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2025

Task 4: Trial Examination

Weighting: 30%

HSC Physics

Booklet 4

Section II - PART 3 - 26 marks

- Attempt Questions 34-38
- Allow about 50 minutes for this part

Instructions:
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.

Extra writing booklets are available upon request. If you use a booklet, clearly indicate which question you are answering and indicate in this paper that a booklet has been used. Use a new booklet for each Question Booklet.

EXTRA BOOKLETS USED: (please circle) YES / NO

IF EXTRA BOOKLETS USED - HOW MANY BOOKLETS USED? (please circle)

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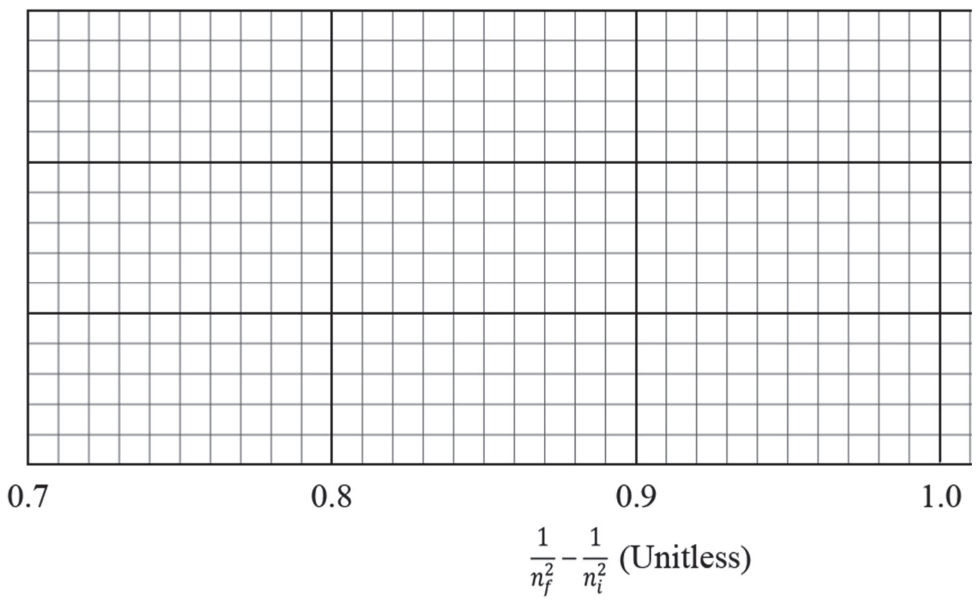
Question 34 (4 marks)

The wavelengths of the Lyman series of light emitted from a hydrogen atom are shown in the table below. **4**

Transition $n_i \to n_f$	$\frac{1}{n_f^2} - \frac{1}{n_i^2}$	Wavelength (nm)	1/Wavelength $(\times 10^6 m^{-1})$
$2 \to 1$	0.75	122	8.2
$3 \to 1$	0.88	103	9.7
$4 \to 1$	0.93	97	10.3
$5 \to 1$	0.96	95	10.5
$6 \to 1$	0.97	94	10.7

Construct a graph on the grid below, using appropriate data from the table, and thus determine an experimental value for Rydberg's constant.



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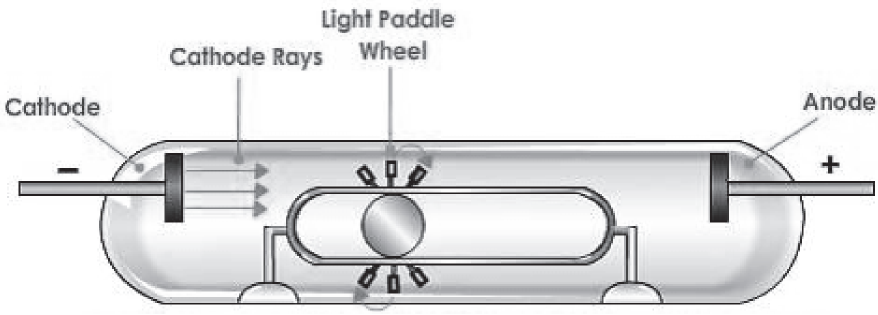
Question 35 (7 marks)

Early experiments determined that cathode rays were beams of small, negatively charged particles, later known as electrons. One of these experiments was the paddlewheel experiment, shown below. **7**



Other experiments that confirmed different properties of electrons, like mass and charge, include those done by Millikan and Thomson.

Explain how the paddlewheel experiment and EITHER the Millikan OR Thomson experiment confirmed properties of the electron. You must include a diagram and a quantitative explanation as part of your response.

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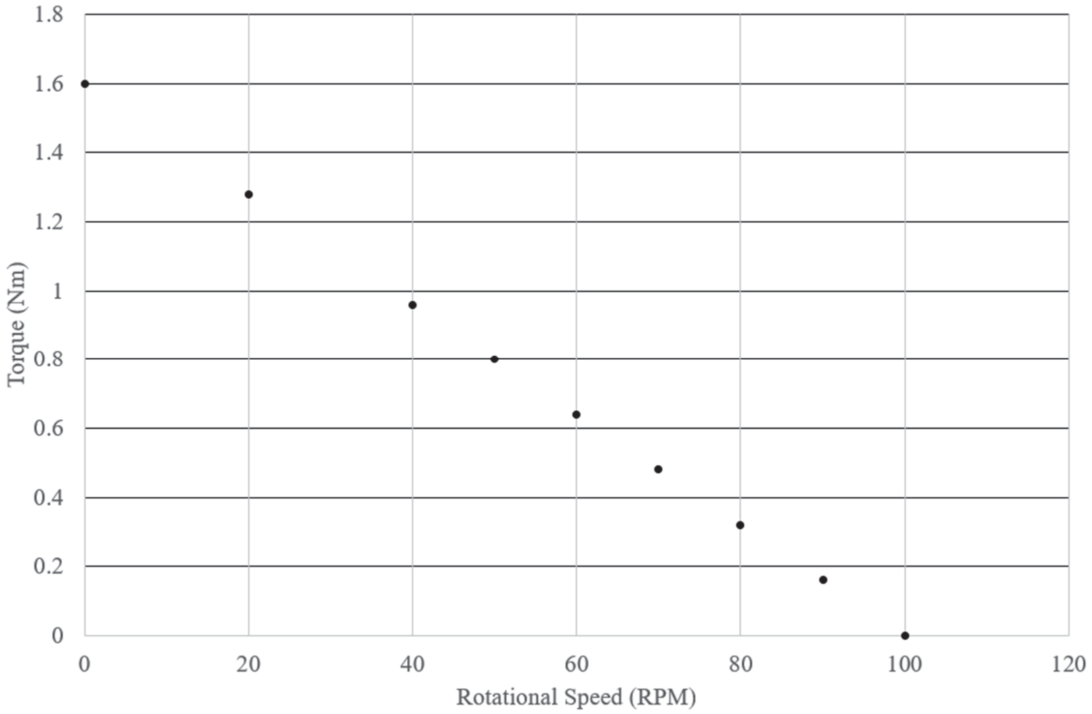
More space for answer provided on next page.

Answer space for Qu 35 continues.

Question 36 (5 marks)

A DC motor was turned on. After some time it reached its maximum rotational speed of 100 RPM (revolutions per minute). **5**

During this time, the RPM and torque were measured at various points and plotted on a graph.



Explain, with reference to data in the graph, why the torque decreases as the rotational speed of the DC motor increases.

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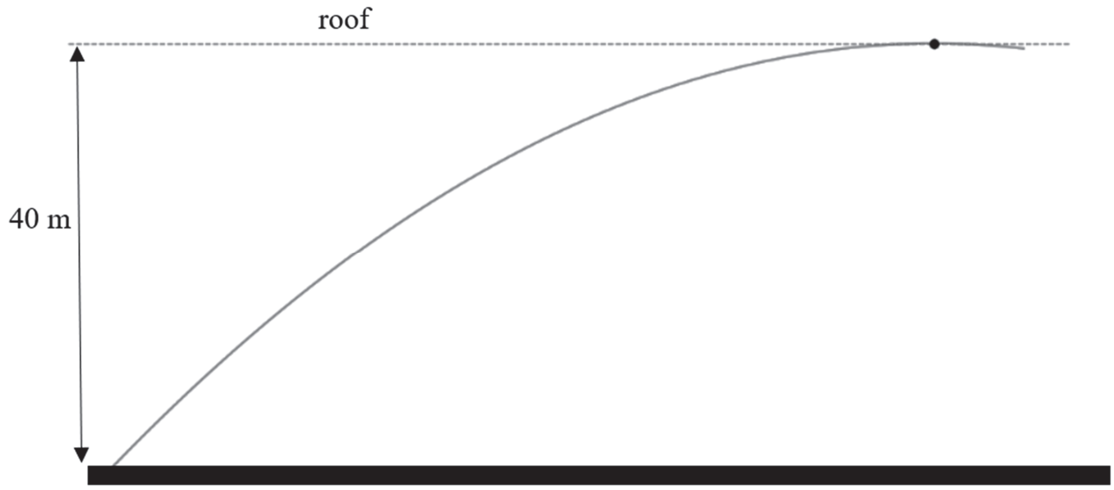
Question 37 (6 marks)

A ball is hit at a speed of 35 ms^{-1} from ground level inside a stadium with a roof that is 40 m above the ground. **6**

At the top of the flight of the ball, it just touches the roof, and continues on its path, with no impact upon its trajectory. The projectile lands at the same level from which it was launched.



Determine the angle at which the ball must be hit so that it just touches the roof, and thus calculate the range of the ball when it lands.

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Question 38 (4 marks)

A student made the following claim about the structure of the hydrogen-1 isotope. **4**

"The atom is made of two fundamental particles. The atom has one electron, bound to the nucleus through the weak nuclear force. The atom has one proton, comprised of three quarks (udd), held together by the strong nuclear force."

Assess the students' claim.

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END OF ASSESSMENT TASK

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Task 4: Trial Examination

Weighting: 30%

HSC Physics
Booklet 3

Section II - PART 2 - 25 marks

- Attempt Questions 29-33
- Allow about 45 minutes for this part

Instructions:
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.

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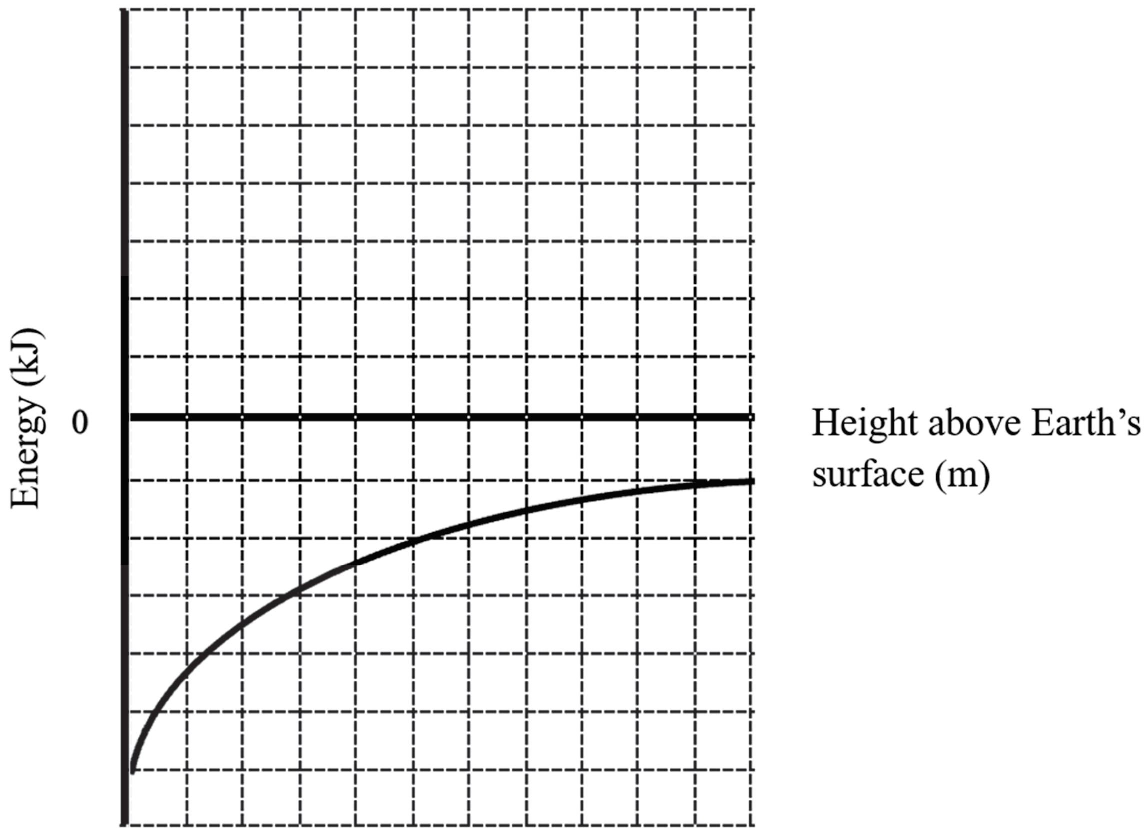
Question 29 (6 marks)

An object is launched vertically from the Earth's surface. After launch, the object has no engine or fuel providing any further force of propulsion.

The line on the graph below represents the gravitational potential energy of the object at a range of heights above the Earth's surface.



(a) Draw the line representing the kinetic energy of the object for the same range of heights. **2**

(b) Derive the equation for escape velocity: $v = \sqrt{\frac{2GM}{r}}$, and thus show the escape velocity of Earth is 11.2 km s^{-1}. **4**

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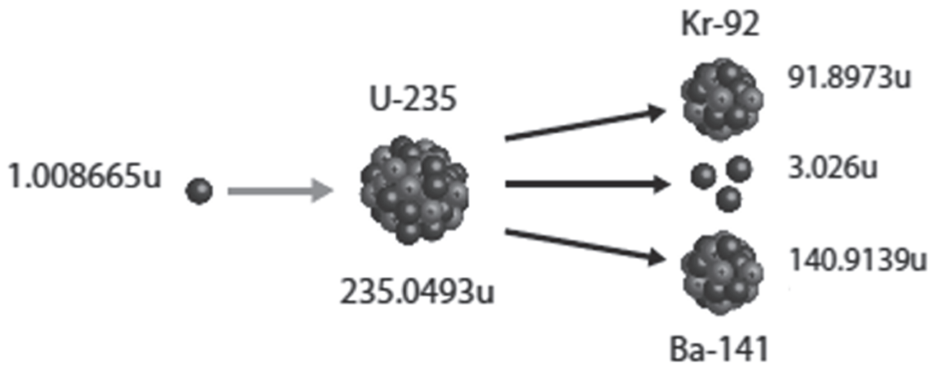
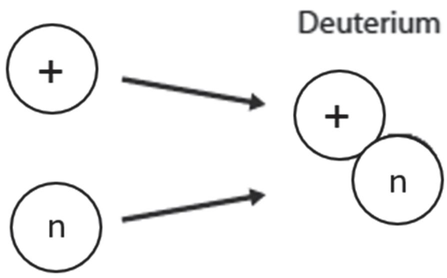
Question 30 (9 marks)

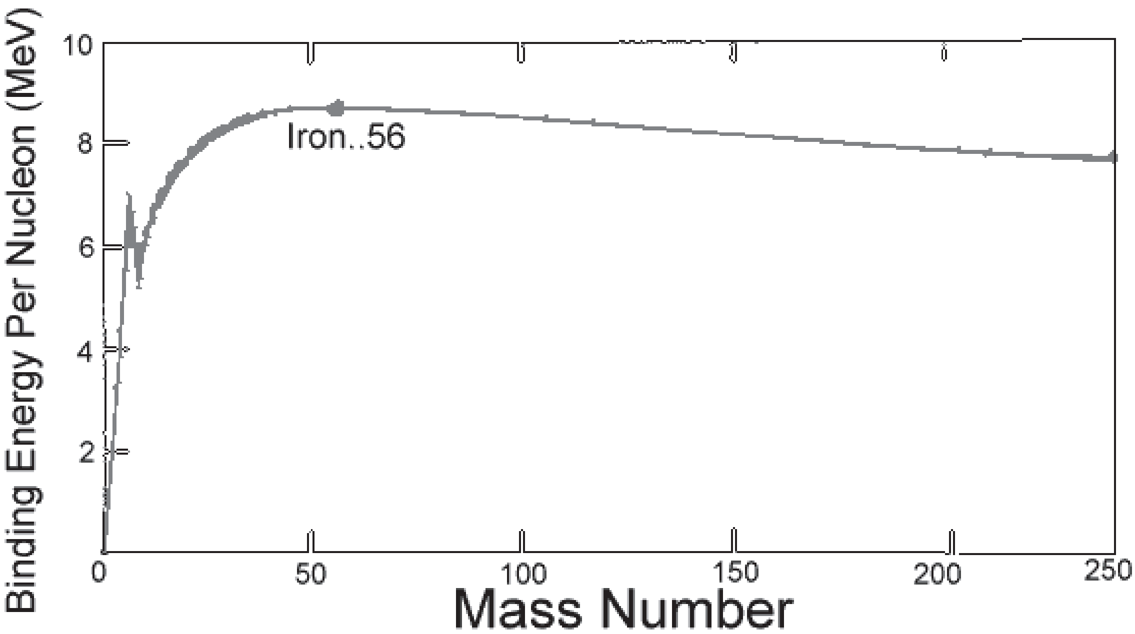
Nuclear fission, shown below, is used in nuclear power reactors to generate electricity. **9**
The mass of each particle is shown in the diagram.



Nuclear fusion occurs in stars and provides the heat and light energy produced by stars.
A diagram of part of this process is shown below.



The binding energy graph below is related to both fission and fusion processes.



Question over page

Analyse, qualitatively and quantitatively, the processes that occur in fission and fusion to release energy in nuclear reactors and stars.

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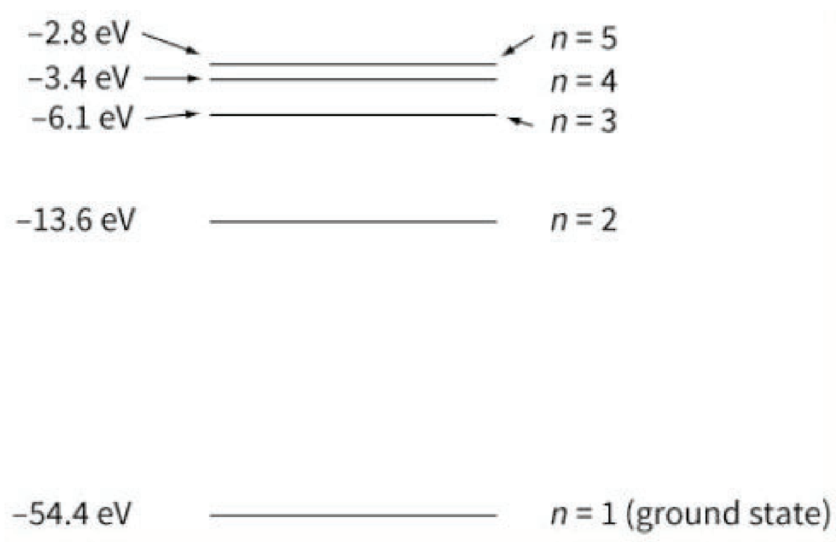
Answer space for Qu 30 continues.

