Knox Grammar School

2024

HSC Trial Examination

Assessment Task Four

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams in pencil
- Calculators approved by NESA may be used
- A formula sheet, data sheet and Periodic Table are provided

Total marks: 100

Booklet 1

Section 1 – 20 marks (pages 3 – 15)

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

Booklet 2

Section II – 26 marks (pages 18 – 26)

- Attempt questions 21-27
- Allow about 45 minutes for this section

Booklet 3

Section II – 26 marks (pages 29 – 37)

- Attempt questions 28-32
- Allow about 50 minutes for this section

Booklet 4

Section II – 28 marks (pages 40 – 46)

- Attempt questions 33-37
- Allow about 50 minutes for this section

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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. Which of the following correctly describes the orbit of a near Earth satellite?

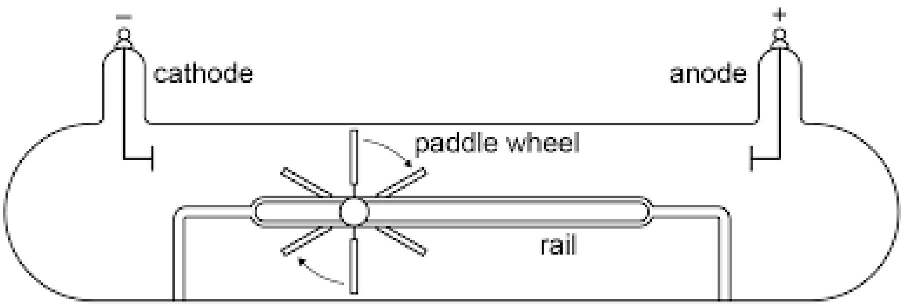
   A. Orbits once a day.

   B. Orbits multiple times per day.

   C. Orbits multiple times per hour.

   D. Stays above the same place on Earth.

2. In a paddlewheel experiment using a cathode ray tube (CRT), a paddlewheel was placed in the path of cathode rays and was observed to rotate when the cathode rays were emitted.



   What was the conclusion drawn from these observations?

   A. The movement of the paddlewheel is caused by air inside the cathode ray tube.

   B. The paddlewheel's motion shows that cathode rays consist of particles with mass and momentum.

   C. The rotation of the paddlewheel indicates that the cathode rays carry energy, which is a property exclusive to waves.

   D. The paddlewheel rotates due to the creation of a magnetic field by the cathode rays, which interacts with the wheel's material.

3. A coil has 10 square loops of wire with a side length of 4 cm. It is placed in a magnetic field of strength 5×10^{-2} T. The coil carries a current of 20 mA.

What is the maximum torque on the coil?

A. 1.6×10^{-5} Nm

B. 4×10^{-4} Nm

C. 1.6×10^{-2} Nm

D. 0.4 Nm

4. Kepler's second law is an example of the Law of Conservation of Energy.

Which statement below best describes this?

A. An orbiting body increases its kinetic energy as it moves closer to the object it is orbiting.

B. An orbiting body increases its gravitational potential energy and decreases its kinetic energy throughout its orbit.

C. An orbiting body decreases its kinetic energy and gravitational potential energy as it moves closer to the object it is orbiting.

D. As an orbiting body moves away from the object it is orbiting, its kinetic energy decreases and its gravitational potential energy increases.

5. A spaceship travels past the Earth at a speed of 0.8 c. An observer in the spaceship measures the length of the spaceship to be 200 m.

What is the length of the spacecraft as measured by an observer on Earth?

A. 72 m

B. 89 m

C. 120 m

D. 333 m

6. Which statements below describe evidence arising from the use of particle accelerators for special relativity and for the existence of fundamental particles?

	Special Relativity	**Fundamental Particles**
A.	Particles produced are short lived, between 10^{-6} and 10^{-23} s.	These collisions are only successful when very high energies are involved, so particles need to be accelerated to exceptionally high speeds.
B.	As a particle approaches the speed of light, it behaves as if it has extra mass, and more force is required to increase its momentum.	The top quark was discovered by colliding particles together at high speeds.
C.	As particles reach relativistic speeds and masses, less centripetal force is required to keep them on a circular path than is expected by classical physics.	The Higgs Boson was discovered in the Large Hadron Collider.
D.	Electrons in a cyclotron moving at relativistic speeds need a higher than expected magnetic field to keep a consistent circular radius.	Particle accelerators were developed to discover and study new particles, including antimatter.

7. Which isotope would produce radiation with the highest ionising energy?

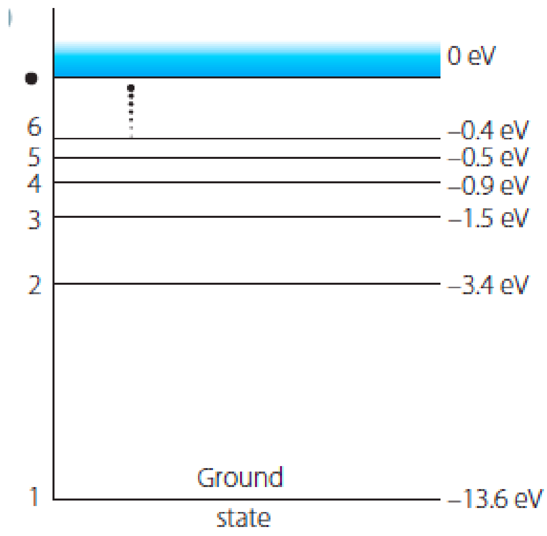
A. $610C$

B. $614C$

C. $2656Fe$

D. $92235U$

8. One of the lines on the hydrogen emission spectrum has a wavelength of 496 nm. The structure of the hydrogen atom is shown below.



Which transition is responsible for the line of wavelength 496 nm?

A. 3 to 2

B. 4 to 2

C. 5 to 2

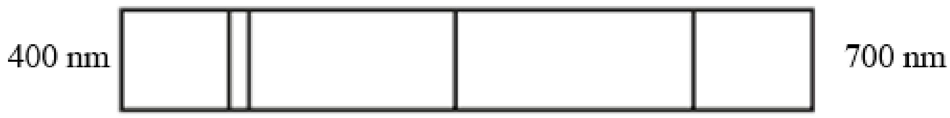
D. 6 to 2

9. There are key pieces of evidence that support the expanding Universe theory.

Which piece of evidence and reason is correctly matched to support the expanding Universe theory?

	Evidence	Reason
A.	Cosmic microwave background radiation	The variations in temperature of the universe shows evidence that energy dispersed after the Big Bang.
B.	Measurement of speed and distance of galaxies	Plotting a graph of velocity against distance allows determination of the age of the universe.
C.	Red shifting of light from galaxies	All galaxies in the universe are moving away from each other which shows forces acting on them from the Big Bang.
D.	Cosmic microwave background radiation	Radiation created in the early stages of the universe would stretch as the universe expanded so would take the form of microwaves and radio waves.

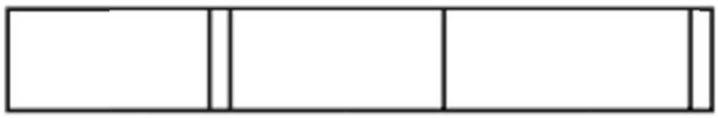
10. The diagram below represents the spectral lines of an element in a laboratory on Earth.



The diagram below shows the spectral lines from the same element as observed in two different stars, each located in a different distant galaxy.

Star P

Star Q



Which of the following is a correct statement about the two stars?

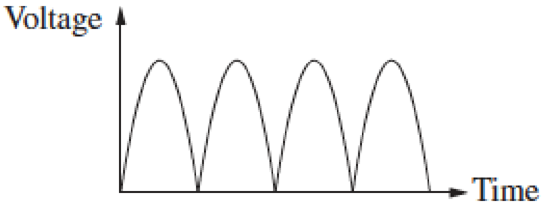
A. Star P is closer to Earth and rotating slower than Star Q.

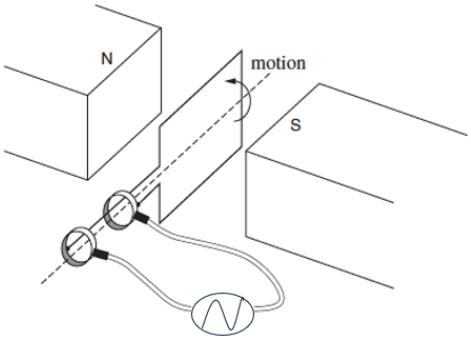
B. Star P has a lower density and is rotating faster than Star Q.

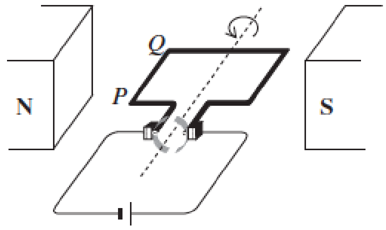
C. Star Q is further away from Earth and is rotating slower than Star P.

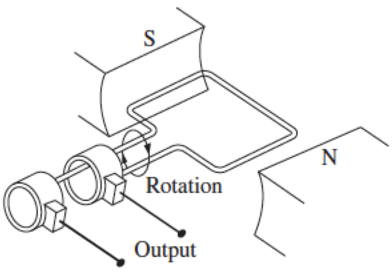
D. Star Q is further away from Earth and has a higher density than Star P.

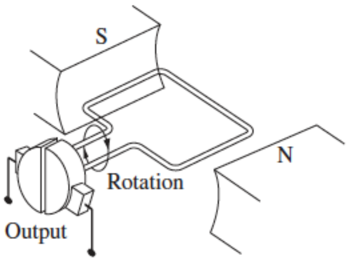
11. The operation of which device below would result in the output on the graph below?



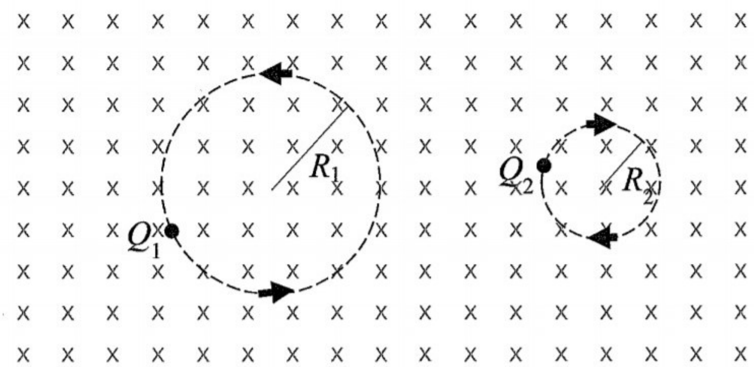
A. 

C. 

B. 

D. 

12. Two charged particles, Q_1 and Q_2 are undergoing uniform circular motion in the same uniform magnetic field as shown in the diagram (not to scale).



What two features of the particles could cause the difference in the paths seen?

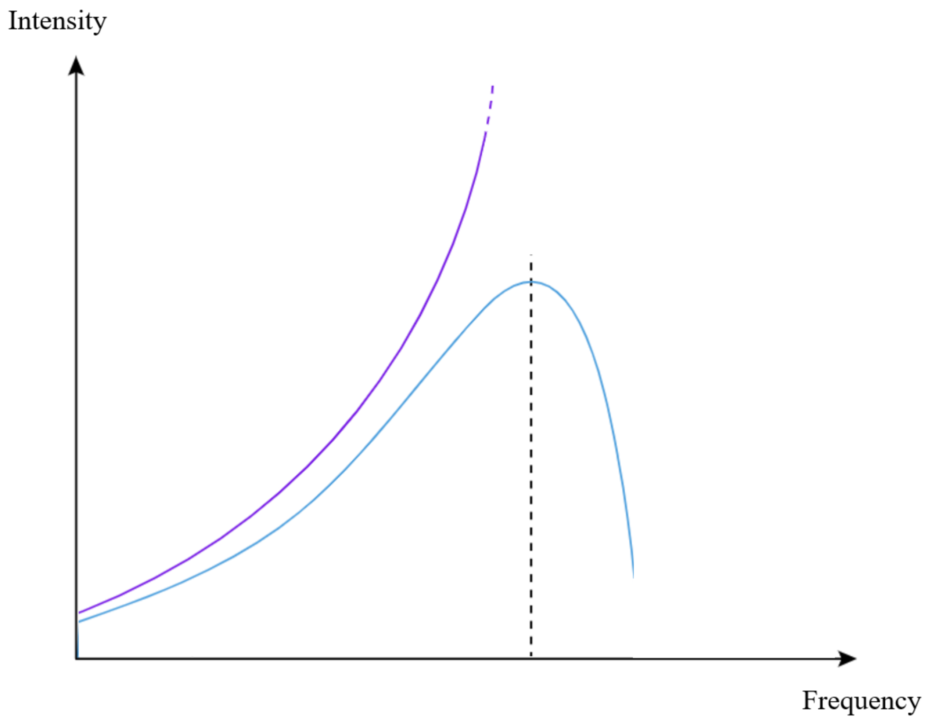
A. Q_2 has a half the mass and half the charge of Q_1.

B. Q_2 has half the mass and double the charge of Q_1.

C. Q_1 has half the mass and is travelling at the same velocity as Q_2.

D. Q_1 has double the mass and is in a weaker magnetic field than Q_2.

13. The graph below shows the intensity of light predicted by classical theory and observed in experiments of blackbody emission.



What would happen to the shape of the curve if the temperature of the blackbody was decreased?

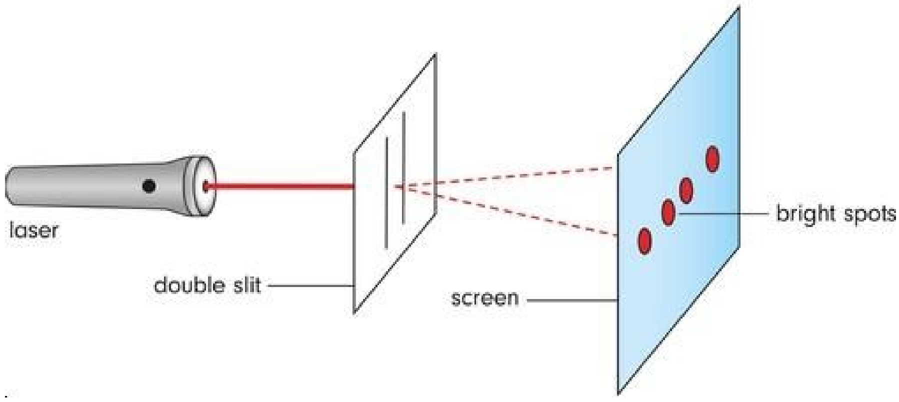
A. Same intensity and peak shifts to left.

B. Lower intensity and peak shifts to left.

C. Lower intensity and peak shifts to right.

D. Higher intensity and peak shifts to right.

14. A double-slit experiment is set up as shown below using a laser of wavelength 630 nm. The light is incident on a double slit with slit separation of 40 μm. This results in a pattern on a screen 645 cm away.



Which change to the experimental setup would result in an increase in the distance between maxima (bright spots) on the screen?

A. Decreasing the distance between slits.

B. Changing the colour of the laser to blue.

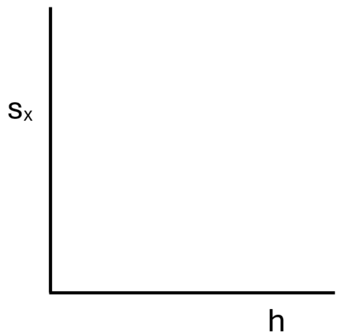
C. Moving the screen closer to the double slit.

D. Replacing the double-slit with a diffraction grating with 25 lines per mm.

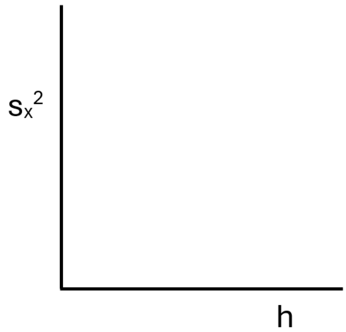
15. A student wanted to investigate the effect that changing the height of a horizontally launched projectile would have on its range. The student wanted to create a linear graph to determine the mathematical relationship between the variables.

Which set of axes below would produce a linear graph?

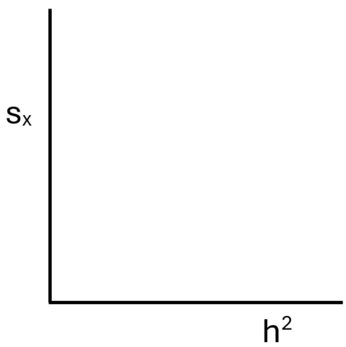
A.



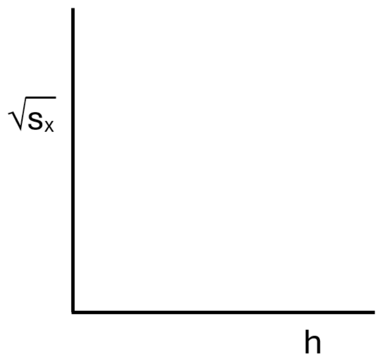
C.



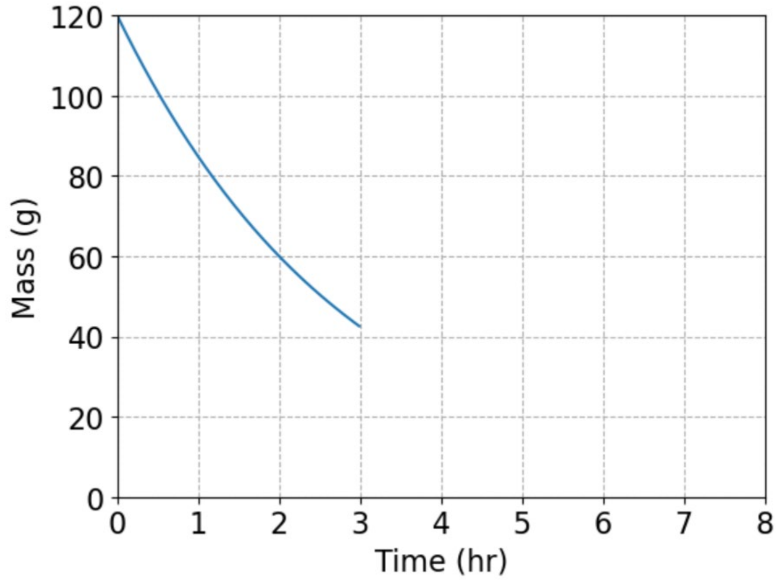
B.



