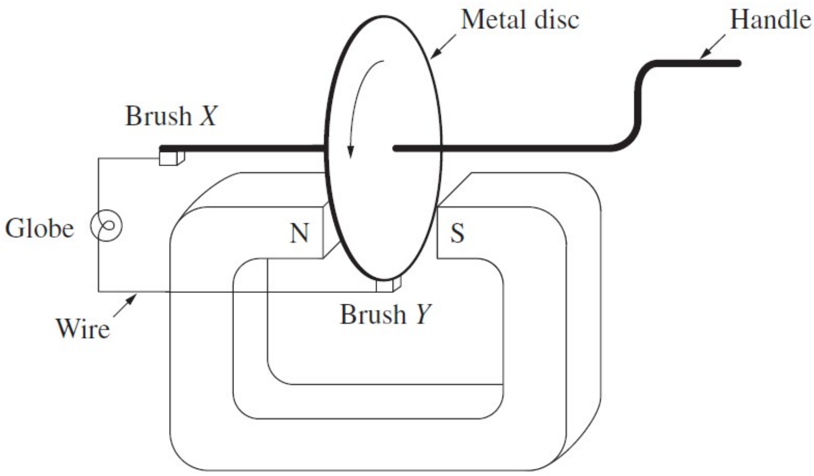
17. What characteristic of electromagnetic waves led Maxwell to believe that light was an electromagnetic wave?

A. Electromagnetic waves were transverse waves.
B. Electromagnetic waves travelled at the speed of light
C. Electromagnetic waves could have a wide range of wavelengths
D. Electromagnetic waves were non-mechanical waves

18. A proton moves at 2.0×10^{6} m s^{-1} perpendicular to a magnetic field and experiences a force of
3.2×10^{-14} N.
What is the strength of the magnetic field?

A. 0.08 T
B. 0.10 T
C. 0.24 T
D. 0.32 T

19. Early electric generators were often very simple. A hand-operated version is depicted below.



Brush X touches the metal axle and Brush Y touches the rim of the disc.
If the metal disc is rotated uniformly as shown, which statement about the current through the globe is correct?

A. No current flows

B. A direct current flows from *Y* to *X*.

C. A direct current flows from *X* to *Y*.

D. An alternating current flows between *X* and *Y*.

20. Millikan measured the charge on the electron by balancing the forces on a charged oil drop. What forces were in balance in Millikan's experiment?

A. magnetic force and gravitational force
B. electric force and gravitational force
C. electric force and magnetic force
D. electric, magnetic and gravitational forces

Section II - 80 marks

Attempt all Questions 21-41

Allow about 2 hours and 25 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Extra writing space is provided at the end of the exam paper. If you use this space, clearly indicate which question you are answering.

Question 21 (4 marks)

The surface of a metal was exposed to incident light of various frequencies. The maximum kinetic energy of the photoelectrons emitted from the metal at each frequency was measured.

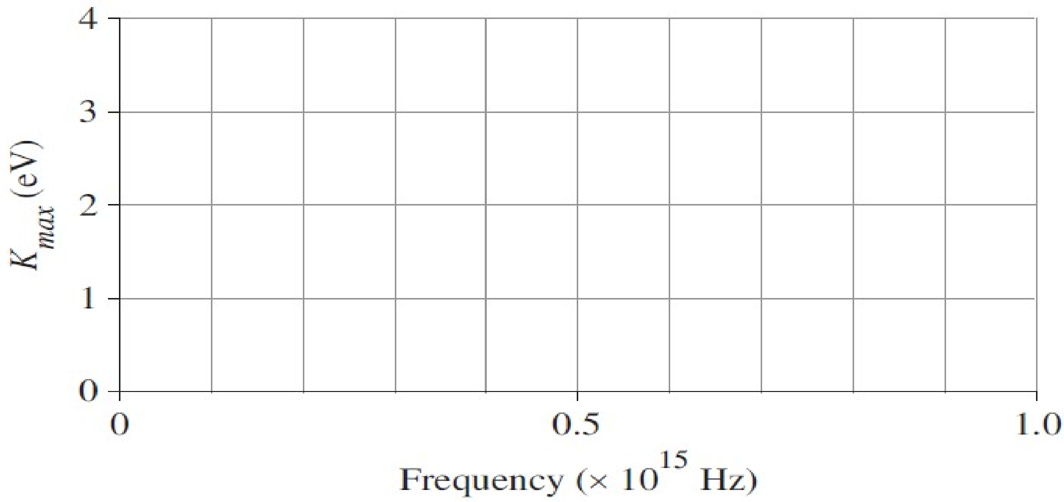
The results of the investigation are recorded in the table below.

Frequency	0.40	0.64	0.72	0.80	0.98

(x 10^{15} Hz)					
K_{max} *(eV)*	0.8	1.7	2.0	2.3	3.1

Plot the results on the axes provided and, hence, determine whether photoelectrons would be emitted from the metal if it was exposed to light with a wavelength of 3 μm.

Include a relevant calculation in your answer.



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Question 22 (6 marks)

(a) In the Hafele–Keating experiment, two highly accurate atomic clocks were flown around the world on commercial flights – one flying eastward and one flying westward – and then compared to atomic clocks that remained on the ground in Washington D.C. The eastward flight moved in the direction of Earth's rotation, while the westward flight moved against the direction of Earth's rotation.

Explain how the Hafele–Keating experiment validated time dilation as predicted by special relativity.

3

(b) The momentum of a particular electron is measured to be 8.7 x 10^{-22} kg m s^{-1}.

Explain why classical physics cannot accurately account for this momentum. Support your answer with a relevant calculation.

3

Question 23 (5 marks)

During nuclear fusion in stars, two deuterium nuclei combine to form a helium-3 nucleus and a neutron, according to the reaction:

$$ {}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n $$

The masses are:

- ${}_{1}^{2}H = 2.0141$ u
- ${}_{2}^{3}He = 3.0160$ u
- ${}_{0}^{1}n = 1.0087$ u

(a) Determine the energy released in joules in this reaction.
3

(b) Calculate the total energy released if 1.5×10^{25} deuterium nuclei undergo fusion.

2

Question 24 (5 marks)

(a) Laser light is shone onto a pair of slits separated by 200 μm to produce a pattern of bright lines on a screen 1.50 m away.

The distance between the third bright line and the central maximum in the pattern is 1.50 cm.

Calculate the wavelength of the laser light.
3

(b) Explain the differences in the patterns produced by coherent monochromatic light and light from an incandescent source, when passed through a double-slit interference apparatus.

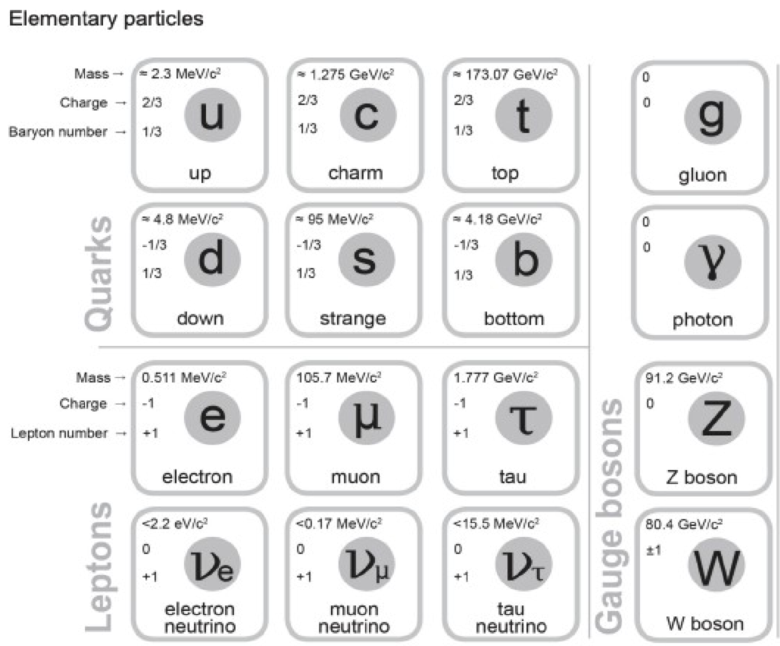
2

Question 25 (2 marks)

The diameter of a hydrogen atom in the Rutherford's model is 1.0×10^{-10} m. An electron travels at a speed of 2.23×10^{6} m s^{-1} in a stable circular orbit around the proton.