Question 31 (3 marks)

The energy levels of helium are shown below. **3**



Calculate the wavelength of light produced by the transition of an electron from level 5 to level 2.

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Question 32 (4 marks)

Experiments and observations are used to provide evidence for different models of light. **4**

The diagrams below show two experiments that support the wave model of light.

Diagram A – double slit experiment

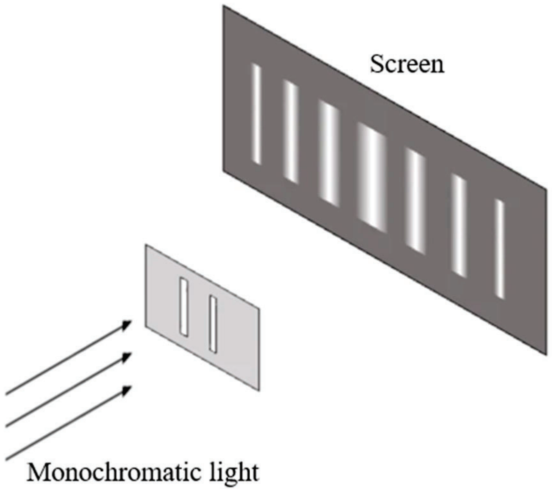
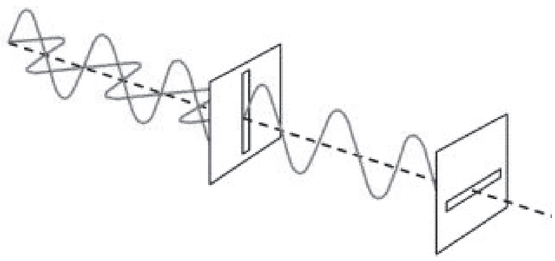


Diagram B – polarisation experiment



Explain how these experiments support the wave model of light.

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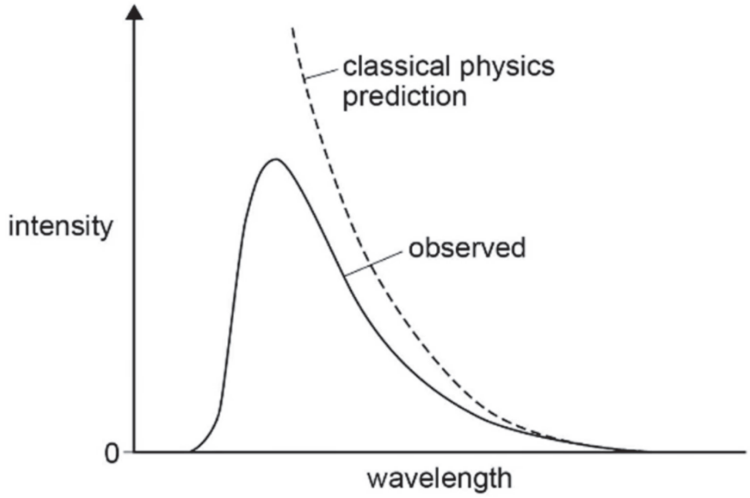
Question 33 (3 marks)

The solid line on the graph below shows how the intensity of radiation from a black body varies with wavelength at a particular temperature. **3**



Use this example to explain how a new scientific model is developed.

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END OF QUESTION BOOKLET 3

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2025

Task 4: Trial Examination

Weighting: 30%

HSC Physics

Booklet 2

Section II - PART 1 - 29 marks

- Attempt Questions 21-28
- Allow about 50 minutes for this part

Instructions:
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.

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IF EXTRA BOOKLETS USED - HOW MANY BOOKLETS USED? (please circle)

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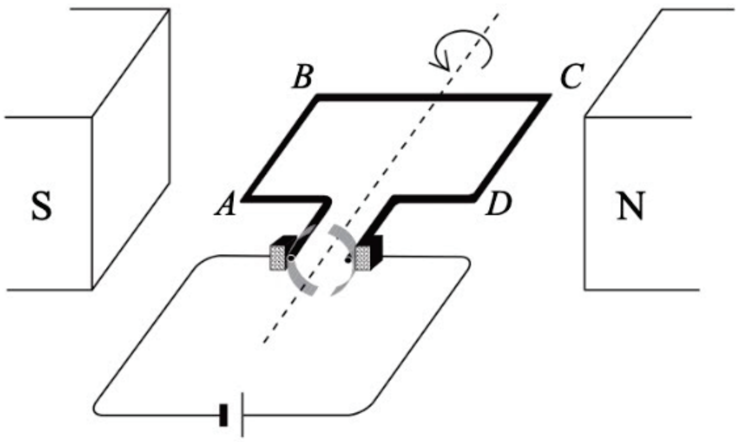
Question 21 (2 marks)

A single coil rotating in a magnetic field is shown below. **2**



Identify TWO ways that the maximum torque on the coil in the diagram could be increased.

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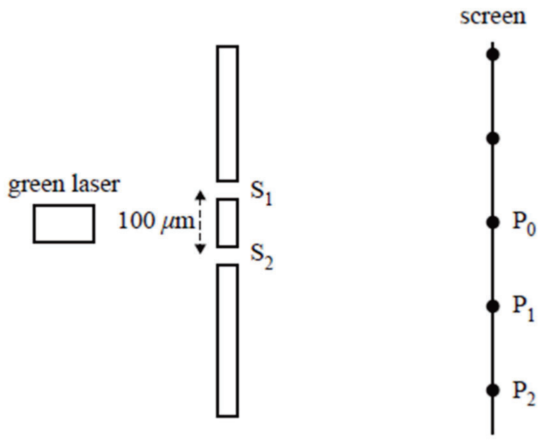
Question 22 (2 marks)

A green laser of wavelength 532 nm illuminates a double slit. The slits are 100 µm apart. The position of the central bright band is labelled as P_0. The first two bright bands to the right are labelled as P_1 and P_2. **2**



Calculate the angle between P_0 and P_2 from the double slit.

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Question 23 (3 marks)

Outline Maxwell's contributions to electromagnetic theory. **3**

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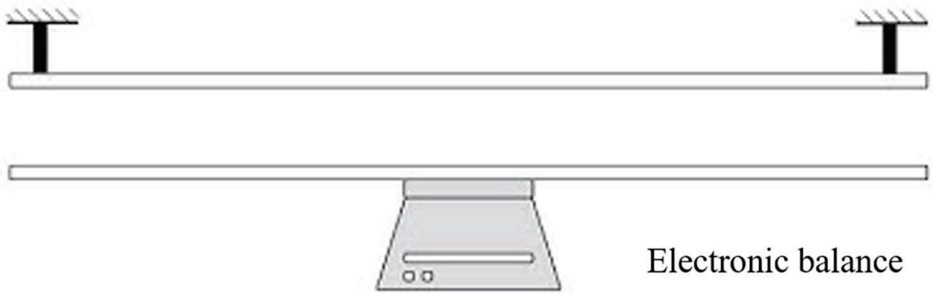
Question 24 (3 marks)

An experiment is set up with two parallel copper rods, A and B, of length 0.75 m as shown below. Rod A is 2.0 mm above Rod B. Rod A is fixed in place and unable to move. Rod B is resting on the electronic balance and is free to move. **3**



The electronic balance is zeroed so it reads 0 g with Rod B resting on the balance. No current is flowing through either rod.

A current of 5.6 A is now passed through both rods, with the current flowing in opposite directions in the two rods.

Determine the mass shown on the electronic balance, in grams, when the current is flowing through both rods.

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Question 25 (4 marks)

In developing his theory of the expanding universe, Hubble collected spectra for various galaxies that were at known distances from Earth. **4**

Explain how Hubble's analysis of spectra showed evidence for the expanding universe theory.

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Question 26 (3 marks)

Outline ONE similarity and ONE difference between the motion of a satellite in orbit, and a charged particle moving perpendicular to a magnetic field. **3**

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Question 27 (7 marks)

The photoelectric effect has a number of observable properties that cannot be explained by classical physics theory.

(a) Analyse how the concept of a cut-off frequency of light in the photoelectric effect applies to both the wave and particle models of light. **4**

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(b) In an experiment using the photoelectric effect apparatus, the stopping voltage for photoelectrons emitted was measured. **3**

Justify how the stopping voltage of the emitted photoelectrons would change if the intensity of the incoming light was doubled.

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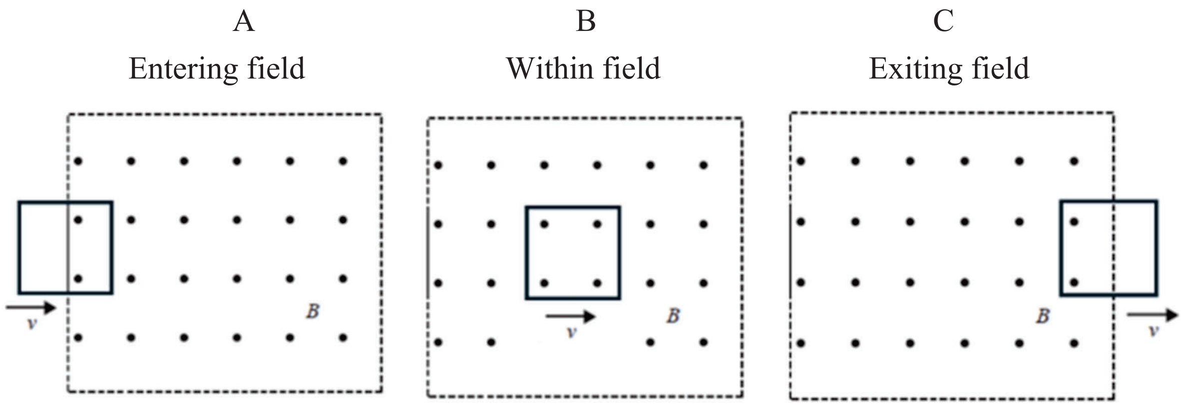
Question 28 (5 marks)

A single square loop of conducting wire was moved through a uniform magnetic field, at constant speed, as shown below. **5**



Analyse how the magnitude and direction of the current will change as the loop passes from outside the magnetic field on the left side (A), within the field (B), and passing out of the field on the right side (C).

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END OF QUESTION BOOKLET 2

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Task 4: Trial Examination

Weighting: 30%

HSC Physics

Booklet 1

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams and tables using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided
- For questions in Section II, 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
- Extra writing booklets can be used. If you use an extra booklet, use a new booklet for each Question Booklet.
- This paper MUST NOT be removed from the assessment room.

Total marks - 100

BOOKLET 1

Section I - 20 marks

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

BOOKLET 2

Section II - PART 1 - 29 marks

- Attempt Questions 21-28
- Allow about 50 minutes for this part

BOOKLET 3

Section II - PART 2 - 25 marks

- Attempt Questions 29-33
- Allow about 45 minutes for this part

BOOKLET 4

Section II - PART 3 - 26 marks

- Attempt Questions 34-38
- Allow about 50 minutes for this part

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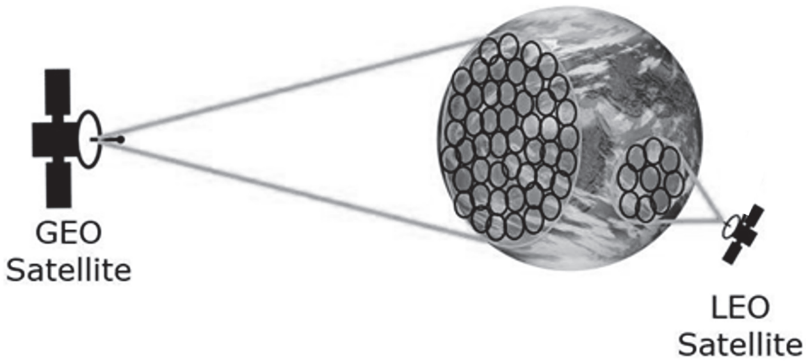
Section I

20 marks

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

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

1. A satellite is moved from a low Earth orbit (LEO) to a geostationary orbit (GEO).



The satellite will now be able to:

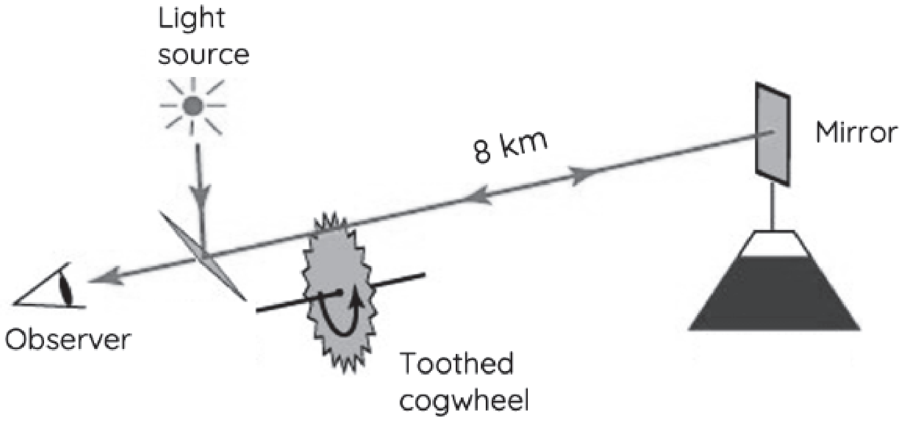
A. image the surface of the entire Earth.

B. take more detailed images of the Earth.

C. continuously monitor the same location on Earth.

D. move over the surface of the Earth and therefore scan a larger area of the Earth.

2. An experimental setup designed to measure the speed of light is shown below.



Which statement best describes the experiment?

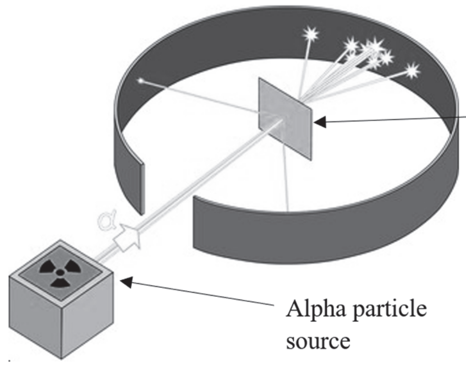
A. A historical method of measuring the speed of light using distance and time.

B. A contemporary method of measuring the speed of light using distance and time.

C. A historical method of measuring the speed of light using frequency and wavelength.

D. A contemporary method of measuring the speed of light using frequency and wavelength.

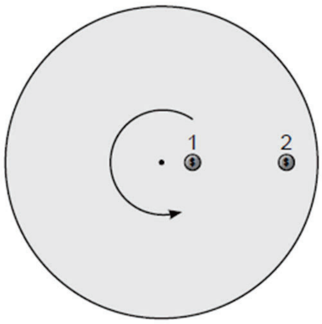
3. The diagram below shows a key experiment in the development of the atomic model.



Which statement correctly identifies the development, and the scientist who proposed the development of the model?

	Scientist	**Development of the model**
A.	Thomson	Existence of the nucleus.
B.	Rutherford	Existence of the proton.
C.	Rutherford	Existence of the nucleus.
D.	De Broglie	That electrons could behave as waves.

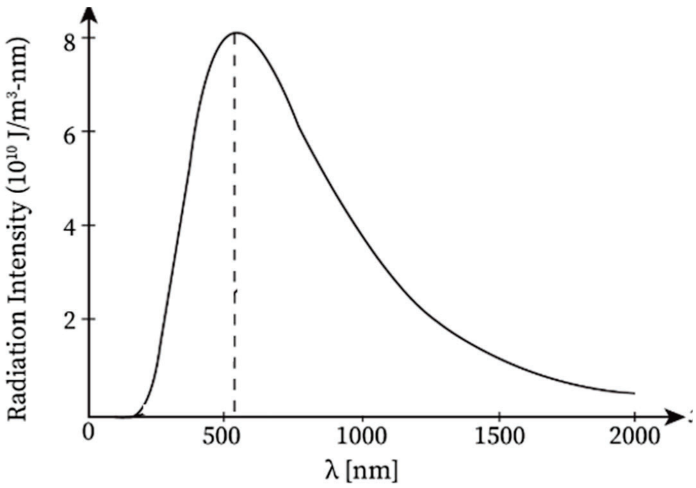
4. Two points are labelled on a rotating disk as shown below.



What is the relationship between the linear (v) and angular (ω) speed at points 1 and 2?

	Angular speed (ω)	**Linear speed (v)**
A.	$\omega_1 < \omega_2$	$v_1 = v_2$
B.	$\omega_1 = \omega_2$	$v_1 = v_2$
C.	$\omega_1 = \omega_2$	$v_1 < v_2$
D.	$\omega_1 < \omega_2$	$v_1 < v_2$

5. The following graph shows the radiation emitted from a black body at a range of wavelengths.



How would the peak intensity and wavelength of maximum intensity of the curve change if the blackbody temperature was increased?

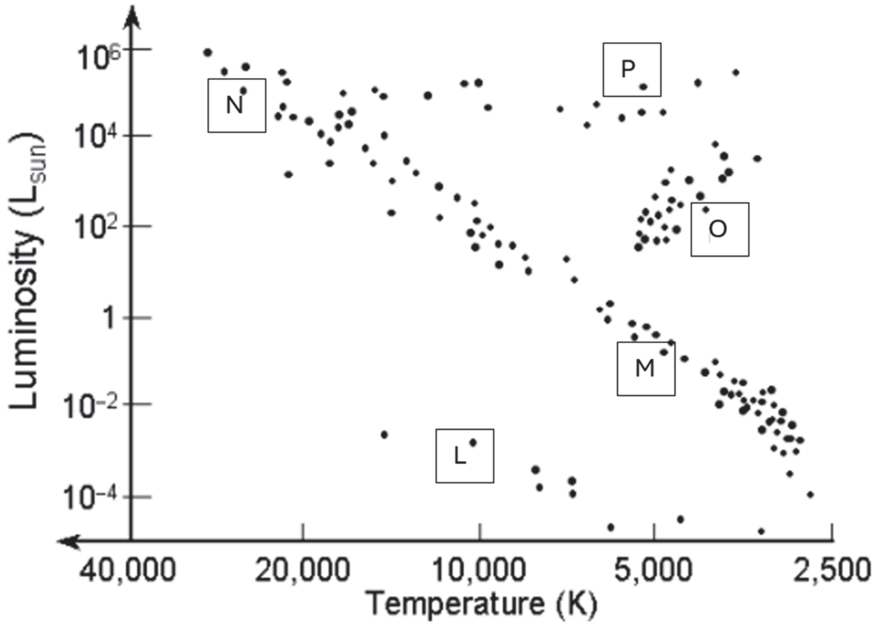
A. Both peak intensity and wavelength of maximum intensity would increase.