D.



16. A student measured the mass of a radioactive source over three hours. The results are plotted below.



What mass of the radioactive source would remain after 7 hours and 20 minutes?

A. 7.88 g

B. 8.25 g

C. 9.45 g

D. 9.90 g

17. Data about the mass and size of two asteroids, Stratos and Fios, is measured. It is found that Stratos has twice the diameter of Fios and three times the mass.

The ratio of the escape velocities of Stratos to Fios is:

A. $\frac{2}{3}$

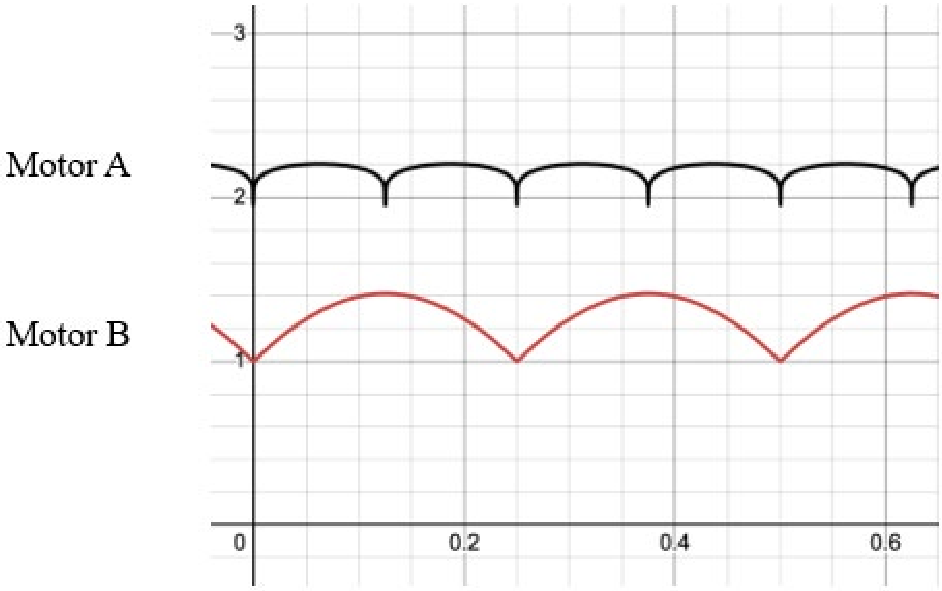
B. $\frac{3}{2}$

C. $\sqrt{\frac{2}{3}}$

D. $\sqrt{\frac{3}{2}}$

18. Two identically sized DC motors were constructed using the same materials. A cross section of each of the two motors showing the magnets and the coils is shown below.

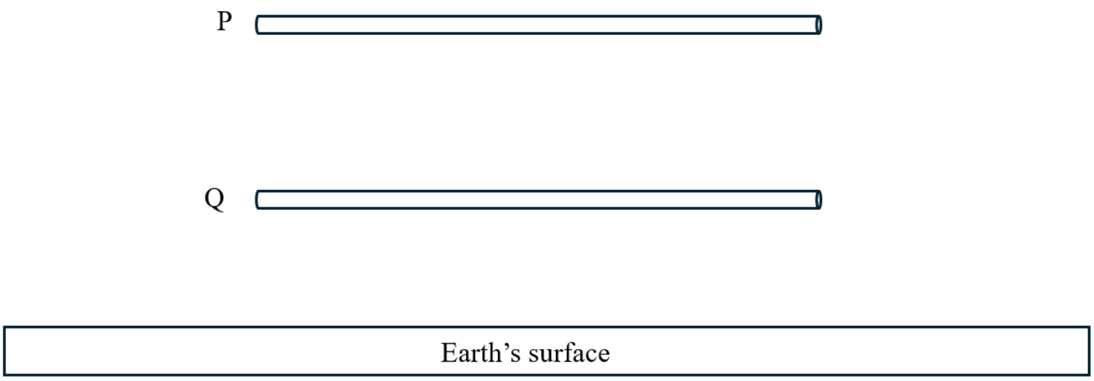
A graph of the torque output for both motors is shown below.



Which of the following correctly describes the effect of the magnets and coils on the torque output shown on the graph above?

	Effect of radial magnets	Effect of increasing number of coils
A.	Reduce the range of the torque on the coil.	Decrease the frequency with which maximum torque occurs.
B.	Ensure the coils are perpendicular to the field for longer.	Increases both minimum and maximum torque on the coil.
C.	Provide torque for a greater proportion of the rotation.	Reduces the range of torque on the coil.
D.	Ensure that torque is never zero.	Reduces the range of torque on the coil.

19. Two current carrying wires, P and Q, were placed as shown below so that there was an attractive force of 4.3 N between them. The mass of each wire is 63 g.



What is the new magnitude of the force on wire Q if the current in wire P is increased from 4.76 A to 14.28 A and reversed in direction?

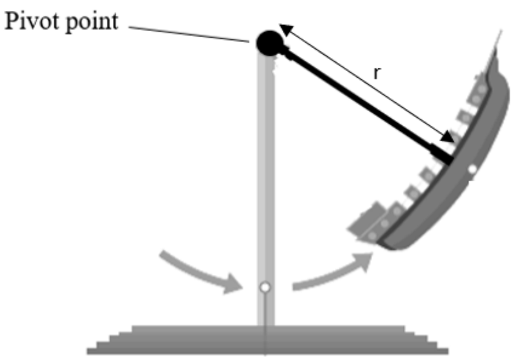
A. 12.28 N

B. 12.90 N

C. 12.96 N

D. 13.52 N

20. A diagram of a pirate ship ride in an amusement park is shown below. The distance from the pivot point to a person on the ride is shown by *r* in the diagram.



Two versions of the ride, A and B, are used in the amusement park.

In Ride A, a 50 kg person on the ride is 15 m from the pivot point (shown by *r*).

In Ride B, a 100 kg person on the ride is 22.5 m from the pivot point (shown by *r*).

Both ships swing as shown above, and eventually rotate in uniform circular motion with the same period.

What is the ratio of the centripetal forces ($F_A:F_B$) acting on the people on Ride A and Ride B when moving in uniform circular motion?

A. 1 : 1.5

B. 1.5 : 1

C. 1 : 3

D. 3: 1

END OF BOOKLET 1

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Physics

Booklet 2
Section II

26 marks
Attempt Questions 21–27
Allow about 45 minutes for this section

Instructions

- Place a student sticker at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing booklets are available upon request. If used, place a sticker with your student number on EACH writing booklet. Clearly label the writing booklet with the question number.

EXTRA BOOKLETS USED: **(please circle)** YES / NO

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

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Question 21 (4 marks)

The mass of Jupiter is 18.98×10^{26} kg. The radius of Jupiter is 6.842×10^{7} m.

(a) The gravitational field strength at a distance from the centre of a mass is given by: **2**

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

What is the gravitational field strength at the surface of Jupiter?

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(b) One of Jupiter's moons orbits the planet with a period of 29300 s. **2**

What is the orbital radius of this moon?

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Question 22 (2 marks)

Outline the role of the caesium atom in modern measurements of time and distance. **2**

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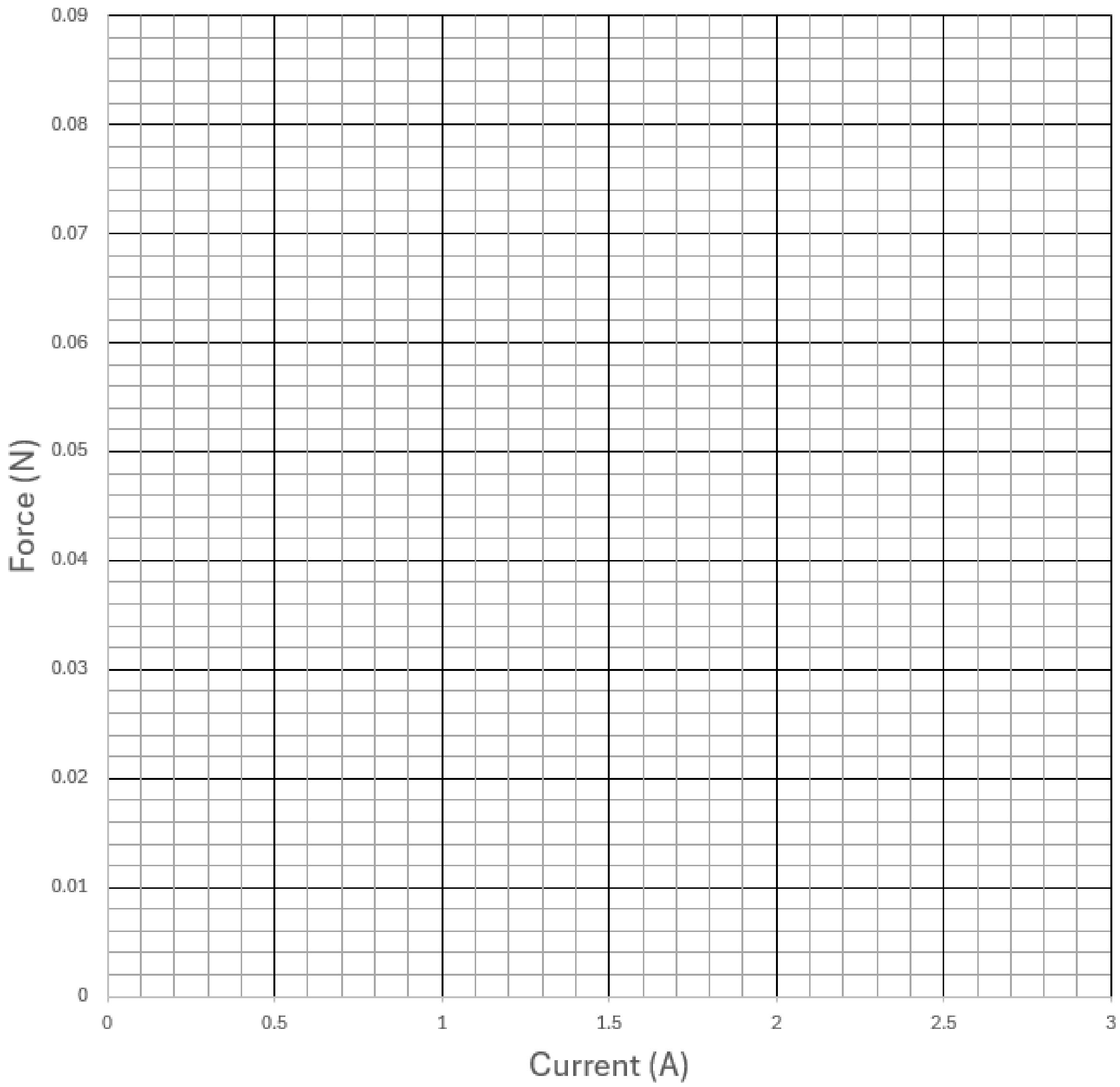
Question 23 (4 marks)

A student used a current balance with a 0.075 m length of wire that was placed perpendicular to a constant magnetic field. The entire length of wire was contained within the field.

The current in the wire was varied and the force on the wire measured. The results of the experiment are shown below.

Current (A)	**Force (N)**
0.5	0.015
1.0	0.039
1.5	0.052
2.0	0.073
2.5	0.083

Plot a graph of the results and thus determine the strength of the magnetic field used in the experiment. **4**



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Question 24 (4 marks)

An electric drill with a DC motor and no load is turned on. It increases speed until it reaches a maximum constant rotational speed. A student suggests that this is due to back emf which means the motor reaches a point where net torque is zero. **4**

Evaluate the student claim.

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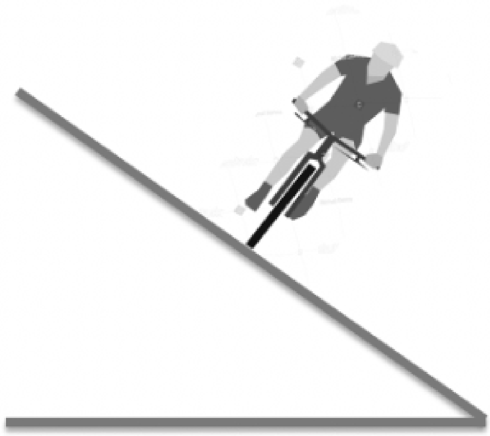
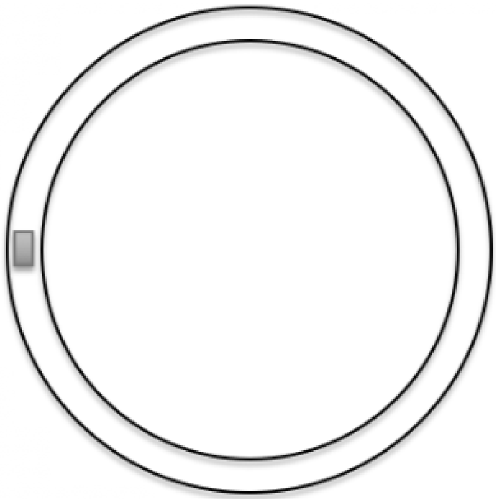
Question 25 (3 marks)

A cyclist is racing on a velodrome (circular racing track) that has banked curves as shown below. **3**





Explain, with the aid of annotations on the diagram, how the banked track provides a greater centripetal force on the cyclist than on a flat (non-banked) track.

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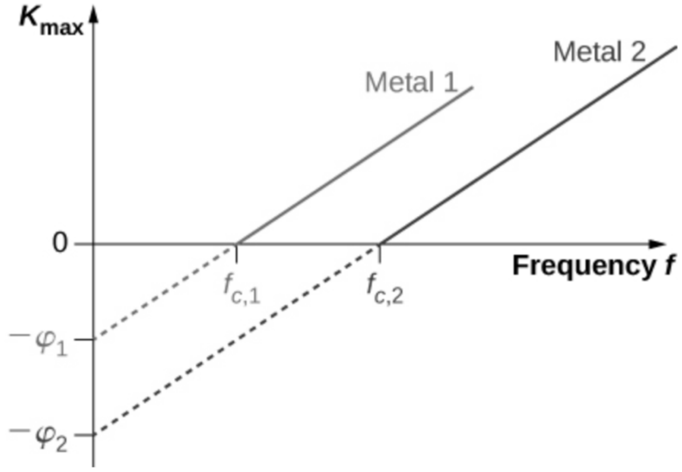
Question 26 (5 marks)

In the photoelectric effect, incident light on the surface of a metal causes electrons to be ejected. The graph below shows the experimental results gained when light of a range of frequencies is shone onto two different metals.



(a) Explain, with reference to particle theory, why the maximum kinetic energy of photoelectrons emitted from the same metal increases as the frequency of the incoming light increases. **3**

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(b) Justify why the two lines on the graph are parallel. **2**

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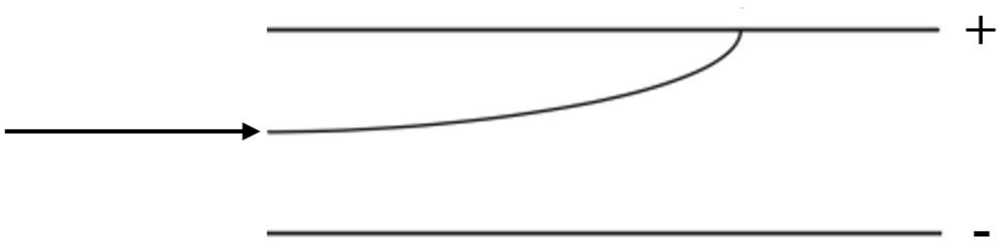
Question 27 (4 marks)

Ignore the effects of gravity in this question. **4**

A charged particle (q_1) enters an electric field that is setup between two parallel plates as shown below. The particle enters halfway between the plates, perpendicular to the electric field.

The potential difference between the plates is then quadrupled (four times larger) while all other variables remained constant. An identical particle (q_2) then enters the field in the same way as q_1. Both particles strike the positive plate.



Determine the ratio of the ranges of the two particles.

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Physics

Booklet 3
Section II

26 marks
Attempt Questions 28-32
Allow about 50 minutes for this section

Instructions

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- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
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EXTRA BOOKLETS USED: **(please circle)** YES / NO

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

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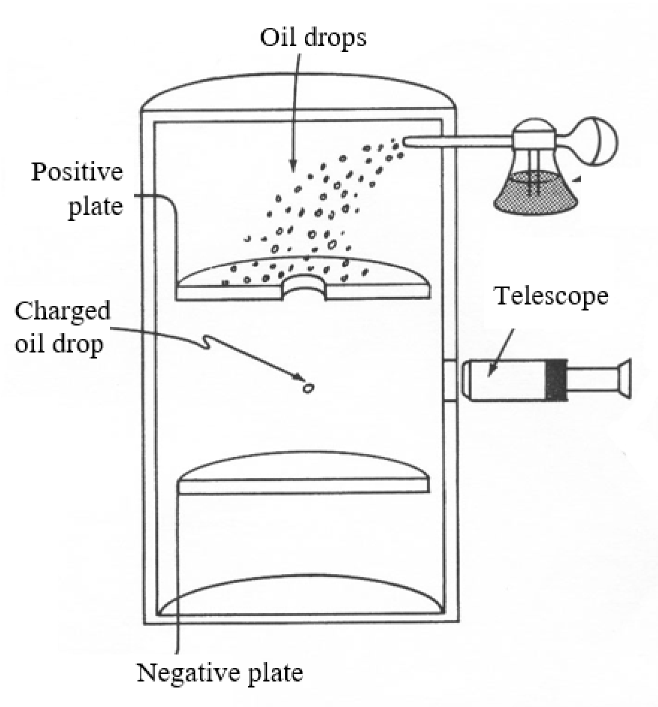
Question 28 (5 marks)

The diagram below shows an apparatus that can be used to conduct Millikan's experiment that measured the charge of an electron. **5**



Explain, using relevant equations, the role of forces and fields in the determination of the charge of an electron.