Calculate the wavelength of the electron as it orbits the proton.
2

Question 26 (2 marks)



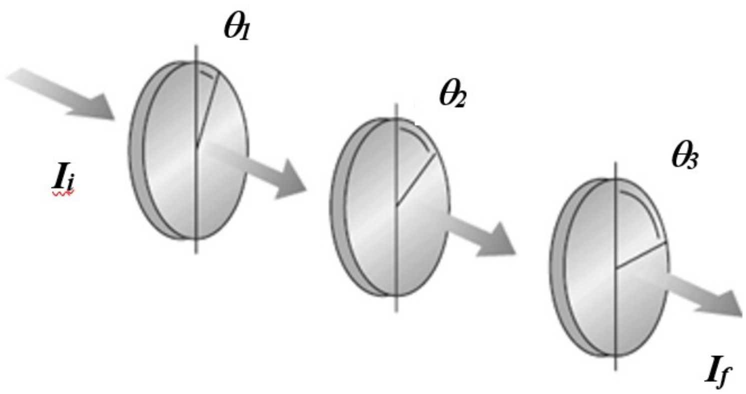
Use the stimulus above to describe the structure of an atom of Hydrogen-2.
2

Question 27 (4 marks)

Describe TWO experiments that have contributed to our understanding of the nucleus of the atom.
4

Question 28 (2 marks)

Three polarising filters are centred on a common axis as shown.



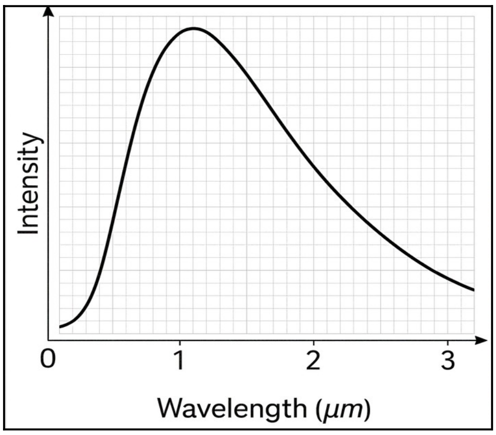
A vertically polarised beam of light is incident from the left onto the first polarising filter with intensity I_i = 10.0 units.

Calculate the transmitted intensity, I_f , when the angles of the polarising filters relative to the vertical plane are changed so that $\theta_1 = 20.0°$, $\theta_2 = 40.0°$ and $\theta_3 = 60.0°$.

2

Question 29 (4 marks)

(a) The image shows the data collected from a black-body at an unknown temperature.



Calculate the temperature of the black-body.
2

(b) Explain how the black-body radiation curve led to the development of the particle model of light.
2

Question 30 (2 marks)

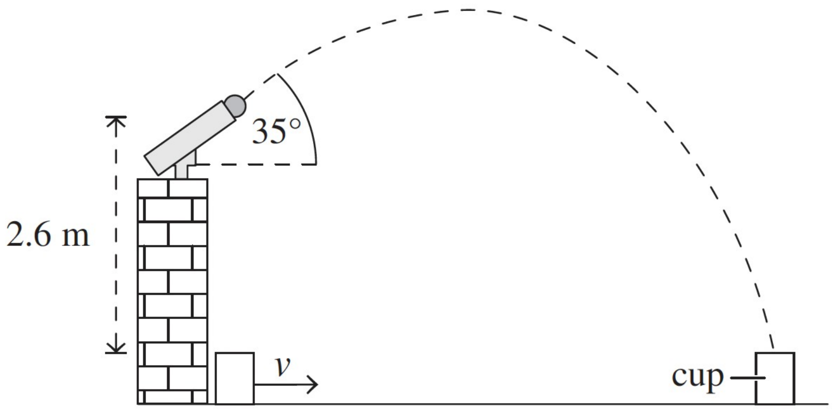
An astronomer notices that the spectral lines from a star show broadening.

Outline two reasons why this spectral broadening could be occurring.
2

Question 31 (4 marks)

A spring-loaded ball launcher is fixed at a 35° angle on a platform, as shown in the diagram.

When a 46 g ball is launched, a target cup is released from the base of the platform and moves along a linear track directly away from the platform at a constant speed. The speed at which the target cup moves along the track can be set by the operator prior to launching the ball.

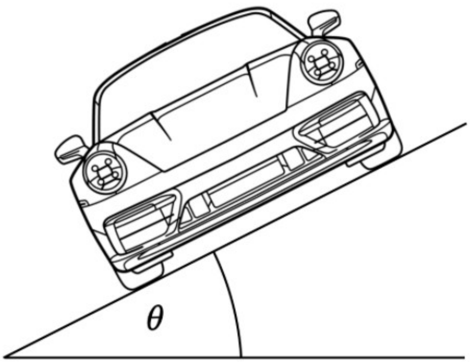


It is known that the spring in the launcher does 19.4 J of work on the ball.

Determine the required speed of the target cup and the distance the target cup must travel so that the ball lands in the cup.
4

Question 32 (4 marks)

A car is travelling on a road that is banked at an angle of θ.



When the car travels at the design speed of this road, there is no sideway friction between the tyres and the road.

(a) Show how the design speed equation for **v** can be derived as shown below.
2

$$v = \sqrt{r\, g \tan\theta}$$

Question 32 continues over the page

Question 32 continued:

(b) Explain what will occur if the car travels slower than the design speed.
2

Question 33 (7 marks)
Titan is the largest moon of Saturn. It orbits Saturn once every 15.9 days at an average distance of 1.22×10^6 km.

(a) Calculate the mass of Saturn.

2

(b) The mass of Titan is 1.35×10^{23} kg. Calculate the total mechanical energy of Titan.

3

Question 33 continues over the page

Question 33 continued:

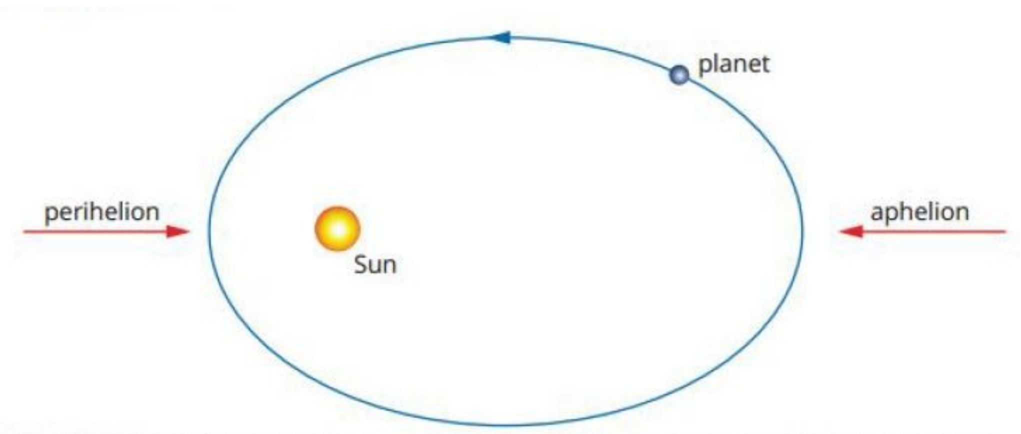
(c) A satellite is launched from the surface of Saturn into an orbit that keeps it directly above a position on the surface of Saturn.