B. Both peak intensity and wavelength of maximum intensity would decrease.

C. Peak intensity would increase, wavelength of maximum intensity would decrease.

D. Peak intensity would decrease, wavelength of maximum intensity would increase.

6. The following Hertzsprung-Russell diagram shows stars at various stages in their life cycle.



Which of the following is a possible evolutionary sequence for a star?

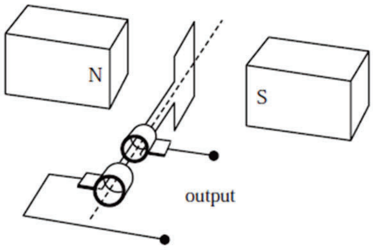
A. N $\rightarrow$ P $\rightarrow$ L

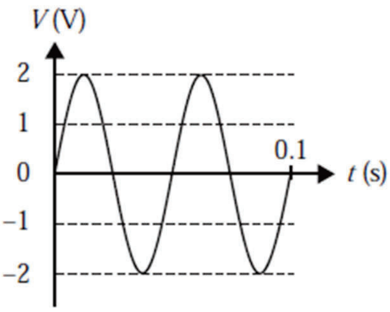
B. M $\rightarrow$ O $\rightarrow$ L

C. M $\rightarrow$ N $\rightarrow$ P

D. L $\rightarrow$ M $\rightarrow$ O

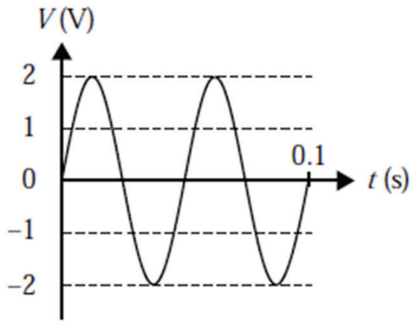
7. An AC generator is operated so that the coil has a constant rotational speed. The output voltage is represented on the graph below.



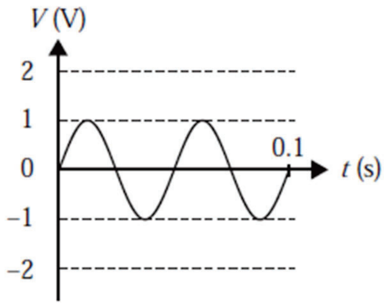


The rotation speed of the coil is halved. Which of the following graphs represents the new output voltage?

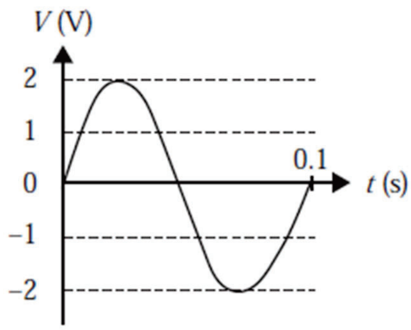
A.



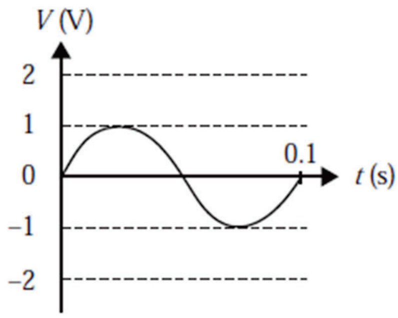
C.



B.



D.



8. A proton moving parallel to a constant electric field is accelerating at 1.15×10^{6} km s^{-1}.

What is the strength of the electric field?

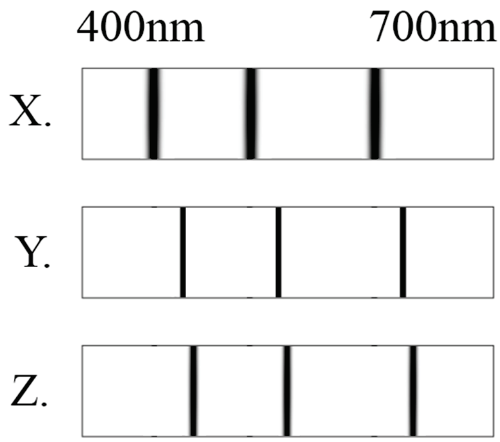
A. 1.9×10^{-21} NC^{-1}

B. 1.9×10^{-18} NC^{-1}

C. 12×10^{-3} NC^{-1}

D. 12 NC^{-1}

9. The spectra of three stars, X, Y and Z, moving away from the Earth are shown.



What is the correct ranking of the THREE stars density (D) and translational velocity (v)?

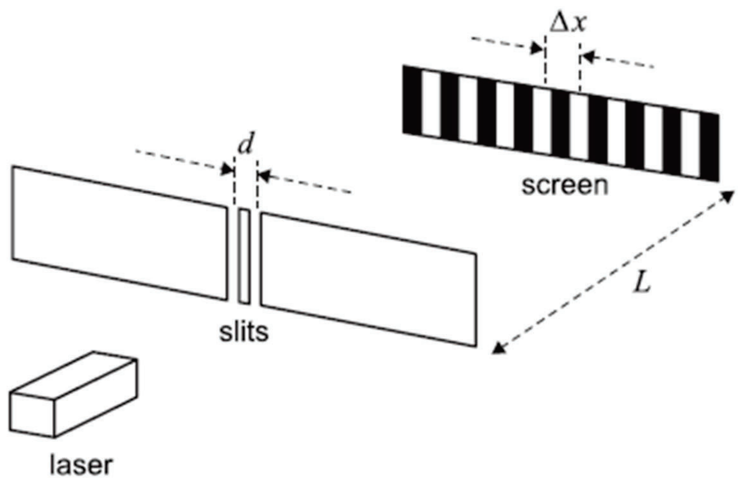
A. $v_z > v_y > v_x$
$D_x > D_y > D_z$

B. $v_x > v_z > v_y$
$D_x > D_z > D_y$

C. $v_x > v_y > v_z$
$D_y > D_z > D_x$

D. $v_z > v_y > v_x$
$D_x > D_z > D_y$

10. A laser was shone onto a double slit which produced an interference pattern on a screen as shown in the diagram.



What changes to the slit separation (d) and distance to screen (L) will both increase the distance between two bright bands (Δx)?

	Slit separation (d)	Distance to screen (L)
A.	Decrease	Increase
B.	Decrease	Decrease
C.	Increase	Increase
D.	Increase	Decrease

11. An astronaut is on a spacecraft travelling at 0.85c past a football field. The astronaut measures the length of the football field at 63.4 m.

What is the length of the football field as measured on Earth?

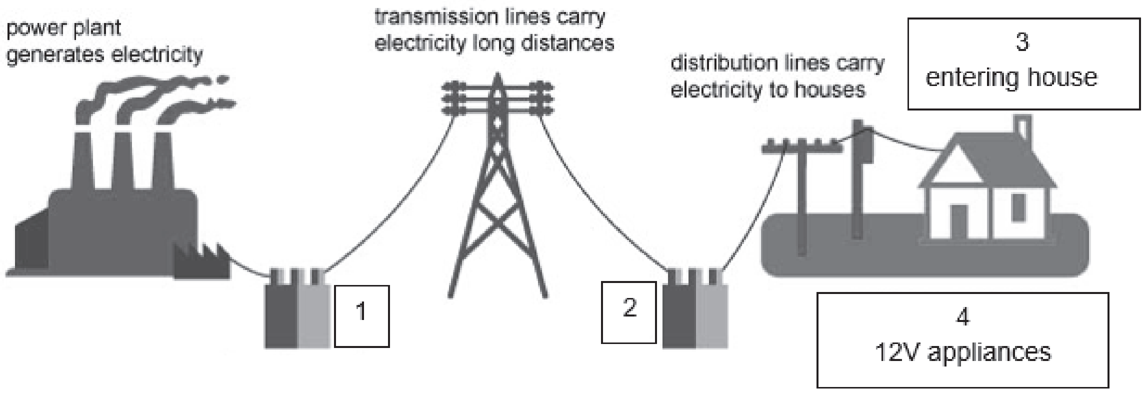
A. 25 m

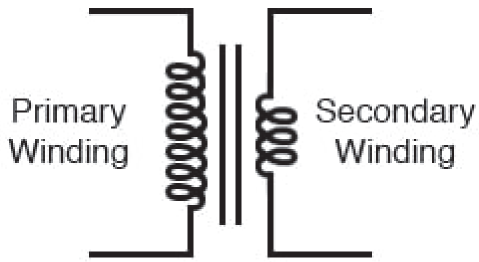
B. 33 m

C. 120 m

D. 164 m

12. The diagrams below show part of the electricity distribution network and a transformer that is found in at least one location within the network.





Where in the distribution network would this transformer be located, and what is its purpose in this location?

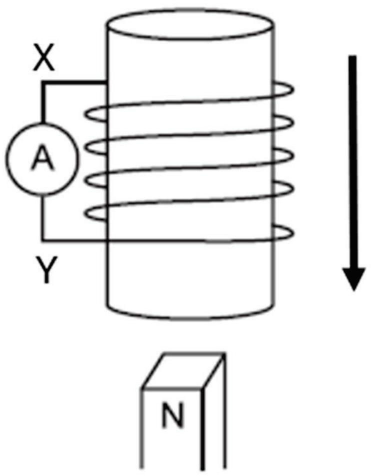
A. 2 – used to step down voltage to the Australian household standard of 240 V.

B. 1 – used to step up voltage so energy is not lost in long distance transmission wires.

C. 2 and 3 – used to step down voltage to allow high voltage appliances to be used in households.

D. 3 and 4 – used to step down voltage so it can be used safely in a range of household appliances.

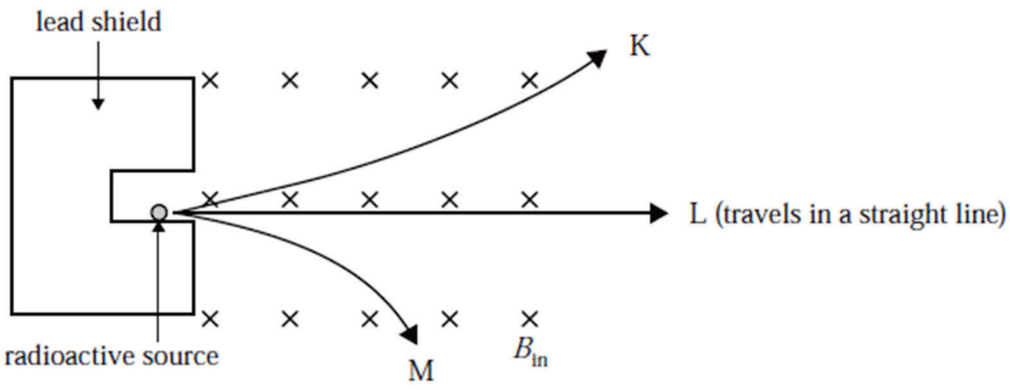
13. A solenoid is lowered onto a magnet that is fixed to a table.



What is the direction of current through the coil, and the direction of the magnetic force on the solenoid as it moves downwards?

	Current direction through coil	Magnetic force on solenoid
A.	X to Y	Upwards
B.	X to Y	Downwards
C.	Y to X	Upwards
D.	Y to X	Downwards

14. Alpha, beta and gamma radiation is passed through a magnetic field. The resulting motion of the radiation is shown below.



Rank the three types of radiation in order of increasing ionising and penetrating power.

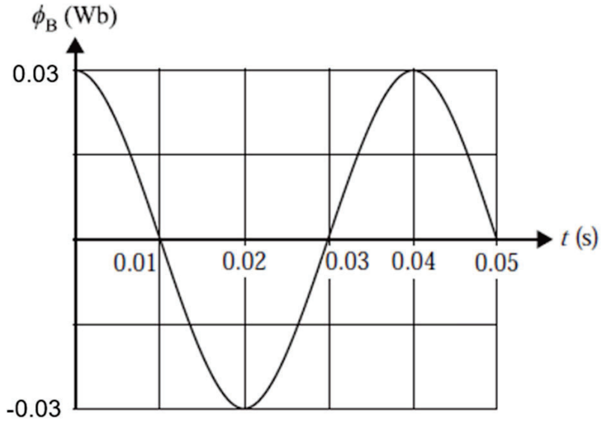
A. Ionising power: L, M, K
Penetrating power: K, M, L

B. Ionising power: K, M, L
Penetrating power: L, M, K

C. Ionising power: K, L, M
Penetrating power: K, M, L

D. Ionising power: L, M, K
Penetrating power: K, L, M

15. The following graph shows how flux changes in a coil over time.



What is the approximate emf generated in this coil between 0.02 and 0.04 s?

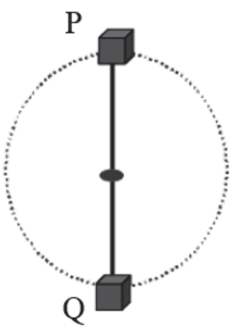
A. +0.03 V

B. - 0.03 V

C. + 3 V

D. - 3 V

16. An object is moving in a vertical circle at a constant speed.

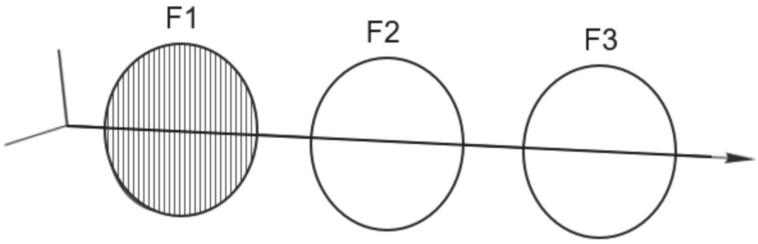


The magnitude of the forces involved with the motion of the object include tension (F_T), gravitational (F_g) and centripetal (F_C) forces.

What is the magnitude of the net force acting on the object at P and Q?

	Net force at P	Net force at Q
A.	F_C	$F_C - F_g$
B.	$F_T - F_g$	$F_T - F_g$
C.	$F_T + F_g$	$F_T - F_g$
D.	$F_T + F_g$	$F_T + F_g$

17. Three polarisation filters are set up as shown below. F1 is oriented vertically, at 0°.



Unpolarised light is passed into F1.

What combination of angles from the vertical for F2 and F3 would result in light leaving F3 at 30% of the initial intensity?

	F2	**F3**
A.	20°	59°
B.	180°	219°
C.	0°	57°
D.	45°	39°

18. A radioactive isotope is known to have one measurable emission for each decay a nucleus in the sample undergoes.

A sample of the isotope was measured to have 148,962,126 emissions in 6 hours and 15 minutes. At the start of the measurement time, the sample had 1.642 x 10^9 nuclei present.

Calculate the approximate half life of the radioactive isotope.

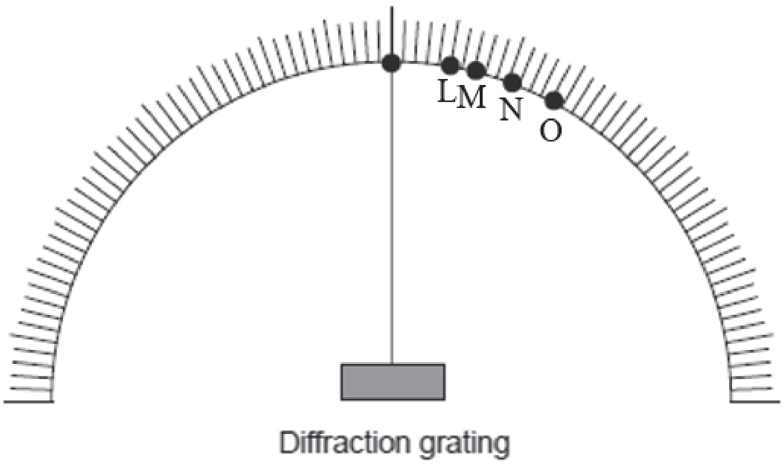
A. 6.5 x 10^3 s

B. 1.6 x 10^5 s

C. 4.7 x 10^5 s

D. 4.2 x 10^6 s

19. A student used a diffraction grating to split the visible wavelengths emitted by hydrogen gas in a discharge tube. The student observed coloured lines at points L, M, N and O.



[This diagram is not drawn to scale.]

Which statement correctly describes the spectral transition lines observed from hydrogen gas?

A. M corresponds to a transition starting at n = 5

B. O corresponds to a transition that started at the n = 7 energy level.

C. L corresponds to the highest energy level transition possible in hydrogen.

D. The electron that produced O transitioned down more energy levels than the electron that produced L.

20. Two satellites orbit the same planet. Satellite A has a period that is 8 times smaller than satellite B.

Calculate the ratio of the speed $v_A : v_B$ of the two satellites.