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Question 28 continued

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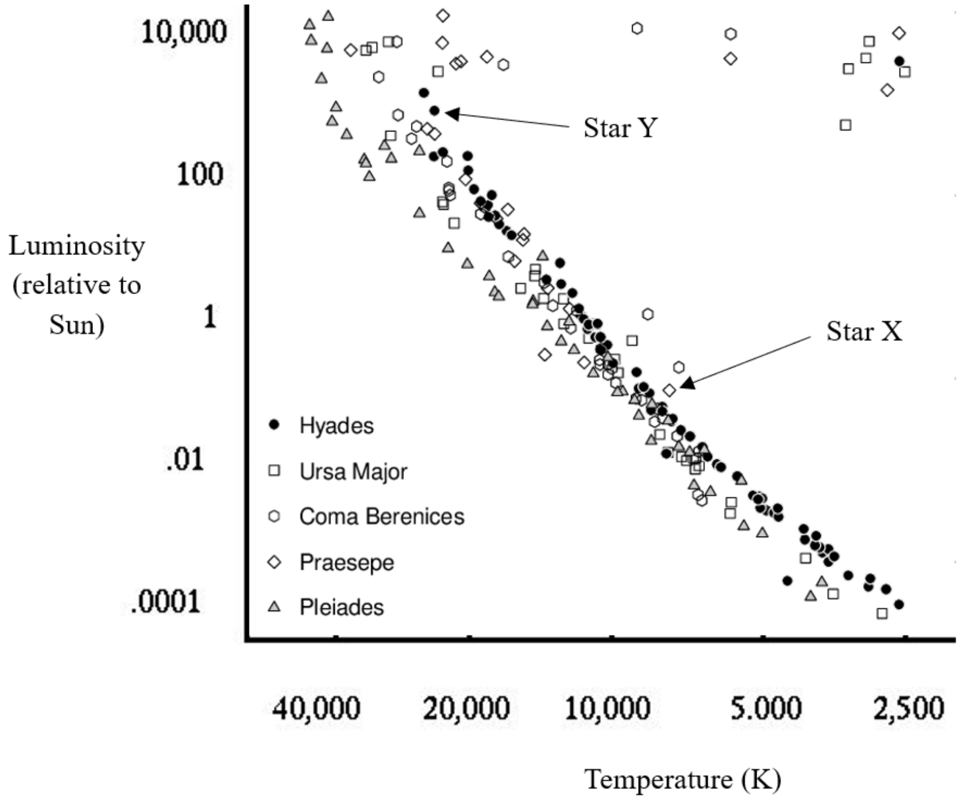
Question 29 (7 marks)

The Hertzsprung-Russell diagram below shows the temperature and luminosity of some stars visible from Earth.



(a) Compare the main sequence nucleosynthesis of Star X and Star Y. **4**

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(b) Outline the processes that lead to the formation of elements up to iron during the lifetime of Star Y. **3**

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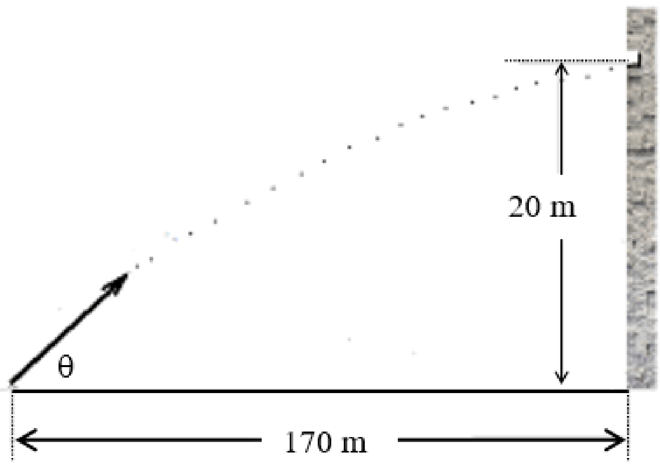
Question 30 (4 marks)

An archer wanted to shoot a target against the wall of a building that was 170 m away. The target was 20 m above the launch height of the arrow. **4**



If the arrow was shot at an angle of 30 degrees above the horizontal, what speed would the arrow need to be launched to hit the target?

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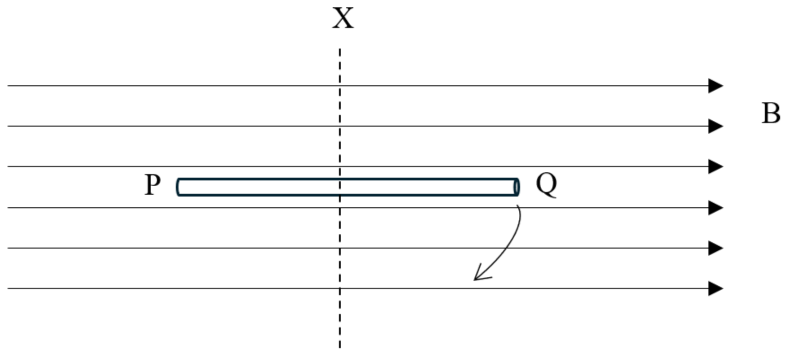
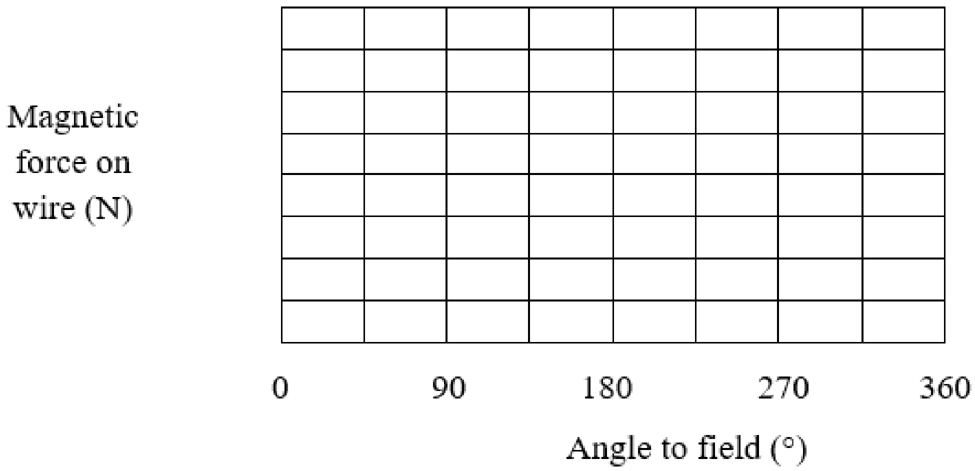
Question 31 (3 marks)

A current carrying wire is placed in a uniform magnetic field as shown in the diagram below. **3**
The wire is initially parallel to the direction of the magnetic field and has a current of consistent magnitude running from P to Q.



The student then rotates the wire through 360 degrees. After 90 degrees of rotation the wire is parallel to the line X in the diagram above.

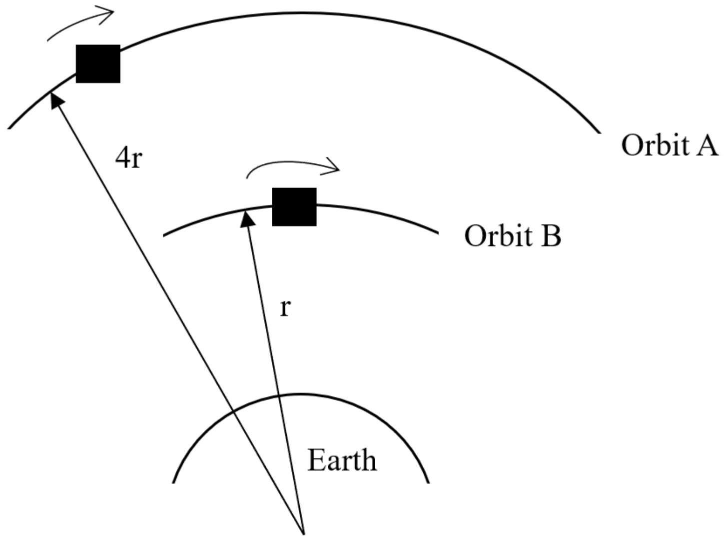
Sketch a graph of the magnetic force acting on the wire against the angle the conductor makes with the field, and justify the shape of your graph.



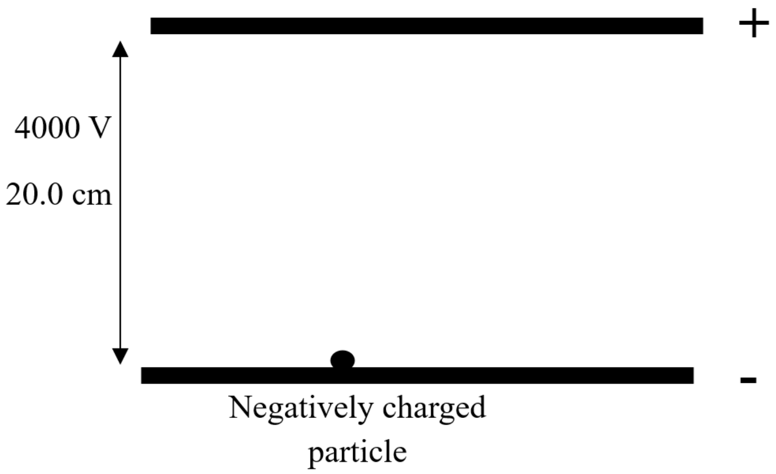
Question 32 (7 marks)

When objects move in gravitational and electric fields there may be changes in the energy of the objects. **7**

A satellite is in orbit around the Earth in Orbit A as shown below. The satellite is moved from Orbit A to Orbit B.



A charged particle of mass 2.753×10^{-28} kg and charge -6.643×10^{-19} C is placed at the negative plate in a uniform electric field as shown below. It is released and moves to the positive plate.



Question continues over page

Question 32 continued

Qualitatively and quantitatively compare the energy changes that occur when the satellite and charged particle move as described on page 35.

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END OF BOOKLET 3

Knox
Grammar
School

Place sticker with student number in this box.

Place a sticker on any writing booklets used.

DO NOT PUT A STICKER ON EVERY PAGE.

Physics

Booklet 4
Section II

28 marks
Attempt Questions 33-37
Allow about 50 minutes for this section

Instructions

- Place a student sticker at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing booklets are available upon request. If used, place a sticker with your student number on EACH writing booklet. Clearly label the writing booklet with the question number.

EXTRA BOOKLETS USED: **(please circle)** YES / NO

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

1 2 3 4 5 or write number here................................

Please turn over

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Question 33 (5 marks)

A ray from an incandescent source of light, with a temperature of 6000 K, was directed on a diffraction grating of 500 lines/mm. A zero, first and second order maxima were observed.

(a) Show that the most intense part of the first order maxima occurs at an angle of 14 degrees. **3**

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(b) Outline why a single angle cannot be calculated for the second order maxima. **2**

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Question 34 (9 marks)

"It doesn't matter how beautiful your theory is. If it doesn't agree with experiment, it's wrong." – *Richard Feynman (Nobel Prize winning physicist)* **9**

Analyse how experimental evidence was used to advance the atomic model, including the work of Rutherford, Bohr and de Broglie.

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Question 34 continued

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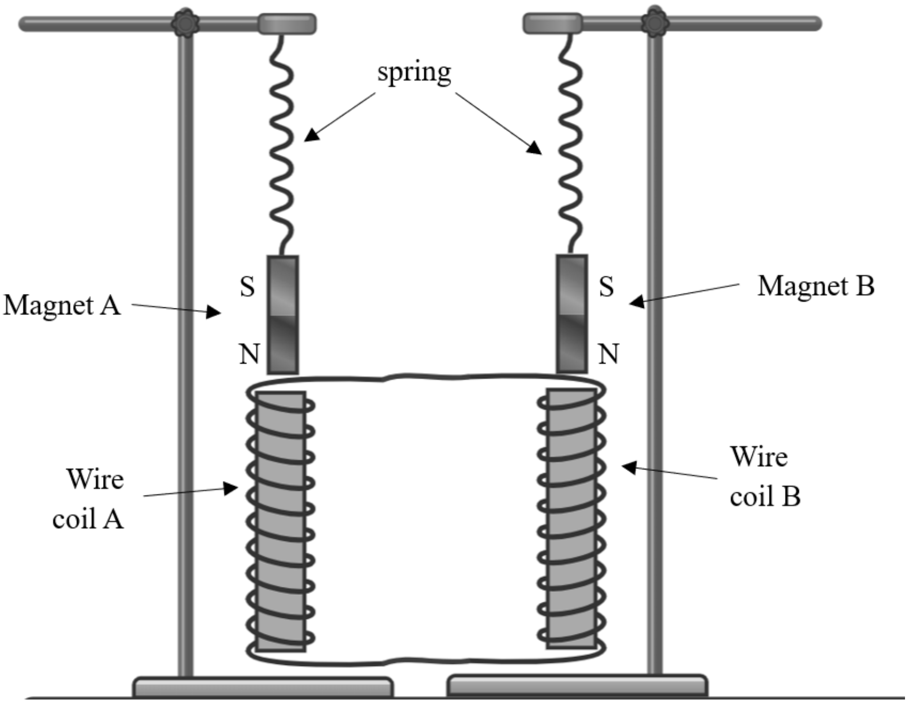
Question 35 (5 marks)

Two identical size and strength bar magnets are attached to two identical springs as shown below. The magnets fully enter the wire coils when the spring is extended. **5**



Magnet A is set to oscillate in and out of the coil with a constant frequency and amplitude.

Analyse the changes that would happen in both coils and to magnet B due to one complete oscillation of magnet A.

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Question 35 continued

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Question 36 (4 marks)

Explain the structure of a helium atom using the Standard Model of matter. **4**

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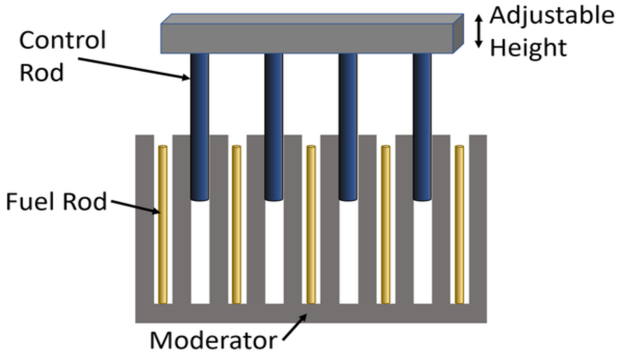
Question 37 (5 marks)

Uranium is a common fuel in the generation of nuclear power.

(a) A diagram representing key features of the core of a nuclear power reactor is shown below. **2**



Outline the method used to control the rate of production of energy in a nuclear reaction in a nuclear power reactor.

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(b) Nuclear fuel is claimed to be more efficient than coal as it releases substantially more energy than the equivalent mass of coal. **3**

Information about coal and the fission of uranium is given below.

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{142}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n $$

Isotope	**Mass (u)**
U-235	235.04
Ba-142	140.91
Kr-92	91.93
Neutron	1.008

- 1 kg of uranium contains 2.55×10^{24} atoms
- The energy from coal is 10 MJ/kg

How many times greater is the energy released from 1 kg of U-235 compared to 1 kg of coal?

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END OF BOOKLET 4

12 Physics 2024 Trial Examination Marking Guidelines

MCQ

1	2	3	4	5	6	7	8	9	10
B	B	A	D	C	B	D	B	D	C

11	12	13	14	15	16	17	18	19	20
D	B	B	A	C	C	D	B	D	C

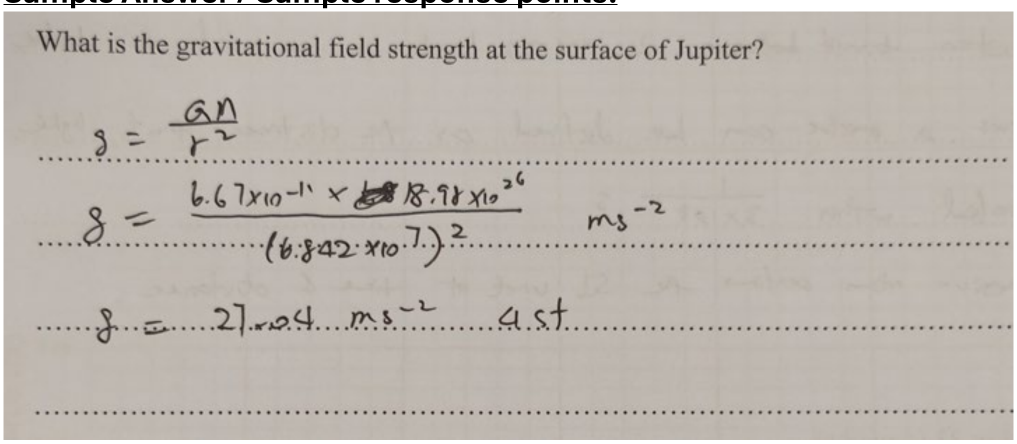
Short Answer

Question 21 (marker – AD)

(a) Band 2-4

Criteria	**Mark**
Correct substitution. Answer presented with correct units	2
Correct substitution OR correct units used	1

Sample Answer / Sample response points:



What is the gravitational field strength at the surface of Jupiter?

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

$g = \frac{6.67\times10^{-11} \times 18.98\times10^{26}}{(6.842\times10^{7})^2}$ ms^{-2}

$g = 27.04$ ms^{-2} 4sf

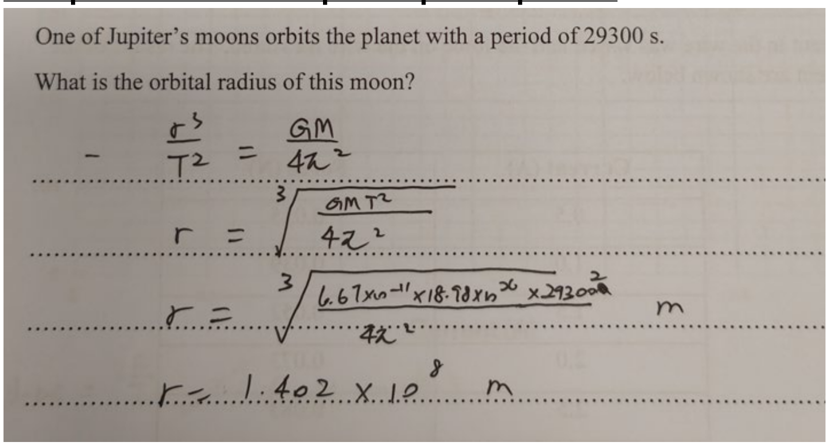
Markers comments:

- Most common issue was students getting incorrect units.
- it is little g so gravitational acceleration (m/s^2). If you are unsure place the units for the values in the equation and have them cancel out which gives N/kg which is also an acceptable answer

(b) Band 2-4

Criteria	Mark
Correct substitution. Answer presented with correct units	2
Correct substitution OR correct units used	1

<u>Sample Answer / Sample response points:</u>


One of Jupiter's moons orbits the planet with a period of 29300 s.

