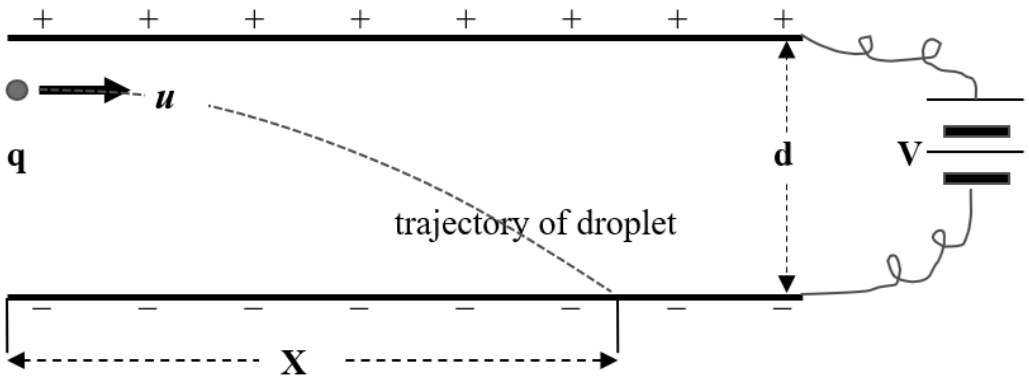
STUDENT NUMBER: _____

Question 1

An investigation was performed to measure the charge on small oil droplets.
The small oil droplets had an electric charge q applied to them before being fired with a known speed u into a region between two parallel charged plates, as shown.

The two plates have a known potential difference V between them and are separated by a known distance d.



The distance the droplets travelled before striking one of the charged plates, **X**, allowed for the calculation of the charge on the droplets.
Which other variables would need to have a known value for the calculation of the charge to be found?

(A) The mass of the droplets and exactly where the droplets entered between the plates.

(B) The diameter of the oil droplets.

(C) The mass of the oil droplets and the size of the droplets.

(D) The strength of the electric field between the plates.

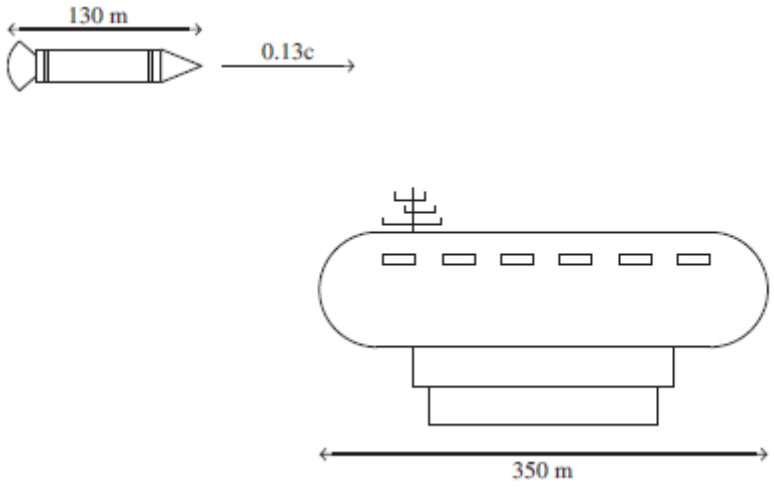
Question 2

The laminated iron core in a transformer

(A) increases the size of eddy currents to generate more electricity.
(B) reduces the size of eddy currents to improve the efficiency of the transformer.
(C) reduces the size of eddy currents to increase heat energy to better control the efficiency of the transformer.
(D) increases the size of eddy currents to provide a constant supply of electricity.

Question 3

An astronaut is travelling aboard a spacecraft. The spacecraft has a length of 130 m and is flying at a speed of 0.13c. The spacecraft travels past a space station that has a length of 350 m, as shown in the diagram.

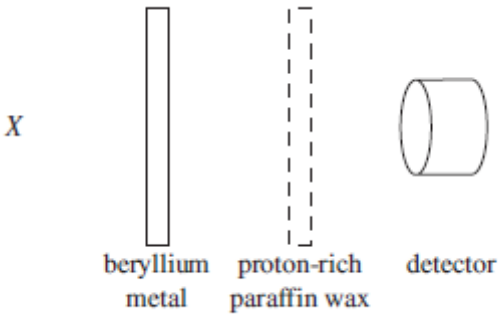


Which of the following correctly shows the length of the space station as perceived by the astronaut?

A. 347 m
B. 349 m
C. 350 m
D. 353 m

Question 4

James Chadwick discovered the neutron. He achieved this by observing the properties of the neutron, performing an experiment similar to the experiment shown in the diagram.

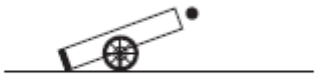


What is X?

A. alpha emitter
B. beta emitter
C. visible light
D. cathode ray

Question 5

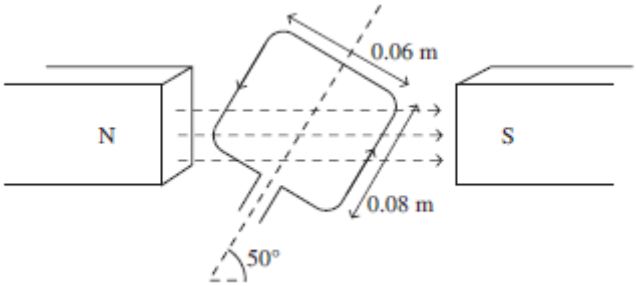
A projectile is launched by a cannon as shown. Which of the following represents the acceleration of the particle at its maximum height?



A. ↑
B. ↓
C. ↘
D. →

Question 6

A coil contains 20 loops and is placed in a magnetic field with its plane at an angle of 50° to the magnetic field, as shown in the diagram.



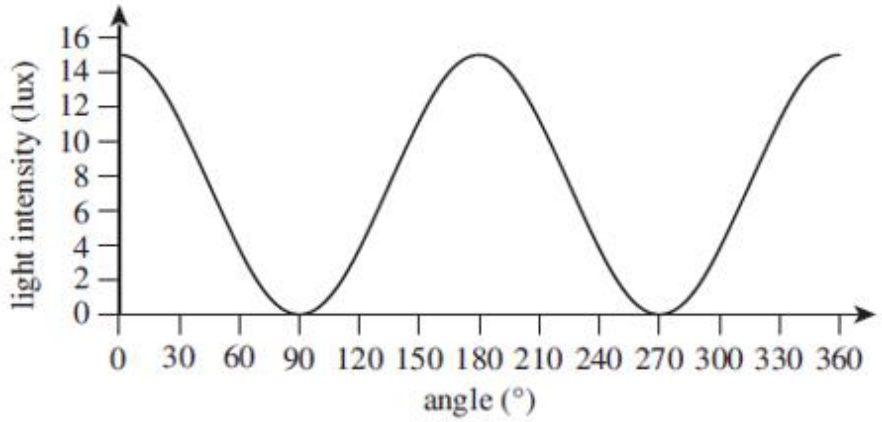
The magnetic field is calculated to be 2.4 mT. An ammeter connected to the coil reads 0.6 mA.
What is the magnitude of the torque acting on the coil and the direction of the coil's rotation?