Identify the energy changes as the satellite moves from the surface of Saturn into orbit.

2

Question 34 (2 marks)

The orbit of a planet is shown.



Account for the changes in velocity of the planet as it moves from perihelion to aphelion.

2

Question 35 (3 marks)

A rocket is launched vertically from a planet. The mass of the planet is 8.6×10^{23} kg.

After the rocket leaves the atmosphere, its engine is turned off and it continues to move away from the planet.

The rocket's speed at two different distances (Point 1 and Point 2) from the planet's centre is shown.

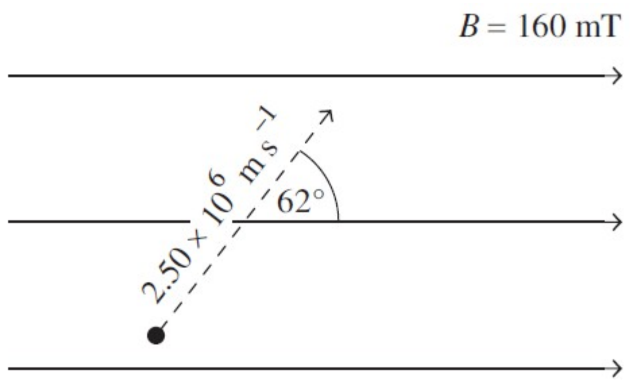
Point	**Distance from the planet's centre (m)**	**The speed of the rocket ($m\ s^{-1}$)**
1	4.3×10^{6}	5500
2	?	2900

Determine the rocket's distance from the planet's centre when it is at Point 2.

3

Question 36 (3 marks)

A charged particle is moving at 2.50×10^6 m s^{-1} at an angle of 62.0° to the direction of a uniform magnetic field of strength 160 mT, as shown in the diagram.



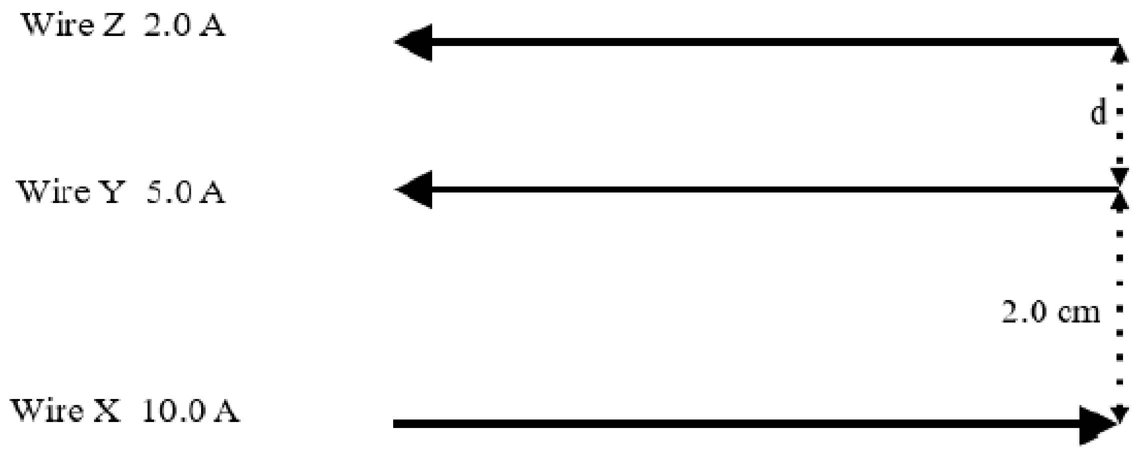
The particle moves in a helical path in the magnetic field with a radius of 0.286 m.

Calculate the charge-to-mass ratio of the particle.

3

Question 37 (3 marks)

Three identical wires are arranged on a horizontal surface with currents flowing as shown below. Wire X and Wire Y are fixed to the table so they cannot move.



What distance, d, between Wire Z and Wire Y is required so that Wire Z does not experience a net force from the other two wires?

3

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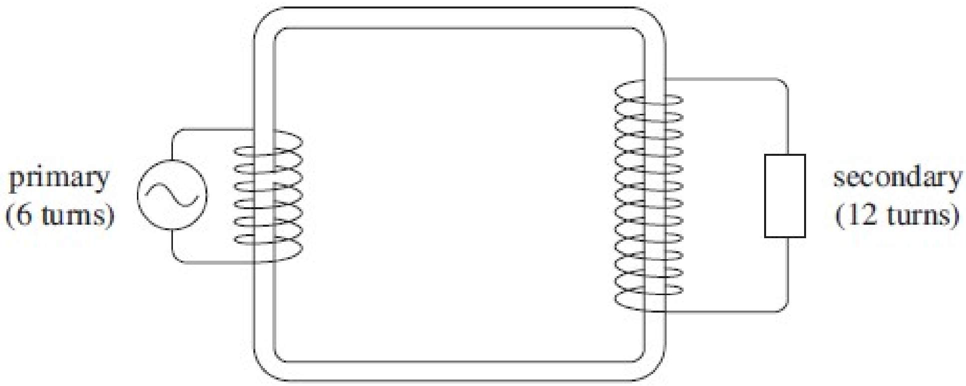
Question 38 (4 marks)

The diagram shows an ideal transformer.



The primary coil is connected to an AC supply. The current in the secondary coil is 5 A.

(a) Calculate the current in the primary coil.

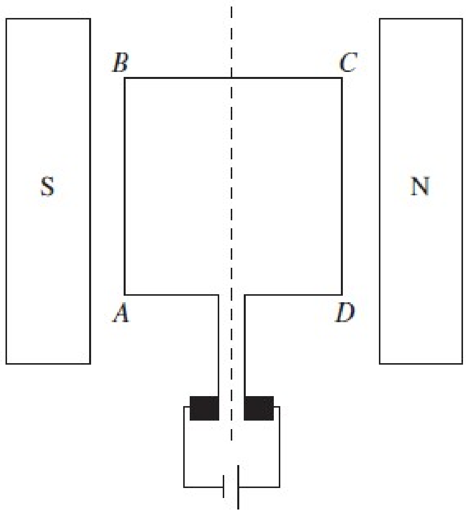
2

(b) Explain why it is important to use AC rather than DC when operating transformers.

2

Question 39 (4 marks)

The diagram shows a simple DC motor with a single loop of wire, *ABCD*.



(a) Compare the forces acting on sides *AB* and *CD* in the position shown.