What is the orbital radius of this moon?

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

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{6.67\times10^{-11}\times18.98\times10^{26}\times29300^2}{4\pi^2}}\ m$$

$$r = 1.402\times10^{8}\ m$$

Markers comments:

- Most common issue was students inputting values into their calculator incorrectly. We recognise there are new calculators and this equation had many values to different powers. We accepted incorrect values if the working shown was correct.
- The most common cause for lost marks is a mistake in the working such as a missing square
- Another issue was occasionally missing or incorrect units
- Far too many students are calculating the altitude. The question does not ask for this and if you give it as your final answer it is technically incorrect. This was not penalised here but may be in the HSC.

Question 22 (marker – AD)

Band 2-5

Criteria	Mark
Both time and distance related correctly to the oscillations of the caesium atom	2
One correct point about time/distance/caesium oscillations	1

Sample Answer / Sample response points:

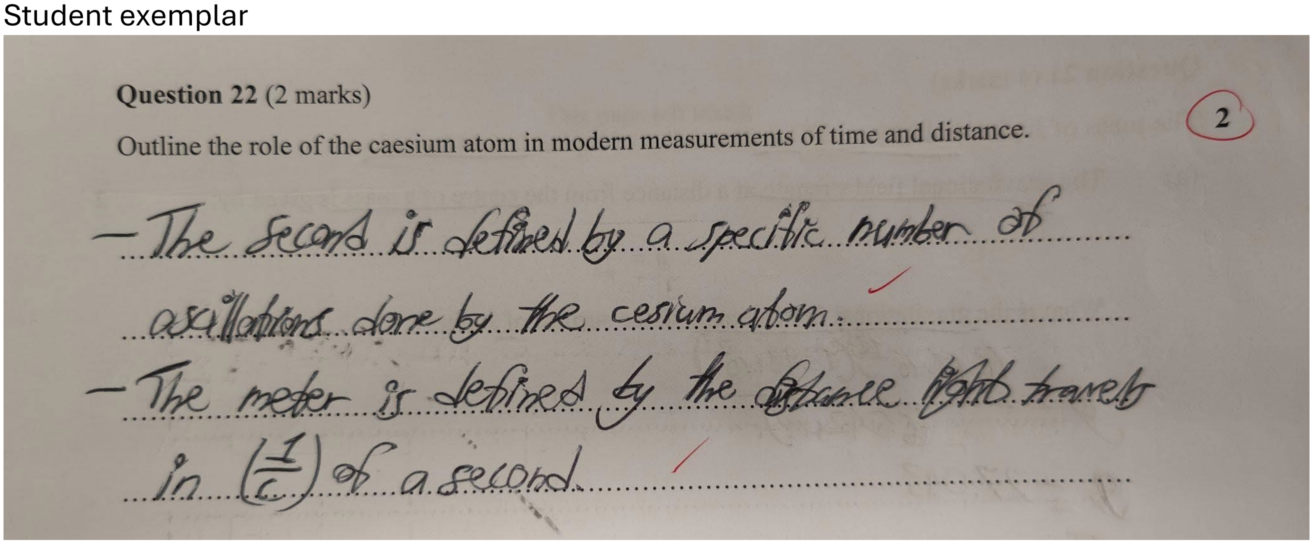
- Caesium atom oscillates with regular and specific frequency
- Set number of oscillations defines one second
- One metre is the distance light travels in 1/c seconds (related to atom oscillations)

Markers comments:
This question was not done well and is clearly a syllabus dot point few students paid appropriate attention to. The dot point is 'conduct investigations of historical and contemporary methods used to determine the speed of light and its **current relationship to the measurement of time and distance**'. As the speed of light is a speed, despite it being a constant, there is an issue if neither the second or the meter are based on constants. The ceasium 133 atom is used to define the second and using this and the speed of light, the meter can be defined.

Misconceptions:

- Many students thought the ceasium atom decayed and the half life defined the second. Many isotopes of ceasium are radioactive however cesium 133 which is used for the second is not. You did not need to know the specific isotope 133 however using radiative decay as your answer is incorrect.
- Many students tried to discuss atomic clocks and special relativity which did not appropriately address the question and were not awarded marks.

Student exemplar



Question 22 (2 marks)

Outline the role of the caesium atom in modern measurements of time and distance.

2

– The second is defined by a specific number of oscillations done by the cesium atom.

– The meter is defined by the distance light travels in $\left(\frac{1}{c}\right)$ of a second.

Question 23 (marker – Disney)

Band 2-5

Criteria	Mark
Graph points correctly plotted and appropriate line of best fit drawn. Slope of line used with full working to determine the magnetic field strength	4
Graph mostly correct with a suitable LOBF Slope of line used to determine magnetic field strength	3
Graph attempted with some errors OR Both parts attempted with multiple errors and/or working not shown	2
One correct step performed	1

Notes:

- Generally well done by the cohort.
- Graph points well plotted, some LOBF could have been better, but not penalised unless very wrong. To note, the LOBF probably should not have gone through the origin but cut around 0.01(ish) on the vertical axis.

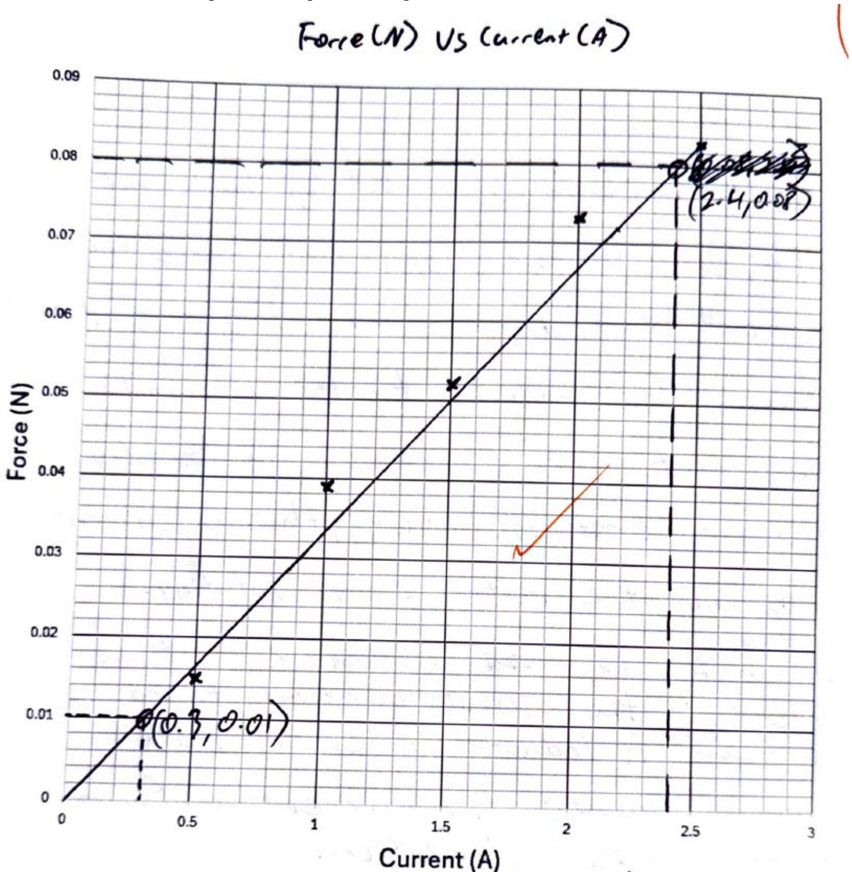
Issues: ALL easily fixed.

- Not stating clearly that the slope = F/I (this needs to be explicitly stated, not just substituted into an equation).
- Inability to read graph points – multiple students read the vertical axis as 0.6 rather than 0.06 giving incorrect values in calculations.
- Inability to rearrange the equation. Multiple students multiplied the slope by length, rather than dividing. This is basic maths you need to ensure is not occurring.

Things not penalised (this time) – but you should probably address.

- Majority of students did not have a unit on their magnetic field. It's part of the course, you should know the unit is Tesla (T) and include it.
- Not showing points on graph – at the very minimum circle them and show which ones you used. For people who had issues reading points, this gave several people an extra mark as I could follow how they gained the (incorrect) number.

Sample Answer / Sample response points:



$F = IlB$

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.08 - 0.01}{2.4 - 0.3} = \frac{1}{30}$

$\frac{F}{I} = \text{gradient} = m$

$\therefore B = \frac{1}{30} \times \frac{1}{0.075} = 0.444\ T$

$\frac{F}{I} \times \frac{1}{l} = B$

$= 0.4\ T$ (1 s.f)

Question 24 (marker – JS)

Band 2-6

Criteria	Mark
Extensive explanation of the role of back emf in maximum speed of a motor Reference to relevant physics laws as integrated part of answer Provides judgement on student claim	4
Correct judgement but has minor error/omission in the explanation of back emf, Faraday's Law, Lenz's Law, and clearly link to Torque. OR Extensive explanation of the role of back emf in maximum speed of a motor Reference to relevant physics laws as integrated part of answer but has slight error in judgement.	3
Sound explanation of back emf, Faraday's Law, and Lenz's Law, but missed the judgement and link to no net torque. OR Correct judgement but basic explanation of back emf, Faraday's Law, Lenz's Law, and link to Torque	2
Some relevant information	1

Sample Answer / Sample response points:

- As coil spins in the magnetic field it experiences a change in flux
- Emf is generated in the coil (Faraday)
- Lenz says the current generates a magnetic field that opposes the cause of the change in flux
- Creates an emf in the opposite direction where E(net) = E(supply) – E(back)
- Eventually with no load, E(supply) = E(back) so E(net) = 0
- With no emf, there is no net current (V=IR)
- If there is no current there is no net force (F=BIl)
- Therefore no torque on the coil
- Thus the student claim is correct

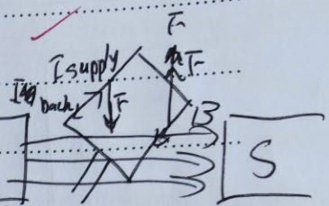
Markers Comments:

Many students still failing to mention that there is a coil spinning inside of a magnetic field and so will experience a change in flux.
Many students are discussing eddy currents in a coil in the opposite direction to the supply current. Current only travels in one direction. Discussing direction of induced emf is sufficient.

Sample Answer:

The student's claim is correct.

Observe that magnetic flux $\phi_B = BA\cos\theta$.



As the coil of the DC motor rotates, we have change in $\theta \Rightarrow$ change in ϕ_B. This $\Delta\phi_B$ will induce an emf $\varepsilon = -\frac{\Delta\phi_B}{\Delta t}$ according to Faraday's Law. According to Lenz's Law, this emf will be oriented so that it induces a current to decrease the initial change in flux $\Rightarrow \varepsilon$ induced opposes supply emf.

Great.

As ε opposes supply emf, the net voltage in the coil is given by $V_{net} = V_{supply} - \varepsilon$.

Now, observe that as our angular speed ω increases, we experience the same $\Delta\phi_B$, but we $\downarrow \Delta t$ (same angle traversed but $\omega = \frac{\Delta\theta}{\Delta t}$ so $\uparrow\omega \Rightarrow \downarrow\Delta t$). As $\varepsilon = -\frac{\Delta\phi_B}{\Delta t}$, $\downarrow\Delta t \Rightarrow \uparrow\varepsilon$ induced $\therefore \downarrow V_{net}$. Eventually, ω will continue to $\uparrow\omega$ until $\varepsilon = V_{supply} \Rightarrow V_{net}$ in coil $= 0$.

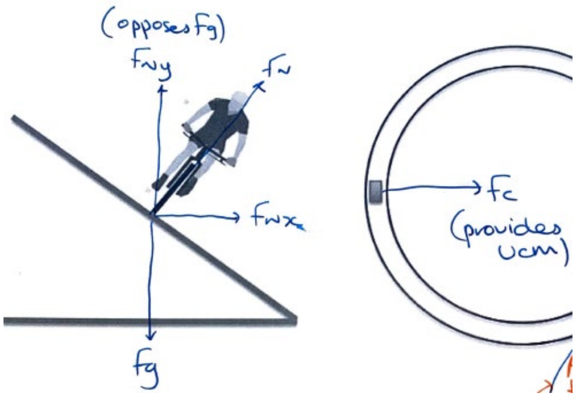
As $V = IR$; $V_{net} = 0 \Rightarrow I_{net} = 0$. Force on wire is given by $F = lIB\sin\theta \Rightarrow F = 0$ ($\because I = 0$). As $\tau = rF\sin\theta$ $\Rightarrow \tau = 0$ ($\because F = 0$). No net τ on motor $\Rightarrow$ No more $\uparrow\omega$ $\Rightarrow \varepsilon$ reaches maximum value so that $\tau = 0$, resulting in a maximum ω $\therefore$ Student's claim is correct.

Question 25 (marker – AD)

Band 2-6

Criteria	Mark
Appropriate vector annotations shown on diagram and linked to explanation of force components	3
Some correct annotations used and linked to forces	2
Correct statement made about centripetal force, but no annotations	1

Sample Answer / Sample response points:



- Vertical component normal force opposed by force gravity
- Leaves horizontal component normal force to contribute to the net force = F_C
- Flat = friction only < Banked = friction + banked horizontal normal component

There were two accepted ways to go about this question

1. The banked track provides a force on the cyclist equal to the x-component of the normal force whilst the flat track does not, therefore it provides a greater centripetal force
2. The banked track provides an additional force to friction which is the x-component of the normal force and this combined force is/can be larger than the centripetal force on the flat track.

Teacher comments

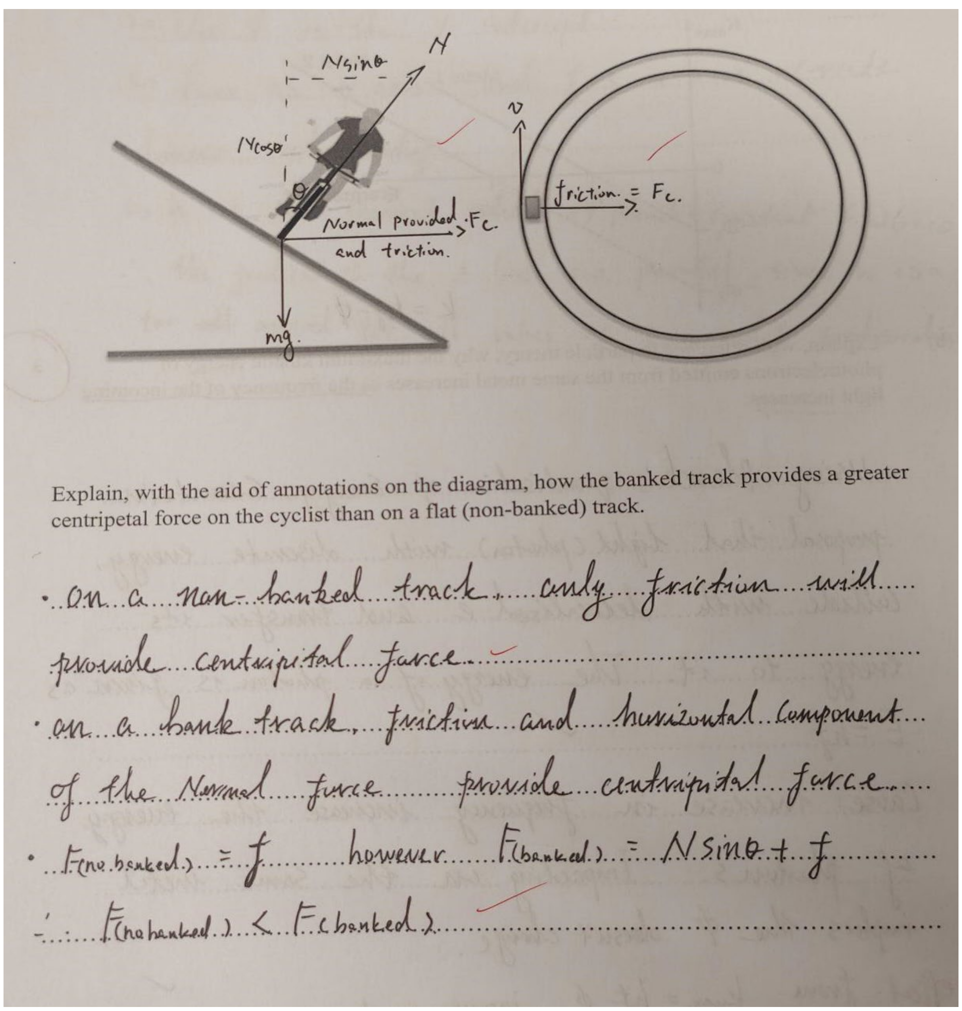
- What went well
    - Many students recognised the banked track provided a greater force due to the addition of Friction with Normal force
    - Many students did good annotations
    - Many students structured their answers well

- most common issues included the following:
    - Missing the comparison between banked and flat. The question was why was the banked track providing a **greater force** and therefore some measure of comparison is required.
    - Far too many students were doing inclined plane physics rather than banked track. The scenarios and therefore the physics are different despite some obvious similarities. In these cases often only 1 mark was awarded as talking

about inclined physics is plainly incorrect and in these answers the only correct information often came in the flat track portion.

- Too many students were deriving equations. You simply needed to say that the banked track provides an x-component of the normal force to the centripetal force whilst the flat track does not.
- Many arrows were the incorrect size and in many annotations the Fc was the same size as the Fnx despite mentioning friction is still present. These were not penalised unless they were significant.
- Some students drew arrows in the wrong directions such as normal force straight up or friction force up the ramp.
- There is a clear misunderstanding for some people regarding what the normal force is and its relationship with gravity. Gravity does not create the normal force. Gravity applies a force on bodies towards the centre of the mass. When any object encounters a surface such as when being pulled by gravity, the surface will push back according to Newtons third law. This is the normal force. On the ground the normal force pushing up from the ground typically matches the gravitational force pulling down (when the object is stationary) but there are many other ways to have a normal force.

Student exemplar



Explain, with the aid of annotations on the diagram, how the banked track provides a greater centripetal force on the cyclist than on a flat (non-banked) track.