(A) 8.89×10^{-8} Nm clockwise
(B) 8.89×10^{-8} Nm anti clockwise
(C) 1.96×10^{-7} Nm clockwise
(D) 1.96×10^{-7} Nm anti clockwise

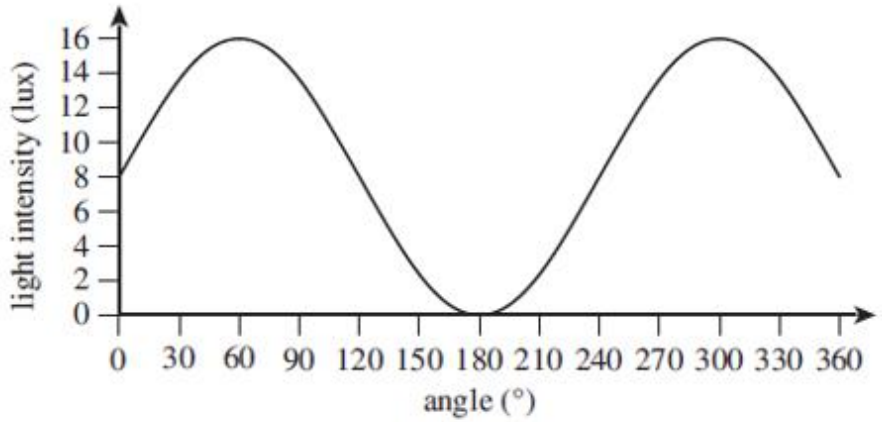
Question 7

A student conducted an investigation to demonstrate Malus' Law. The student used two polarising filters and changed the filters' axes of polarisation to different angles. They recorded their results in a graph. Which graph shows an expected result for the experiment?

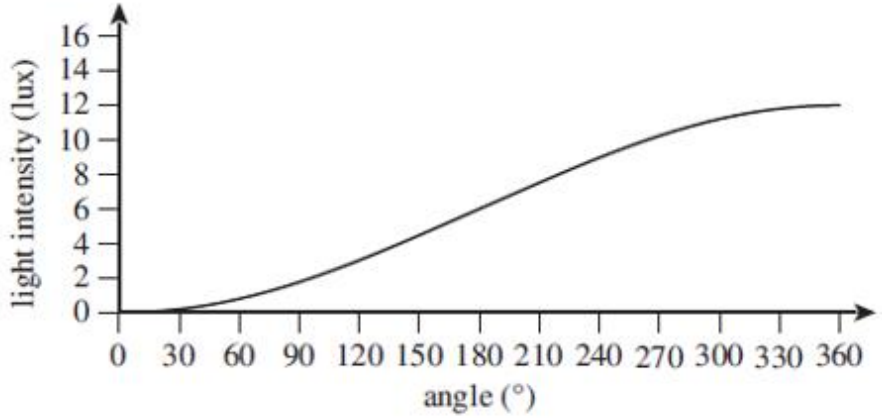
A.



B.



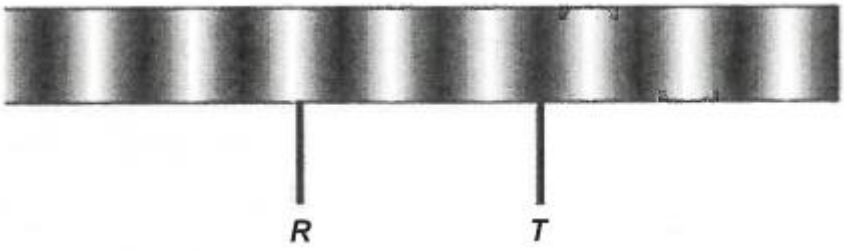
C.



D. None of A, B, C

Question 8

The diagram shows the regular light and dark interference pattern produced by a laser beam through two close slits 0.10 mm apart on a screen 1.6 m away from the slits. The distance between maximum at R and minimum at T on the interference pattern is 18 mm.



According to this information in the diagram, what is the wavelength of the incident light used in this experiment?

A. $1.1. \times 10^{-8}$ m
B. 2.2×10^{-7} m
C. 4.5×10^{-7} m
D. 4.5×10^{-4} m

Question 9

Two satellites have the same mass. One (LEO) is in low earth orbit and the other (GEO) is in geostationary orbit. The total energy of a satellite is half its gravitational potential energy. Which row of the table correctly identifies the satellite with the lower orbital period and the satellite with the lower total energy?

	Lower orbital period	Lower total energy
A	LEO	GEO
B	LEO	LEO
C	GEO	GEO
D	GEO	LEO

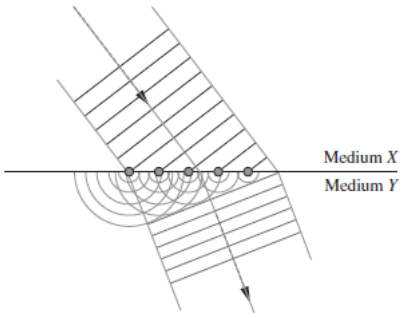
Question 10

Which of the following is NOT required for the operation of AC induction motors?

(A) Brushes
(B) Stator winding
(C) Magnetic fields
(D) Current applied to the rotor

Question 11

The diagram shows a model used to explain the refraction of light passing from medium *X* into medium *Y*.



Which line in the following table correctly compares light speed, frequency and refractive index in each of mediums X and Y.

	Light Speed	**Frequency**	**Refractive Index**
A	X > Y	X > Y	X > Y
B	X > Y	X = Y	X < Y
C	X > Y	X < Y	X = Y
D	X < Y	X = Y	X < Y

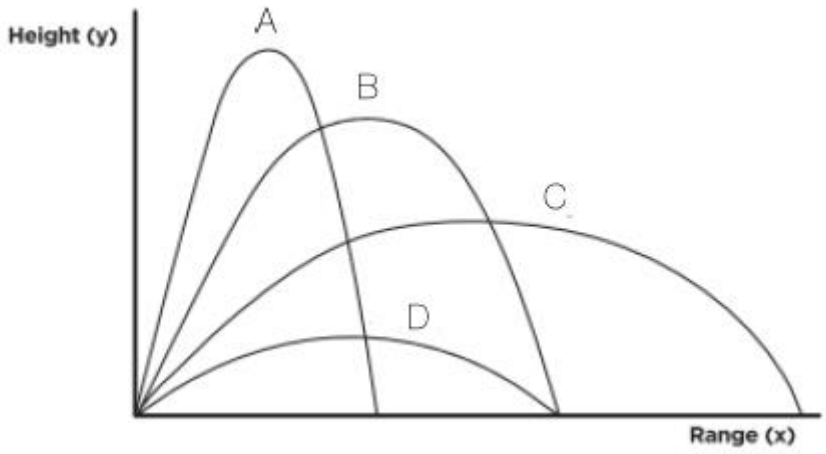
Question 12

De Broglie contributed to quantum theory by investigating matter waves. At what velocity will an electron have a wavelength of 1 mm?

A. 7.3×10^{-4} m s^{-1}
B. 0.73 m s^{-1}
C. 3.0×10^{8} m s^{-1}
D. An electron is a particle and cannot have a wavelength.