A. $v_A : v_B = 1:1$

B. $v_A : v_B = 2:1$

C. $v_A : v_B = 4:1$

D. $v_A : v_B = 8:1$

END OF BOOKLET A

BOOKLET 1

MCQ Answers

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

Calculation Solutions

Qu 8

$F = m \times a \qquad F = Eq$

swap with

$E \times q = m \times a$

$E = \dfrac{m \times a}{q}$

$E = \dfrac{\cancel{9.109 \times 10^{-31}}\ 1.673 \times 10^{-27} \times 1.15 \times 10^{9}}{1.602 \times 10^{-19}}$

$E = 12.01$ 1

Qu 11

$l = l_0 \sqrt{1 - \dfrac{v^2}{c^2}}$

$v =$

$l_0 =$

$63.4 = l_0 \sqrt{1 - 0.85^2}$

$l_0 = \dfrac{63.4}{0.5268} = 120.3\ m.$

Qu 15

$$-\left(\frac{\Delta\phi}{t}\right) = -(\text{slope}) = -\left(\frac{0.03-(-0.03)}{0.02}\right)$$

$$= -3$$

Qu 17

$$I = I_0 \cos^2\theta$$

$$\frac{I}{I_0} \Rightarrow \frac{30}{50} = \cos^2\theta$$

$$\theta = \cos^{-1}\left(\sqrt{30/50}\right)$$

$$\theta = \cos^{-1}(0.7746)$$

$$\theta = 39.23^\circ$$

Qu 18

need harder distractors

A. ~~1.8 s~~

B. ~~45.5 s~~

C. 6.5 x 10³ s ✓

D. 1.6 x 10⁵ s ✓

$$N_t = 1.642\times10^9 - 148962126$$

$$N_t = 1.4930\times10^9$$

$$t = (6\times60\times60) + (15\times60) = 22500\,s$$

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

$$1.4930\times10^9 = 1.642\times10^9 e^{-\lambda\times22500}$$

$$\ln\left(\frac{1.4930\times10^9}{1.642\times10^9}\right) = -\lambda\times22500$$

$$\lambda = 4.2279\times10^{-6}\,s^{-1}$$

↳ option 4.2×10^6 (in case stop here)

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

$$t_{1/2} = \frac{\ln 2}{4.2279\times10^{-6}}$$

→ if use 2 not ln 2 ⇒ $4.73\times10^5\,s$

$$t_{1/2} = 1.64\times10^5$$

16

Qu 20

atellites orbit the same planet . $V = \frac{2\pi r}{T}$

iod that is 8 times smaller than satellite B.

f the speed $v_A : v_B$ of the two satellites. $T_B = 8T_A \quad \therefore r = \frac{vT}{2\pi}$

$$\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_B^2} \quad \therefore \frac{\left(\frac{vT_A}{2\pi}\right)^3}{T_A^2} = \frac{\left(\frac{vT_B}{2\pi}\right)^3}{T_B^2}$$

$$\therefore \frac{V_A^3 T_A^{\cancel{3}}}{(2\pi)^3 \times \cancel{T_A^2}} = \frac{V_B^3 8^{\cancel{3}} T_A^{\cancel{3}}}{(2\pi)^3 \times \cancel{T_A^2} \times \cancel{8^2}}$$

$$\therefore \frac{V_A^3}{V_B^3} = \frac{8 \times \cancel{(2\pi)^3} \times \cancel{T_A}}{\cancel{(2\pi)^3} \times \cancel{T_A}}$$

END OF BOOKLET A

$$\frac{V_A}{V_B} = \sqrt[3]{\frac{8}{1}} = \frac{2}{1}$$

BOOKLET 2

Question 21 (Band 2-4)

Identify TWO ways that the maximum torque on the coil in the diagram could be increased

Marking Guidelines	Marks
Two clear methods to increase torque identified.	**2**
One method to increase torque identified.	**1**

Markers Comments:

- This question was very well answered.
- Average = 1.87/2
- Students who use the formula below (see formula sheet), were able to easily answer this question

$$\tau = nIA \perp B$$

Sample Answer/Key Points:

- Number coils (n)
- Magnetic field strength (B)
- Current in coil (I)
- Area of coil (A)

Question 22 (Band 2-5) Examiner: GN

Calculate the angle between P_0 and P_2 from the double slit.

Marking Guidelines	Marks
Full working using the diffraction equation to correctly determine angle to 2nd maxima. Significant figures ignored in marking this question but should be three significant figures.	**2**
A relevant and correct step in the process to determine 2nd maxima or identifies the use the diffraction equation.	**1**

Markers Comments:

Cohort average = 1.7/2 (85%)

- Question was done very well as the average suggests.
- Most students used the diffraction equation
- It is recommended students annotate the stimulus to support their response.
- Some confusion of 100 micrometres. It should be written in scientific notation to reduce transcribing errors so 100 x 10^{-6} m.
- Most recognised that the wavelength need to be written as 532 x 10^{-9} m and not substituted into the equation as 532.
- Too many silly mistakes cost students. Show all working and not simply substitute into your calculator.

Sample Answer/Key Points:

$\lambda = 532\times10^{-9}$ m $\quad d = 100\times10^{-6}$ m $\quad m = 2$

$d\sin\theta = m\lambda$

$100\times10^{-6}\sin\theta = 2\times532\times10^{-9}$

$\theta = \sin^{-1}\left(\frac{2\times532\times10^{-9}}{100\times10^{-6}}\right)$

$\theta = 0.609°$ (3sf)

Calculate the angle between P_0 and P_2. **2**

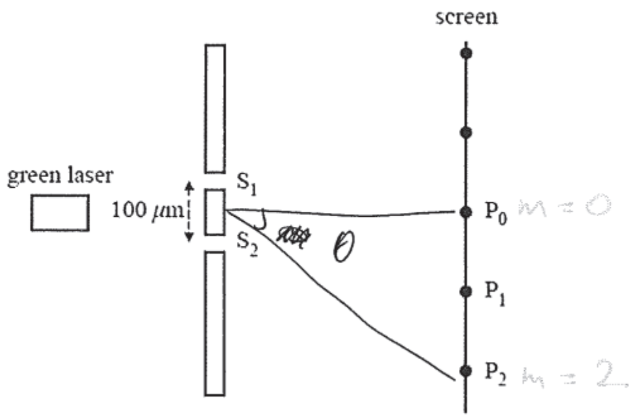
$d = 100 \times 10^{-6} m$ $m\lambda = d \sin \theta$

$\lambda = 532 \times 10^{-9} m$ $2 \times 532 \times 10^{-9} m = 100 \times 10^{-6} m \sin \theta$

$m = 2$ $\theta = 0.6096°$ 0.6096385972

$\theta = ?$ $= 0.610°$ (to 3 sig figs)

Student Sample:



Calculate the angle between P_0 and P_2 from the double slit.

$d = 100\ \mu m = 100 \times 10^{-6} m$

$\lambda = 532\ nm = 532 \times 10^{-9} m$

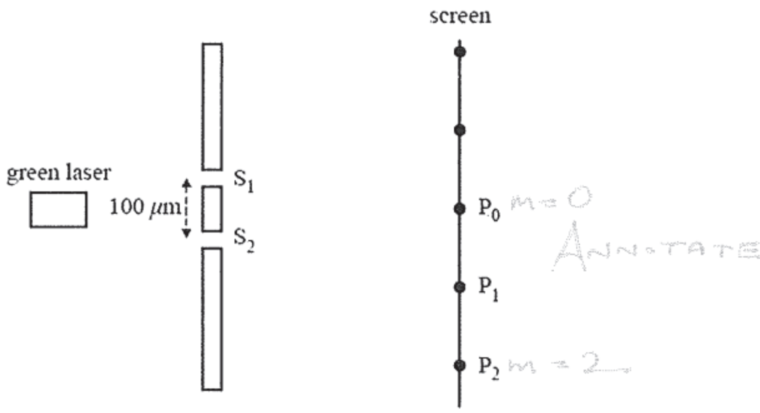
$m = 2$

$d \sin \theta = m\lambda$

$100 \times 10^{-6} \sin \theta = 2(532 \times 10^{-9})$

$\sin \theta = 0.01064$

$\theta = 0.6096...$



Calculate the angle between P_0 and P_2 from the double slit.

$d \sin\theta = m\lambda$ $\quad m = 2$ $\quad \lambda = 532 \times 10^{-9}$ m $\quad d = 100 \times 10^{-6}$ m

$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$

$= \sin^{-1}\left(\frac{2 \times 532 \times 10^{-9}}{100 \times 10^{-6}}\right)$

$\theta = 0.610°$ (3 s.f.)

Question 23 (Band 2-5) Examiner: GN

Outline Maxwell's contributions to electromagnetic theory

Marking Guidelines	Marks
Three contributions outlined **OR** two thorough contributions to electromagnetic theory outlined.	**3**
Two contributions to electromagnetic theory outlined **OR** One thorough contribution to electromagnetic theory outlined	**2**
A relevant and correct point made.	**1**

Markers Comments:

Cohort average = 2.36/3 (79%)

- Question was generally answered well.
- Students need to consider for three marks best to address THREE different contributions or if TWO they must be thorough in depth/detail.
- Students need to be careful repeating the same contribution even if words used are slightly different.
- Students need to ensure their answer represents the work of the Physicist in the question.

Sample Answer/Key Points:

- determined that light made from E + B fields → unified electricity + magnetism
- determined a theoretical value for speed of light using $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$
- predicted EM waves of different frequencies/wavelengths

- Identified that light was perpendicular, oscillating electric and magnetic fields (EM waves)
- Predicted EM waves travel at 3×10^8 ms^{-1} (in a vacuum)
- Predicted EM waves caused by oscillating charged particles
- Predicted EM waves of a range of frequencies and wavelengths.

Students could also outline Maxwell's four mathematical equations (Gauss' Law of Electricity and Magnetism, Faraday's Law and Ampere-Maxwell Law).

Student Samples:

- Maxwell contributed to electromagnetic theory with 3 predictions he derived from his 4 equation

(1.) He predicted the unification of electric and magnetic fields → Faraday's and Ampere's Law → oscillating E field generates an oscillating B field and vice versa

(2.) He predicted the speed of light using the permeability (μ_0) and permitivity (ε_0) of free space → $\frac{1}{\sqrt{\mu_0 \varepsilon_0}} = C$

(3) He predicted the electromagnetic spectrum → light existed beyond the visible range.

4

OK!

1. Based on Ampere's Law and Faraday's Law, Maxwell proposed the light is created by osillating electric and magnetic fields :
2. Based on this theory he predicted the speed of light based on the electric and magnetic permeability constants $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \approx 3 \times 10^8$ m/s
3. Maxwell also predicted the there were EM waves that were beyond the visable spectrum, UV and infared etc

4

Question 24 (Band 2-6)

Determine the mass shown on the electronic balance, in grams, when the current is flowing through both rods

Marking Guidelines	Marks
Complete and correct working to determine the mass value **in grams**.	**3**
Working to determine the mass value in grams with errors or omissions or correct mass in kg determined.	**2**
Some relevant step towards calculating mass.	**1**

Markers Comments: average 2.33/3

- RTQ – answer in grams. What a silly way to lose a mark!
- Several incorrectly converted from kg to grams. Also, a silly way to lose a mark!
- Kg are SI units for mass. Also, a silly way to lose a mark!
- Mostly done very well. Generally, well set out to work towards the correct answer.
- Opposite currents repel – no marks lost for getting this wrong aspect but you should know this.

Sample Answer/Key Points:

Determine the mass shown on the electronic balance, in grams, when the current is flowing through both rods.

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

$$= 0.75 \times \frac{4\pi \times 10^{-7}}{2\pi} \times \frac{5.6 \times 5.6}{2.0 \times 10^{-3}}$$

$$= 0.002352\,N$$

since currents are in opposite directions the force between the 2 wires is repulsive.

$\therefore$ ~~F_B acts downwards~~

lovely!

$\therefore F_B = 0.002352\ N$ downwards

$\therefore$ balance exerts $F_N = 0.002352N$ upwards to balance rod B (so $F_{net,B} = 0N$)

$\therefore F_N = \Delta m g = 0.002352\,N$

$\therefore \Delta m = \frac{0.002352}{g} = \frac{0.002352}{9.8}$

$= 2.4 \times 10^{-4}$ kg

$= 0.24g$ (2sf)

$\therefore$ since balance is initially zeroed it reads 0.24g when current is flowing.

Question 25 (Band 2-6)

Explain how Hubble’s analysis of spectra showed evidence for the expanding universe theory

Marking Guidelines	**Marks**
Extensive explanation clearly and logically links Hubble’s analysis of galactic/stellar spectra with the theory of the expanding universe.	**4**
Thorough explanation links Hubble’s analysis of spectra with the theory of the expanding universe with some omissions or errors.	**3**
Sound description of some aspect of Hubble’s analysis or the expanding universe theory.	**2**
Some relevant information.	**1**

Markers Comments: average 2.90/4

- Logical sequence: spectra of galaxies all red-shifted →used Doppler Effect (waves stretched)→showed that galaxies moving away → furthest ones moving away fastest (greater red-shift) (could be shown graphically or related through the stretching of the ‘fabric of space idea)→universe is expanding
- Light from galaxies is red-shifted – galaxies are NOT red-shifted!
- Hubble studied absorption spectra not emission spectra.

- Referring to shifted left or right is not helpful as the spectra are not always displayed in the same fashion.
- Hubble didn't set out to prove the Big Bang Theory – it developed from his observations.
- Many students didn't link the red-shifted spectral lines to the moving away of galaxies through 'Doppler Effect or stretching of waves' – this is key Physics theory to support the point.
- A proportion of students got carried away with Hubble's constant from the Hubble graph but failed to recognise the key aspect of the graph in this question is that further galaxies move away faster. The existence of the constant does NOT suggest an expanding universe but further galaxies move away faster DOES.

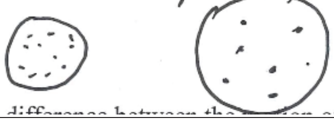
<u>Sample Answer/Key Points:</u>

galaxies that were at known distances from Earth.

Explain how Hubble's analysis of spectra showed evidence for the expanding universe theory.

4

- Relative to the spectral lines of ~~stable~~ certain elements (eg H) on Earth, Hubble discovered that the spectral lines from almost all stars from distant galaxies were redshifted
- By the Doppler effect, object moving away → λ of light emitted gets 'stretched' → $\uparrow \lambda$ towards red end of spectrum → ∴ redshift
  ∴ concluded stars were moving away from Earth
- Hence, stars moving away from Earth insinuated that space between objects in the universe was 'stretching' which ↑ distance between objects & thus evinced the expanding universe theory.



← expanding universe ↑ space between stars/galaxies/Earth

Question 26 (3 marks)

Outline ONE similarity and ONE difference between the ... of a satellite in orbit and a ...

- measured red shift for elemental spectral lines
- showed - all galaxies showed shift to red end
  ($\uparrow \lambda$ $\therefore$ λ has "stretched")
  - further away $\Rightarrow$ more red shift
  (λ has "stretched" to a greater extent)
- theorised that space expands, carrying galaxies away, as light travels it also "expands" or stretches. $\Rightarrow$ "stretched"
- further away galaxy $\rightarrow$ light has longer to stretch/expand $\therefore$ more red shift

Question 26 (Band 2-5)

Outline one similarity and one difference between the motion of a satellite in orbit, and a charged particle moving perpendicular to a magnetic field.

Marking Guidelines	Marks
Clear and correct similarity and difference outlined with reference to relevant Physics.	**3**
Clear and correct similarity or difference outlined with reference to relevant Physics OR One similarity and one difference outlined without reference to relevant Physics.	**2**
Some relevant detail.	**1**

Markers Comments: average 2.20/3

- An 'outline' response requires more than an identify response. Just writing *they both undergo UCM* is an 'identify response' - *they both undergo UCM under the influence of a centripetal force* is an 'outline response'.
- Some students have 'Review theory' written because your knowledge is lacking in this area.
- Many students wrote the differences in the similarity section and then went looking for other differences (usually harder and weaker ones) to put in the difference section. Why?
- Writing something like "*this box is blue whereas that box is small*" is NOT a difference. Differences should be outlined in comparable features.
- Satellites effectively move in UCM not elliptical orbits. Many students identified that a similarity was that both moved in UCM and then a difference was that satellites move in elliptical orbits not circular orbits????
- Some students chose incorrect equations to support their response. Review this area of knowledge.
- Some students wrote extra booklets but the 6 lines provided should have been more than adequate (see sample response answered in 2 lines below).
- Question is about motion – similarities and differences in motion. Mass was chosen by some students, factors affecting radius by others – these among other differences were not accepted as they are not motion.
- The question features a magnetic field but a number of students wrote about and drew an electric field! RTQ! What a way to waste marks!

Sample Answer/Key Points:

- *Similarity: both undergo UCM under influence of F_c*
- *Difference: UCM for satellite caused by F_c provided by F_g whereas UCM for particle caused by F_c provided by F_B*

charged particle moving perpendicular to a magnetic field.

3

Similarity : both the satellite and the charged particle are able to move in uniform circular motion (say) ∴ the centripetal force acting on them is perpendicular to its tangential velocity.

Difference : F_c for satellite is a gravitational force of attraction between the satellite & the body its orbiting whilst F_c for charged particle is F_B (whereby $v \perp F$ ∴ right hand palm rule)

provided by the B field

because the charged particle is moving.

Question 27a (Band 2-6)

Analyse how the concept of a cut-off frequency of light in the photoelectric effect applies to both the wave and particle models of light

Marking Guidelines	Marks
Extensive analysis of cut-off frequency with detailed information in the context of both models of light.	**4**
Thorough analysis of cut-off frequency in the context of both models of light.	**3**
Sound description of some aspect of cut-off frequency or a model of light.	**2**
Some relevant point made.	**1**

Markers Comments:

- Average mark: 2.25/4
- Better answers were all well-structured and started by defining of cut-off frequency before analysing into the wave and particle models.
- Extensive answers had good links between E and f; discussed 1:1 ratio of photon to photo-electron, saying that if Ephoton > Ebound, then electrons escape metal surface, etc.
- Not knowing which equations relate to photoelectric (PE) effect was problematic – you need to know when to apply equations to situations:
    - e.g. DeBoglie's "matter wave" equation, $\lambda = \frac{h}{mv}$, does not apply to PE.
- Students who did not know this section well assumed that both the particle and wave models applied to a cut-off frequency – only the particle model does.

Sample Answer/Key Points:

Question 27 (7 marks)

The photoelectric effect has a number of observable properties that cannot be explained by classical physics theory.

(a) Analyse how the concept of a cut-off frequency (f_0.) of light in the photoelectric effect applies to both the wave and particle models of light. **4**

· Cut-off frequency is an phenomena in the photoelectric effect that below a certain f of light, no e^- were emitted ~~ejected~~. ✓ DEFN

· Classical wave theory of light could not explain this, as ~~each~~ light would continually strike the e^-'s, eventually transfering ~~granting~~ ~~then~~ sufficient energy to overcome ϕ (Min Energy needed to escape, this is the work function ⇒ Should be e^- at any f, violating threshold f. GOOD

. Particle model of light could explain such a concept   Extra Writing Space.

27. assuming photons transfer all of their energy to one e^-, the Energy of a photon is $E=hf$, dependent on the f ⇒ if the f too low, and then is not enough E to overcome ϕ, then there will be no e^- ejected GOOD

⇒ affirming ~~the~~ ~~cw~~ and explaining the concept of threshold frequency.

Question 27b (Band 2-5)

Justify how the stopping voltage of the emitted photoelectrons would change if the intensity of the incoming light was doubled.