- on a non-banked track only friction will provide centripetal force
- on a bank track friction and horizontal component of the Normal force provide centripetal force
- $F_{(no\ banked)} = f$ however $F_{(banked)} = N\sin\theta + f$

$\therefore F_{(no\ banked)} < F_{(banked)}$

Question 26 (marker – JS)

(a) Band 2-5

Criteria	Mark
Extensive explanation of the breakdown of energy in the photoelectric effect referencing photons, work function, Kmax and frequency.	3
Sound-thorough explanation of the energy in the photoelectric effect with components missing or not linked clearly	2
Some correct points made	1

<u>Sample Answer / Sample response points:</u>

- Energy of incident light is quantised where photon energy = hf
- Some of this energy used to release a single electron IF energy of that photon is greater than the work function (work function = energy required to remove least tightly bound electron)
- Excess energy released as KE of photoelectron (Kmax)
- If frequency increases, incoming photon energy increases, work function of metal stays the same, more excess so Kmax is higher

Markers Comments:

Many students did not discuss work function with much detail. To achieve full marks this was required. It is not possible to discuss the MAX KE without saying that the work function is the MINIMUM amount of energy required to move the least tightly bound electron.

Sample Answer:

Planck proposed that light is emitted in quantised packets of energy via $E=hf$, which Einstein concluded to be called photons.

Photo Electric Effect

- Incident light of energy $E=hf$ is shone onto a metal. One photon of light transfers all energy to one electron. Energy required to unbound least bound electron from metal = ϕ

Leftover energy once electron is free from metal is kinetic energy → K_{max}

∴ According to conservation of energy $E_{Total} = E_1 + E_2$

h is a constant $\quad hf = K_{max} + \phi$

In the same metal[23]

ϕ is constant $\quad$ ~~K_{max}~~ ∴ $f \propto K_{max}$ $\quad \uparrow f \rightarrow \uparrow K_{max}$

(

b) Band 2-5

Criteria	Mark
Links h to slope and clearly justifies parallel nature	2
Links h to slope – does not address parallel nature	1

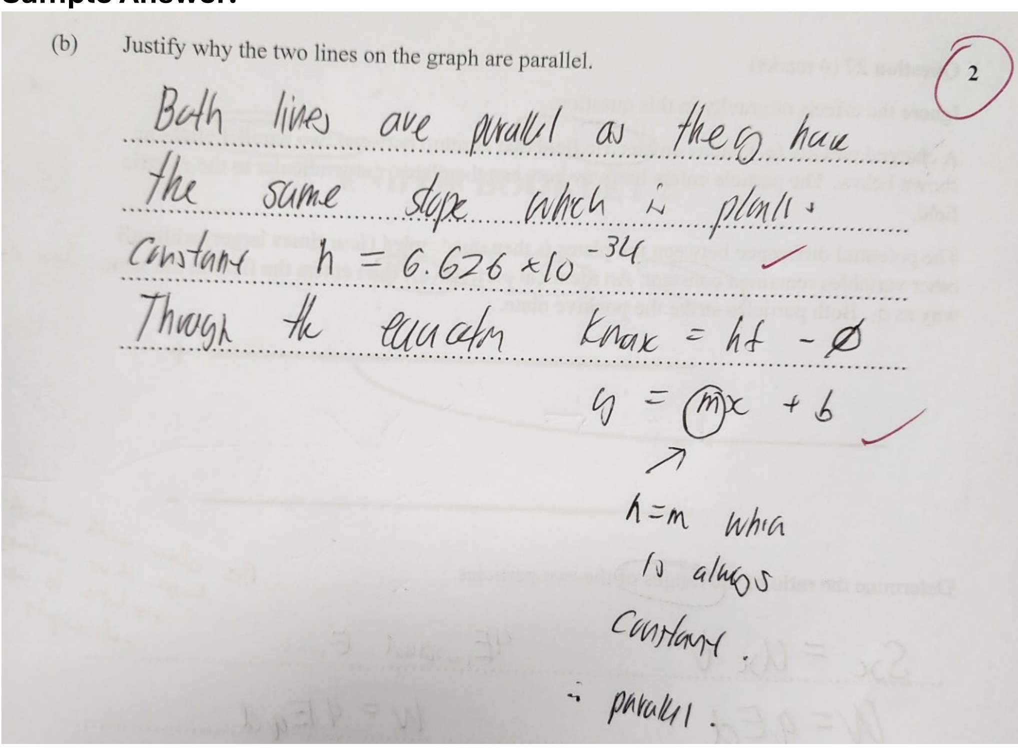
Sample Answer / Sample response points:

- Kmax = hf = φ is the equation for straight LOBF (y = mx + b)
- Thus m = h
- h = Planck's constant so all slopes will have the same value and be parallel

Markers Comments:

Most students did well in this question. Some students didn't use the equation which made it very difficult to justify the slope being equal to Planck's constant and therefore a constant and therefore parallel (although possible). Some students didn't link to the question and simply said the slopes were the same, but didn't make the final logic step saying therefore they were parallel Other students simply said the slope was 'h' and did not clearly link that 'h' is Plank's constant. This was required for 2/2.

Sample Answer:



(b) Justify why the two lines on the graph are parallel.

2

Both lines are parallel as they have the same slope which is planks constant $h = 6.626 \times 10^{-34}$

Through the equation $K_{max} = hf - \phi$

$y = mx + b$

$h = m$ which is always constant.

∴ parallel.

Question 27 (marker – AD)

Band 2-6

Criteria	Mark
Clear and logical determination of ratio, showing full working and derivations as appropriate	4
Mostly clear and logical determination of ratio, with some steps or derivations missing	3
Several correct steps shown in the determination of ratio	2
One correct step and/or derivation shown	1

Sample Answer / Sample response points:

- $E=V/d$, $F = eq$, and $F = ma$ so $a=Vq/md$
- Therefore V is proportional to a and if V is quadrupled then a must also quadruple for q_2
- Vertical displacement is $s_y=u_yt+1/2a_yt^2$
- $u_y = 0$ so $s_y=1/2a_yt^2$
- $t = \text{Sqrt } 2s_y/a_y$
- t is therefore proportional to 1/sqrt (a) so the ratio for times is 1 : 1/sqrt4 = 1:½ = 2:1
- As $s_x=u_xt$ due to no horizontal acceleration s_x is proportional to t
- Therefore Ratio of ranges (s_{x1}:s_{x2}) is also 2:1

Teacher comments:

- How students performed here was very much an I understand or I did not understand, splitting the most common marks into 2 and 4. Many students were able to do the beginning steps and identify that the acceleration is proportional to V so is quadrupled and this was worth 2 marks. Other similar attempts such as going through W = qV may have been also worth up to 2 marks depending on the depth.

- The largest issue was not knowing where to go from there. The next step is to determine the ratio of times through $s_y=u_yt+1/2a_yt^2$ to then find the ratio of ranges through $s_x=u_xt$
- Some students were able to start this process and make decent progress and could then achieve ¾ however full marks were reserved for showing the full process correctly
- Another common issue was using a different SUVAT eq ($v=u+at$ or $v^2 = u^2 +2as$). Students who used these often either made the mistake of thinking the final velocity was the same or got a ratio for final velocities and could go no further
- Communication! too often were students not using subscripts or writing steps that followed on to a random other part of the page with no clear flow or connection between steps.
- A potential issue noted is that some students are using d = half the distance between the plates. If this was a question requiring calculation of some value, this likely would have resulted in an incorrect answer. However as it was a ratio question, it does work because V could mean the voltage between the midpoint and one plate. In this case students were able to achieve full marks for this if they did everything else correctly however if this was unintentional due to a misunderstanding of d, you need to take care and if this was intentional you should highlight that so the marker doesn't assume you've made a mistake.

ges of the two particles.

$F = qE$

$ma = qE$

$ma = \frac{qV}{d}$

$a \propto V \Rightarrow a_2 = 4a_1$

$S_y = u_y t + \frac{1}{2} a_y t^2 \qquad u_y = 0$

$S_y = \frac{1}{2} a_y t^2 \qquad S_{y1} = S_{y2}$

$\frac{1}{2} a_{y1} t_1^2 = \frac{1}{2} a_{y2} t_2^2 \qquad S_x = U_x t \quad U_x$ constant.

$t_1^2 = 4 t_2^2 \qquad S_x \propto t$

$S_{x1} = 2 S_{x2}$

$t_1 = 2t_2 \qquad S_1 : S_2 \Rightarrow 2 : 1$

Determine the ratio of the ranges of the two particles. $V_B = 4V_A$

$F = qE \quad E = \frac{V}{d}$ so $F = \frac{qV}{d}$

$ma_y = \frac{qV}{d} \quad (F = ma).$

$a_y = \frac{qV}{dm} \qquad a_x = 0$

$S_x = u_x t + \frac{1}{2} a_x t^2 = u_x t \quad (a_x = 0).$

$S_y = u_y t + \frac{1}{2} a_y t^2 \qquad \frac{1}{2} d = \frac{1}{2} a_y t^2 \quad (u_y = 0)$

$d = a_y t^2. \quad t^2 = \frac{d}{a_y}. \quad t = \sqrt{\frac{d}{a_y}}$

$S_x = u_x \sqrt{\frac{d}{a_y}} = u_x \sqrt{\frac{dmd}{qV}}$

now particle is identical and launched at same velocity, so u_x & plate distance constant, d^2 constant, m constant and q constant $= u_x \sqrt{\frac{d^2 m}{qV}}$.

so ratio of $S_{xA} : S_{xB}$ is $\sqrt{\frac{1}{V_A}} : \sqrt{\frac{1}{V_B}}$

let $V_A = 1$ $\rightarrow = \sqrt{\frac{1}{V_A}} : \sqrt{\frac{1}{4V_A}} = \sqrt{\frac{1}{V_A}} : \frac{1}{2}\sqrt{\frac{1}{V_A}} = 1 : \frac{1}{2}$ or $\underline{2:1}$

$F = Eq \quad F = ma \quad \therefore Eq = ma \quad \therefore a = \frac{qE}{M}$

$a_{q_1} = \frac{q_1 E_1}{M_1} \quad a_{q_2} = \frac{q_2 E_2}{M_2} \quad \begin{matrix} q_1 = q_2 \\ M_1 = M_2 \end{matrix}$

$\therefore a \propto E$

$E = \frac{V}{d} \quad V_2 \times 4 = E_2 \times 4 . \quad \therefore E_2 = 4E_1$

$a_{q_2} = 4a_{q_1}$

$s_y = \frac{1}{2} a_y t^2 \quad u_y = 0 \quad s_{y1} = s_{y2}$

$t = \sqrt{\frac{2s_y}{a_y}} \quad \therefore t \propto \sqrt{\frac{1}{a}}$

$t_2 \propto \sqrt{\frac{1}{4a_{q_1}}} \quad t_1 \propto \sqrt{\frac{1}{a_{q_1}}}$

$t_2 = \sqrt{\frac{1}{4}}\, t_1$

$t_2 = \frac{1}{2} t_1$

$s_x = u_x t \quad s_x \propto t$

$s_{x1} \propto t_1 \quad s_{x2} \propto t_2$

$s_{x2} \propto \frac{1}{2} \times t_1$

$\boxed{s_{x2} \propto \frac{1}{2} s_{x1}}$

$\boxed{\begin{matrix} s_{x1} : s_{x2} \\ = 2 : 1 \end{matrix}}$

Question 28 (marker – AS)

Band 2-6

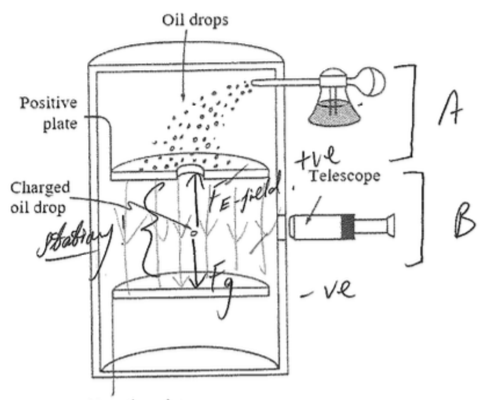
Criteria	Mark
Extensive linking of fields and forces to steps of experiment Extensive and fully correct explanation, using appropriate equations, of experimental result (multiple values) and final charge determination	5
Thorough linking of fields and forces to steps of experiment Description of result of experiment linked to electron charge	4
Sound description of both fields/forces in experiment	3
Sound description of aspects of experiment	2
Relevant information presented	1

<u>Sample Answer:</u>

Question 28 (5 marks)

The diagram below shows an apparatus that can be used to conduct Millikan's experiment that measured the charge of an electron. **5**

5



Explain, using relevant equations, the role of forces and fields in the determination of the charge of an electron.

As charged oil droplets fall from A:

↳ Under the influence of GRAVITATIONAL FIELD:

⇒ Accelerates ↓ into B, influenced by $F_g = mg$

THUS: e^- contained within oil droplet falls into

$\boxed{B}$ ⇒ where it experiences the ELECTRIC FIELD & GRAVITATIONAL FIELD @ same time

The +ve plate is on top, while -ve plate is on bottom: SUCH THAT: oil droplet exp. an Electric field force (ESA) to the top of the page, opposing the F_g.

More space provided for response over page

29

Question 28 continued

- The electric field force is increased until the oil droplet is stationary.

$\Rightarrow F_g = F_E \Rightarrow qE = mg$ ← mass of oil drop

$\cancel{\Rightarrow m = \frac{qE}{g}}$ $\quad q = \frac{mg}{E}$

F_E

F_g

$$q = \frac{mg}{\frac{V}{d}} = \frac{mgd}{V}$$

The electric field is then switched off, and the $\underbrace{\text{TERMINAL VELOCITY}}_{\text{constant } v \text{ as } F_g = F_{friction \text{ in air}}}$ is used to find the VOLUME of the oil droplet.

From the Volume, as density is known, m = MASS of droplet was found.

$\Rightarrow q = \frac{m g d}{V}$ (m ← found, d ← known, V ← known) could be determined.

It is observed that q was always a multiple of $\approx 1.6 \times 10^{-19}$ C $\Rightarrow$ This showed that this value was a discrete charge which makes up all q & the smallest difference $\Rightarrow$ charge of an electron (quantisation of e^- charge

Notes:

- be careful with language used - question says ‘***forces and fields’*** so it is wise to explicitly refer to both types of forces and both types of fields
- gravity is not the same as gravitational field
- **misconception**: F = mg and F = ma are not the same equation - F = mg refers to the gravitational or weight force acting on an object WHEREAS F = ma is NL 2 linking net force

and acceleration of an object - they are not interchangeable! and the oil drop is not accelerating....

- many students omitted the last part of the process regarding the multiple charge values determined by Millikan which were used to find a common factor that represented the charge of a single electron.
- this is an explain question - just using equations is not enough!
- knowing g, mass of OIL DROP (not electron), E (or V and d) enable determination of q - this is important detail!

Question 29 (marker – AS)

(a) Band 2-6

Criteria	Mark
Explicit comparison with extensive explanation of RELEVANT correct similarities and differences (total of 4 S or D) in synthesis of helium with **NO additional incorrect details**	4
Thorough explanation of more than one similarity and one difference in synthesis of helium OR extensive relevant detail about nucleosynthesis with NO explicit comparison OR comparison with extensive explanation of RELEVANT similarities and differences with a significant error	3
Sound description of at least one similarity and one difference in synthesis of helium OR Incorrect identification of types of synthesis – with some correct statements made	2
A valid and relevant piece of information presented	1

Sample Answer and sample response points:

Similarities:

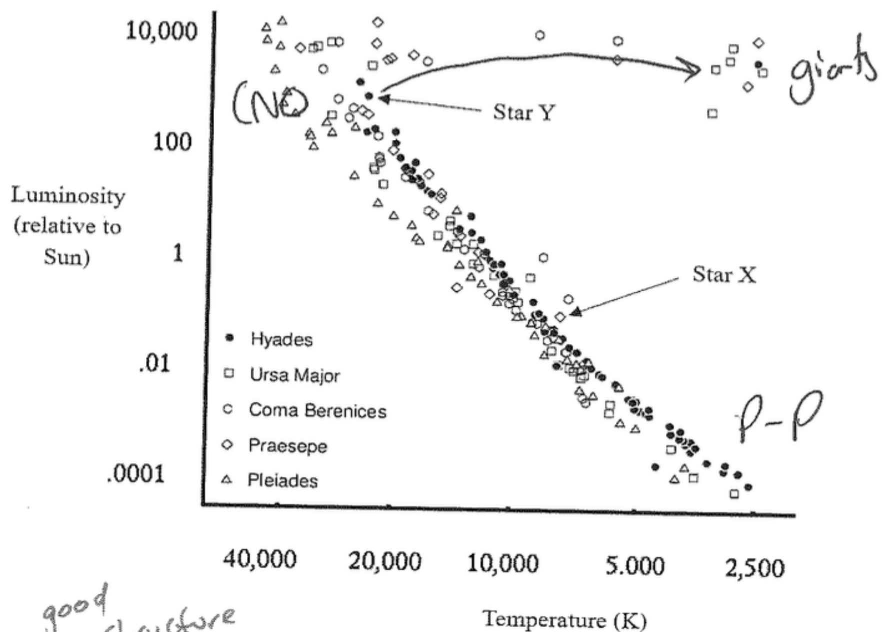
- both convert hydrogen to helium
- both produce same number of neutrinos (2), positrons (2) (could give net equations here)
- both do some CNO and some PP fusion reactions

Differences:

- Y = predominantly CNO, faster overall fusion rate, cyclic method, uses carbon catalyst, 3 gamma photons
- X = predominantly p-p, slower overall fusion rate, linear method, no catalyst, 2 gamma photons

Question 29 (7 marks)

The Hertzsprung-Russell diagram below shows the temperature and luminosity of some stars visible from Earth.



good structure

(a) Compare the main sequence nucleosynthesis of Star X and Star Y. **4** 4

Similarities	Differences
• Both Stars X and Y fuse hydrogen to helium in their core and yield a net reaction of: $4\,^{1}_{1}H \rightarrow \,^{4}_{2}He + 2e^{+} + 2\nu + \text{energy}$	• Star Y undergoes ~~fuse~~ nucleosynthesis through the Carbon-nitrogen-oxygen (CNO) cycle and Star X undergoes nucleosynthesis through the proton-proton (P-P) chain

XTRA BOOKLET

good response.

Q29.
Differences contd.