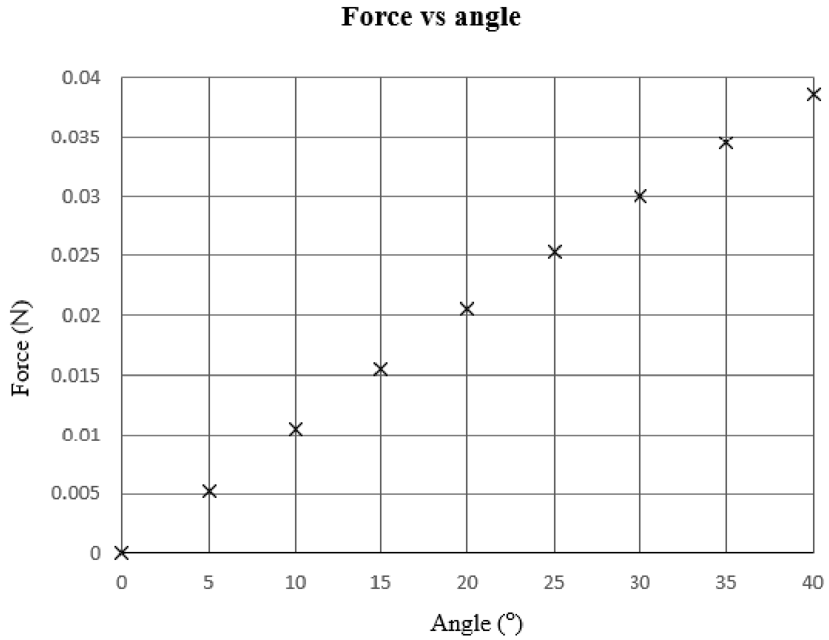
2

(b) Outline one way the torque produced by the motor could be doubled. Support your answer with a relevant equation.

2

Question 40 (5 marks)

An investigation was conducted to explore the relationship between the force on a current carrying conductor and the angle the conductor makes with a magnetic field.
The results are shown by the graph.



(a) Identify TWO variables which should be controlled to make this a valid investigation.

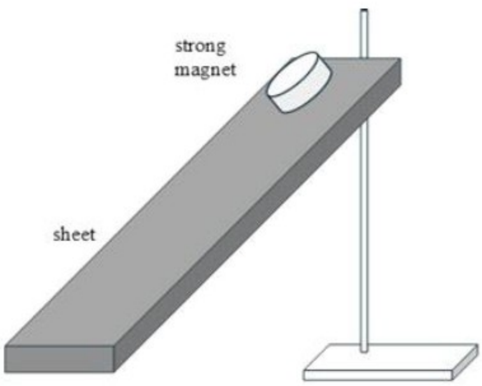
2

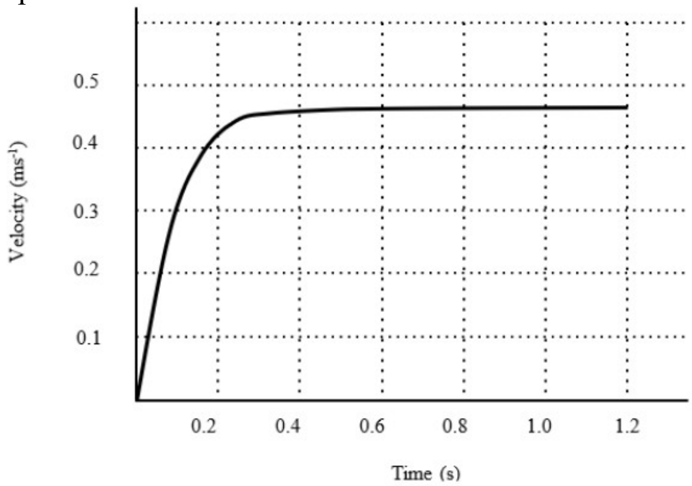
(b) The student used the points on the graph to conclude that the force is directly proportional to the angle. Assess the validity of the student's conclusion.

3

Question 41 (5 marks)

A thick, frictionless copper sheet was set up to make a smooth ramp. A strong magnet was placed at the top of the ramp and is allowed to slide from rest. As it slides down, its velocity over time is recorded and shown in the graph below.





Using appropriate laws and physics concepts, explain the shape of the graph.

5

End of Exam. Well done ☺

Extra writing space – clearly indicate which question you are answering.

Extra writing space

Extra writing space

Extra writing space

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CHERRYBROOK TECHNOLOGY HIGH SCHOOL

2025 PHYSICS
AP4 Marking Guidelines

SECTION I Multiple Choice (20 marks)

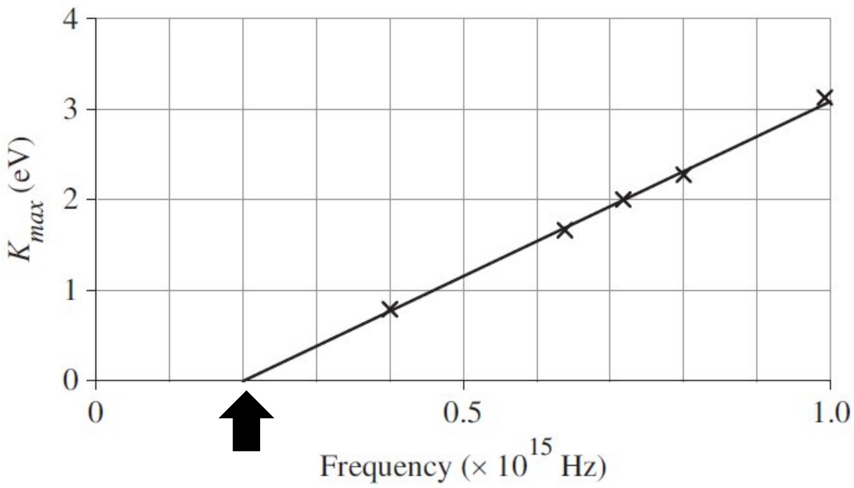
	A	B	C	D
Question 1	○	○	●	○
Question 2	○	○	○	●
Question 3	○	●	○	○
Question 4	○	○	○	●
Question 5	●	○	○	○
Question 6	●	○	○	○
Question 7	○	●	○	○
Question 8	○	○	●	○
Question 9	○	○	●	○
Question 10	○	○	●	○
Question 11	○	○	●	○
Question 12	○	●	○	○
Question 13	●	○	○	○
Question 14	○	●	○	○
Question 15	○	●	○	○
Question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

Section II – 80 MarksMS(Q21-Q27,Q38,39), JZ(Q28-Q36,), WF-(Q35-Q41)

Q21(a) Plot the results on the axes provided and, hence, determine whether photoelectrons would be emitted from the metal if it was exposed to light with a wavelength of 3 μm.
Include a relevant calculation in your answer.

Criteria	Marks
• Plots all data points correctly AND • draws a line of best fit AND quotes f_o from the extrapolated graph • Determines that photoelectrons are not emitted based on a relevant calculation	4
Plots all data points AND provides correct steps in the calculation	3
Plots all data points with one error or omission AND provides a correct step in the calculation	2
Provides some relevant information	1

Sample Answer:



threshold frequency = x-intercept = 0.2×10^{15} Hz

Finding the frequency of incident light gives:

$$f = \frac{c}{\lambda}$$

$$= \frac{3.00\times10^{8}}{3\times10^{-6}}$$

$$= 0.1\times10^{15}\ \text{Hz}$$

As 0.1×10^{15} Hz is less than the threshold frequency of 0.2×10^{15} Hz, photoelectrons would not be emitted if the metal was exposed to this light.

Marker's comments: Students are reminded to use crosses not dots to plot the points for a graph. The graph needed to show extrapolation to the Frequency axis so that the threshold frequency f_o could be clearly read off the x-intercept. Many students tried to calculate gradients and then use the formula for K_{max} to derive an expression for the equation of the line and through this equation, determine the threshold frequency and then compare it to the frequency of the incident light. This was a possible (but very time consuming) way to achieve the answer. However, students who only used one point on the graph to attempt this technique were not awarded marks.

Q22(a) Explain how the Hafele–Keating experiment validated time dilation as predicted by special relativity.