Marking Guidelines	**Marks**
Extensive justification correctly links stopping voltage, photoelectron behaviour and light intensity.	**3**
Explanation provides some detail regarding stopping voltage and photoelectrons or regarding photoelectrons and light intensity.	**2**
Some relevant detail.	**1**

Markers Comments:

- Average mark: 2.14/3
- Better responses **defined Stopping Voltage** and **Intensity** before saying what effect intensity had on stopping voltage.
- **Ohm's Law (V = I × R) does not apply to all circuits or conditions.** For the equation to be valid, a resistor must behave ohmically, meaning its resistance (R) remains constant regardless of changes in voltage (V) or current (I). In the case of the photoelectric effect, this condition is not relevant. The behaviour of stopping voltage and photo current is governed by quantum principles, not Ohm's Law. Therefore, **you cannot use V = I × R to explain or calculate values in photoelectric effect scenarios.**

Sample Answer/Key Points:

(b) In an experiment using the photoelectric effect apparatus, the stopping voltage for photoelectrons emitted was measured.

3

Justify how the stopping voltage of the emitted photoelectrons would change if the intensity of the incoming light was doubled.

Stopping voltage is the voltage required to 'just' prevent any photoelectrons from reaching opposite plate. V_{stop} is $= \frac{K_{max}}{q}$ ~~[illegible]~~

Great

- when intensity of light is doubled the number of photons incident on the metal will ↑ (2x) ↳ ⇒ $V_{stop} \propto K_{max}$ (q constant)
- ∴ only no. of photoelectrons will ↑ (one photon transfers all its energy to one electron)
- as the no. of photoelectrons doesn't effect K_{max} (only photocurrent) there will be no change to the stopping voltage

7

Question 28 (Band 2-6) Examiner: GN

Holistically marked (full range of marks from zero to five)

Analyse how the magnitude and direction of the current will change as the loop passes from outside the magnetic field on the left side (A), within the field (B), and passing out of the field on the right side (C)

Marking Guidelines	Marks
Extensive analysis correctly addresses all changes in current direction and magnitude from A -> B -> C associated with constant v motion of the square conducting loop through the external magnetic field. Links to Faraday and Lenz's laws must be addressed in the analysis that includes a mathematical relationship.	**5**
Thorough analysis addresses most changes in current direction and magnitude associated with motion of loop through the external magnetic field with some *minor omissions* or *one key error* (overlooks Faraday or Lenz (mathematical equation and link) or a direction is incorrect although is clearly addressed in response.	**4**
Sound analysis explains some changes in current direction and magnitude associated with motion of loop through external magnetic field with *key omissions* or several errors.	**3**
Basic correct identification of some aspect of current direction and/or magnitude associated with the motion of the loop through the external magnetic field.	**2**
Some relevant detail that is correct.	**1**

<u>Markers Comments:</u>

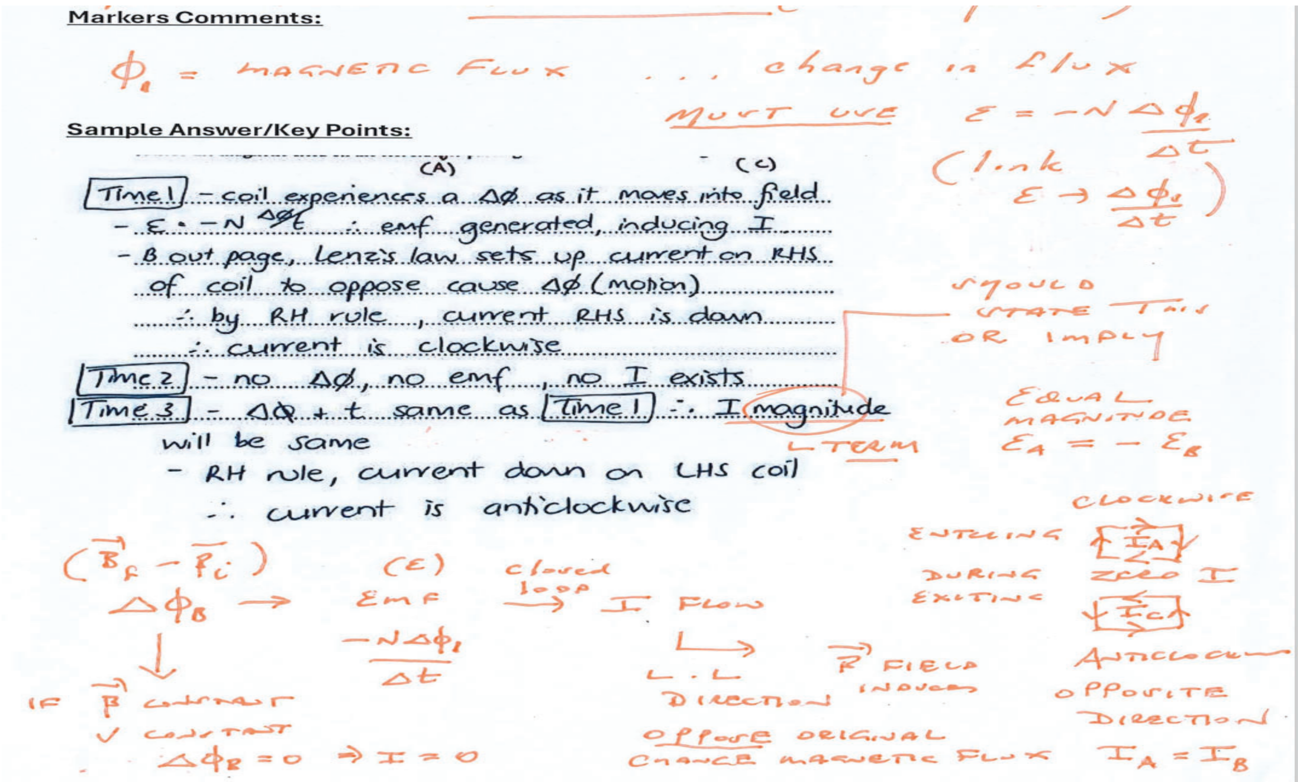
Cohort average = 3.45/5 (69%)

- Analyse = to identify components of a subject, explore the relationships between those components, and draw out and relate the implications of those relationships.
- Students need to RTQ and ATQ. When reading the questions, students must engage with the stimulus. This question lends itself to linking the stimulus to your analysis. See samples below for how to do this. The marker does refer to this and includes in your response.
- Most students could engage with the loop moving relative to the external magnetic field at a constant speed and the importance of this.

- It is recommended students look at their layout. Use the terms in the question, time A, time B and Time C, magnitude of current and direction of current as subheadings and dot points in their response. MAKE IT EASIER TO MARK FOR THE MARKER 😊

- Students need to ensure they get the order right in their response and link to mathematical relations/equation for Faraday and Lenz's Law.
    - Change in magnetic flux -> induced emf -> current in square loop -> address magnitude of current and direction of current via Lenz's Law.
- Students need to be clear and specific on their direction choice as either clockwise/anticlockwise or show on stimulus/draw a labelled diagram.
- Analysis of current magnitude and direction are key features of this question.
- Question refers to a 'single square loop of conducting wire', so in a closed loop with resistance a current will flow. Some students referred to 'eddy currents' which is incorrect. We use the term 'eddy currents' if we have a piece of conducting material (e.g. sheet of metal) and not a conducting wire as stated in the question.

Sample Answer/Key Points:



Markers Comments:

ϕ_B = MAGNETIC FLUX ... change in flux

MUST USE $\mathcal{E} = -N\frac{\Delta\phi_B}{\Delta t}$

(link $\mathcal{E} \rightarrow \frac{\Delta\phi_B}{\Delta t}$)

Sample Answer/Key Points:

(A) (C)

$\boxed{\text{Time 1}}$ – coil experiences a $\Delta\phi$ as it moves into field

– $\mathcal{E} = -N\frac{\Delta\phi}{\Delta t}$ ∴ emf generated, inducing I

– B out page, Lenz's law sets up current on RHS of coil to oppose cause $\Delta\phi$ (motion)

∴ by RH rule, current RHS is down

∴ current is clockwise

$\boxed{\text{Time 2}}$ – no $\Delta\phi$, no emf, no I exists

$\boxed{\text{Time 3}}$ – $\Delta\phi$ + t same as $\boxed{\text{Time 1}}$ ∴ I magnitude will be same

– RH rule, current down on LHS coil

∴ current is anticlockwise

SHOULD STATE THIS OR IMPLY

EQUAL MAGNITUDE $\mathcal{E}_A = -\mathcal{E}_B$

L-TERM

CLOCKWISE

ENTERING I_A

DURING ZERO I

EXITING I_C

ANTICLOCKWISE OPPOSITE DIRECTION

$I_A = I_B$

$(\vec{B}_f - \vec{B}_i)$

$\Delta\phi_B \rightarrow$ (E) EMF $-N\frac{\Delta\phi_B}{\Delta t}$ $\xrightarrow{\text{closed loop}}$ I FLOW → L.L DIRECTION

$\vec{B}$ FIELD INDUCED

OPPOSE ORIGINAL CHANGE MAGNETIC FLUX

IF $\vec{B}$ CONSTANT ✓ CONSTANT $\Delta\phi_B = 0 \rightarrow I = 0$

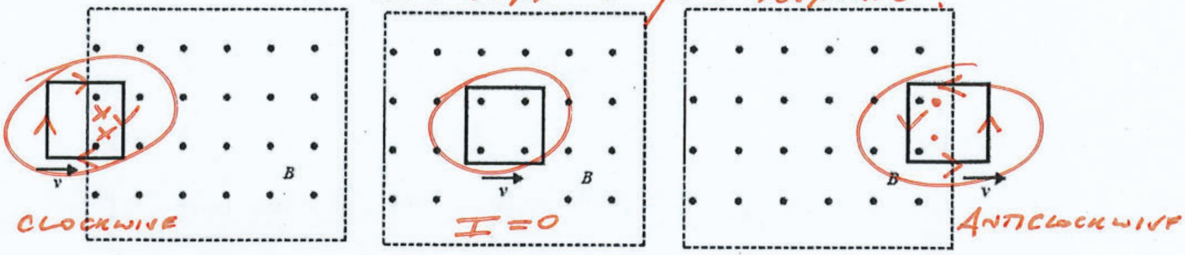
Student sample

constant speed, as shown below.

You should annotate the stimulus

A B C

Entering field — it will — Within field — support your response — Exiting field



Analyse how the magnitude and direction of the current will change as the loop passes from

---

Question 28 (5 marks)

A single square loop of conducting wire was moved through a uniform magnetic field, at constant speed, as shown below. 5

ANTICLOCKWISE I.

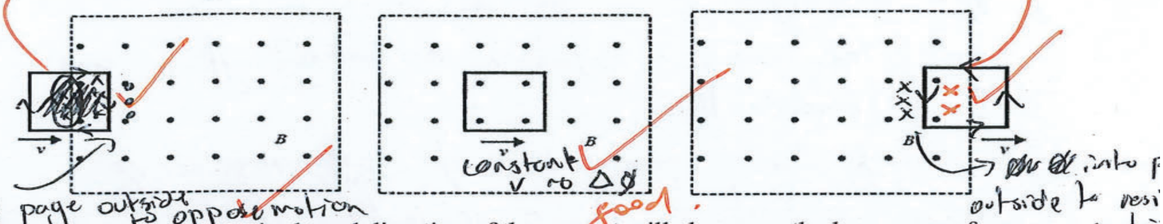
5

H

CLOCKWISE, I.

A B C

Entering field Within field Exiting field



Analyse how the magnitude and direction of the current will change as the loop passes from outside the magnetic field on the left side (A), within the field (B), and passing out of the field on the right side (C).

At (A)

- The loop of wire enters the field ∴ experiencing a Δ in Φ, as it enters the field.
- ∴ By Faraday's Law $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ an emf is induced in the loop. Since the loop is complete current flows and ∴ By Lenz's Law, the direction of induced current will ~~oppo~~ oppose the motion and change in flux
∴ Current will flow clockwise to form an ~~in~~ out of the page field outside of the loop as labelled on diagram
∴ opposing ΔΦ ~~with~~

↓ see extra writing

Q28.

- At (B)

- ~~[illegible]~~ Loop is in the field at constant v

so ∴ accel. is 0

∴ There is no $\Delta \phi$ and ∴ no emf induced by Faradays law.

∴ Magnitude of current is 0 ~~[illegible]~~ as nothing flows

At (C)

- Loop is exiting the field. ∴ Experiences a $\Delta \phi$

∴ By Faraday's Law an emf is induced and by Lenz's law ~~t~~ the direction of current flow will oppose $\Delta \phi$

∴ Current will flow counterclockwise to form into the page field outside of the loop, attracting the loop back into the permanent field ∴ opposing motion and $\Delta \phi$.

↳ Since v is constant throughout magnitude of I at (C) will = (A) since $\Delta \phi$ would be the same although current runs in different directions.

:)

BOOKLET 3

Question 29a (Band 2-5)

Draw the line representing the kinetic energy of the object for the same range of heights

Marking Guidelines	Marks
Accurately drawn trend, maintaining that U+K = const.	**2**
A trend showing a decrease in Kinetic Energy as Height above Earth's surface increases.	**1**

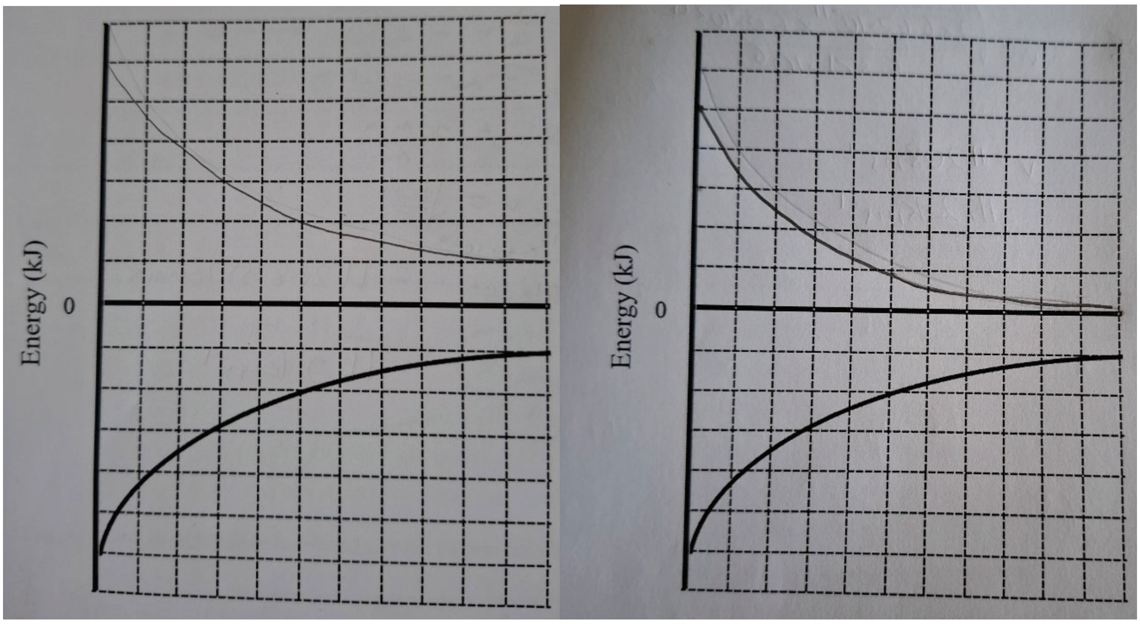
Markers Comments:

An object launched vertically will abide by the law of conservation of energy. U+K is a constant.

The most common mistake was to assume incorrectly that this was representing the energy of orbiting objects at different heights, where $K = -\frac{1}{2}U$.

Sample Answer

The total energy must be constant, Left represents energy just at the escape velocity, right represents a situation where total energy is less than zero and object does not escape. Both are correct.



Question 29b (Band 2-5)

Show that the equation for escape velocity is $v = \sqrt{\frac{2GM}{r}}$ and thus show the escape velocity of Earth is 11.2 km s^{-1}

Marking Guidelines	Marks
Clear and logical derivation of the velocity from Conservation of Energy or from identifying that Total Energy is zero for escape velocity. Showing full working and clear substitution of all variables used to calculate the escape velocity of Earth.	**4**
As above with minor omissions.	**3**
As above with major omissions.	**2**
One correct step in the calculation or derivation shown	**1**

Markers Comments:

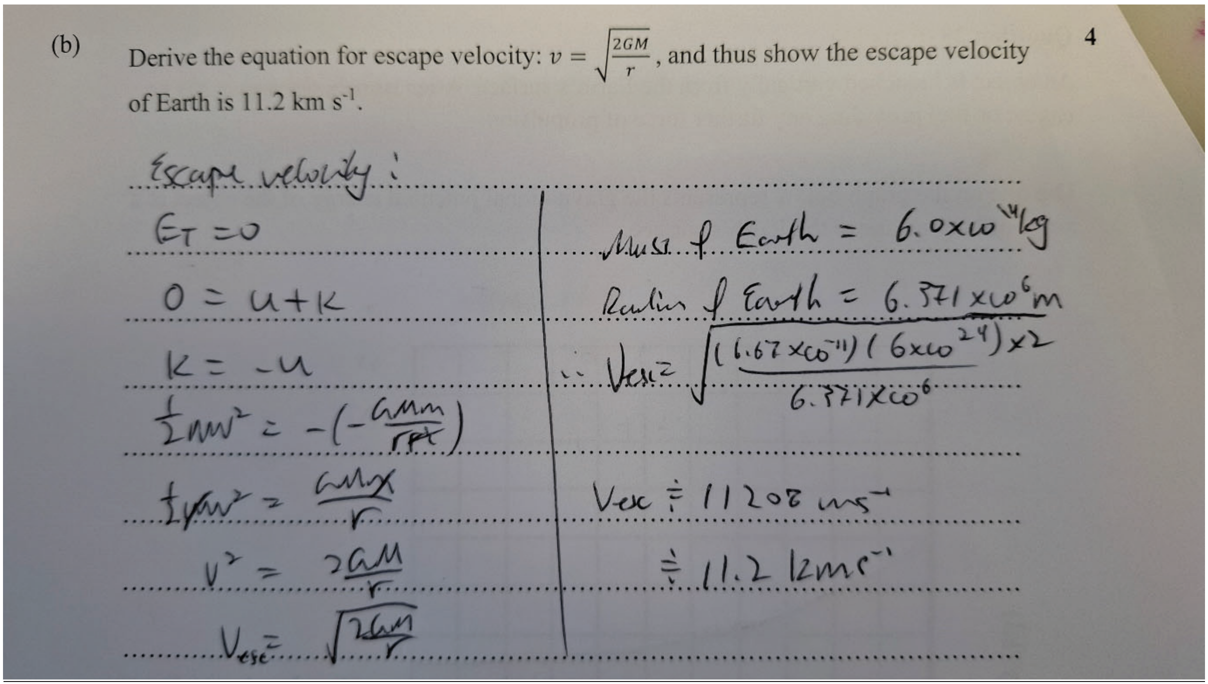
Most students did well on this question and most marks lost were due to not showing all working.