• The CNO ~~process~~ cycle in Star Y has ~~less~~ more steps than the P-P process in Star X

• The CNO ~~p~~ cycle ~~(star Y)~~ in Star Y uses carbon as a catalyst whereas ~~Star X~~ the P-P chain in Star X does not use a catalyst

• The CNO cycle ~~prod~~ in Star Y produces energy ~~through~~ in the form of 3 gamma ray photons (3γ) ~~but the~~ while the P-P chain in Star X produces energy through 2 gamma rays (2γ)

Notes:

- be careful to explicitly COMPARE using words/phrases, like ‘both’, ‘however’, ‘whereas’, ‘as opposed to’, ‘unlike’- many did not and it cost marks
- many had enough information for the 2 differences and 2 similarities required to get 4/4 but did not highlight them effectively and missed out on easy marks
- this answer and in fact NO ANSWER requires you to memorise and regurgitate the entire CNO cycle and PP chain - you have wasted your time and mine!
- lazy/sloppy/poorly chosen language is misleading and unclear - practice using the appropriate scientific terms
- structure for the verb makes this response easier for you and the marker
- the question is about NUCLEOSYNTHESIS - your sims and diffs must be about this!
- misconception abound here mainly around CNO releasing more energy than PP (it does not)
- misconception about CNO fusing heavier elements (it does not)
- misconception about hydrogen burning (it fuses)
- misconception about MS stars fusing up to iron (they only fuse to He)
- misconception that CNO and PP have same reaction (they don’t actually as they produce different number of gamma ray photons ((unless you just write energy))
- misconception that Star Y is older/at the end of its life than X
- misconception that fission occurs in stars - it doesn't

(b) Band 2-5

Criteria	Mark
Thorough outline of process of post main sequence fusion Incorporation of effect of forces and conditions in process	3
Sound outline of process of post main sequence fusion with relevant conditions identified	2
A valid and relevant piece of information presented	1

Sample Answer / Sample response points:

- Y becomes a giant/Supergiant
- once hydrogen fusion finished/insufficient H remaining then
- Fusion slows, outwards forces reduce, overall contraction of core due to force of gravity outweighing fusion forces
- resulting hotter, denser core allows synthesis of sequentially heavier elements (overcomes Coulombic repulsion) via a range of fusion reactions (one of which may be the triple alpha reaction)
- Process continues as each fuel used up until reaching Fe

Notes:

- lazy/sloppy/poorly chosen language is misleading and unclear - practice using the appropriate scientific terms
- question is about processes that enable formation of elements up to iron and this is strictly POST MAIN SEQUENCE - your response must be about processes in PMS stars! Many misinterpreted this question and wrote irrelevant detail.
- misconception CNO cycle ONLY fuses H to He and does it while star is on MS - it DOES NOT fuse heavier elements; it is not relevant in post-MS stars
- misconceptions abound here mainly around triple alpha process which is just one of a plethora of possible fusion reactions in stars AND ***can only fuse 3 helium nuclei into one carbon nucleus*** NOT fuse a range of elements into iron! and around fusion up to iron occurring in MS stars (MS stars ONLY fuse H to He!!)
- language no ‘burning’ only fusion.
- diagrams can be helpful here
- information after Fe created NR to ATQ

(b) Outline the processes that lead to the formation of elements ~~up to~~ iron during the lifetime of Star Y. **3**

• Star Y is initially a main sequence star and fuses hydrogen to helium

~~in a star there~~

~~As star Y begins to run out of~~

→ in the star there is an equilibrium b/w the inward force of gravity and outward force of fusion that keeps it stable

• As it begins to run out of hydrogen, the rate of fusion ~~the gravitat~~ gravitational force > fusion outward force and the star will contract

↳ however, after this initial contraction, the star will expand and cool to form a red giant (~~but its core is~~ ~~has~~ ~~a~~ (see diagram)

↳ The core of a red giant is hotter and denser and can now ~~fa~~ facilitate the fusion of heavier elements all the way up to iron (as after iron fusion reactions are no longer energy releasing)

good response

3

Question 30 (marker – AS)

Band 2-6

Criteria	Mark
Determination of speed of arrow presented with full logic and working	4
Determination of speed of arrow presented with minor errors or missing steps in working	3
Assumption of target at top of flight (max = 2) OR Attempt to determine speed with multiple separate errors	2
A correct step presented	1

Sample Answer / Sample response points:

← 170 m →

If the arrow was shot at an angle of 30 degrees above the horizontal, what speed would the arrow need to be launched to hit the target?

$S_x = 170\,m$

$S_y = 20\,m$

$\theta = 30^\circ$

$a_y = -9.8\,ms^{-2}$

$u_y = u\sin 30 = \frac{u}{2}$

$u_x = u\cos 30 = \frac{u\sqrt{3}}{2}$

$S_y = u_y t + \frac{1}{2} a_y t^2$

$20 = \frac{u}{2}t + -4.9t^2$

$-4.9t^2 + \frac{u}{2}t - 20 = 0$

$t = \frac{-\frac{u}{2} \pm \sqrt{\frac{u^2}{4} + 392}}{-9.8}$

$S_x = u_x t$

$170 = \frac{u\sqrt{3}}{2} \times t$

$170 = \frac{u\sqrt{3}}{2} \times \left(\frac{-\frac{u}{2} + \sqrt{\frac{u^2}{4} + 392}}{-9.8}\right)$

$340 = u\sqrt{3}\left(\frac{-\frac{u}{2} + \sqrt{\frac{u^2}{4} + 392}}{-9.8}\right)$

~~$-3332 = u\sqrt{3}\sqrt{}$~~

$-3332 = u\sqrt{3}\left(-\frac{u}{2} + \sqrt{\frac{u^2}{4} + 392}\right)$

$\cancel{\theta} = 170 = \frac{u\sqrt{3}t}{2}$

$u\sqrt{3}t = 340$

$t = \frac{340}{u\sqrt{3}}$ ✓

XTRA BOOKS

33

$\boxed{Q30.}$

$S_y = U_y t + \frac{1}{2} a_y t^2$

$20 = \frac{u}{2} \times \frac{340}{u\sqrt{3}} - 4.9 \left(\frac{340}{u\sqrt{3}}\right)^2$

$20 = \frac{170}{\sqrt{3}} - 4.9 \left(\frac{115600}{3u^2}\right)$

$15.9488 = \frac{115600}{3u^2}$

$3u^2 = 7248.15$

$\underline{u = 49 \ ms^{-1}}$ (2 s.f)

Notes:

- misconception setting the final vertical velocity = 0 was a popular but flawed concept. We have done a question like this in a weekly! A maximum of 2 gained if this method was used with correct subsequent marking.
- use of subscripts helps you and the marker.
- allocating - or + direction is vital
- coherent working helps you and the marker.
- some assumed initial vertical velocity = 0 which would mean initial velocity = 0 .....? How was the arrow fired then????
- you must make symbols u and v look different in working

Question 31 (marker – AS)

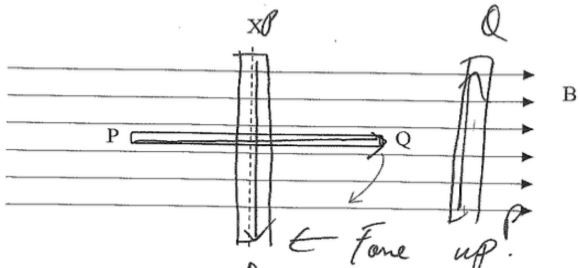
Band 2-5

Criteria	Mark
Graph drawn accurately sinusoidal nature (direction not required - either option accepted as below) Justification based on force on wire equation and related to angles presented	3
Graph drawn mostly accurately with some justification using force on wire equation	2
A correct and relevant piece of information presented	1

Sample Answer / Sample response points:

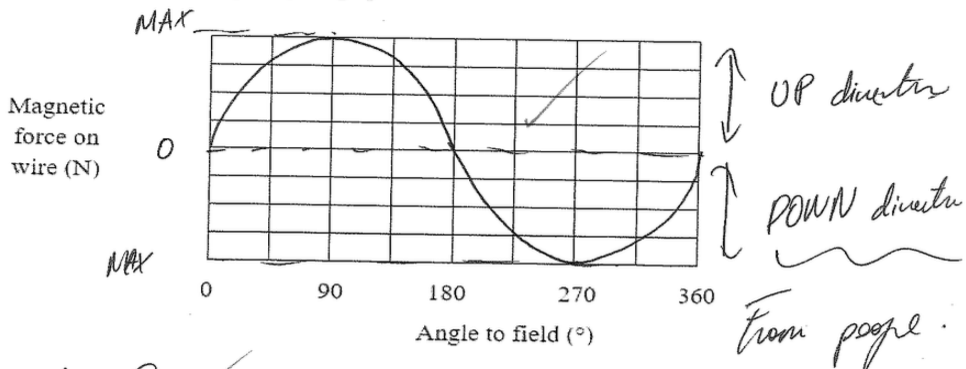
Question 31 (3 marks)

A current carrying wire is placed in a uniform magnetic field as shown in the diagram below. The wire is initially parallel to the direction of the magnetic field and has a current of consistent magnitude running from P to Q. 3



The student then rotates the wire through 360 degrees. After 90 degrees of rotation the wire is parallel to the line X in the diagram above.

Sketch a graph of the magnetic force acting on the wire against the angle the conductor makes with the field, and justify the shape of your graph.



$F = BIl\sin\theta$ As B, I, l all constant,

$F \propto \sin\theta$, θ is the $\angle$ of rotation.

$\Rightarrow$ Sine graph. Also, noting the direction of F Δs after 180°,

we can set the +ve to be up,

−ve to be down.

3

- $F = BIl \sin\theta$
- Φ proportional το sinθ
- When θ = 0/180 – then force = 0 (sin 0 = 0)
- When θ = 90/270 – then force = maximum magnitude (sin 90 = 1)

Notes:

- overwhelmingly well completed
- BOTH a full sinusoidal curve or the ‘absolute value’ version accepted
- sinusoidal nature essential - most attempts were really poor with varying amplitude/straight lines/bizarre shapes!
- must start at zero to be consistent with information provided by stimulus
- link to equation must be clear

Question 32 (marker – RR)

Band 2-6

Criteria	Mark
Extensive quantitative analysis of both situations using relevant kinetic energy, potential energy and total energy equations Extensive qualitative explanation of the changes in kinetic and potential energy in both situations Clearly stated similarities and differences Answer is concise with no irrelevant information and presented logically and clearly	7
Thorough quantitative analysis of both situations using relevant kinetic energy, potential energy and total energy equations Thorough qualitative explanation of the changes in kinetic and potential energy in both situations Clearly stated similarities and differences	6
Thorough qualitative and quantitative explanation of both situations with some key information missing or not clearly explained Similarities and differences implied or not presented	5
Sound qualitative and quantitative description of both situations with key information missing, poor use of equations, explanations not clear Similarities and differences implied or not presented	4
Sound qualitative OR quantitative description of energy changes in both situations	3
Limited qualitative OR quantitative description of energy changes	2
One piece of relevant information	1

Notes:

Overall Comments:

- Generally, this question was not approached well. Students who annotated the stimulus and had a clear structure produced better responses as they were able to break down the problem into achievable subsections.
- To do well on this question there were numerous key ideas that needed to be discussed.
- Although most students had some correct statements answering part of the question, Students would have received lower marks for missing key sections required for a thorough response, included contradictory or incorrect information and not address the verb (no clear similarities or differences).
- You cannot use an equation that is not on the data sheet without deriving – in this case, the kinetic energy of a satellite and velocity of an orbiting satellite.

The key parts of the question include:

Potential Energy

- Qualitatively describing the initial and final potential energy of both satellites and charged particles.

- Quantitatively showing the proportionality of the potential energy of a satellite using the equation from the formula sheet $U = -\frac{GMm}{r}$.
- Quantitatively calculating the initial and final potential energy of the charged particle using $U = qV$.

Kinetic Energy

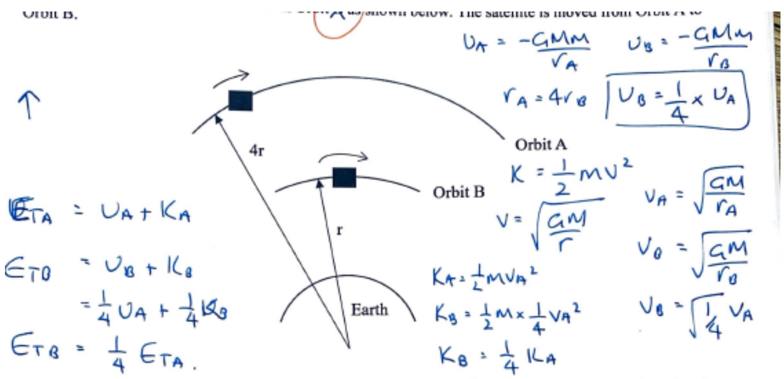
- Qualitatively describing the initial and final Kinetic energy of both satellites and charged particles.
- Quantitatively showing the proportionality of the Kinetic energy of a satellite by deriving the equation for Kinetic energy of a satellite using Centripetal Force $F_c = \frac{mv^2}{r}$ and Gravitational Force equations $F = \frac{GMm}{r^2}$.
- Quantitatively calculating the initial and final Kinetic energy of the charged particle using $W = \Delta K$.

Total Energy

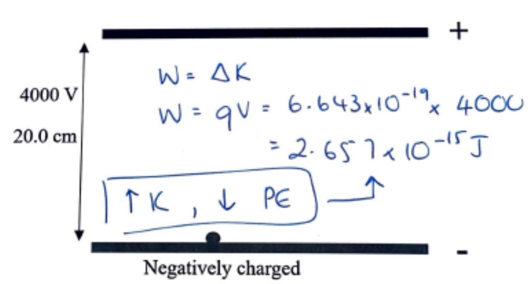
- Qualitatively describing the initial and final total energy of both satellites and charged particles.
- Quantitatively showing the proportionality of the total energy of a satellite by deriving the equation for total energy $TE = -\frac{GMm}{2r}$.
- Quantitatively calculating the initial and final total energy of the charged particle showing conservation of momentum $\Delta TE = \Delta K + \Delta U = 0$.

Compare

- Clear and correct similarities
- Clear and correct differences.



A charged particle of mass 2.753×10^{-28} kg and charge -6.643×10^{-19} C is placed at the negative plate in a uniform electric field as shown below. It is released and moves to the positive plate.



Specific Comments

- Address the question – Focus on Energy Changes (Kinetic/Potential/Total). Derivations and discussions of Forces, Fields, Acceleration, Velocity were all irrelevant unless linked explicitly to energy changes. For example, calculating a velocity provides no value unless you then link it to kinetic energy and more importantly a change in kinetic energy.
- Address the question – This question is a **Compare** question. You must be clear and explicit about what is a similarity and what is a difference. Writing an analysis on each situation side by side is not a clear comparison. Use headings Similarities and Differences and write simple and clear statements. For example:
    - Similarities:
        - Both situations have a reduction in potential energy.
        - Both situations have an increase in kinetic energy.
    - Difference:
        - Total energy is conserved for the charged particle, but the total energy reduces as the satellite is moved from 4r->r.
- Statements such as both have a change in kinetic and potential is a very weak statement. To improve state if they increase or decrease and even better if you provide a quantitative value or proportionality.
- Misconception Conservation of energy does not apply to orbit transfer, the total energy of the system decreases as the orbit gets closer to Earth. Work is done by the satellite to reduce the energy.
- Misconception Mathematically for conservation of energy many students wrote $\Delta K = \Delta U$. This is inaccurate and will give you the wrong sign for final and initial values. The Total energy does not change which is given by $\Delta TE = \Delta K + \Delta U$, hence when energy is conserved $\Delta K + \Delta U = 0$ or $\Delta K = -\Delta U$.
- Misconception Some students discussed the initial or final value of potential energy being important. The actual value of the energy is never important. Only the change in energy is.
- Misconception When the GPE becomes more negative many students claimed that the potential energy increased. This is a mistake, if a number is becoming a larger negative number it is decreasing (Moving to the left on the number line). -4 is less than -1 not bigger.

Student exemplar:

Question 32 continued

Qualitatively and quantitatively compare the energy changes that occur when the satellite and charged particle move as described on page 35.

Satellite: Work is done on the satellite in bringing it from orbit A to orbit B. (work done externally), and in this way the satellite will increase in kinetic energy as work is done to it externally ($W = \Delta K$).

~~The amount of work done in bringing the satellite to B is $W = Fs$ where~~

• In orbit B, the satellite will have less gravitational potential energy than in A as GPE increases to 0 at infinite distance.

Quantitatively,

$$U_i = -\frac{GMm}{4r} \quad \text{and} \quad U_f = -\frac{GMm}{r}$$

So U has ~~decreased~~ increased in magnitude by a factor of 4.

($\frac{U_f}{U_i} = 4$, but U is -ve so this is a decrease).

· NB Law of Conservation of Energy does not apply as external work was done.

In orbit A, the both orbits, $F_c = F_g$

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

$v^2 = \frac{GM}{r}$ $\frac{1}{2}mv^2 = K_e = \frac{1}{2}\frac{GMm}{r}$

$= \frac{GMm}{2r}$. In orbit A, $Ke_A = \frac{GMm}{8r}$ and in B, $Ke_B = \frac{GMm}{2r}$.

So Ke_A is $\frac{1}{4}$ times ~~the~~ Ke_B and

So the kinetic energy has increased by a factor 4 in orbit B vs orbit A.

Charged Particle:

· Has no work done to it externally.

· Will gain ~~the~~ Ke as it moves to +ve plate

- loses electric potential energy as it is converted to Ke

END OF BOOKLET 3

See extra booklet

32. Law of Conservation of Energy applies
as work is done (?)
Work done (ΔK) $= qV$.
$q = -6.643 \times 10^{-19} C$
$V = -4000 V$.
So $\Delta K = (-6.643 \times 10^{-19} C)(-4000 V)$
$= 2.6572 \times 10^{-15} J$.
And as $\Delta U = -\Delta K$ (or Δ electric potential energy)
$2.6572 \times 10^{-15} J$ of electric potential
energy is transformed / lost into the
kinetic energy.