Criteria	Marks
Explains in detail (relating cause and effect) how the Hafele-Keating experiment validated time dilation as predicted by special relativity	3
Outlines the relative speed and time predictions for ONE flight OR Outlines the time predictions for both flights	2
Provides some relevant information	1

Sample Answer:

The atomic clocks on the eastward flight (with Earth's rotation) were moving faster relative to the atomic clocks on the ground. The atomic clocks on the westward flight (against Earth's rotation) were moving slower relative to the atomic clocks on the ground. The theory of special relativity predicts that the atomic clocks on the eastward flight would show slightly less elapsed time compared to the atomic clocks on the ground, while the atomic clocks on the westward flight would show slightly greater elapsed time. The results of the Hafele-Keating experiment matched the predictions, thus validating time dilation as predicted by special relativity.

Marker's comments: Students found it difficult to clearly express their answers. There was confusion in applying the terms 'moving faster/slower' as it was often not clear whether these terms referred to the relative velocity of the plane compared to the plane on the ground, or the rate the clock was 'ticking'. For reference, the clocks moving Eastwards lost 59ns of time slowing down relative to the clocks staying on the ground while the clocks moving Westwards gained 273ns of time, speeding up relative to the clocks on the ground.

Q22(b) Explain why classical physics cannot accurately account for this momentum. Support your answer with a relevant calculation.

Criteria	Marks
Explains why classical physics cannot account for the electron's momentum. AND Supports the answer with a relevant calculation	3
Shows some understanding of the limitations of classical physics	2
Provides some relevant information	1

Sample Answer:

According to classical physics, momentum (p) is calculated by multiplying an object's mass (m) and its velocity (v). Therefore, the velocity of an electron with a momentum of 8.7×10^{-22} kg m s^{-1} would be:

$$v = \frac{p}{m}$$

$$= \frac{8.7 \times 10^{-22}}{9.109 \times 10^{-31}}$$

$$= 9.6 \times 10^{8} \text{ m s}^{-1}$$

This speed is not possible as it exceeds the speed of light. Hence, classical physics cannot account for this momentum. Relativistic effects need to be considered to account for the electron's momentum.

Marker's comments: Most student completed the correct calculation and added additional information accounting for the value.

Q23(a) Calculate the energy released in joules for this reaction.

Criteria	Marks
Correctly calculates energy released in joules using mass-energy equivalence.	**3**
Correctly calculates the mass defect with clear working and correct substitution.	**2**
Shows correct method but with minor calculation or substitution/unit error	**1**

Sample Answer:

Δm = (m of reactants) - (m of products)

Δm = (2×2.0141) - (3.0160+1.0087)

Δm = 0.0035 u

Δm = 0.0035 u x 1.661 x 10^{-27}

Δm = 5.8135 x 10^{-30} kg

$E=mc^2$

E = 5.8125 x 10^{-30} x (3 x $10^{8})^{2}$

E = 5.23215 x 10^{-13} J

Marker's Comments: This question was done well be most students. However, a few left their answers in eV.

Q23(b) Calculate the total energy released if 1.5×10^{25} deuterium nuclei undergo fusion.

Criteria	Marks
Correctly calculates the number of fusion events and total energy released.	**2**
Attempts correct method but with minor error in calculation.	**1**

Sample Answer:

$$\textit{Fusion events} = \frac{1.5\times10^{25}}{2} = 7.5 \times 10^{24}$$

$$E_{total} = 7.5 \times 10^{24} \times 5.23 \times 10^{-13}$$

$$E_{total} = 3.92 \times 10^{12}\ \text{J}$$

Marker's comments: Most students completed this question well.

Q24(a) Calculate the wavelength of the laser light.

Criteria	Marks
Correct answer provided using correct calculations	**3**
Correct steps taken towards a correct answer but one error made	**2**
One correct step in calculation shown.	**1**

Sample Answer:

Using $d\sin\theta = m\lambda$ where, as θ is small, $\sin\theta$ is approx. $= \tan\theta = x/L$

$x/L = 0.0150/1.5 = 0.010$

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

$\lambda = 200 \times 10^{-6} \times 0.010/3$

$\lambda = 6.67 \times 10^{-7}$ m

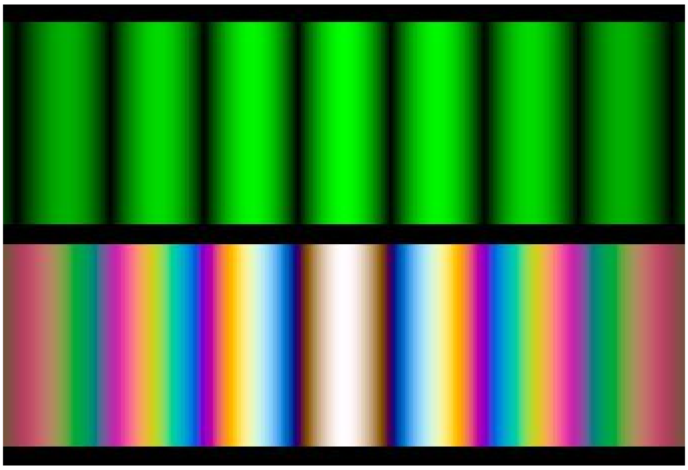
Marker's comments: Some students were a little confused with the value of 'm' to use (m=3) and either left this number out of the formula or used a '2' instead.

Q24(b) Explain the differences in the patterns produced by coherent monochromatic light and light from an incandescent source, when passed through a double-slit interference apparatus.

Criteria	Marks
Correct explanation includes reference to monochromatic light and coherent light Reference to the spread of colours using an incandescent source is explained	**2**
Response includes reference to the need for a single wavelength to observe bright and dark regions	**1**

Sample Answer:

An incandescent light source emits light over a range of wavelengths. To obtain an interference pattern with alternating bright and dark regions, a coherent monochromatic light source is required, i.e. one which emits light with a single wavelength that is in phase. Each different wavelength from an incandescent source produces bright spots on an interference pattern at different places/angles, producing a rainbow-like effect.



Coherent monochromatic source

Incandescent light source

Marker's comments: Many students thought the Incandescent light source would produce no interference effects. Students need to remember to describe the features of the pattern and not just use the expression 'interference pattern'.

Q25 Calculate the wavelength of the electron as it orbits the proton.

Criteria	Marks
Correctly determines the de Broglie wavelength by substituting in the appropriate equation	**2**
Calculates the wavelength with limited or no working shown	**1**

Sample Answer:

The de Broglie wavelength for the electron is $\lambda = \frac{h}{mv}$ or

$$\lambda = \frac{6.626 \times 10^{-34}}{9.109 \times 10^{-31} \times 2.23 \times 10^{6}}$$

$$\lambda = 3.26 \times 10^{-10} \text{ m}$$

Marker's comments: Some student tried to incorrectly solve this problem by using classical physics formula for circular motion which assumes the electron is a particle.

Q26 Use the stimulus to describe the structure of an atom of hydrogen-2.

Criteria	Marks
Describes the structure of hydrogen-2, correctly identifies all three relevant elementary particles (proton, neutron, electron), and refers accurately to their quark composition for nucleons	**2**
Describes the structure of hydrogen-2, identifying the proton, neutron AND/OR electron AND includes accurate quark composition for at least one nucleon	**1**

Sample Answer:
A hydrogen-2 atom is made of 1 proton, 1 neutron and an electron. The proton and neutron are made up of quarks. The proton has two up quarks and one down quark (uud), and the neutron has one up quark and two down quarks (udd). The electron is a fundamental particle – a lepton and is not made of quarks.

Marker's comments: This question was answered well but a few student forgot to mention the electron.

Q27 Describe how TWO experiments have contributed to our understanding of the nucleus of the atom.