There were three mistakes that appeared across the cohort.

1. You must provide the criteria for the escape velocity. U+K is not typically 0 in most situations, so some statement on why you can use U+K=0 must be given. Stating that Energy total = 0, was just enough, but it is better to state this idea in words (See Sample).
2. When calculating the escape velocity from the formula, you should show all values used to calculate the escape velocity: gravitational constant, radius and mass of Earth. If these were omitted, you could be redeemed by writing the unrounded escape velocity. This shows that you correctly calculated the value in your calculator.
3. Numerous students attempted to derive this equation using forces, such as equally the centripetal force and the gravitational force. This object is not in orbit. You must revise when you can use certain equations and when you can't.

Sample Answer/Key Points:

Compare the responses: the difference between a 4/4 and a ¾ below can be small details.



(b) Derive the equation for escape velocity: $v = \sqrt{\frac{2GM}{r}}$, and thus show the escape velocity of Earth is 11.2 km s^{-1}. 4

Escape velocity:

$E_T = 0$

$0 = U + K$

$K = -U$

$\frac{1}{2}mv^2 = -\left(-\frac{GMm}{r_E}\right)$

$\frac{1}{2}\cancel{m}v^2 = \frac{GM\cancel{m}}{r}$

$v^2 = \frac{2GM}{r}$

$V_{esc} = \sqrt{\frac{2GM}{r}}$

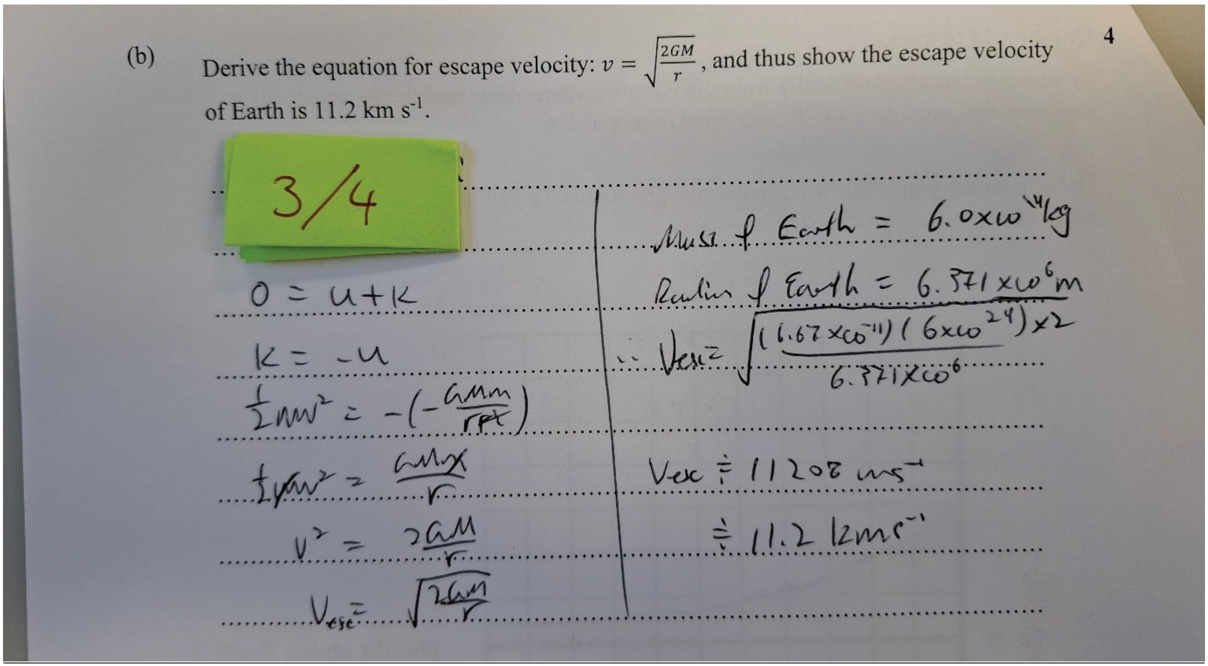
Mass of Earth $= 6.0 \times 10^{24}$ kg

Radius of Earth $= 6.371 \times 10^{6}$ m

$\therefore V_{esc} = \sqrt{\frac{(6.67\times10^{-11})(6\times10^{24})\times 2}{6.371\times10^{6}}}$

$V_{esc} \doteqdot 11208$ ms^{-1}

$\doteqdot 11.2$ kms^{-1}



(b) Derive the equation for escape velocity: $v = \sqrt{\frac{2GM}{r}}$, and thus show the escape velocity of Earth is 11.2 km s^{-1}. 4

3/4

$0 = U + K$

$K = -U$

$\frac{1}{2}mv^2 = -\left(-\frac{GMm}{r_E}\right)$

$\frac{1}{2}\cancel{m}v^2 = \frac{GM\cancel{m}}{r}$

$v^2 = \frac{2GM}{r}$

$V_{esc} = \sqrt{\frac{2GM}{r}}$

Mass of Earth $= 6.0 \times 10^{24}$ kg

Radius of Earth $= 6.371 \times 10^{6}$ m

$\therefore V_{esc} = \sqrt{\frac{(6.67\times10^{-11})(6\times10^{24})\times 2}{6.371\times10^{6}}}$

$V_{esc} \doteqdot 11208$ ms^{-1}

$\doteqdot 11.2$ kms^{-1}

Question 30 (Band 2-6)

Analyse, qualitatively and quantitatively, the processes that occur in fission and fusion to release energy in nuclear reactors and stars

Marking Guidelines	Marks
All three parts of the stimulus used to extensively analyse the processes that occur in fission and fusion to release energy in nuclear reactors and stars	**9**
All three parts of the stimulus used to extensively analyse the processes that occur in fission and fusion to release energy in nuclear reactors and stars, but was missing a minor component or had a minor error.	**8**
All three stimuli used with thorough level of detail to analyse the processes that occur in fission and fusion to release energy in nuclear reactors and stars, but was missing some minor components or had some minor error.	**7**
At least TWO stimuli used to analyse to thoroughly analyse the processes that occur in fission and fusion to release energy in nuclear reactors and stars. May have missed the application of post main sequence stars, or unpacked the need for control rods in nuclear reactors.	**6**
Demonstrates a thorough understanding of Fission AND Fusion with sound links to their use in stars and nuclear reactors, AND links to the stimulus.	**5**
Demonstrates a Sound understanding of Fission AND Fusion with some links to their use in stars OR nuclear reactors	**4**
Demonstrates a Basic understanding of Fission AND Fusion with some links to their use in stars OR nuclear reactors	**3**
Demonstrates a Basic understanding of Fission OR Fusion	**2**
Some relevant information.	**1**

<u>Markers Comments:</u>

Across the cohort there were a total of three 9 mark responses. Most common mark were 5s and 6s. Average across cohort was 5.46/9.

Most students did a poor job of scaffolding this question. Students should have started with a description of fission and fusion and related this to mass defect / binding energy per nucleon. Many students jumped straight into the application in stars or nuclear reactors without laying the foundation for a good response. Other students started with a calculation instead of using a calculation to improve response. Overall, this was a very disappointing aspect of this question. Remember, when answering longer response questions, start with the foundations (FISSION AND FUSION to RELEASE ENERGY) and build upon those ideas.

Common issue was not converting mass defect in u to kg before using E=mc^2. Alternatively, students could multiply the mass defect in u by 931.5 to get an answer in MeV.

The number of students redrawing diagrams that was in the stimulus was ridiculous. Annotate stimulus (eg. Figure A) and REFER to them in your response. Redrawing is a WASTE of time.

Many students alluded to the stimulus, but didn't REFER – eg. "as seen in the binding energy graph" or "as seen in Fig. 1" (labelled stim) Most questions with a stimulus will require you to refer to the stimulus. Using this phrase makes it very easy for the marker to see the reference.

A lot of students are saying that atoms 'want' to become iron. This is poor terminology. Please don't personify atoms in exam responses! Iron has the most binding energy per nucleon, and thus atoms smaller than iron can release mass/energy when fusing up to iron, and atoms larger than iron can release mass/energy when fissioning above iron.

Codes:

MD→E Means student didn't discuss mass defect leading to a release in energy. This should have been part of the start of your response when outlining what fusion and fission are.

To get a 9 students needed to analyse all components as listed below to an extensive standard. Most students who scored an 8 had a very minor error, or didn't explain as well as they could have. Students who received 7 typically still had very good understanding of fission and fusion and linked to all three stimuli, but may have missed some detail such as Post Main Sequence and/or the use of moderators and control rods in nuclear reactors. Students who received 6 marks typically had a thorough understanding of fission and fusion, referred to all the stimuli, but missed some components (such as post main sequence, control rods and moderators), but still had correct calculation. Most 5 mark responses either showed a basic understanding of fission and fusion, mostly used the stimulus well AND had the correct calculation. Others showed a sound understanding that may have lacked some components of application in stars and nuclear reactors, and made a small error in calculation.

Key Points:

Introduction – fission and fusion.

- Both fission and fusion release energy by 'losing' mass. This lost mass is known as the mass defect (Δm). This lost mass comes from an increased binding energy/nucleon as seen in the graph.
- Binding energy graph shows that heavy elements with a mass number greater than iron-56 (eg. uranium-235) will undergo fission as it is more energetically favourable to produce two smaller nuclei (like krypton-92 and barium-141). These nuclei can be seen to have an increased binding energy/nucleon, and will therefore be able to undergo fission to release energy.
- Lighter elements (below Iron-56) such as hydrogen will be able to 'fuse' (join together) to release mass/energy.
- The energy released can be calculated using the mass/energy equivalence: $E = \Delta mc^2$ where Δm is the mass defect/loss of mass.

Fission – reactors:

- Produce energy from the nuclear reaction, usually involving uranium (or similar heavy fuel like thorium or plutonium)
- Fuel is contained in fuel rods in a nuclear reactor core, surrounded by movable control rods, a moderator and coolant.
- A thermal (slow, low-energy) neutron strikes the uranium atom making it unstable, causing it to split into two smaller nuclei, in this case Kr-92 and Ba-141. Three neutrons are emitted (usually 2-3) and energy (do an energy calc here)
- Emitted neutrons are slowed by a moderator through collision and transfer of kinetic energy so they are slow enough to cause fission
- The ratio of neutrons : uranium atoms is controlled through raising or lowering control rods – lowered rods absorb more neutrons and slow the rate of fission (and vice versa)
- Energy released is used to heat water to steam and spin a turbine to generate electricity

Fusion – stars

- Fusion – joining of two smaller nuclei with the net release of energy – in stars often hydrogen or isotopes of hydrogen like deuterium/tritium to form helium (MS fusion)
- Need high temp/pressures to overcome the coulombic repulsion forces involved in joining two positive nuclei – hence stars with high core temperatures

- MS fusion – should outline PP and CNO cycles and distinguish types of stars they occur in
- Discussion of how MS fusion ends and conditions that occur that allow fusion of higher elements
- PMS fusion – outline how PMS occurs to gradually fuse larger elements (up to iron) - discuss binding energy graph and how PMS will finish at iron as this is the element with the highest binding energy and thus anything past iron will be more energetically favoured to form via fission

Student Answer

9

Analyse, qualitatively and quantitatively, the processes that occur in fission and fusion to release energy in nuclear reactors and stars.

FANTASTIC INTRODUCTION!

(c) shows the binding energy per nucleon is highest for ~~FA~~ Iron-56.

Fission involves the splitting of nuclei into smaller daughter nuclei (mass number ↓)

so is energetically favourable for nuclei with mass number above 56.

this is as the binding energy per nucleon will increase overall, so Σ binding energy reactants < Σ binding energy products and energy is released ~~generated~~ from the reaction

(energy released when products form > energy absorbed to break binding energy of reactants.

Similarly, Fusion is energetically favourable for mass number < 56 as it involves two nuclei combining to a larger, heavier one (mass number ↑). as shown in (c) ~~~~ binding energy/nucleon also ↑ generally up to Iron-56.

The above explains the use of fusion in stars, fusing light nuclei (lighter than Iron-56) into heavier nuclei and use of fission in nuclear reactors, such as with $^{235}_{92}U$, splitting it into lighter nuclei to release energy.

$\boxed{\text{Fission}}$ $^1_0n + ^{235}_{92}U \rightarrow 3^1_0n + ^{92}_{36}Kr + ^{141}_{56}Ba$ as shown on prev. page is a common reaction used in nuclear reactors. $E = \Delta mc^2$ from prev. page

Note that this absorbs ~~requires~~ 1 neutron and releases 3 neutrons, a net increase of 2 free neutrons that can initiate further reactions. This can grow exponentially and lead to too much energy released (dangerous). thus Nuclear reactors use: $\boxed{\text{Control Rods}}$

$= (0.22077)(931.5\ \frac{MeV}{c^2} \times c^2)$

$= 205.6$ MeV released per reaction

$\boxed{\text{Moderator}}$ material that absorbs energy from fast moving neutrons, slowing them down (as each collision of neutron with material → transfers momentum and energy → ↓ kinetic energy of neutron → slows down neutron)

This is as only slow neutrons ~~~~ are able to initiate the reaction above and lead to fission (fast neutrons can instead pass through nuclei)

↳ material that absorbs free neutron ~~~~

↳ can be lowered/raised to increase/decrease ~~~~ rate of nuclear reaction as desired

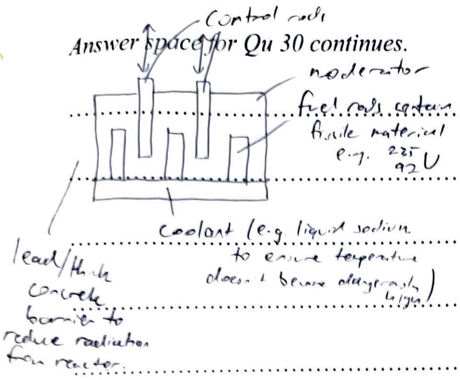
(e.g. so that on average 1 free neutron is released to initiate another reaction per reaction → constant rate of reaction)

>1 (raised) → rate of reaction ↑

<1 (lowered) → rate of reaction ↓

More space for answer provided on next page.

Answer space for Qu 30 continues.



$\boxed{\text{Fusion}}$ Once a protostar gains enough pressure, it becomes a main sequence star and begins fusing $H \to He$ in its core.

Lighter mass stars predominantly use proton-proton chain

Net equation: $4\,^1_1H \to \,^4_2He + 2\,^0_1e^+ + 2\nu + 2\gamma$

partial process shown in $\boxed{B}$

Heavier mass stars ~~predominantly~~ CNO cycle.

$4\,^1_1H \to \,^4_2He + 2\,^0_1e^+ + 2\nu + 3\gamma$

uses Carbon as a catalyst

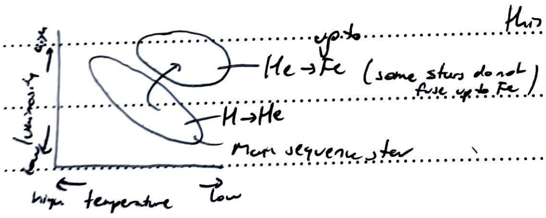
This ~~generates~~ releases energy ~~the~~ as described previously.

~~the ... nucleons ...~~

Once the core runs out of H fuel, the star becomes a post main sequence star (red giant/supergiant) and fuses heavier elements up to Fe-26 (e.g. triple α process $\to$ He $\to$ C) this also releases energy as prev. page.

56?

This allows stars to release heat and light energy (as in $\boxed{B}$)



Question 31 (Band 2-5)

Calculate the wavelength of light produced by the transition of an electron from level 5 to level 2

Marking Guidelines	Marks
Calculation of the wavelength using the Energy difference between level 5 and level 2, including units.	3
Mostly correct calculation of the wavelength – missing units or with minor errors or missing steps in working	2
A correct step in the calculation of the wavelength of light. Or Correctly calculates a wavelength using Rydberg's Equation from level 5 to level 2.	1

Markers Comments:

Overall, well done by most of the cohort. Biggest and very common mistake was to use Rydberg's equation to calculate wavelength. This gave 434nm which is incorrect. The question is for Helium. Rydberg's equation only works for Hydrogen! Students who correctly calculated using Rydberg's equation were able to receive 1 mark.

To get full marks, you needed the correct answer of 110nm (2sf) or 115nm (3sf). Some students rounded up to 120nm which is incorrect. These students received 2 marks.

Sample Answer/Key Points:

$\Delta E = E_i - E_f = -2.8 - (-13.6) = 10.8\,eV$

$10.8 \times 1.602 \times 10^{-19} = 1.7302 \times 10^{-18}\,J$

$E = hf \quad f = c/\lambda \quad \therefore E = hc/\lambda \quad \therefore \lambda = hc/E$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^{8}}{1.7302 \times 10^{-18}} = 1.149 \times 10^{-7}\,m$$

$\lambda = 1.1 \times 10^{-7}\,m$ (2sf)

Question 32 (Band 2-5)

Explain how these experiments support the wave model of light

Marking Guidelines	Marks
Extensive explanation of both experiments with clear links to supporting the wave model of light.	**4**
Thorough explanation of both experiments with clear links to supporting the wave model of light	**3**
Sound explanation of at least one experiment with links to supporting the wave model of light.	**2**
Some relevant information	**1**

Markers Comments:

Overall, students did well on describing the wave features of the double slit experiment, Diffraction and Interference which are **ONLY** wave properties. However, many students did not describe the wave properties that describe polarisation.