See full explanation on next page:

Similarities	Differences
· Both the satellite and particle gain kinetic energy and lose potential energy - Quantitatively, satellite's GPE multiplies by 4 in magnitude and this is a loss of GPE as GPE is -ve. - Satellite's K_e increases by a factor of 4 when moved from ~~B to A~~ A to B. - Particle gains 2.6572×10^{-15} J of Ke and loses 2.6572×10^{-15} J electrical potential energy by law of Conservation of Energy.	· In the satellite, GPE is lost, ~~and~~ but in the particles electric potential energy is lost. · Work is done externally to move the satellite from A to B, but all work done on the particle is from the electric field - Hence $\Delta U = -\Delta K$ applies for particle but not satellite

Question 33 (marker – Disney)

(a) Band 2-6

Criteria	Mark
Correct use of Wien's law and diffraction equation to determine maximum wavelength of light and angle of maxima Full working shown	3
Attempt to determine wavelength using Wien's law and some attempt to use diffraction equation to determine wavelength	2
Attempt to use diffration equation without determination of wavelength	1

Sample Answer / Sample response points:

degrees. ... most intense part of the first order maxima occurs at an angle of 14

3

$d = \frac{1}{1000n}$

$= \frac{1}{1000 \cdot 500}$

$= 2.0 \times 10^{-6}\ m$

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

$= \frac{2.898 \times 10^{-3}\ mk}{6000\ k}$

$= 4.83 \times 10^{-7}\ m$

$d \sin\theta = m\lambda$

$\therefore \sin\theta = \frac{\lambda}{d}$ $(m=1)$

$\theta = \sin^{-1}\left(\frac{4.83\times10^{-7}}{2.0\times10^{-6}}\right)$

$= 13.975...$

$\doteq \cancel{14.0}\ 14°$ AED (2sf)

Notes:

Generally a pretty good attempt by most of the cohort. The majority of students knew what to do in this question, but very few could execute the basic skills correctly to get full marks.

- Most students recognised the need to use Wien's Law to find the maximum intensity wavelength – BUT
- A significant number of students used the correct substitution for the Wien's Law equation but then gave the answer to the calculation as 483. No matter how many different teachers and calculators we use, not one of us can divide the two numbers required and get 483. We all get 4.83×10^{-7}. There was absolutely no need to do a conversion there – especially as the value in the next equation had to be in metres. If you do a conversion (ONLY when required) then you need to show the correct answer to the equation FIRST).
- A signficant number of students did not substitute the value for b in the Wien's Law equation. Substitute all values, in all equations.
- A significant number of students could not calculate a value for d (1/500 x 1000) and used values like 500, 0.500 etc when 2×10^{-6} was the correct value.

- This led to a very large number of students substituting incorrect values into the d sin theta equation and then magically getting 14° as their answer – which was impossible with their calculation. **IF YOU CANNOT GET THE REQUIRED VALUE, GO BACK AND FIND YOUR MISTAKE**. Yes, we checked. Just because you wrote 14° doesn't mean you get the marks.

(b) Band 2-5

Criteria	**Mark**
Relates properties of incandescent light to diffraction equation to show range of angles	2
Makes valid and correct statement regarding incandescent light or diffraction equation	1

<u>Sample Answer / Sample response points:</u>

- Incandescent light has a range of wavelengths
- By wave equation sin theta related to wavelength – so a range of angles will occur in the second order maxima
- Second order maxima is a SINGLE maxima with a continuous spectrum from the continuous range of wavelengths in incandescent light.

<u>Notes:</u>

- Very poorly done, vast majority of the cohort scored zero for this question.
- Given we did this experiment with diffraction gratings – it was problematic that so many people didn't recognise that there would be clearer points. Many students described blurry, hard to find spots.
- Read the question – given part (a) required to you find the peak wavelength of a continuous spectrum, how is it that less than a handful of students could bring that continuous spectrum idea into part (b)??

Question 34 (marker – Disney)

Band 2-6

Criteria	Mark
Extensive analysis of THREE scientists work including: - Proposed atomic model - Experiment descriptions – setup and results - Linking experimental results to model features - Clear indications of how atomic model progressed	9
Extensive-thorough analysis of THREE scientists work with features above, but minor errors in experimental details or linking of results to atomic model features	8
Thorough analysis of THREE scientists work: • with multiple errors in detail or linking to model not explicit • but holistic understanding of experiments and atomic models	7
Extensive analysis of TWO scientists (third missing) OR Thorough analysis/explanation of THREE scientists with conceptual misunderstanding or failure to clearly link experimental results to atomic model features	6
Sound-Thorough of THREE scientists with experiment and/or atomic model descriptions and some attempt to link, but key details missing and/or conceptual understanding issues OR Thorough of TWO (third missing) multiple errors in detail but holistic understanding of experiments and atomic models with some attempt to link model to experiment	5
Sound description/explanation of TWO scientists work with some description of relevant features of atomic model	4
Sound description of ONE scientist work linked to atomic model OR Sound description of at least TWO experiments not linked to atomic model advancement	3
Several correct points made	2
Any relevant information	1

Notes – General:

- Generally quite well done by a substantial group of the cohort. 6 students scored 9/9, 11 students scored 8/9 and 10 students scored 7/9. This shows a good level of knowledge, good construction of an answer and above average analysis skills.
- Generall the setout of the responses was very well done, lots of headings, diagrams etc. BUT
    - A lot of diagrams were very small and hard to see, unlabelled, and not referred to in the response. This effectively rendered them useless. Ensure all diagrams are labelled, and you either add a description or have VERY detailed annotation. A diagram of a piece of gold foil and an alpha particle DOES NOT describe the gold foil experiment.
- Focus of question is experimental evidence and advancing the model. This requires the response to be focused around TWO things:
    - ONE - Detailed descriptions of experiment setups, results and purpose.
    - TWO - How the experimental results led to a specific advance in a feature of the atomic model.
    - NOT: limitations, or theories unrelated to any experiments
    - The vast majority of responses were more focused on:
        - Details unrelated to experiments
        - Not including an experiment in any way
        - Pages and pages of limitations that had nothing to do with any further experiments (eg: angular momentum)
    - The vast majority of responses would easily have gained an extra 1-3 marks simply with a little more focus on the experiment detail.

Notes – Rutherford:

- Required a description of the Geiger-Marsden experiment.
    - Purpose: to confirm the Plum Pudding model (misconception – GM was not to "prove the existence of the nucleus").
    - Setup: needed a lot more description than the unlabelled diagram
    - Results: needed to discuss electrostatic repulsion of alpha particles from the positively charged nucleus. (Misconceptions – particles did not bounce, reflect, collide – they were deflected by an electrostatic force).

Linking Rutherford evidence to model: (this part almost universally missing, or not done explicitly)

Evidence from experiment	How it shows specific features of the model
Majority of alpha particles passed straight through with no deflection	Shows nothing deflecting the particles, thus concluded that most of the atom was empty space

Some particles deflected by small angles	Deflection from passing by a positively charged object that repelled the alpha particles.
Some particles (1/8000) deflected at an angle greater than 90 degrees	These are the particles that came closest to the positive structure and were repelled, causing a change in direction. 1/8000 suggests the structure was very small and dense.

Note that this linking shows ADVANCING the model as the model then changed because of this experiment. This idea was not present in the majority of student responses.

Notes – Bohr:

- Needed an acknowledgement of the limitations of the Rutherford model regarding the non-emission of electromagnetic radiation. Also required a reason why there SHOULD be emission of radiation and WHY it should spiral into the nucleus.
- Bohr's postulates should be stated. Huge misconceptions here – technically there are four postulates. In class (and in the slide notes, and implied by the syllabus) we discussed THREE. **Firstly** that electrons exist in quantised energy levels and UCM occurs due to electrostatic attraction. **Secondly** that electrons exist in stationary states where they are not accelerating (no explanation for this). **Thirdly** that electrons can move up and down the quantised energy levels by absorbing and emitting photons of light/energy. The **fourth** is not really used in the HSC syllabus and was not discussed in class. This is around angular momentum. This is also not relevant to this question as it was not related to experiments Bohr (or de Broglie) did.
- The experimental evidence for Bohr is two part:
    - The observations of non-emission of electromagnetic radiation. This counts as experimental evidence.
    - The emission spectra of hydrogen. This also counts as experimental evidence.

Linking Bohr evidence to model:

Evidence from experiment	**How it shows specific features of the model**
Non emission of electromagnetic radiation from atoms (as predicted by Rutherford's model).	Postulate 2 of 'stationary states' – a state where the electrons are orbiting but not accelerating. If electrons are not accelerating (charged particles) then they do not emit electromagnetic radiation – thus addressing limitation of Rutherford
Hydrogen spectra with distinct lines at specific wavelengths that were unique to hydrogen but consistent for all hydrogen atoms.	Postulate 3 of electrons moving between energy levels (which are fixed for a particular type of atom). Thus when electrons transition down in hydrogen they release energy equal to

	the gap between energy levels. This corresponds to a series of wavelengths of light emitted that are constant for the hydrogen atom, confirming a fixed set of energy levels for electrons in atoms.

- At this point, a lot of students went to on to explain how Bohr couldn't explain hyperfine lines, angular momentum, Zeeman effect – absolutely NONE of which were in any way relevant to this response. NONE of these were "fixed" by de Broglie – thus not relevant to the question. Many students spent over a page on these limitations that added nothing to the response.

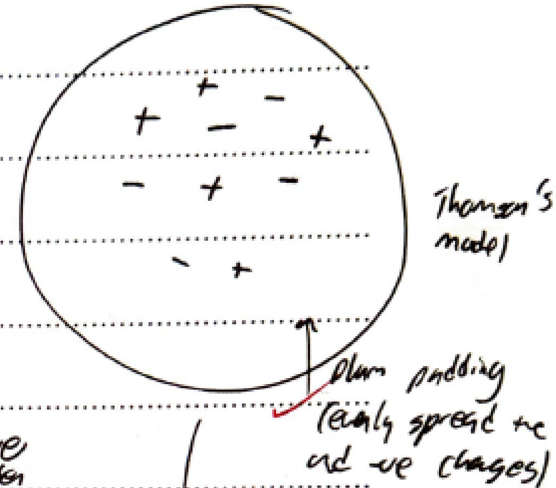
Notes - de Broglie:

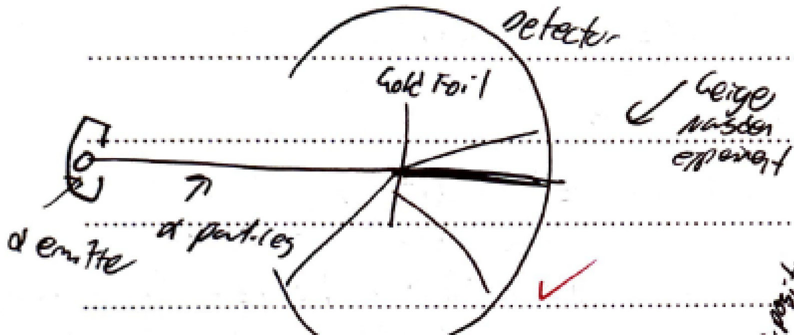
- A lot of misconceptions here. Very few students could describe the Davisson Germer experiment OR the de Broglie atomic model. Those who could, mostly did not understand the order in which this part of the model was progressed.
  - FIRST – de Broglie proposed that if waves (light) could be particles, then particles (matter) should show wave properties. He proposed an equation that linked waves and matter (wavelength = h/mv). He then worked out what the theoretical wavelength of an electron would be if this equation was correct.
  - SECOND – there was an experiment (Davisson Germer) which DIFFRACTED electrons (not reflected or bounced) off a nickel crystal with the space between atoms approximately equal to the proposed wavelength of the electron. Thus the nickel crystal acted as a diffraction grating. An intensity pattern was detected (not seen, electrons are not light) that showed an interference pattern. It was also noted that the measured wavelength (using d sin theta) matched the proposed wavelength. Note that the conclusion from this experiment was that electrons can behave as waves AND that de Broglie's proposed equation was correct and no longer theoretical. NOT anything to do with standing waves, atomic model, or electrons not emitting EMR.
  - LAST – there was a further proposal that since electrons can be waves, that the electrons in atoms are actually standing waves, which can only occur with whole integer wavelengths. Thus the electron standing waves can only have 1 OR 2 OR 3 OR…. wavelengths.
    - This explains the quantisation of energy levels proposed by Bohr.
    - This also explained what a 'stationary state' was. A wave does not emit EMR.

Sample Answer / Sample response points:

Rutherford

-Conducted Geiger Marsden experiment to prove Thomson's plum pudding model



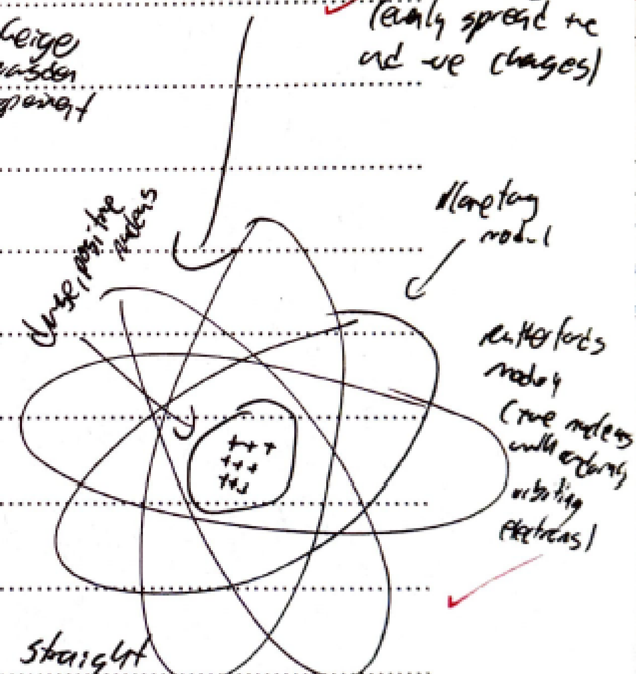


→ needs a description or more detailed labels

- If Thomsons model was correct, α particles would pass straight through Gold foil, and α particles would only be detected straight infront of α emitter (evenly spread particles don't have enough mass / charge to collide with / electrostatic repulsion α particles to cause them to deviate).

why?

good!



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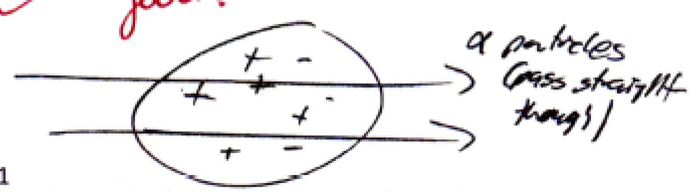
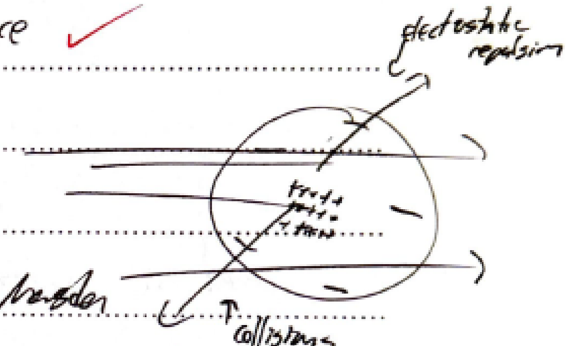


- However, as shown, the α particles were deflected, some at small angles, some at large angles (approximately 1/8000)
- Therefore, Rutherford proposed 'planetary model,' where there is a dense accumulation of positive charges that has enough mass ~~so~~ to ~~collide~~ deflect by electrostatic repulsion with α particles (causing large deviations) and enough charge to exert significant electrostatic repulsive force on α particles (causing small deviations)
  - note: as only 1/8000 α particles deviate, proposed that atom is largely empty space



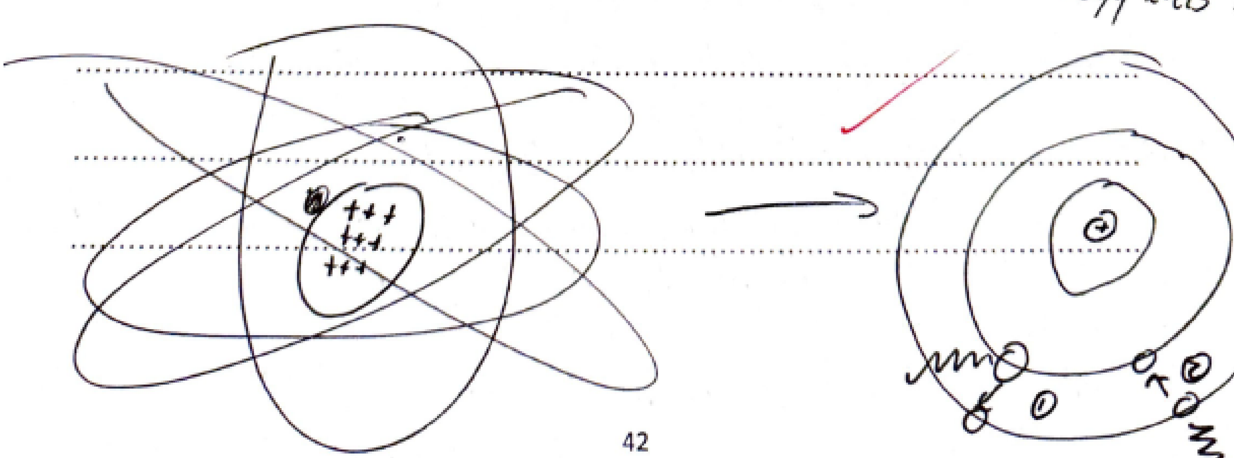
- Therefore, Thomson's model didn't agree with the ~~results~~ experimental evidence of the Geiger Marsden experiment, so atomic model advanced to Rutherford's planetary model

good.

Bohr

Rutherford 'Planetary' model

Bohr 'discrete energy levels model'



(3a)

-Rutherford didn't propose ~~with~~ arrangement of electrons around nucleus

agree with experimental evidence

- Also ~~was unable to opt explain~~ model didn't agree with experimental evidence that orbiting electrons didn't emit ~~em~~ radiation (as they were accelerating (and charged particles).
- Couldn't explain why electrons didn't lose energy and spiral into nucleus.