Criteria	Marks
• Describes TWO relevant experiments	**4**
Describes ONE relevant experiment and outlines another relevant experiment	**3**
• Outlines TWO relevant experiments OR • Describes ONE relevant experiment	**2**
• Provides some relevant information	**1**

Sample Answer:
Two experiments are 1.Rutherford's gold foil experiment and 2.Chadwick's discovery of the neutron.
1.Most alpha particles passed straight through the foil, indicating the atom is largely empty. However, a small number were deflected at large angles, some even bouncing back, which suggested a concentrated positive charge. This led Rutherford to propose the nuclear model, where electrons orbit a central, massive, positive nucleus.
2. Chadwick bombarded beryllium with alpha particles, observing a radiation that, when passed through paraffin wax, caused protons to be ejected with significant force but was unaffected by electric or magnetic fields. This indicated the presence of neutral particles with a mass similar to that of protons, which were named neutrons. This discovery explained the remaining mass of the atom not accounted for by protons and electrons and clarified the nucleus's composition as containing both protons and neutrons.
Marker's comments: Most student provided great detail in this answer, often using a page at the back of the exam paper to write additional information. Rutherfords experiment was recalled well but there was some confusion in recalling Chadwick's experiment. Students are reminded to read the question carefully – it was about the **nucleus** of the atom not just 'the atom'.

Q28 Calculate the transmitted intensity, I_f, when the planes of the polarising filters are changed so that $\theta_1 = 20.0°$, $\theta_2 = 40.0°$ and $\theta_3 = 60.0°$.

Criteria	Marks
Correctly calculate I_f	**2**
Show some relevant working out *Students must recognise θ is the angle between polarising axes	**1**

Sample Answer:

$I_f = 10 \times \cos^2 20 \times \cos^2 20 \times \cos^2 20 = 6.89$ units

Marker's comments: Many students failed to recognise in malus's Law formula, θ is the angle between polorising axes.
A polarising filter reduces the intensity of unpolarised light by 50%. The light is already vertically polarised before entering the first filter.

Q29(a) Calculate the temperature of the black-body.

Criteria	Marks
Correctly calculate T with correct unit: K	**2**
Identify peak wavelength 1.1×10^{-6} m from the graph OR Applied Wien's law formula with wrong λ and T is expressed in the correct unit: K	**1**

Sample Answer:
λ max = 1.1 μm

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

$$T = \frac{2.898 \times 10^{-3}}{1.1 \times 10^{-6}}$$

$T = 2.6 \times 10^3$ K

Marker's comments: A few students carelessly wrote °C as the unit for T or did not correctly convert λ to metre.

Q29(b) Explain how the black-body radiation curve led to the development of the particle model of light.

Criteria	Marks allocated
Describe the prediction made by classical physics	**1**
Describe how radiation is emitted using the particle model	**1**

Sample Answer:
Classical physics predicts radiation emitted by blackbody as continuous waves. As wavelength decreases, intensity would increase infinitely. This violates Law of conservation of energy. Plack proposed radiation is emitted in packets of energy known as quanta.
Marker's comments
Students need to describe the classical Physics prediction of the relationship between wavelength and intensity. Just quoting 'UV catastrophe' or 'disobey law of conservation of energy' without explaining will not be awarded a mark.
Similarly, students will not be awarded a mark by just mentioning 'quantised energy' or 'quantisation' without linking to the blackbody radiation curve.

Q30 Outline two reasons why this spectral broadening could be occurring.

Criteria	Marks
Outlines two valid reasons for spectral broadening	**2**
Outlines one valid reason	**1**

Sample Answer:

Answers can include

- Doppler shift due to a binary star system
- fast rotation of star
- increased density of the star.

Marker's comments: Syllabus states spectra of stars provide information on density. Therefore, mentioning high pressure without referring to density will not be awarded a mark.

Q31 Determine the required speed of the target cup and the distance the target cup must travel so that the ball lands in the cup.

Criteria	Marks allocated
Correctly calculate the launch velocity	**1**
Use kinematic equations to calculate time of flight and horizontal range	**2**
Identify the speed of the target cup as u_x	**1**

Sample Answer:

Finding the launch velocity of the ball gives:

$$v = \sqrt{\frac{2W}{m}}$$

$$= \sqrt{\frac{2 \times 19.4}{0.046}}$$

$$= 29.04\ldots \text{ m s}^{-1}$$

The required speed of the target cup is equal to the horizontal component of the ball's launch velocity. Therefore, the required speed is:

$u_x = 29.04\ldots\cos(35) = 23.8 \text{ m s}^{-1}$

Finding the time it takes to reach the top of the ball's trajectory gives:

$$t_{\text{up}} = \frac{v_y - u_y}{a_y}$$

$$= \frac{0-(29.04\ldots\sin(35)}{-9.8}$$

$$= 1.69\ldots \text{ s}$$

Finding the vertical displacement from the ball's initial position to the top of its trajectory gives:

$$s_{\text{up}} = u_y t_{\text{up}} + \frac{1}{2} a_y t_{\text{up}}^2$$

$$= (29.04\ldots\sin(35)) \times 1.69\ldots + \frac{1}{2} \times -9.8 \times 1.69\ldots^2$$

$$= 14.15\ldots \text{ m}$$

Finding the vertical displacement from the top of the ball's trajectory to the target cup gives:

$$s_{\text{down}} = 14.15\ldots + 2.6$$

$$= 16.75\ldots \text{ m}$$

Finding the time from the top of the ball's trajectory to the target cup gives:

$$t_{\text{down}} = \sqrt{\frac{2s_{\text{down}}}{a_y}}$$

$$= \sqrt{\frac{2 \times 16.75\ldots}{9.8}}$$

$$= 1.84\ldots \text{ s}$$

Finding the total time of flight gives:

$$t = t_{\text{up}} + t_{\text{down}}$$

$$= 1.69\ldots + 1.84\ldots$$

$$= 3.54\ldots \text{ s}$$

Therefore, the distance the target cup must travel is:

$$s_x = u_x t$$

$$= 23.8 \times 3.54\ldots$$

$$= 84 \text{ m}$$

Marker's comments: Work done on the ball is to increase the kinetic energy of the ball only. During its fight to reach maximum height, the kinetic energy is converted to gravitational potential energy. Some students mistakenly used W = K + U

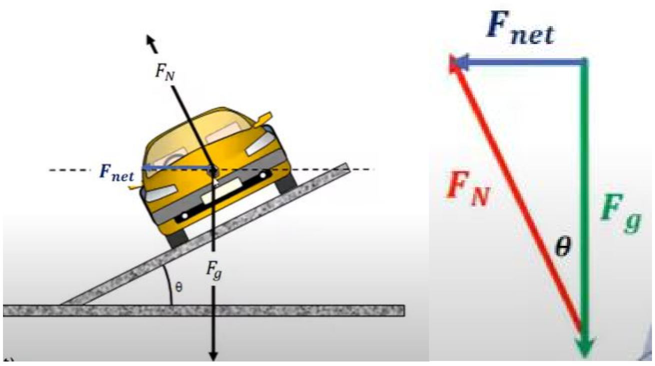
The trajectory is not symmetrical. Time of flight is not twice of the time taken to reach maximum height.

Rounding error is not penalised in this question. However, students need to be careful not to round answers until in the last step of calculation.

Q32(a) Show how the design speed equation for v can be derived as shown below

Criteria	Marks
Use a force vector diagram to derive design speed	**2**
Made some attempt to derive v	**1**

Sample Answer:



$$\frac{Fc}{mg} = \tan\theta$$
$$Fc = \frac{mv^2}{r}$$

Marker's comments: Students need to use a vector diagram (Fc, F_N and F_g to derive design speed. Use maths equations $\frac{N\sin\theta}{N\cos\theta}$ to derive the formula will not be awarded full marks as it has no meaning in Physics.