Question 13

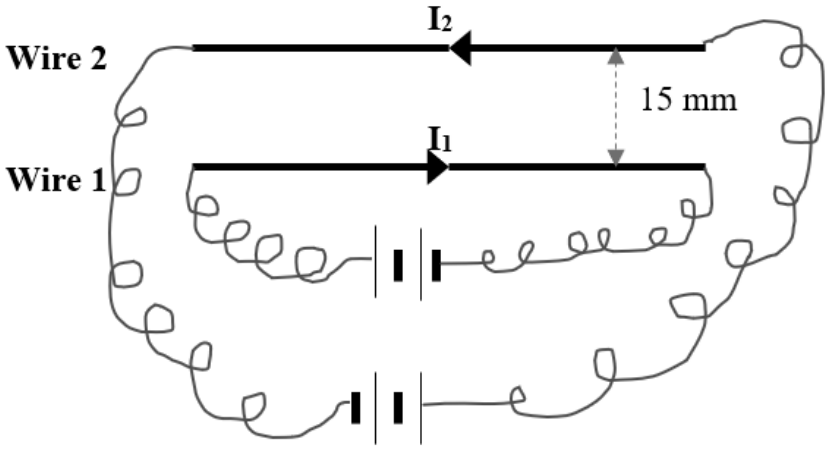
Below is a diagram of several projectiles launched at the same speed and different angles. Which trajectory has the longest time of flight?



Question 14

Two parallel wires, each of length ***l***, are placed so that wire 2 is being suspended above wire 1, due to the force caused by the currents flowing in each wire $\mathbf{I_1}$ and $\mathbf{I_2}$, balancing the weight of wire 2.

Wire 2 is suspended 15 mm above wire 1.



If both the currents are doubled to what distance above wire 1 will wire 2 move?

(A) 22.5 mm

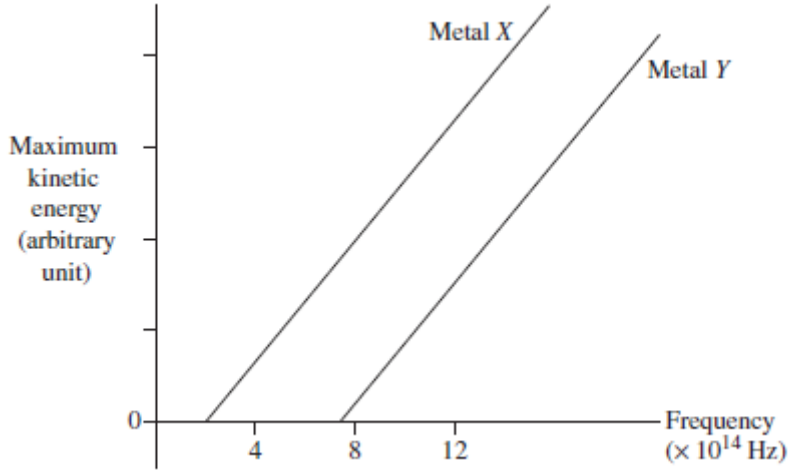
(B) 30 mm

(C) 45 mm

(D) 60 mm

Question 15

The graph shows the relationship between the frequency of light used to irradiate two different metals, and the maximum kinetic energy of photoelectrons emitted.



Suppose that light having a frequency of 8×10^{14} Hz is used to irradiate both metals.

Compared to the photoelectrons emitted from metal *X*, photoelectrons emitted from metal *Y* will

A) Take a shorter time to gain sufficient energy to be ejected
B) Have a lower maximum velocity
C) Have a higher maximum velocity
D) Take a longer time to gain sufficient energy to be ejected

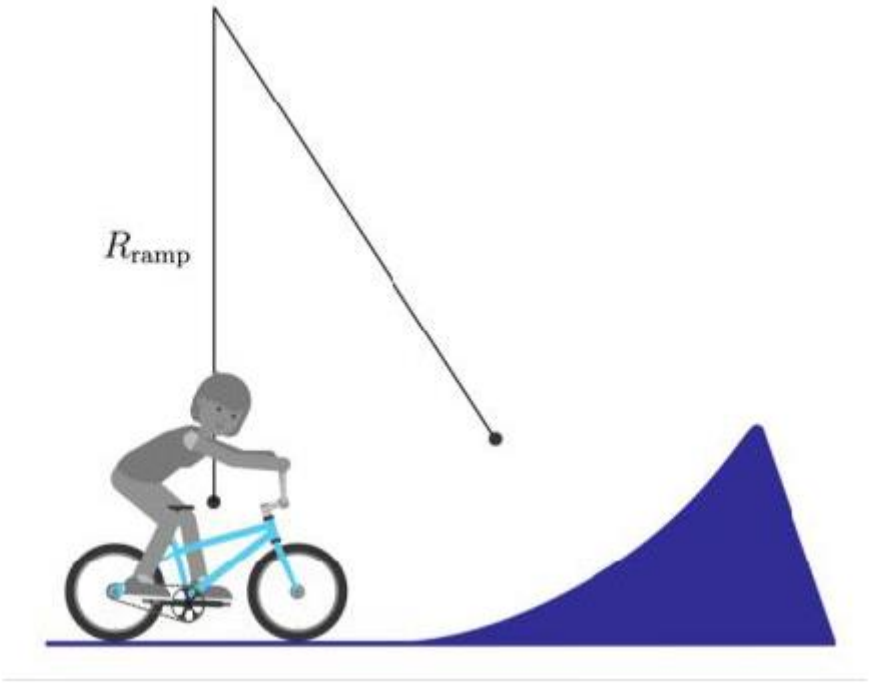
Question 16

What fundamental particle must be emitted from the nucleus of an atom as a net result of the process of fusion in which four protons are fused into a helium nucleus?

(A) quark
(B) electron
(C) hydrogen atom
(D) neutrino

Question 17

When a bike travels up a circular ramp as the cyclist goes up the ramp they apply a force parallel to the ramp to maintain a constant speed.



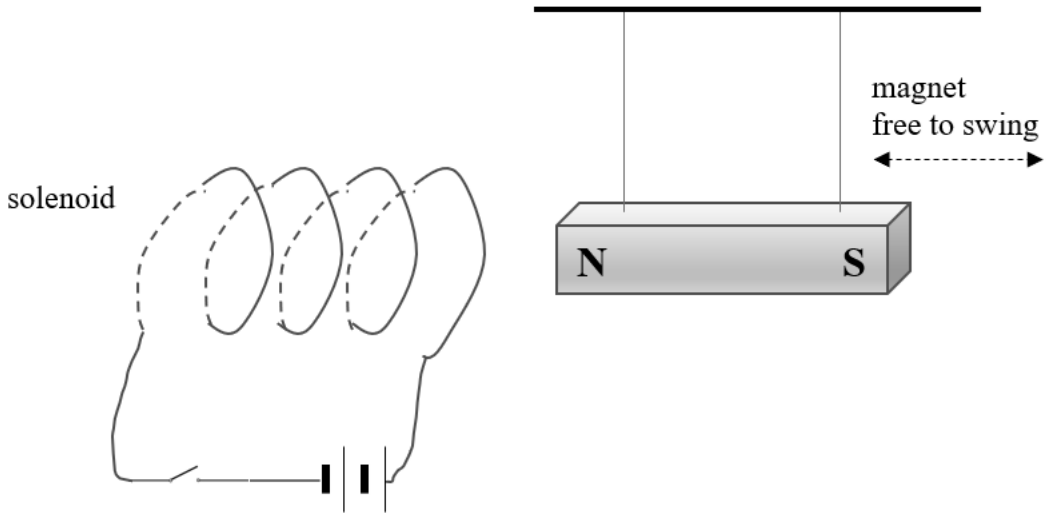
Which of the following statements is correct when the bike is on the ramp?

A) The magnitude of the normal force on the bike is constant
B) The normal force on the bike is the bikes centripetal force
C) The normal force on the bike is equal in magnitude to the bikes weight force
D) The direction of the net force on the bike is towards the centre of the circle

Question 18

A solenoid is connected to a DC power source with a switch connected in series.