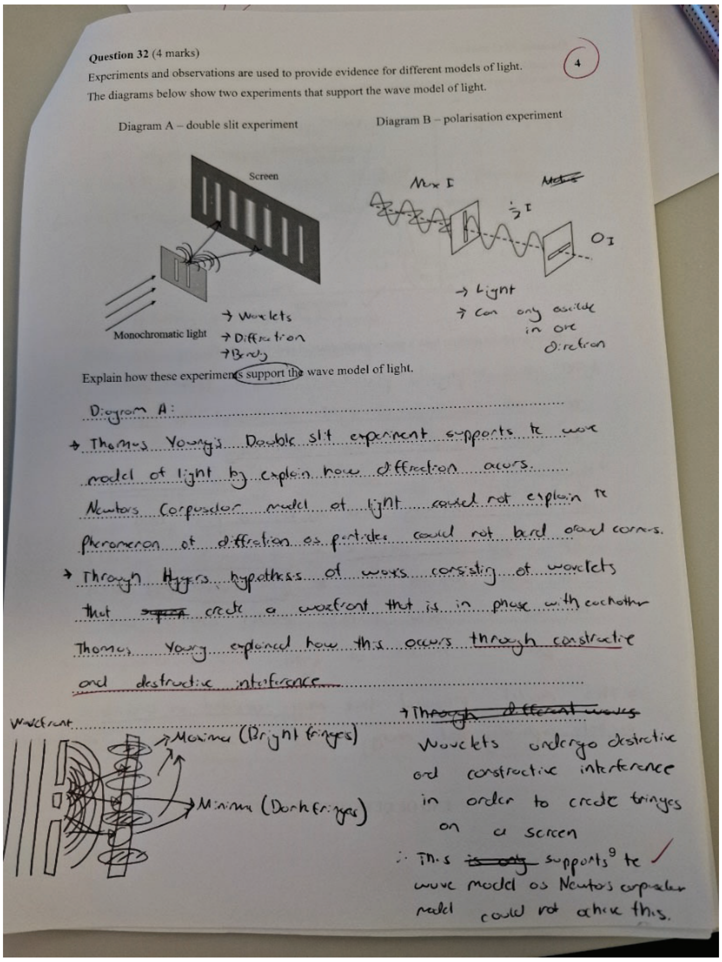
For polarisation you must link some wave properties of light to the observations of light being blocked by the polariser. This should be done by linking that **light is a transverse wave where the electric field oscillates in a plane perpendicular to the direction of travel which can be blocked or transmitted depending on the angle of the polariser**.

If this were a graded at a band 6 level very few responses would receive 4/4 as the terminology and phrasing across the cohort when describing polarisation was poor.

Lastly, numerous students described the physics of what was occurring but did not clearly answer the question. You should be aiming to ensure that you have clear links between the experimental observations and the wave model of light. This can often be done by adding simple statements to your response. For example, note the difference between the following two sentences:

- Diffraction and interference of light produce a pattern on the screen which supports the wave model of light.
- Diffraction and interference of light, which can only be described as waves properties, produce a pattern on the screen supporting the wave model of light.

Sample Answer/Key Points:



Question 32 (4 marks)

Experiments and observations are used to provide evidence for different models of light.

The diagrams below show two experiments that support the wave model of light.

Explain how these experiments support the wave model of light.

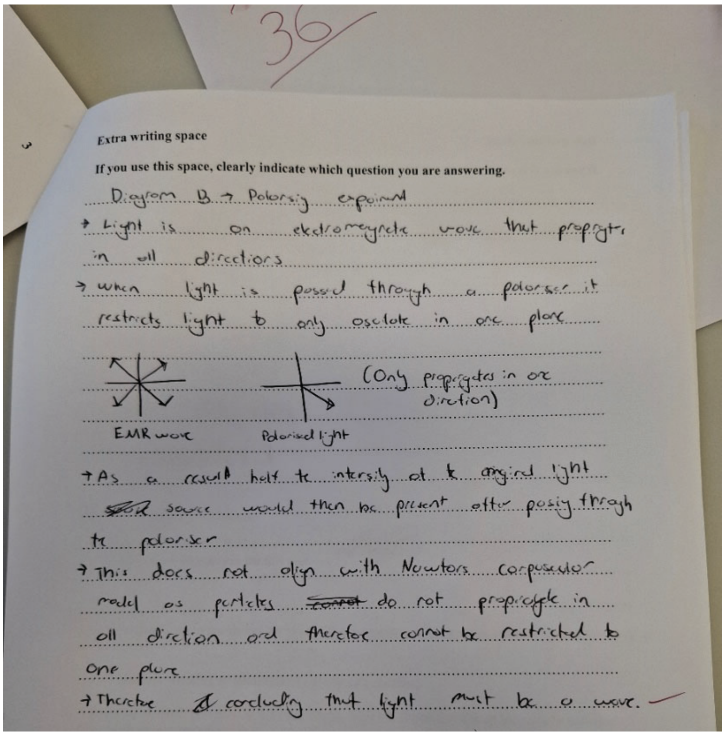
Diagram A:

→ Thomas Young's Double slit experiment supports the wave model of light by explain how diffraction occurs. Newtons Corpuscular model of light could not explain the phenomenon of diffraction as particles could not bend around corners.

→ Through Huygens hypothesis of waves consisting of wavelets that create a wavefront that is in phase with eachother Thomas Young explained how this occurs through constructive and destructive interference.

→ ~~Through different waves~~ Wavelets undergo destructive and constructive interference in order to create fringes on a screen

∴ This ~~is only~~ supports the wave model as Newtons corpuscular model could not achieve this.



Extra writing space

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

Diagram B → Polarising experiment

→ Light is an electromagnetic wave that propagates in all directions

→ when light is passed through a polariser it restricts light to only oscilate in one plane

→ As a result half the intensity of the original light source would then be present after passing through the polariser

→ This does not align with Newtons corpuscular model as particles ~~cannot~~ do not propagate in all direction and therefore cannot be restricted to one plane

→ Therefore concluding that light must be a wave.

Question 33 (Band 2-5)

Use this example to explain how a new scientific model is developed.

Marking Guidelines	Marks
Thorough explanation of the development of scientific models, clearly linked to the stimulus. Includes ideas related to: - Observations that are not supported by current model and - New model is developed that explain the observations.	**3**
Basic explanation of the development of scientific models, clearly linked to the stimulus. Or Thorough explanation that omits a link to the stimulus.	**2**
Some relevant information provided related to the development of scientific models.	**1**

Markers Comments:

The vast majority of marks for this question was due to not answering the question properly. The question was not: Explain the scientific developments related to this example but rather explain how a new scientific model is developed. Many students were awarded 1/3 for answering the first question rather than the given question.

The key points in developing a new scientific model are below and should be clearly stated in your response:

- Observations are made that are not supported by the current model
- New model is developed to explain all known observations.

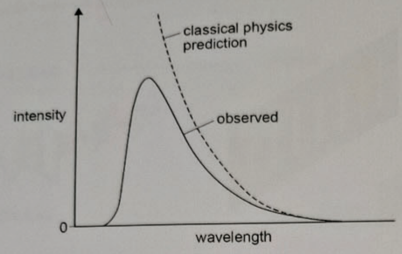
Numerous students discussed Wien's law as the updated model, although it could be awarded here it would be preferable to use Planks quantisation, E=hf and his mathematical fit to the observed trend as the updated model.

Consistent with the above point, the graph does not mention temperature. In fact, the graph provided is consistent with ALL temperatures. As a result, bringing in temperature into this question usually highlighted a misunderstanding of the physics.

Sample Answer/Key Points:

Question 33 (3 marks)

The solid line on the graph below shows how the intensity of radiation from a black body varies with wavelength at a particular temperature.



Use this example to explain how a new scientific model is developed.

The classical physics predicted an infinite intensity of radiation as it approached smaller wavelengths, starkly contrasting with observed experimental data and defying the conservation of energy. Thus, Planck proposed a new idea of the quantised nature of light, where energy was carried in quanta as $E = hf$. Whilst having no proof, this simple mathematical fix made all theory line up perfectly with observed data. This model was then built upon by Einstein through investigating the photoelectric effect, and was later discovered to be true. Thus, new scientific model was hypothesised based on observational data, then supported with further evidence from later experiments aiming to validate the model. ✓✓

3

END OF QUESTION BOOKLET 3

10

BOOKLET 4

Question 34 (Band 2-6)

Construct a graph on the grid below, using appropriate data from the table, and thus determine an experimental value for Rydberg's constant

Marking Guidelines	Marks
Graph points plotted correctly and appropriate LOBF drawn Slope of graph correctly calculated and linked to Rydberg equation Slope used to determine Rydberg's constant, showing full working	**4**
Graph points plotted correctly and appropriate LOBF drawn Slope of graph correctly calculated Slope used to determine Rydberg's constant with substantial working / minor errors or omissions	**3**
Graph plotted with an LOBF drawn OR Attempt to calculate slope OR link slope to Rydberg's constant	**2**
Points plotted correctly on graph OR scales/axes provided on graph OR Correct statement made about Rydberg equation and graph	**1**

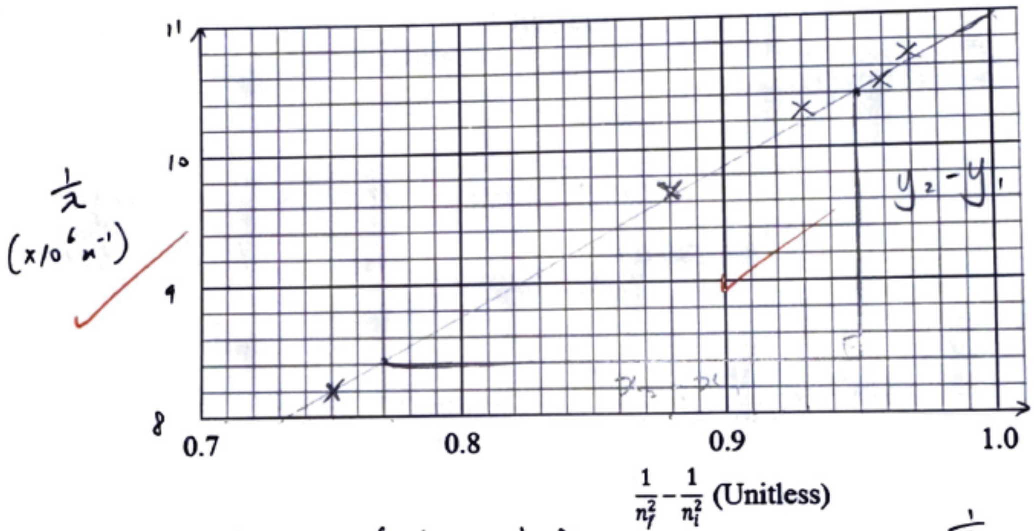
Markers Comments:

Overall quite well done by the majority of the cohort. Pleasingly most people could plot a decent graph, find the slope, link to a relevant equation and come up with the correct answer.

Common issues:

- Failure to label the axes correctly.
- Using scales from 0-15 (not penalised – just rolled eyes at). It was clear that a 0,0 axis was not required, so the vertical axis should have been 8-11 ONLY.
- Clear link between the Rydberg formula and the slope was not included (a statement that "X" is the slope is not enough if not clearly linked to the formula on the data sheet).
- Plotting the wrong quantity on the vertical axis. 1/wavelength should have been plotted – several students plotted wavelength.
- Poor plotting and/or poor LOBF gave answers that were too far away from the correct answer (if graph was correct). Answers too far away from the correct were penalised.

Sample Answer/Key Points:



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

$R = \dfrac{\frac{1}{\lambda}}{\frac{1}{n_f^2} - \frac{1}{n_i^2}}$ $\therefore$ slope $= R$

slope $R = \dfrac{(10.4 - 8.41) \times 10^6}{0.95 - 0.77}$

$= \dfrac{1.99 \times 10^6}{0.18}$

$= 1.105\ldots \times 10^7$ m^{-1}

$= 1.1 \times 10^7$ m^{-1} (2 sf)

Question 35 (Band 2-6)

Explain how the paddlewheel experiment and EITHER the Millikan OR Thomson experiment confirmed properties of the electron. You must include a diagram and a quantitative explanation as part of your response

Marking Guidelines	Marks
Paddlewheel experiment linked to particle nature of CRT beam through transfer of momentum Millikan or Thomson experiment clearly described, including diagram of setup and explanation of key fields/forces involved Extensive explanation of the outcome of the experiment, linked to confirmation of the relevant property of the electron Quantitative explanation of Millikan or Thomson presented including role of forces in determining the property	**7**
Paddlewheel and Thomson/Millikan – thorough Diagram and quantitative included Minor errors or not clear link to property	**6**
Paddlewheel and Thomson/Millikan – thorough Quantitative included Minor errors / diagram missing / unclear link to property (multiple of)	**5**
Sound of both experiments Attempt at quantitative (even identification of formulas) Major errors and/or omissions	**4**
Limited for both, with some attempt at diagram, explanation or quantitative – major steps missing or incorrect	**3**
Limited information on one experiment	**2**
One correct piece of information	**1**

Markers Comments:

Given this is essentially a historical physics question, a large number of students have no idea about the historical context.

1. At the time of these experiments THERE WAS NO ELECTRON.
2. A cathode ray was not "a beam of electrons" – it was a beam of something, with debate occurring about whether it was light or particles.
3. Likewise, neither Millikan or Thomson knew the particle was an "electron" – they knew there was a negatively charged particle. These facts were already known and were not "discovered" in the oil-drop or q/m experiment.

While I did not penalise for use of "electron" instead of "cathode ray" the HSC probably will. It shows a lack of understanding of the purpose and conclusions of these experiments.

Paddlewheel comments:

- This experiment was ONE of many done with cathode rays. It showed that the cathode ray beam had mass through the ability to transfer momentum to the paddlewheel causing it to spin. It did NOT confirm a negative charge, shadows, ability to bend in electric or magnetic fields – ONLY that it had a mass.
- Many students gave the property of the electron as momentum, which is not a great identification as momentum changes with velocity, or is zero if stationary. The property you needed to identify was MASS. Linked to momentum through $p = mv$
- Better responses gave more than "there was momentum in the paddlewheel so the cathode ray had mass" – that response was very very common. Good responses discussed the change in momentum of the paddlewheel (zero to X) thus the increase in momentum must be matched by the decrease in momentum of the cathode ray particles (law of conservation of momentum). Try to extend explanations of this kind rather than just making statements.
- Descriptions of E and B fields, maltese cross and other CRT experiments showed a lack of understanding and was penalised holistically.

Millikan comments

While it was clear that most students could replicate the overall idea of this experiment, the detail was poor. Note the following common issues:

- Lack of description and use of forces (gravitational force and electric field force).
- Lack of description of the setup – including diagrams with no labels. If your diagram has no labels, it is actually not adding ANYTHING to your answer as you have communicated nothing extra.
- Lack of clarity about why the forces were equal
- Lack of a description of the results – oil drops had a number of different charges, however all charges on the oil droplets were multiples of a specific number.
- Lack of link between the different charges and how they formed – the multiple charges were formed when multiple electrons were on the oil drops, thus linking to the charge property of the electron – this part was missing from about 95% of responses.

However, there were excessively detailed descriptions of things that had NOTHING to do with Millikan OR are not part of the HSC explanation.

- Paragraphs of how the oil drops got ionised. Lasers, radiation etc. Our slide notes have nothing on this. You were told just to say they were charged. Time wasted on this was always balanced by a lack of detail in other areas. Stick to what we taught you, but include ALL that we taught you.

- Millikan determining the mass of the electron. NOT HIS EXPERIMENT. Yes the q/m was used later, but this had nothing to do with Millikan and demonstrates lack of understanding of his experiment.
- "Proving" quantisation of charge – no idea where you are getting this concept from, it is not a syllabus point and NOT the point of Millikan's experiment. He was measuring the value of the charge. It's not really a quantisation thing (suggesting quantum physics) – it's just that there is a particle. Lose this wording, it makes your answer confusing.

Thomson comments

Students who understood this generally did it very well. They gave the different parts (finding velocity, then measuring radius with B field only). There is some work to be done on making your diagrams more clear AND INCLUDING LABELS, but generally those who knew this did well.

Other students need to review this process. Again, lots of confusion about forces, lack of description of the setup of the experiment, lack of ability to describe the two sections of the experiment, lack of ability to show how q/m was generated and lack of conclusions to the experiment.

Sample Answer/Key Points:

Paddlewheel sample:

Cathode Ray tube

It was observed that the cathode rays when shined on the paddles of the paddle wheel caused the paddle wheel to spin. Thus the unknown object of the cathode ray must hold the property to transfer momentum in collisions as $p = mv$, this means that the cathode ray was likely to be particles with mass as opposed to waves which did not exert contact forces like collisions.

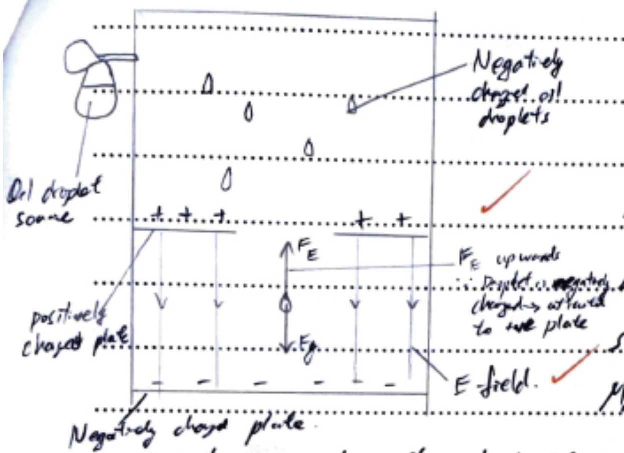
Thus the paddlewheel experiment confirmed the particle ~~[illegible]~~ property of the electron.

good!

Millikan sample:

Answer space for Qu 35 continues.

Millikan — charge of an electron.



• By spraying negatively charged oil droplets into a chamber, allowing them to fall under gravity into an E-field between two oppositely charged plates below and adjusting the E-field so that the oil droplet is suspended, Millikan could calculate the charge (q) of an electron.

∴ Done by suspending the oil droplet such that,

$$F_E = F_g$$

$$qE = mg$$

$$q = \frac{mg}{E} \quad \because E = \frac{V}{d}, \quad \frac{1}{E} = \frac{d}{V}$$

$$q = \frac{dmg}{V}$$

∴ By measuring d (distance between electric plates), m (mass of oil droplet) g (gravitational acceleration) & V (potential difference between plates) Millikan found that the charges of oil droplets were multiples of a certain base number ⟹ ∴ This base charge was the charge of an electron, with multiples due to multiple electrons being on the same oil droplet ⟹ hence the charge of an electron can be determined quantitatively

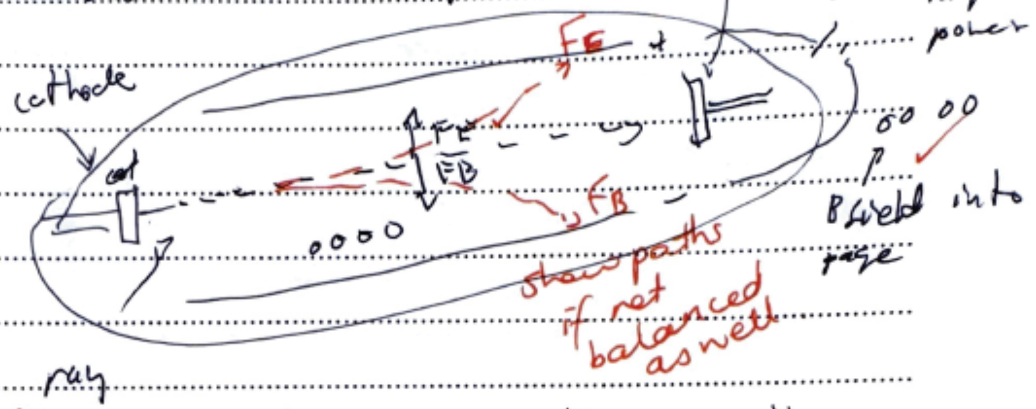
~~⟹ Also confirmed that electrons are present~~

force?