Q32(b) Explain what will occur if the car travels slower than the design speed.

Criteria	Marks allocated
Explain why the car will slide down the track or how the car will maintain the radius	**1**
Identify the car will slide down the track	**1**

Sample answer: The radius and Fc will decrease. The car will slide down the track towards the centre. Sideway friction between the tyres and the road is needed to maintain Fc and keep the car on the track at the same radius.

Marker's comments: Many students recognised the car will slide down the track. However, the reason is not well explained.

Q33(a) Calculate the mass of Saturn.

Criteria	Marks
Correctly calculate the mass	**2**
Show correct substitution into Kepler's third Law formula	**1**

Sample answer:

(a) Calculate the mass of Saturn. 2

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}, \quad r = 1.22\times10^6 \times 10^3\,m, \quad T = 15.9\times24\times60\times60$$

$$\therefore M = \frac{4\pi^2 \times (1.22\times10^9)^3}{6.67\times10^{-11} \times (24\times60\times60\times15.9)^2}$$

$$\approx 5.69\times10^{26}\,kg \quad (3\,s.f.)$$

Marker's comments: Quite a number of students did not convert distance and time to SI unit before substituting into Kepler's 3rd Law formula.

Q33(b) The mass of Titan is 1.35 x 10^{23} kg. Calculate the total mechanical energy of Titan

Criteria	Marks
Correct calculate the total mechanical energy	**3**
Show correct substitution into the total mechanical energy formula	**2**
Show the correct formula to calculate total mechanical energy OR Correct calculate U or K	**1**

Sample answer:

$$U + K = -\frac{GMm}{2r}$$

$$= -\frac{6.67\times10^{-11} \times 5.69\times10^{26} \times 1.35\times10^{23}}{2(1.22\times10^9)}$$

$$= -2.10\times10^{30}\,J$$

Marker's comments: Gravitational potential energy is always negative as indicated in the formula. The total mechanical energy is negative for any planet or satellite that is <u>in orbit.</u>

Q33(c) Identify the energy changes as the satellite moves from the surface of Saturn into orbit.

Criteria	Marks
Identify changes to gravitational potential energy AND kinetic energy	**2**
Identify change to gravitational potential energy OR kinetic energy	**1**

Sample answer: Both kinetic energy and gravitational potential energy increase.

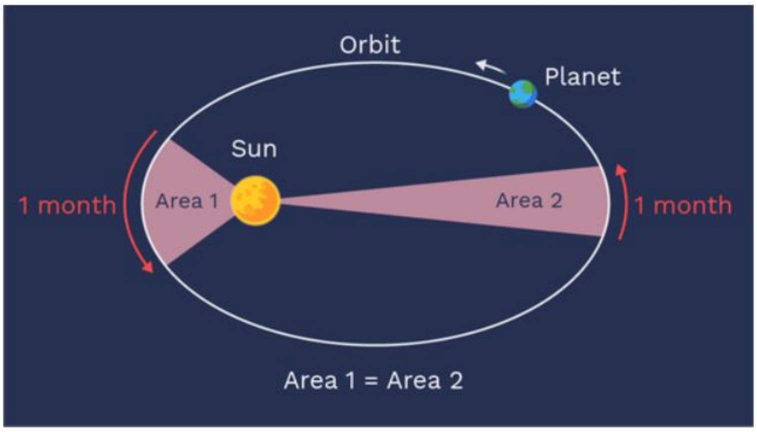
Marker's comments: Many students wrongly applied conservation of mechanical energy. Law of conservation of mechanical energy only applies when the satellite is orbiting Saturn. The satellite is leaving the surface of Saturn,it needs to have sufficient kinetic energy to leave the surface (recall how the escape velocity is derived). As the satellite is getting further away, kinetic energy must keep increasing.

The question asks about the energy changes not energy transformation.

Q34 Account for the changes in velocity of the planet as it moves from perihelion to aphelion.

Criteria	Marks
Correctly identify the velocity change AND provide explanation.	**2**
Correctly identify the velocity decreases as the planet moves from perihelion to aphelion.	**1**

Sample answer: The velocity will decrease. At perihelion, the object is moving fastest, and at aphelion, it's moving slowest. This is a consequence of Kepler's Second Law, which states that a line joining the Sun to the planet sweeps out equal areas in equal times.



Students can also use conservation of mechanical energy.

Marker's comments: Some students use orbital velocity formula to state the relationship between v and r. However, r is orbital radius, not the distance from the Sun.

Q35 Determine the rocket's distance from the planet's centre at Point 2.

Criteria	Marks
Correctly calculate the value of r_2	**3**
Show correct substitution into the conservation of mechanical energy formula	**2**
Use law of conservation of mechanical energy $K_i + U_i = K_f + U_f$	**1**

Sample answer:

$E_i = K + U$ $\qquad\qquad$ $E_f = K + U$

$= \frac{1}{2}mv_1^2 - \frac{GMm}{r_1}$ $\qquad\qquad$ $= \frac{1}{2}mv_2^2 - \frac{GMm}{r_2}$

By law of conservation of energy, $E_i = E_f$

$\therefore \frac{1}{2}mv_1^2 - \frac{GMm}{r_1} = \frac{1}{2}mv_2^2 - \frac{GMm}{r_2}$

$\frac{1}{2}v_1^2 - \frac{1}{2}v_2^2 - \frac{GM}{r_1} = -\frac{GM}{r_2}$ $\qquad$ $G = 6.67\times10^{-11}$, $M = 8.6\times10^{23}$ kg,

$r_2 = \dfrac{-GM}{\frac{1}{2}v_1^2 - \frac{1}{2}v_2^2 - \frac{GM}{r_1}}$ $\qquad$ $v_1 = 5500\text{ ms}^{-1}$, $v_2 = 2900\text{ ms}^{-1}$, $r_1 = 4.3\times10^6$ m

$= \dfrac{-6.67\times10^{-11}\times8.6\times10^{23}}{\frac{1}{2}(5500^2 - 2900^2) - \frac{6.67\times10^{-11}\times8.6\times10^{23}}{4.3\times10^6}}$

$\approx 2.4\times10^7$ m

Marker's comments:

Always use $K_i + U_i = K_f + U_f$ when applying conservation of energy,
NOT $\Delta U = \Delta K$, because Δ means final – initial. This will lead to wrong working out as $K_f - K_i = U_i - U_f$ after we arranged the formula.

Many students used Kepler's Law. However, the rocket is not orbiting the planet. The speeds of the rocket given in the question are not orbital velocity. Therefore, the total mechanical energy is NOT $-\frac{GMm}{2r}$

Q36 Calculate the charge-to-mass ratio of the particle.

Criteria	Marks
Correctly calculate q/m ratio	**3**
Use the component of velocity $\perp$ B for both F_B and Fc calculations	**2**
Use F_B = Fc	**1**

Sample answer:

Its velocity perpendicular to field: $2.5\times10^6 \sin 62°$.

$F_B = F_C$

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

$\frac{q}{m} = \frac{v}{Br}$ $\qquad$ $v = 2.5\times10^6\sin62°$, $B = 160\times10^{-3}$ T, $r = 0.286$ m

$= \dfrac{2.5\times10^6\sin62}{160\times10^{-3}\times0.286}$

$\approx 4.82\times10^7\text{ C kg}^{-1}$ (3 s.f.)