A magnet is placed near the end of the solenoid, suspended by cotton threads and free to swing.



At the instant that the switch is closed:

(A) back EMF would begin to be generated in the solenoid and the magnet would swing to the left.
(B) a surge of current would flow through the solenoid and the magnet would not move.
(C) a back EMF would be generated in the solenoid and the magnet would not move.
(D) a surge of current would flow through the solenoid and the magnet would swing to the right.

Question 19

Laser light with a wavelength of 620 nm was passed through double slits with a separation of 60 µm. The screen was placed 2.00 m behind the slits. How far from the centre of the central maximum is the next bright spot in the interference pattern on the screen?

(A) 21 cm

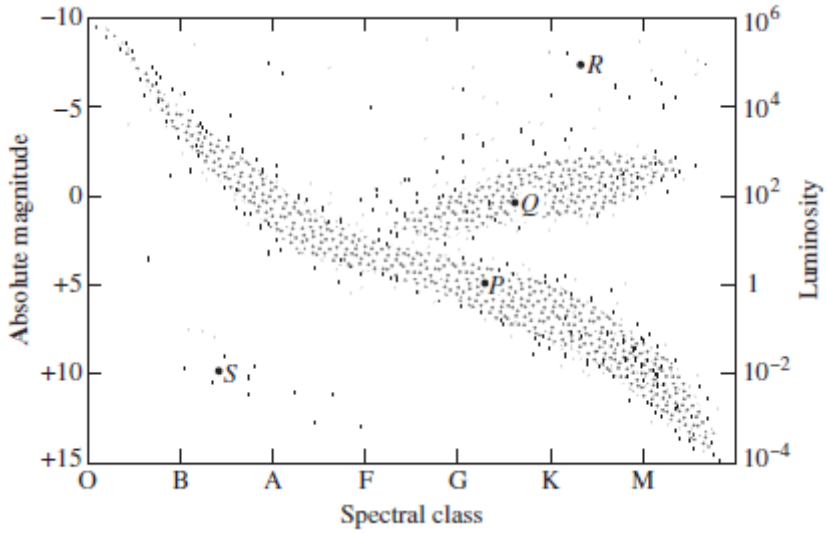
(B) 10 cm

(C) 1.0 cm

(D) 2.1 cm

Question 20

Four Stars PQRS are labelled on the Hertzsprung Russell Diagram



Which statement is correct?

A) R is a blue star whereas S is a red star
B) S has a greater luminosity than Q
C) P is at a more advanced state of its evolution than R
D) S has a higher surface temperature than R

STUDENT NUMBER: _____

Question 21 (5 marks)

(a) In the past, Earth's rotation was much faster than it is today. Calculate the apparent weight of a 60.0 kg person standing on the equator if Earth's rotational period was 4 hours exactly. (3 marks)

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(b) Identify and describe the effects of two other factors which affect the gravitational field strength on the surface of the earth. (2 marks)

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Question 22 (5 marks)

A proton entered a uniform magnetic field that had a magnitude of 0.80 T. The initial velocity of the proton was 3.3×10^{6} m s^{-1} perpendicular to the magnetic field.

(a) Explain why the proton travelled in a circular path at a constant speed after entering the magnetic field (2 marks)

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(b) Determine the radius of the circular path taken by the proton. (3 marks)

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Question 23 (2 + 3 + 4 = 9 marks)

Question 23 Part 1 (2 marks)

The Earth can be modelled as a black body. The average surface temperature of Earth is about 15 °C.

(a) What is the peak wavelength of the radiation emitted by Earth? (1 mark)

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(b) To which part of the electromagnetic spectrum does this peak wavelength correspond? (1 mark)

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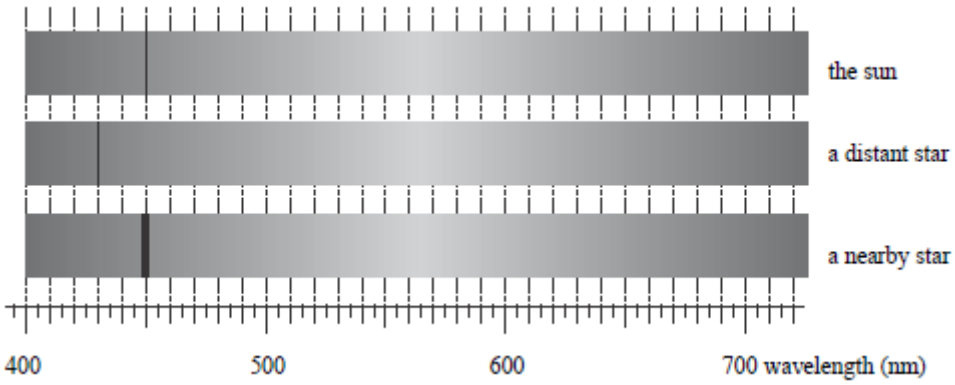
Question 23 Part 2 (3 marks)

Light from the sun is passed through a spectroscope to produce a visible spectrum. A student views this spectrum and observes a number of dark lines as shown below. In the diagram only one of these dark lines due to hydrogen is shown.



The position of this hydrogen line in the visible spectrum is shown for the sun, a distant star and a nearby star.

Explain why the line is in a different position for the distant star compared to the sun and give possible reasons for the line from the nearby star having a different shape from that of the sun. (3 marks)

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Question 23 Part 3 (4 marks)

The experiment showing interference of light passing through two narrow slits is known as Young's double slit experiment. Young carried out the experiment in 1801 and the presence of the light and dark banded interference pattern was regarded as strong evidence to support the wave model of light.

For a maximum:

$d\sin\theta = m\lambda = \frac{dx}{L}$ where:

λ = wavelength
L = distance from slits to screen
d = distance between the two slits
x = distance from the central maximum
θ = the angle from the central maximum
m = integer: 0 for the central maximum, 1 for the first maximum, etc.

For a minimum:

$d\sin\theta = \left(m - \frac{1}{2}\right)\lambda = \frac{dx}{L}$ where:

m = 1 is the first dark band, m = 2 is the second dark band, etc.

Laser light of wavelength 650 nm is used in a double slit experiment. The distance between the double slits and the screen is 38.5 cm. The double slits are 0.085 mm apart.

(a) What is the angle of the first order bright band. (1 marks)

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(b) What is the distance from the central band to the first order bright band. (1 marks)

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(c) How would the pattern change if a laser of wavelength 550 nm was used? Justify your response. (2 marks)

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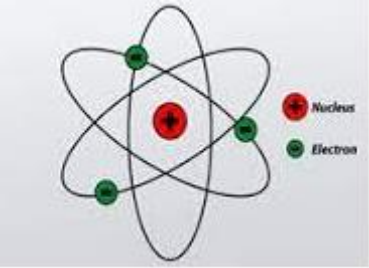
Question 24 (3 + 5 = 8 marks)

Question 24 Part 1 (3 marks)

Rutherford's Model of the Atom Characteristics & Features	
The labelled diagram shows the model of the atom proposed by Rutherford.	

Outline the Supporting Evidence or Conclusions for Rutherford's model

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State the observations or features unaccounted for in Rutherford's model

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Question 24 Part 2 (5 marks)

The work of Bohr, de Broglie and, later, Schrödinger demonstrated that the quantum mechanical nature of matter was a better way to understand the structure of the atom. How does the nature of the electron proposed in each of the three models developed by Bohr, de Broglie and Schrödinger differ and what were the post deBroglie views on the physical nature of the electron? (5 marks).