Thomson sample:

Answer space for Qu 35 continues.

Thomsons q/m ratio experiment



1) Thomson shined ~~so~~ the cathode ray through parallel ~~ex~~ electric plates as well as a ~~B~~ B field into page.

it was noted that the cathode ray would curve towards the positive electron plate ~~signalling~~ if no B field present signalling a ~~positive~~ negative charge.

2) Thomson ~~aligned~~ adjusted the E and B fields until the cathode ray proceeded straight. At this point, both a B and E field exerted a force on the cathode ray with $F_E = F_B$ thus

$$Eq = qv_{\perp}B$$

$$E = vB$$

$$v = \frac{E}{B}$$

good

3) after, he turned off the E field leaving just the B field exerting a force on the cathode ray.

continued at back.

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

Q8 35) at this point, ~~due to~~ the B field always exerts a force on the ~~particle~~ cathode ray perpendicular to velocity, thus the cathode ray would turn in a circle in UCM where the centripetal force for UCM was provided by the F_B

$\therefore F_c = F_B$

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

$\frac{mv}{r} = qB$

$\frac{q}{m} = \cancel{\frac{vB}{r}} \frac{v}{rB}$

recalling that $v = \frac{E}{B}$

$\frac{q}{m} = \frac{E}{B} \times \frac{1}{rB}$

$= \frac{E}{B^2 r}$

thomson recorded the ~~...~~ r of the beam circular motion and ~~...~~ used the derived formula to find the property q/m ratio of the unknown thing in the cathode ray tube

After this, this experiment was ~~...~~ repeated with different metal anodes, recording the same observations. Thus Thomson further discovered that this ~~...~~ cathode ray was made up of something present in all metals.

Thus through his experiment, Thomson confirmed the q/m property of the electron and the ~~universalness~~ commonness of electrons in all metals.

Question 36 (Band 2-6)

Explain, with reference to data in the graph, why the torque decreases as the rotational speed of the DC motor increases

Marking Guidelines	Marks
Extensive explanation of types of emf in a motor (supply, back, net) and relationship to changing torque Graph used to justify motor as ideal using 0 torque value at max speed	5
Thorough explanation of types of emf in a motor (supply, back, net) and relationship to changing torque OR No identification as ideal motor	4
Sound explanation of how changing emf affects torque in a motor	3
Limited description of emf and/or torque in a motor	2
A correct point made	1

Markers Comments:

Overall this is a concept that was poorly understood by the majority of the cohort. An area of URGENT review for nearly everyone.

Key points that need to be reviewed/understood by the entire cohort:

- A clear understanding of the reason for back emf in ANY spinning coil. You do not need a coil of increasing speed to generate back emf. This was not able to be explained by very many students. Use Faraday's law to discuss change in flux in a spinning coil.
- The fact that back emf opposes the supply emf (voltage in circuit that is causing the coil to spin via the motor effect in the first place). BACK EMF DOES NOT GENERATE AN OPPOSING CURRENT, OPPOSING MAGNETIC FIELD OR OPPOSING TORQUE. There is an opposing emf, thus decreasing the NET emf, supply emf value stays constant, thus net emf is lower: emf(net) = emf(supply) – emf(back).
- There is thus ONE emf (the net emf) that causes ONE current to flow in the circuit. Multiple students are under the very mistaken impression there are two opposing currents in the same coil. An absolutely impossible event.
- Likewise there is not any ability to have two opposing torques. One current provides one torque.

THEN:

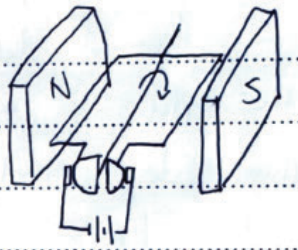
- When the RPM increases, the change in flux is constant, but the time is decreased as moving faster, thus the emf increases (link to the equation at this point). Majority of students are under the very mistaken impression that change in flux increases. However, area and magnetic field are constant, thus the flux magnitude is constant. It is ONLY time that changes.

- As back emf magnitude increases, the net emf drops – from here you needed to link emf to current (V = IR) and then current to torque (torque = nBIA) – this last step of linking the emf to torque was done well by some students, but ignored completely by most. You CANNOT just say that there is a link between two quantities, you MUST show why – this is usually in the form of an equation from the data sheet.

LASTLY:

- You needed to reference the graph to realise the final torque was zero – thus there is zero net emf and emf(supply) = emf(back). You did not need to call it an ideal motor to get full marks, but this fact needed to be acknowledged in order to get 5 marks. (Note that the sample did not do this very well, the sample is a "just" 5 marks).

Sample Answer/Key Points:



- As seen in the diagram, a DC motor produces torque through the current carrying wire in a magnetic field experiencing $\tau = nIAB\sin\theta$.

-> The torque causes the motor to accelerate in rotational speed.

- However, as the rotational speed increases, by Faraday's law, the wire's movement through the field causes it to experience a change in flux, inducing an emf, which will counteract the motion that caused the change in flux, by Lenz's law.

-> The back emf will counteract the emf created by the power pack, reducing net emf E_{net}.

6

Extra writing space

Q. 36:

- Since $\tau = nIAB\sin\theta$ and $I = \frac{V}{R}$, $V = emf$

  $\tau \propto I \propto V$ when all other factors are constant.

  $\rightarrow \downarrow E_{net} \rightarrow \downarrow I \rightarrow \downarrow \tau$

- This can be seen in the graph, where torque started at 1.6 Nm at 0 RPM, steadily decreased to 0 Nm at 100 RPM.
- Also, the ~~...~~ decrease in torque can be seen as linear against RPM.

  $\rightarrow$ This is due to $\varepsilon = -N\frac{\Delta\phi}{\Delta t}$, $\varepsilon \propto -\frac{\Delta\phi}{\Delta t}$

  $\rightarrow \Delta\phi = BA\cos\theta$, $\frac{\Delta\phi}{\Delta t} = \frac{BA\cos\theta}{t} \rightarrow \frac{\Delta\phi}{\Delta t} \propto$ rotational speed

  $\rightarrow \varepsilon \propto -$rotational speed

- Thus, as rotational speed ~~increase~~ of the motor increases, a proportional, stronger back emf is induced, $E_{net} = E_{power} - E_{back}$, reducing net emf, which reduces the current in the wire, ultimately reducing torque, until the motor experiences 0 torque at max RPM of 100.

why??

Question 37 (Band 2-6)

Determine the angle at which the ball must be hit so that it just touches the roof, and thus calculate the range of the ball when it lands

Marking Guidelines	**Marks**
Correct calculation of both angle and range Full working shown, including all intermediate units Final answer given to correct significant figures.	**6**
Substantially correct calculation with minor errors OR missing units Majority working shown, all key steps present.	**5**
Calculation shows all key steps correct One major error OR multiple minor errors	**4**
Some parts of calculation correct – key step(s) missing Multiple major and/or minor errors.	**3**
Some correct steps performed and/or multiple correct statements made	**2**
A correct step in the calculation shown	**1**

Markers Comments:

- A well attempted question overall with an avg of 4.70/6.
- This question was marked based on the criteria above.
- Very pleasing to see that students used and applied Physics equations adapted from the Formula and Data sheet.
- Aim to reduce your cognitive load “thinking” and show ALL WORKING and annotations of the stimulus – this will ultimately decrease the chance of “Silly or stupid mistakes”
- Better responses showed CLEAR and LOGICAL steps in their calculation.
- Better responses had a clear STRUCTURE and showed FULL WORKING.

Sample Answer/Key Points:

$u = 35 ms^{-1}$ $s_y = 40m$ $v_y @ 40m = 0 ms^{-1}$

$u_x = (35\cos\theta)$ $u_y = (35\sin\theta)$

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

$0 = (35\sin\theta)^2 + (2\times -9.8 \times 40)$

$(35\sin\theta)^2 = 784$

$(\sin\theta)^2 = 784/35^2 = 0.64$

$\theta = \sin^{-1}\sqrt{0.64} = 53.13°$

$\boxed{\theta = 53.13°}$ $\therefore$ $v_y = u_y + a_y t$

$v_y = 35\sin 53.13 = 28 ms^{-1}$

$\therefore -28 = 28 + (-9.8)t$

$\therefore t = 5.714 s$

$s_x = u_x \times t = 35 \times \cos 53.13 \times 5.714$

$= 119.99 = 120 m$

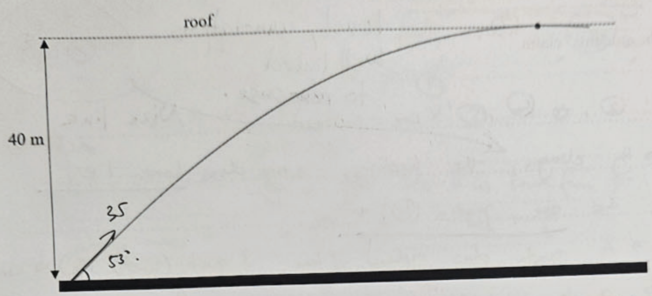
Student Sample Answer

Question 37 (6 marks)

6

A ball is hit at a speed of 35 ms^{-1} from ground level inside a stadium with a roof that is 40 m above the ground. $\rightarrow v_y = 0$.

At the top of the flight of the ball, it just touches the roof, and continues on its path, with no impact upon its trajectory. The projectile lands at the same level from which it was launched.



Determine the angle at which the ball must be hit so that it just touches the roof, and thus calculate the range of the ball when it lands.

$v_y^2 = u_y^2 + 2as_y$, $a_y = -g$, $u_y = u\sin\theta$, $s_y = 40$

$= (35\sin\theta)^2 - 2g(40\text{ m})$ $\quad = 35\sin\theta$.

$0 = (35\sin\theta)^2 - 2(9.8)40$ At ~~max~~ height (top of flight, $v_y = 0$)

$1225\sin^2\theta = 784$ nice working

$\sin^2\theta = 0.64$ + sub

$\sin\theta = 0.8$

$\theta = 53.130°$

$= 53°$ (2sf).

$\Rightarrow$ $v_y = u_y + a_y t$, due to symmetrical nature of flight, $u_y = -v_y$.

$-u_y = u_y + a_y t$; $a_y = -g$.

$2u_y = gt$

$t = \frac{2}{9.8} \times (\sin 53.130°) \times 35$

$= \frac{2}{9.8} \times 0.8 \times 35$

$= 5.714\text{ s}$

$\Rightarrow$ $s_x = u_x t$, $u_x = u\cos\theta$

$= u\cos\theta \times t$

$= 35\cos(53.130°) \times 5.714\text{ s}$

$= 120\text{ m}$

$= 1.2 \times 10^2\text{ m}$ (2sf).

range is 120 m.

Question 38 (Band 2-5)

Assess the students' claim.

Marking Guidelines	Marks
Multiple pros and cons presented with justification and links to the student claim as to whether correct or incorrect. Justified conclusion presented.	**4**
Pros and cons presented with some justification as to correct/incorrect Conclusion presented	**3**
Some attempt to identify correct and incorrect statements	**2**
One correct or incorrect statement identified	**1**

Markers Comments:

- A well attempted question overall with an avg of 2.68/4.
- This question was marked holistically based on the criteria above.
- Better responses "unpacked" and annotated the student claim and then used these annotations in their response (see sample student answer below).
- The Key Verb in this question is "Assess." It was pleasing to see the responses that addressed the key verb and "packaged" their written responses as "Pro's or Support the Student claim" and "Con's or refute the Student claim." The Assess Key verb also requires a justified conclusion.
- Avoid writing statements or ideas with little to no justification.
- Link ideas and statements with justification or Physics reasoning and then linking back/relating to the claim.
- The electron is bound to the nucleus by the electromagnetic force between oppositely charged particles (proton and electron). This knowledge/understanding is part of the Mod 8 HSC Course. Many students identified the electrostatic force, which is incorrect at the HSC level.

Sample Answer/Key Points:

Pros:

- Atom has one electron: correct, one single electron is in orbit around the nucleus
- Atom has one proton: correct, the hydrogen-1 isotope (all H isotopes) have only one proton
- Proton has three quarks: correct, protons are made of three quarks

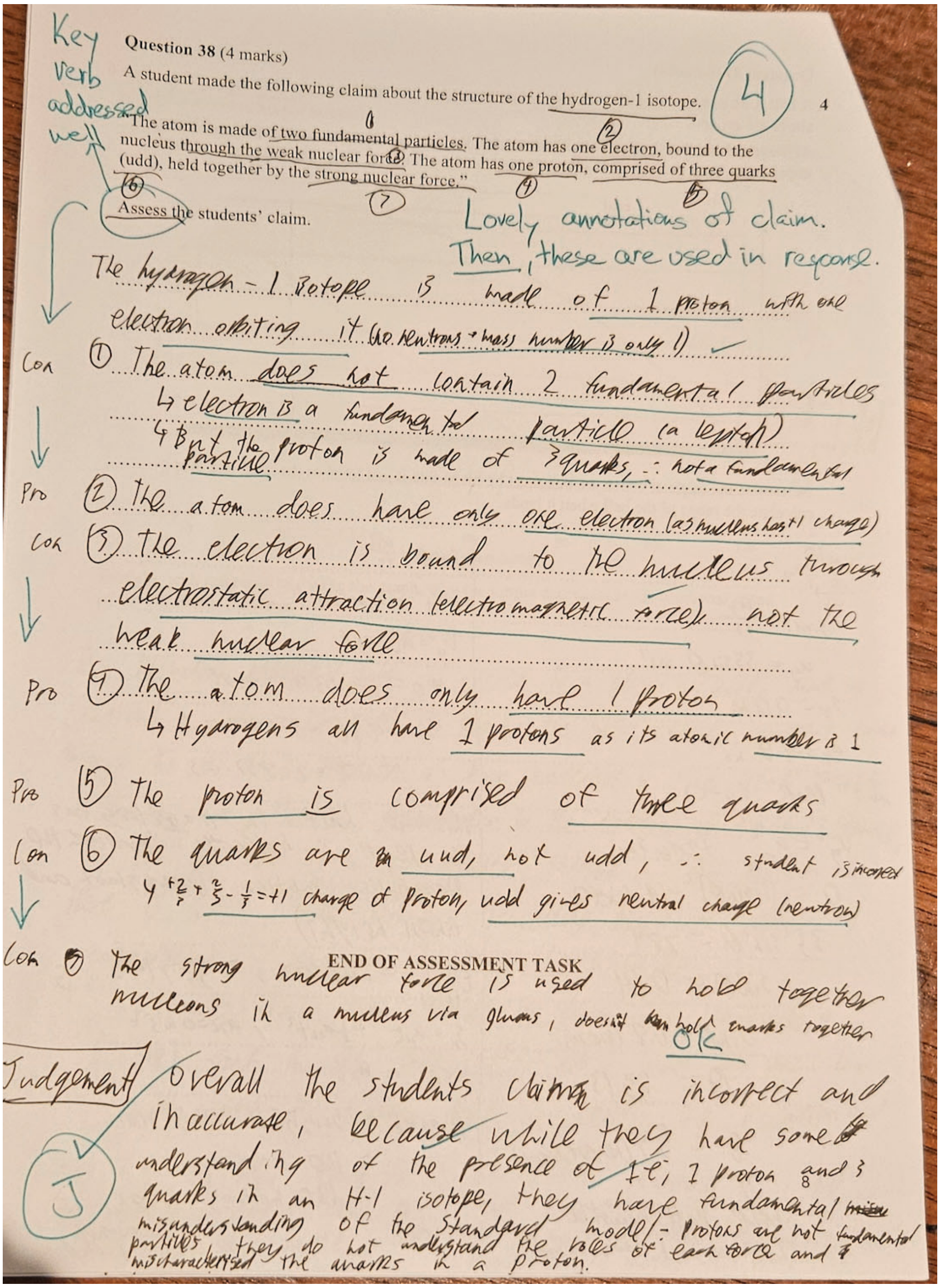
- Quarks held together by strong nuclear force: correct, the strong nuclear force is responsible for holding together quarks to form both protons and neutrons, this is mediated by the gluon (strong nuclear boson)

Cons:

- Atom is made of two fundamental particles: incorrect, while the electron is a lepton and is fundamental, the proton is made of quarks, thus is not a fundamental particle
- Electron bound to nucleus by weak nuclear force: incorrect, the electron is bound to the nucleus by the electromagnetic force between oppositely charged particles (proton and electron)
- Proton quarks are udd: incorrect, a proton is made of uud quarks.

Provides a Justified and strong conclusion.

Student Sample Answer



Key verb addressed well

Question 38 (4 marks) 4

A student made the following claim about the structure of the hydrogen-1 isotope.

"The atom is made of two fundamental particles. The atom has one electron, bound to the nucleus through the weak nuclear force. The atom has one proton, comprised of three quarks (udd), held together by the strong nuclear force."

Assess the students' claim.

4

Lovely annotations of claim. Then, these are used in response.

The hydrogen-1 isotope is made of 1 proton with one electron orbiting it (no neutrons + mass number is only 1)

Con ① The atom does not contain 2 fundamental particles
↳ electron is a fundamental particle (a lepton)
↳ But the proton is made of 3 quarks, ∴ not a fundamental particle

Pro ② The atom does have only one electron (as nucleus has +1 charge)

Con ③ The electron is bound to the nucleus through electrostatic attraction (electromagnetic force) not the weak nuclear force

Pro ④ The atom does only have 1 proton
↳ Hydrogens all have 1 protons as its atomic number is 1

Pro ⑤ The proton is comprised of three quarks

Con ⑥ The quarks are ~~an~~ uud, not udd, ∴ student is incorrect
↳ $+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$ charge of proton, udd gives neutral charge (neutron)

END OF ASSESSMENT TASK

Con ⑦ The strong nuclear force is used to hold together nucleons in a nucleus via gluons, doesn't ~~hen~~ hold quarks together

OK

Judgement Overall the students claim is incorrect and inaccurate, because while they have some understanding of the presence of 1e, 1 proton and 3 quarks in an H-1 isotope, they have fundamental ~~misu~~ misunderstanding of the Standard model / - protons are not fundamental particles, they do not understand the roles of each force and ~~t~~ mischaracterised the quarks in a proton.

J

8