Marker's comments:

Many students failed to use the component of v $\perp$ B to calculate F_c. F_c is in the same direction to F_B and in circular motion, F_c is perpendicular to v. So if you used v sin62 to calculate F_B, you should do the same for F_c.

Q37 What distance, d, between Wire Z and Wire Y is required so that Wire Z does not experience a net force from the other two wires?

Criteria	Marks
• Correctly calculates the distance between Wire Z and Wire Y to achieve zero net force by • Substitutes into correct formulae (1) $F_{YZ} = (\mu_0 / 2\pi) \cdot (I_Y I_Z / d)$ • Uses correct logic in equating the forces (1) $F_{YZ} = F_{XZ}$ • Obtains correct answer *0.02m or 2cm* (1)	
Two of the above	**2**
One of the above	**1**

Sample answer:

F per unit length = $(\mu_0 / 2\pi) \cdot (I_1 I_2 / r)$

Force on Wire Z from Wire Y FYZ = $(\mu_0 / 2\pi) \cdot (IY\ IZ / d)$

Force on Wire Z from Wire X FXZ = $(\mu_0 / 2\pi) \cdot (IX\ IZ / (0.02 + d))$

To cancel net force on Z: FYZ = FXZ

$(5 \times 2) / d = (10 \times 2) / (0.02 + d)$

$10 / d = 20 / (0.02 + d)$

$10(0.02 + d) = 20d$

$0.2 + 10d = 20d$

$0.2 = 10d$

$d = 0.02$ m = 2 cm

Marker's comments: Please ensure that you write out the full equation in your answers. The paper states that full working MUST be shown.

Q38(a) Calculate the current in the primary coil.

Criteria	Marks
Shows formula and substitution for correct calculation of I=10A	2
Provides correct substitution or only correct answer (no units)	1

Sample answer:

(a) $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ and $V_p I_p = V_s I_s$

Therefore:

$$I_p = \frac{N_s I_s}{N_p}$$

$$= \frac{12 \times 5}{6}$$

$$= 10 \text{ A}$$

Marker's comments: Most students answered this well, a few did not show working out or forgot the units.

Q38(b) Explain why it is important to use AC rather than DC when operating transformers.

Criteria	Marks
Explains both reasons for using AC and reasons why DC is not used	2
Shows some understanding of electromagnetic induction AND the difference between AC and DC	1

Sample answer:
Transformers operate on the principle of electromagnetic induction, which relies on a changing magnetic field. AC produces a continuous change in current direction, creating a fluctuating magnetic field that is essential for inducing voltage in the secondary coil. On the other hand, DC provides a constant current that does not create this changing magnetic field, rendering transformers ineffective.
Marker's comments: Most students answered this question well with respect to reasons for using AC when operating transformers, but not all students gave reasons why DC could not be used.

Q39(a) Compare the forces acting on sides *AB* and *CD* in the position shown..

Criteria	Marks
Compares the magnitude and direction of the forces acting on sides AB and CD	2
Compares the magnitude OR direction of the forces acting on sides AB and CD	1

Sample answer:
The magnitude of the forces acting on sides AB and CD in the position shown are the same. The direction of the force acting on side AB is into the page, whereas the direction of the force acting on side CD is out of the page

Marker's comments: Many students forgot to compare the magnitude of the force. Students are reminded that the terms 'up or upward' and 'down or downward' are vague and do not mean the same as 'out of the page' and 'into the page'.

Q39(b) Outline one way the torque produced by the motor could be doubled. Support your answer with a relevant equation.

Criteria	Marks
Outlines the impact on the maximum torque AND Supports the answer with the equation: $\tau = nIA_{\perp}B$	**2**
Outlines the impact on the maximum torque	**1**

Sample answer:

In accordance with $\tau = nIA_{\perp}B$, doubling the number of loops (n) would double the maximum torque (τ) produced by the motor.

Other options include doubling I or A or B

Marker's comments: Most students answered this question well. A few used unspecific terminologies such as 'increase the number of turns'.

Q40(a) Identify TWO variables which should be controlled to make this a valid investigation.

Criteria	Marks
Identifies two variables that should be controlled	**2**
Identifies one variable that should be controlled	**1**

Sample answer: Magnetic field strength and current in the conductor (or any relevant variable)

Marker's comments: Many students just wrote "Magnetic Field" or "Conductor" More detail needed to sufficiently answer question.

Q40(b) The student used the points on the graph to conclude that the force is directly proportional to the angle. Assess the validity of the student's conclusion.

Criteria	Marks
Relates the formula F = BILsinθ to the graph to conclude the statement is invalid	**3**
Identifies that the conclusion is invalid with a partial explanation.	**2**
Identifies that the conclusion is valid because the data presents as a straight line but fails to identify the sine nature of Force and angle at angles above 40 degrees. OR Identifies that it is invalid but has insufficient evidence.	**1**

Sample answer:

The student's conclusion that the force is directly proportional to angle is invalid.
Force on a current-carrying conductor in a magnetic field is given by F = BILsin θ.
This shows a sinusoidal (not linear) relationship with angle. A graph of F vs. angle would be a sine curve, not a straight line.

It may be stated that the student's conclusion was valid since a straight LOBF could reasonably be fitted through the data. This is acceptable as long as the justification is valid.

Marker's comments: Students who spoke of it being valid within teh data set received a mark. However, this question was assessing a higher level of understanding, which most students answered well.

Q41 Using appropriate laws and physics concepts, explain the shape of the graph.

Criteria	Marks
Provides a comprehensive explanation that analyses the velocity–time graph of the magnet, explains the change in magnetic flux through the conducting ramp, relates this to the production of eddy currents and induced magnetic fields opposing the motion (Lenz's Law), and links the opposing magnetic force to the gravitational component along the ramp. Justifies how the equilibrium of forces results in terminal velocity.	**5**
Provides a clear explanation that relates the motion of the magnet to changing flux and induced opposing fields, identifying the reduction in acceleration until constant velocity is reached. Uses appropriate scientific terminology but lacks either full force balance reasoning or explicit application of Lenz's Law.	**4**
Provides an explanation that makes a connection between either forces or motion and induced currents, magnetic fields, or flux change. Communicates partial understanding but omits key links between flux, induced fields and terminal velocity.	**3**
Provides a description that identifies the motion shown on the velocity–time graph with limited link to electromagnetic induction, OR describes flux change producing opposing fields without reference to constant velocity.	**2**
Provides minimal relevant information, for example naming induction or describing motion without explanation.	**1**

Sample answer:

The velocity of the magnet increases at first as gravity accelerates it down the ramp. As it moves, the changing magnetic flux through the copper ramp induces eddy currents, as described by Faraday's Law. By Lenz's Law, these currents generate magnetic fields that oppose the magnet's motion, consistent with the conservation of energy.

With increasing velocity, the rate of flux change rises, producing stronger eddy currents and therefore a greater opposing magnetic force. This reduces the magnet's net force, causing its acceleration to decrease. Eventually, the induced opposing force balances the component of gravity along the ramp. At this point, the forces are in equilibrium and the magnet no longer accelerates.

The magnet then travels at a constant speed, known as terminal velocity. This shows how motion, flux change, and induced fields interact, with the lost gravitational potential energy converted into electrical energy and dissipated as heat in the conductor.

Marker's comments: Common errors included confusing gravity with magnetic forces, with some students incorrectly suggesting friction or the magnet being pulled back up rather than reaching terminal velocity. Many mentioned Faraday's or Lenz's laws but didn't clearly link changing flux to emf and an opposing magnetic field. Others misused Newton's laws, vaguely invoked conservation of energy, or misread the graph by saying the magnet stops instead of levelling off. A number of responses also listed laws or equations without relating them back to the graph's shape.