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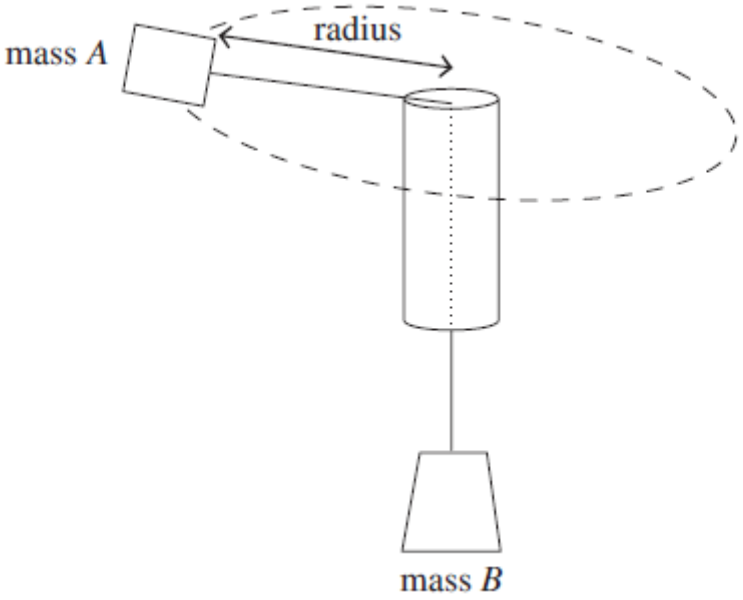
Question 25 (9 marks)

A student conducted several tests on circular motion in accordance with the diagram



Mass A was swung on a circular path and mass B provided the necessary weight force

The student measured the time for mass *A* to make 10 rotations. Averaged results after conducting three trails for each of the test conditions are presented in each row of the table.

Table: Average measured time for mass A to make 10 rotations				
Test	**Mass of A (g)**	**Mass of B (g)**	**Radius of circle (m)**	**Average Time for 10 rotations (s)**
1	50	50	0.125	10
2	50	50	0.200	13
3	50	50	0.250	14
4	50	50	0.375	17
5	50	75	0.125	8
6	50	100	0.125	7
7	50	200	0.125	5
8	125	50	0.125	16
9	250	50	0.125	22
10	750	50	0.125	27

(a) Outline THREE different experiments conducted using the information from the table. (3 marks)

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(b) For Tests 5, 6 and 7, identify the dependent, independent and TWO controlled variables. (3 marks)

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(c) If the student repeated all of the tests with 20 rotations would the experiment that used 10 rotations or the experiment that used 20 rotations be more accurate and reliable? Justify your answer. (1 mark)

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(d) Assuming there are no frictional forces, derive an equation for the orbital radius of mass A in terms of v and g. Justify your answer. (2 marks)

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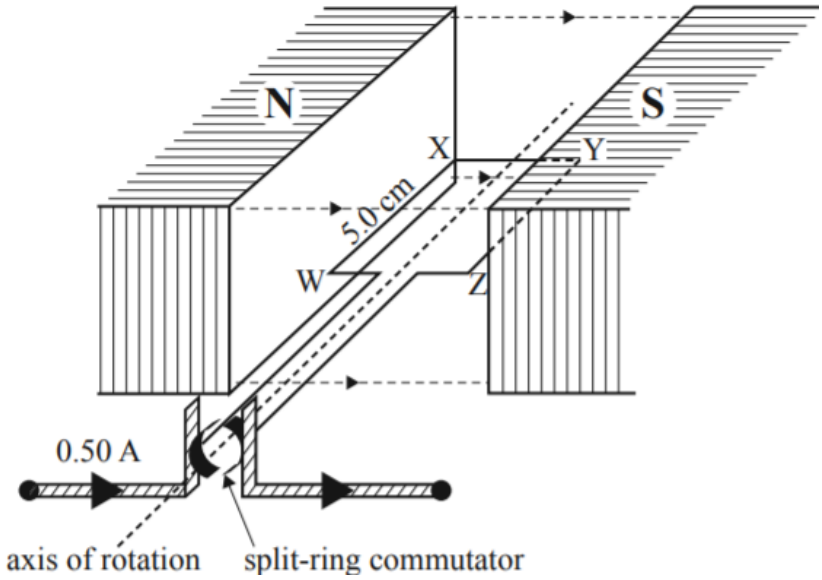
Question 26 (4 marks)

A model representing a motor is shown below.



(a) What type of motor is it? (1 mark)

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(b) While in the position shown in the diagram, a current of 0.50 A is flowing in the rotating coil. The coil has 10 turns and the magnetic field across the coil has a strength of 1T. The side WX of the rectangular coils has a length of 5.0 cm and the side XY is 3 cm. Calculate the magnitude of the maximum torque on the coil and the direction of its rotation. (3 marks)

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Question 27 (5 marks)

UV light of frequency 2.4 x 10^{15} Hz strikes magnesium whose work function is 3.7 eV.

(a) What is the energy transferred by each photon? (1 marks)

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(b) Calculate the maximum kinetic energy of the ejected electrons. (1 marks)

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(c) Calculate the maximum speed of the electrons. (1 marks)

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(d) Calculate the stopping voltage for the electrons. (2 marks)

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Question 28 (6 marks)

(a) Account for the release of energy in both the processes of fission and fusion. Support your answer with examples. (3 marks)

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(b) When 2 protons fuse to form a deuterium nucleus, a positron and a neutrino are released. Calculate the binding energy per deuterium nucleus formed, assuming the mass of a neutrino to be negligible. (Assume the mass of a deuterium nucleus to be 3.3435×10^{-27} kg). (3 marks)

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Question 29 (6 marks)

(a) Two projectiles are launched with the same initial speeds and angles to the horizontal. Projectile A has a mass of m, while projectile B has a mass of 2m. Explain why the two projectiles will have the same range. (2 marks)

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(b) The train line between Sydney and Newcastle is designed so that it can take slow moving freight trains as well as much faster passenger trains at speeds up to 100 km h^{-1}. The track has many tight curves along the route. For a section of track banked at 20 degrees to the horizontal around a curve with a radius of 400 m, what is the design speed for a train? (2 marks)

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(c) If a rocket is launched at 100 ms^{-1} at 45 degrees from its position on top of a 150 m high cliff determine its time of flight (2 marks)

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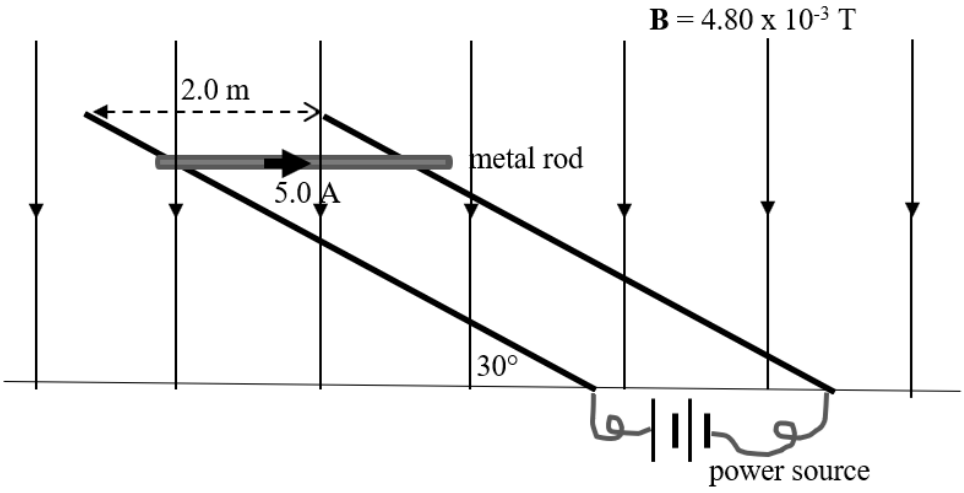
Question 30 (11 marks)

A straight metal rod sits on parallel metal tracks spaced 2.0 m apart which are angled at 30° to the horizontal. The apparatus exists within a vertical magnetic field of strength 4.80 x 10^{-3} T, as shown.