- In order to ~~solve~~ solve this, Bohr proposed that electrons exist in discrete energy levels called stationary states!
    - Electrons can't exist between levels → thus solving Rutherford problem of not proposing how electrons orbited
- Proposed that electrons existed in 'stable states' within them energy levels, so didn't lose energy, and thus didn't emit EM radiation or spiral into nucleus (solving Rutherfords problem)
- Proposed that electrons can transition between energy levels through absorption(1)/emission(2) of energy what was?
    - Note: using Rydberg equation, this was proven correct, as predicted wavelengths of $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ matched experimental evidence of Balmer series

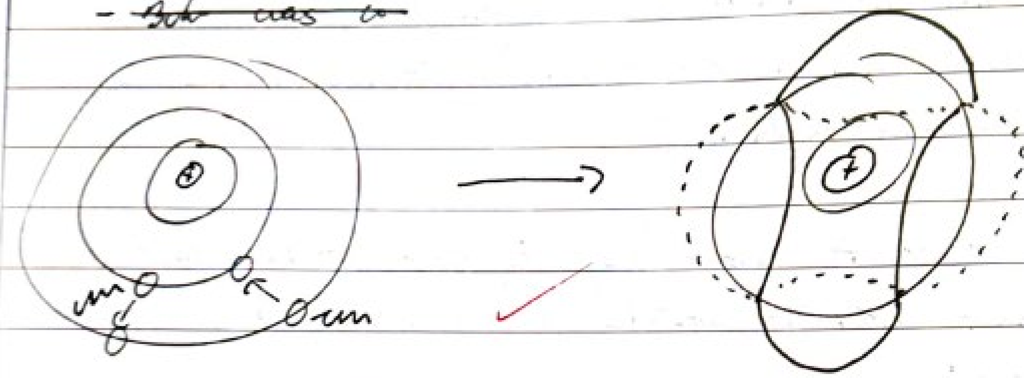
- Thus, as Rutherfords model ~~couldn't~~ didn't agree with experimental evidence showing electrons didn't

H spectra

emit EM radiation, Bohrs model ~~opposed this~~ ~~so~~ advanced atomic model to propose discrete energy levels.

de Broglie

- ~~Bohr was to~~



Bohr - discrete energy levels

de Broglie - matter waves

- Bohrs model couldn't actually explain why electrons were in a stable state → just that they are
- Also couldn't explain emission/absorption spectra of larger elements than hydrogen (model didn't agree with experimental evidence)
- de Broglie ~~[illegible]~~ asserted that if waves have particle properties, particles have wave properties (wave particle duality) $\lambda = \frac{h}{mv}$

wave properties ↑ particle properties

- Davisson Germer experiment ~~shot~~ ~~light~~ fired electrons at nickel crystal → and observed interference pattern → calculated λ matched de Broglies equation → provides evidence for wave particle duality

~~[illegible]~~ Extra writing booklet

- Thus, using experimental evidence, de Broglie ~~a~~ proposed that electrons ~~orbited~~ as standing waves, which are stable

  - As ~~sh~~ electrons ARE standing waves, they don't emit EM radiation, ~~as~~ they aren't accelerating charged particles - Associated # λ on, i.e n>2 has two full λ

- Thus, Bohrs model couldn't explain experimental evidence around electrons not emitting EM radiation -> de Broglies matter wave equation ~~th~~ and Davisson Germer experimental evidence advanced atomic model!

Thus, claim correct. well done!

Question 35 (marker – GS)

Criteria	Mark
Extensive analysis of both coil and magnet behaviour in terms of motion (speed, frequency, direction movement) Extensive use of relevant physics theory including electromagnetic induction, motion and electric circuits	5
Thorough explanation of both coil and magnet behaviour using relevant theory – minor errors or omissions and/or unclear links between theory and behaviour	4
Sound explanation of the behaviour of coils and/or magnets using mostly correct and relevant theory	3
Some relevant theory or correct descriptions of the behaviour of the coils and/or magnets	2
A relevant point made	1

Notes:

Overall Comments:

- This question was marked **holistically**.
- Most students knew **Faraday's Law** and could explain it well.
- A sizable portion of students need to work on how they express **Lenz's Law**.
- A large group of students forgot to mention nor explain the **Right-Hand Grip Rule**.
- Many students wrote **answers that were not very** extensive (**details were lacking**) – remember, in a question that is holistically marked, your level of detail is compared to others.

Examples of responses that lacked detail and how they could have improved them:

Actual Student Response (limited detail)	Extensive response (much more detail)
As Magnet A enters Coil A, Coil A experiences a change in flux.	As Magnet A enters Coil A, Coil A experiences an **increase in flux** from Magnet A's N-pole.
The induced EMF creates a current within the coil travelling to the other coil.	The induced EMF creates a current in Coil A. **The direction of the current can be determined using RHG rule (Thumb = N-pole of B-field and fingers = I direction)**. Therefore, the current flows down Coil A and up Coil B in an **anticlockwise direction**.
The magnetic field in Coil A is mirrored in Coil B.	Current flows **from bottom to top of Coil B (anticlockwise)**. **Using RHG rule (Fingers = I direction and Thumb = N-pole of B-field), it can be determined that the top of Coil B becomes a magnetic N-Pole**.

...current flows in Coil A then into Coil B creating a magnetic field that interacts with Magnet B.	...current flows in the closed circuit. The **direction of the current** can be determined using **RHG rule** (Thumb = N-pole of B-field and fingers = I direction). Therefore, the **current flows down Coil A and up Coil B in an anticlockwise direction. Since the direction of the current is known in Coil B, the position of the N-pole of Coil B's B-field can also be determined** using the **R.H.G. rule**. A **N-pole is created at the top of Coil B , which will repel the N-pole of Magnet B**, causing it to move upwards.
As Magnet A moves down, Coil A experiences a change in flux due to the strengthening of the coil.	As Magnet A **moves closer to** Coil A, Coil A experiences an **increase in flux** from Magnet A. Coil A will create/induce a B-field that opposes the increasing flux of Magnet A (Lenz's L.)

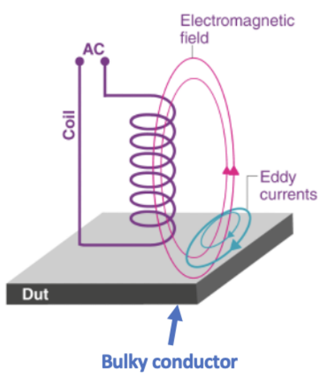
A misconception:

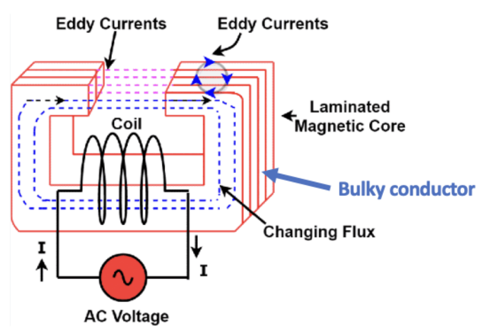
- Many a student response: "...and an **Eddy current** is induced, which flows through the two coils and around the rest of the circuit, since the wire is a closed circuit".

Explanation:

In this question the current produced is **not** an "Eddy current", it's simply an "**induced current**".

An Eddy current circulates in loops or "eddies" within the material (a circulating current within a conductor – **not** along the whole length of the conductor/connecting lead). Eddy currents are typically produced in **bulky conductors** (like metal sheets or iron cores), resembling the swirling patterns of eddies in water, when they are exposed to a changing magnetic field.





Examples of Eddy Currents:

- **Transformers**: Eddy currents are generated **in the iron core** of a transformer (not the wire coil) due to the alternating magnetic field, leading to energy losses.
- **Metal Detectors**: Eddy currents are induced in **metal objects** when exposed to the magnetic field of the detector, allowing the device to sense the presence of metal.
- **Magnetic Braking**: Eddy currents are used in braking systems of trains and roller coasters, where the interaction between a magnetic field on the side of the track and **the metallic disc wheels of the roller coaster/train, which** creates retarding/repelling magnetic force that slows down the vehicle.

Sample Answer / Sample response points:

Magnet A is set to oscillate in and out of the coil with a constant frequency and amplitude.

Analyse the changes that would happen in both coils and to magnet B due to one complete oscillation of magnet A.

As magnet A enters the coil A there will be a change in flux as it will change the area of magnet inside the coil by $\Delta\Phi = \Delta(BA\cos\theta)$ ✓

⇒ thus by faraday's law, the change in flux will induce an emf on the wire ⇒ by Lenz's law we ~~know~~ know that the emf will oppose the motion of the magnet

More space over page

only because the circuit is closed

Question 35 continued

and thus creating a current that will produce an opposing force ~~with~~ (by RHG rule) ✓ there will be a North end at the top as labelled which will produce a current flowing initially down the coil and then up coil B ⇒ ✓

producing a north end on ~~wire~~ coil B at the top (extra booklet) which will repele magnet B ~~pushing~~ creating a force that pushes it upwards. ~~Once~~

- Once ~~the~~ magnet A becomes the second half of the oscillation → ~~the~~ by Lenz's law the emf will swap directions to reduce the motion out of the coil by now placing opposite temporary poles with south at the top due to the new emf ~~that~~ (Faraday's law) and they will attract magnet B down which's opposite to the first half of the oscillation.

Question 36 (marker – GS)

Criteria	Mark
Extensive explanation of all components of the helium atom incorporating relevant fundamental particles and fundamental forces and bosons involved	4
Thorough explanation of most components of the helium atom with some detail missing, but both particles and forces considered	3
Sound explanation of the particle components of the helium atom – forces not considered OR Sound explanation of both particle and force components, with significant errors and/or omission of detail	2
A correct point made	1

Marker's Comments:

- Students either summarised and learned the Standard Model of Matter or they didn't.
- The Fundamental **forces** and their respective **bosons** must be **included**.

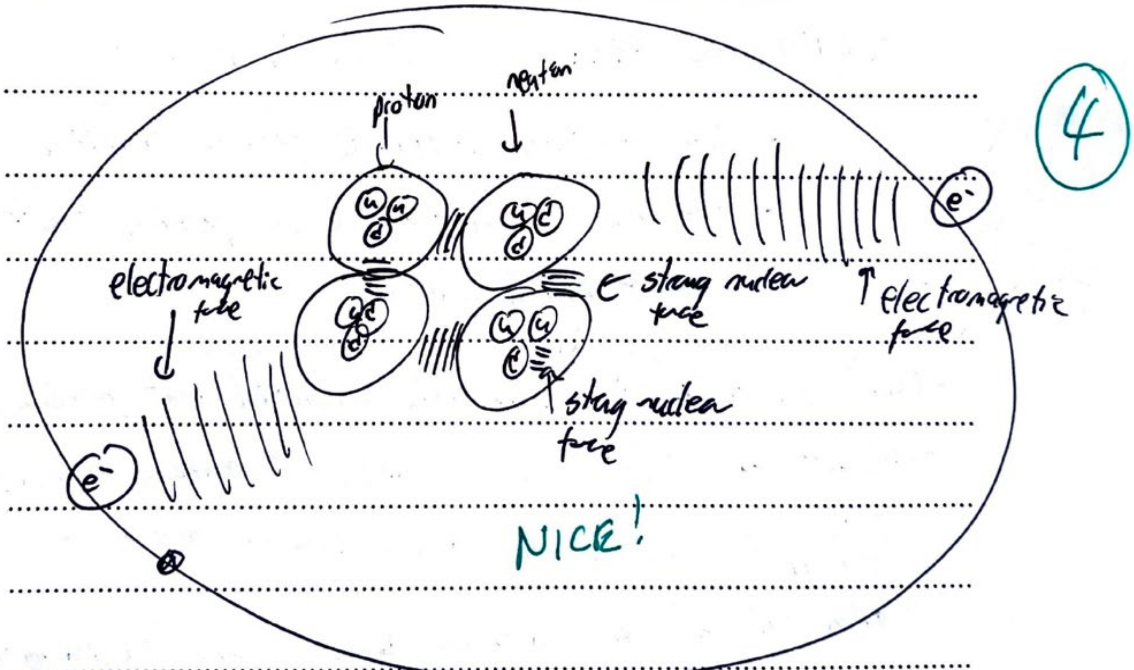
Below is a comprehensive summary for those students who do not have one yet:

<table>
<tr><td rowspan="3">Helium Atom</td><td rowspan="3">Particles</td><td rowspan="2">Nucleus (Hadrons)</td><td rowspan="2">Baryons</td><td>2 x Protons</td><td>2 x (3 Quarks)</td><td>2 x Up
1 x Down</td></tr>
<tr><td>2 x Neutrons</td><td>2 x (3 Quarks)</td><td>1 x Up
2 x Down</td></tr>
<tr><td>Orbiting the Nucleus</td><td>Leptons</td><td colspan="2">2 x electrons</td><td></td></tr>
</table>

<table>
<tr><td rowspan="4">Helium Atom</td><td rowspan="4">Forces between:</td><td>Quark
Quark</td><td>Nuclear Strong Force</td><td>Mediated by force carriers called Gluons</td></tr>
<tr><td>Quark
Lepton</td><td>Electromagnetic Force (attraction)</td><td>Mediated by force carriers called Photons</td></tr>
<tr><td>Lepton
Lepton</td><td>Electromagnetic Force (repulsion)</td><td>Mediated by force carriers called Photons</td></tr>
<tr><td>All particles with mass</td><td>Gravitational Force</td><td>Mediated by force carriers called Gravitons.
(not yet found)</td></tr>
</table>

Sample Answer / Sample response points:

Explain the structure of a helium atom using the Standard Model of matter. **4**



Nucleus

- 2 protons, 2 neutrons
  - Protons contain 2 up quarks, 1 down quark ($+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=1$ charge)
  - neutrons contain 1 up quark, 2 down quarks ($+\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$ charge)
  - d, u quarks bond by strong nuclear force, p, n bond by strong nuclear force → mediated by gluon

Electrons

(−1 charge)

- 2 electrons (leptons) in UCM due to electrostatic attraction between the nucleus and the electrons → electromagnetic force mediated by photon.

Question 37 (marker – Disney)

(a) Band 2-5

Criteria	Mark
Detailed outline of the purpose and use of control rods in maintaining desired neutron:fuel ratio	2
Some correct statement about control rods OR neutron:fuel ratio	1

Sample Answer / Sample response points:

- Control rods raised (increase rate)/lowered (decrease rate)
- Control rods absorb neutrons to keep 1:1 ratio which controls rate of fission

Exceptionally poorly done by the cohort due to not reading or understanding the question.

- Majority of the cohort explained how you ensure a nuclear reaction happens (including information on fuel rods and the moderator, and occasionally the coolant). This was NOT the question.
- The question was on the rate of energy production. Once the nuclear reaction is occurring, you don't adjust the number/mass of fuel rods or moderator. Thus the moderator CANNOT be used to control the rate of energy production.
- Any information that referred to fuel rods and moderator was incorrect and could actually cost you marks in a HSC question as it shows you do not have a full understanding of the process.
- To control the rate of energy production you also need to discuss how you increase AND decrease rate.

Majority of students were also discussing the use of control rods to prevent an uncontrolled reaction. Again, this was NOT the question – a reactor has already dealt with this issue and is running a controlled reaction. The question then asked how you control the rate of ENERGY production. RTQ.

reaction in a nuclear p...

the control rods ~~can be~~ are rods that can be lowered or raised to control the ~~p~~ fission of radioactive materials in the fuel rods, & are made of materials ~~designed to~~ made to absorb neutrons

↳ – When ~~t~~ fission reaction is occurring too rapidly, the ~~t~~ control rods are lowered to absorb more neutrons ~~&~~ & thus ↓ ~~r~~ rate of fission & energy production (as fission produces energy)

– When fission is occurring too slowly, control rods are raised to ↑ rate of fission & hence energy production.

nice!

(b)

Criteria	Mark
Correct calculations showing full working and final comparative statement	3
Correct calculations showing mostly full working No final comparative statement	2
One correct step in the calculation of fission energy	1

<u>Sample Answer / Sample response points:</u>

Generally a hit or miss with this calculation.

- Students who knew what they were doing generally got most of the way to a correct answer.
- Significant issues with lack of working out. With several different methods to arrive at a correct answer, simply putting a bunch of numbers on a page with no working, no explanation (and then getting calculations wrong) means I cannot follow your logic and this cost a proportion of responses marks.
- A significant number of students could not even start this question, using the mass of uranium alone rather than finding the mass defect.

Issues to address:

- SHOW ALL WORKING. I could not follow some responses, especially when a mistake had already been made so the "expected" answers were not being put forward.
- USE INTERMEDIATE UNITS. At times I could not tell if numbers were in eV, MeV, J, MJ due to the lack of working out. At least with units on each step I could start to determine what you had intended.
- Answer the question – quite a few students calculated the correct energy, but then did not compare to coal – thus not answering the question.

Two methods of determining the answer are found in the two sample answers provided.

Sample 1: converting mass defect into mass in kg, then finding E in J, then MJ, then comparison

How many times greater is the energy released from 1 kg of U-235 compared to 1 kg of coal? mass defect in Uranium: $\Delta m = (1.008 + 235.04 - 140.91 - 91.93 - 3 \times 1.008)\,u$

$= 0.184 \times 1.661 \times 10^{-27}$ (kg)

$\because E = mc^2$ $\therefore$ Hence the energy released by an atom of uranium is:

$$E = (0.184 \times 1.661 \times 10^{-27}) \times (3.0 \times 10^8)^2$$

$$= 2.8 \text{ J} \times 10^{-11}$$

$$= 2.8 \times 10^{-11} \times 10^{-6} = 2.8 \times 10^{-17} \text{ MJ}$$

$\therefore$ Energy released per 1 kg of U is ~~2.8×10~~ $2.8... \times 10^{-17} \times 2.55 \times 10^{24} = 7.0 \times 10^{7}$ MJ/kg

$\therefore$ Hence, the energy released ~~from~~ from U is 7.0×10^{6} times greater than coal.

$\uparrow$

$\left(\dfrac{7.0 \times 10^{7}}{10} \text{ times greater} \right)$

Sample 2: converting mass defect directly into MeV then back to J or MJ, then comparison

How many times greater is the energy released from 1 kg of U-235 compared to 1 kg of coal?

Consider: energy released from 1 · U-235 atom

i.e $\Delta m = m_{reactants} - m_{products}$

$= 1 \times 1.008 + 235.04 - 140.91 - 91.93 - 3 \times 1.008$

$= 0.184$ amu.

$\Rightarrow$ 1 atom releases 0.184×931.5 MeV of energy

$= 171.396$ MeV $\Rightarrow 171.396 \times 10^{6} \times 1.602 \times 10^{-19}$ J

$= 2.74576 \times 10^{-11}$ J

$\Rightarrow$ 2.55×10^{24} atoms release $2.74576 \times 10^{-11} \times 2.55 \times 10^{24} = 7.00 \times 10^{13}$ J

$\Rightarrow \dfrac{7.00 \times 10^{13}}{10 \times 10^{6}} = 7 \times 10^{6}$ times more energy.

END OF BOOKLET 4

nice!