A current of 5.0 A flows through the metal rod.



(a) Neglecting the effects of gravity, what force would act on the metal rod as it sits motionless on the rails? (2 marks)

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(b) Suggest a procedure that could be used to find the mass of the metal rod, given that gravity is taken into account but friction is ignored. (3 marks)

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C) Discuss the validity of this statement and illustrate its meaning with reference to specific examples:

"Lenz's law is simply a consequence of the conservation of energy."

(4 marks)

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(d) Describe magnetic flux and identify whether is it a vector or a scalar? (2 marks)

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Question 31 (6 marks)

(a) A spacecraft is travelling at 0.87c between Earth and Teegarden's Star, a distance of 12.51 lightyears from Earth's frame of reference. Calculate the distance of the journey in the spacecraft's frame of reference. (2 marks)

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(b) Outline how special relativity imposes a limitation on the maximum velocity of the spaceship. (1 mark)

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(c) A muon is an elementary particle which decays into an electron. When at rest the decay time of a muon is 2.2 μS, but when observed moving at a relativistic velocity its decay time is measured as 8.8 μS. Explain how these muons provide evidence for Einstein's theory of special relativity and hence calculate the speed of the muons. (3 marks)

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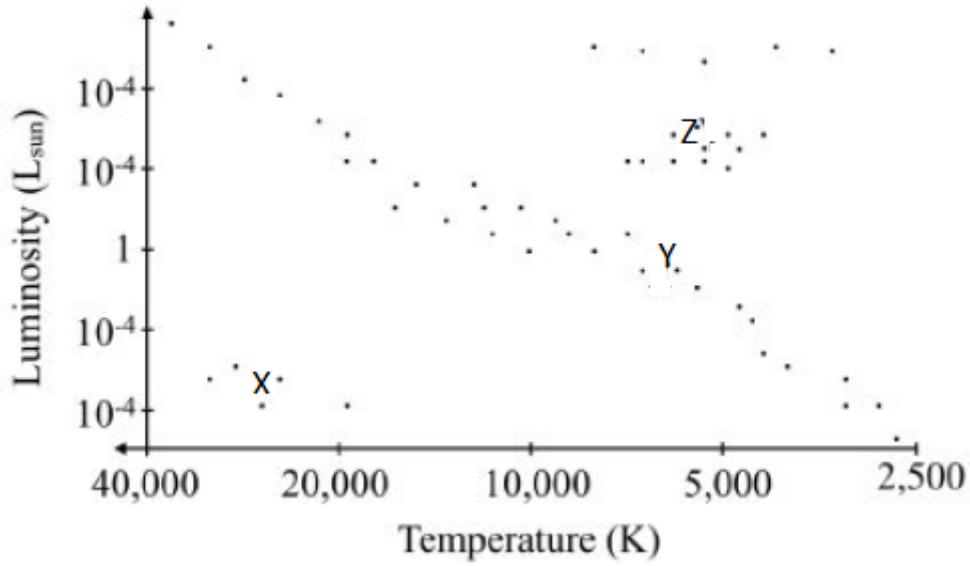
Question 32 (6 marks)

Question 32 refers to the HR Diagram: WARNING BELOW DIAGRAM VERTICAL SCALE MISTAKENLY PRINTED AS 10-4 REPEATING – DO NOT REUSE DIAGRAM (BHZ)



(a) Identify what star luminosity is and also describe and justify the nature of the numerical scales adopted on the axes shown (2 marks)

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(b) Identify the types of stars characteristically at the locations marked X, Y and Z in the H-R Diagram. Also outline the most likely dominant nucleosynthesis reactions at Y (4 marks)

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B+12 ANSWERS

Newington College

Discover what's possible

Physics

2022 Year 12 HSC Trial Examination

General Instructions

- Reading time: 5 minutes
- Working time: 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Attempt ALL questions
- Do NOT write in pencil
- A separate Multiple Choice Answer Sheet is provided to answer Questions 1–20
- A data sheet, formulae sheet and Periodic Table are provided at the back of the paper
- Write your Student Number at the top of pages so indicated

Total marks – 100

Section 1 Multiple Choice 20 marks

Allow about 35 minutes for this section

Questions 1–20 — 20 marks

Section 2 Written Response 80 marks

Allow about 2 hours and 25 minutes for this section

Question 21-32 — 80 marks

Section I – 20 marks

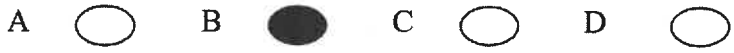
Attempt Questions 1-20

Allow about 35 minutes for this section

Use the multiple-choice answer sheet.

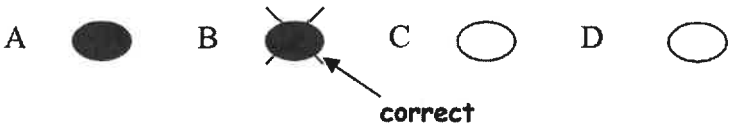
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

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



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

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



Student Number BHZ ANSWERS

Physics teacher _____

2022

TRIAL HSC EXAMINATION

Physics

Multiple Choice Answer Sheet

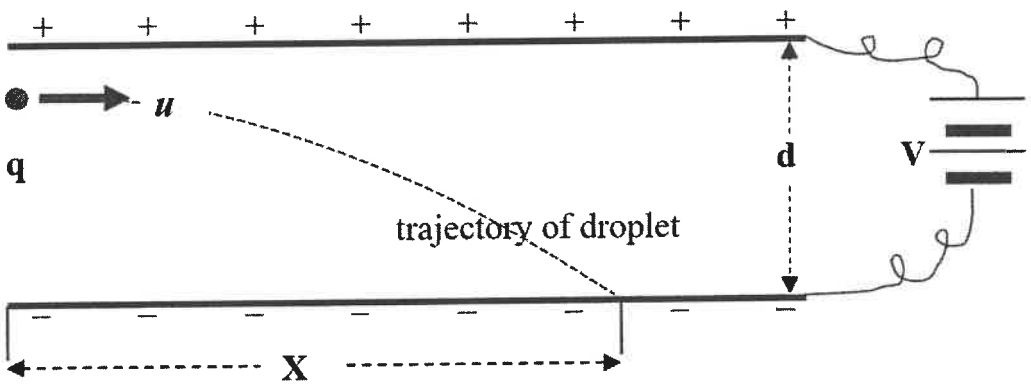
1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D
11.	A	B	C	D
12.	A	B	C	D
13.	A	B	C	D
14.	A	B	C	D
15	A	B	C	D
16.	A	B	C	D
17.	A	B	C	D
18.	A	B	C	D
19.	A	B	C	D
20.	A	B	C	D

STUDENT NUMBER: _____

Question 1

An investigation was performed to measure the charge on small oil droplets.
The small oil droplets had an electric charge q applied to them before being fired with a known speed u into a region between two parallel charged plates, as shown.

The two plates have a known potential difference V between them and are separated by a known distance d.



The distance the droplets travelled before striking one of the charged plates, **X**, allowed for the calculation of the charge on the droplets.
Which other variables would need to have a known value for the calculation of the charge to be found?

(A) The mass of the droplets and exactly where the droplets entered between the plates.

(B) The diameter of the oil droplets.

(C) The mass of the oil droplets and the size of the droplets.

(D) The strength of the electric field between the plates.

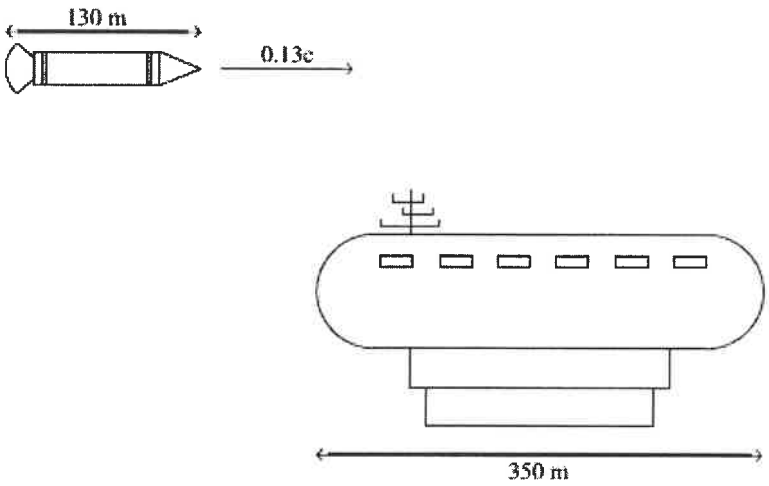
Question 2

The laminated iron core in a transformer

(A) increases the size of eddy currents to generate more electricity.
(B) reduces the size of eddy currents to improve the efficiency of the transformer.
(C) reduces the size of eddy currents to increase heat energy to better control the efficiency of the transformer.
(D) increases the size of eddy currents to provide a constant supply of electricity.

Question 3

An astronaut is travelling aboard a spacecraft. The spacecraft has a length of 130 m and is flying at a speed of 0.13c. The spacecraft travels past a space station that has a length of 350 m, as shown in the diagram.

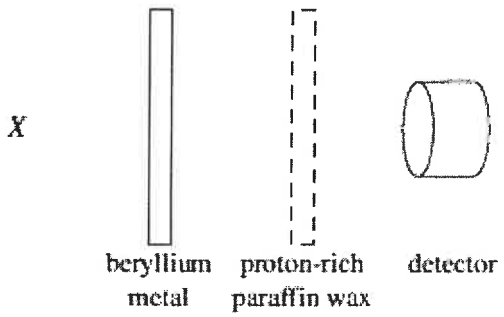


Which of the following correctly shows the length of the space station as perceived by the astronaut?

A. 347 m
B. 349 m
C. 350 m
D. 353 m

Question 4

James Chadwick discovered the neutron. He achieved this by observing the properties of the neutron, performing an experiment similar to the experiment shown in the diagram.

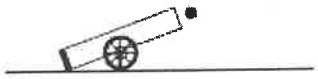


What is X?

A. alpha emitter
B. beta emitter
C. visible light
D. cathode ray

Question 5

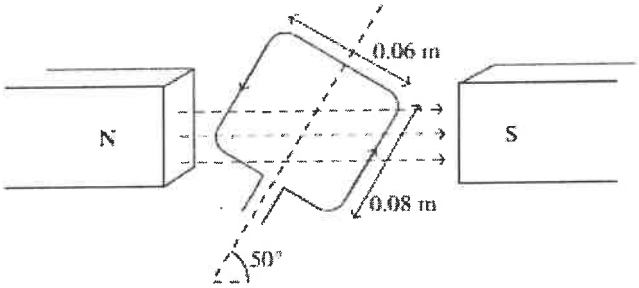
A projectile is launched by a cannon as shown. Which of the following represents the acceleration of the particle at its maximum height?



A. ↑
B. ↓
C. ↘
D. →

Question 6

A coil contains 20 loops and is placed in a magnetic field with its plane at an angle of 50° to the magnetic field, as shown in the diagram.



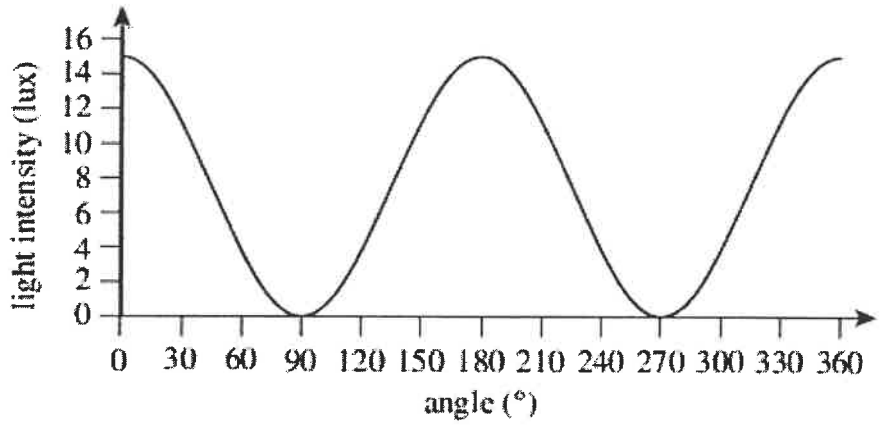
The magnetic field is calculated to be 2.4 mT. An ammeter connected to the coil reads 0.6 mA.
What is the magnitude of the torque acting on the coil and the direction of the coil's rotation?

(A) 8.89×10^{-8} Nm clockwise
(B) 8.89×10^{-8} Nm anti clockwise
(C) 1.96×10^{-7} Nm clockwise
(D) 1.96×10^{-7} Nm anti clockwise

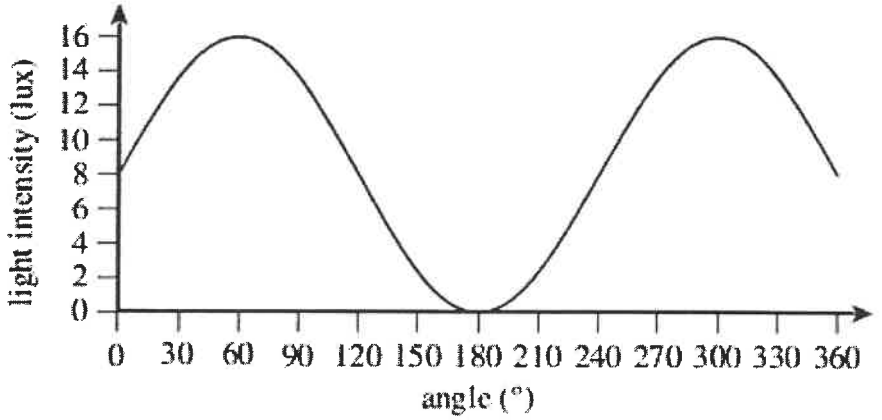
Question 7

A student conducted an investigation to demonstrate Malus' Law. The student used two polarising filters and changed the filters' axes of polarisation to different angles. They recorded their results in a graph. Which graph shows an expected result for the experiment?

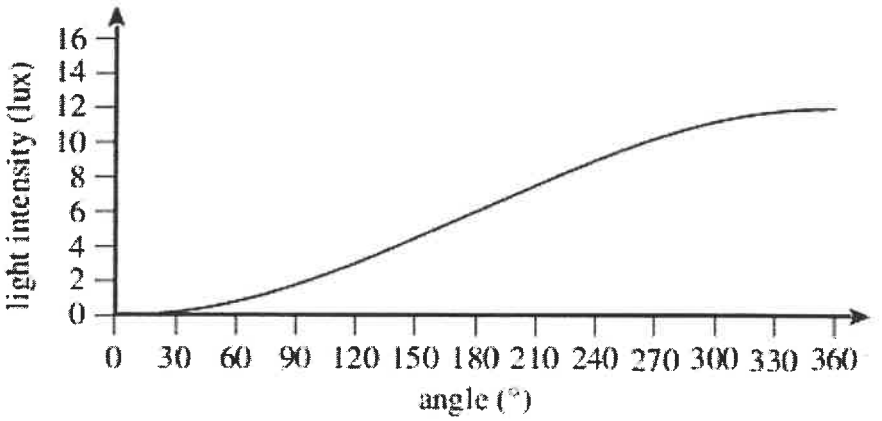
A.



B.



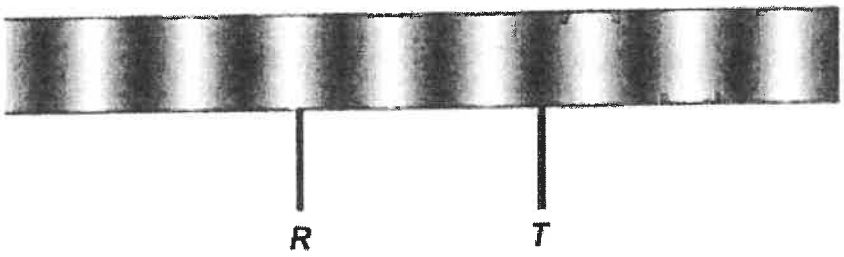
C.



D. None of A, B, C

Question 8

The diagram shows the regular light and dark interference pattern produced by a laser beam through two close slits 0.10 mm apart on a screen 1.6 m away from the slits. The distance between maximum at R and minimum at T on the interference pattern is 18 mm.



According to this information in the diagram, what is the wavelength of the incident light used in this experiment?

A. $1.1. \times 10^{-8}$ m

B. 2.2×10^{-7} m

C. 4.5×10^{-7} m

D. 4.5×10^{-4} m

Question 9

Two satellites have the same mass. One (LEO) is in low earth orbit and the other (GEO) is in geostationary orbit. The total energy of a satellite is half its gravitational potential energy. Which row of the table correctly identifies the satellite with the lower orbital period and the satellite with the lower total energy?

	Lower orbital period	Lower total energy
A	LEO	GEO
B	LEO	LEO
C	GEO	GEO
D	GEO	LEO

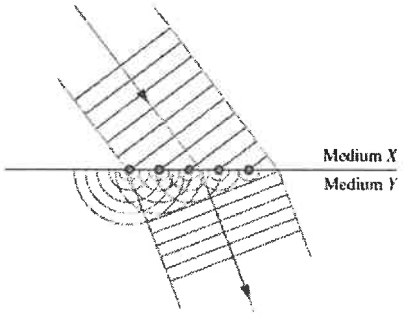
Question 10

Which of the following is NOT required for the operation of AC induction motors?

(A) Brushes
(B) Stator winding
(C) Magnetic fields
(D) Current applied to the rotor

Question 11

The diagram shows a model used to explain the refraction of light passing from medium X into medium Y.



Which line in the following table correctly compares light speed, frequency and refractive index in each of mediums X and Y.

	Light Speed	Frequency	Refractive Index
A	X > Y	X > Y	X > Y
B	X > Y	X = Y	X < Y
C	X > Y	X < Y	X = Y
D	X < Y	X = Y	X < Y

Question 12

De Broglie contributed to quantum theory by investigating matter waves. At what velocity will an electron have a wavelength of 1 mm?

A. 7.3×10^{-4} m s^{-1}

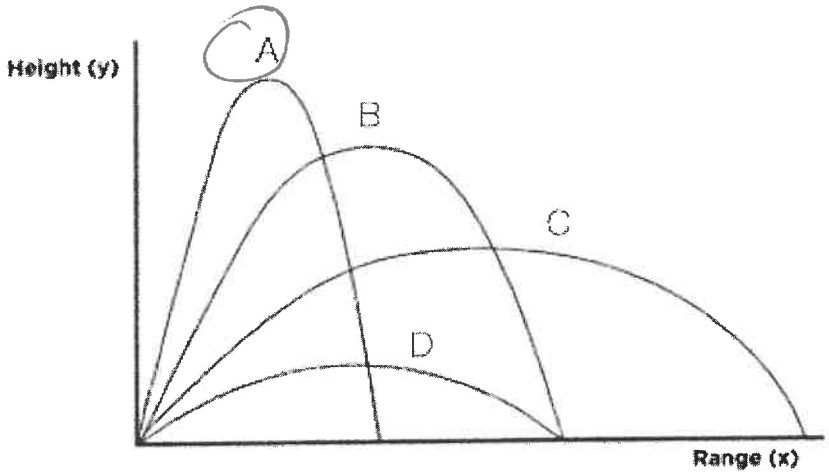
B. 0.73 m s^{-1}

C. 3.0×10^{8} m s^{-1}

D. An electron is a particle and cannot have a wavelength.

Question 13

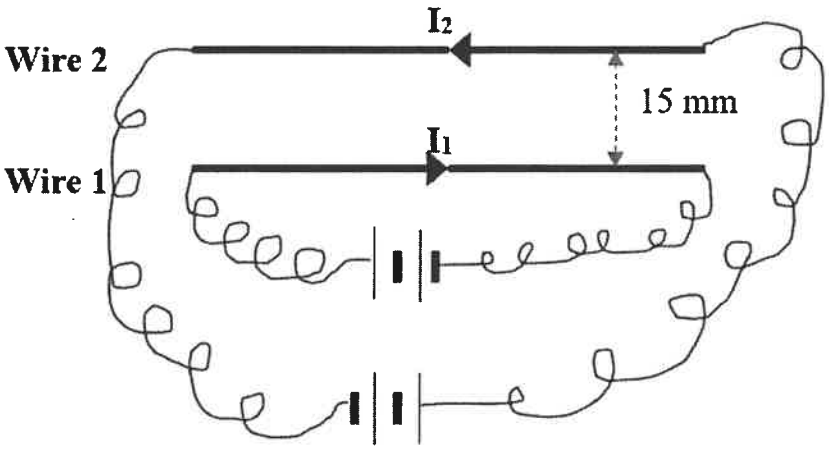
Below is a diagram of several projectiles launched at the same speed and different angles. Which trajectory has the longest time of flight?



Question 14

Two parallel wires, each of length *l*, are placed so that wire 2 is being suspended above wire 1, due to the force caused by the currents flowing in each wire I_1 and I_2, balancing the weight of wire 2.

Wire 2 is suspended 15 mm above wire 1.



If both the currents are doubled to what distance above wire 1 will wire 2 move?

(A) 22.5 mm

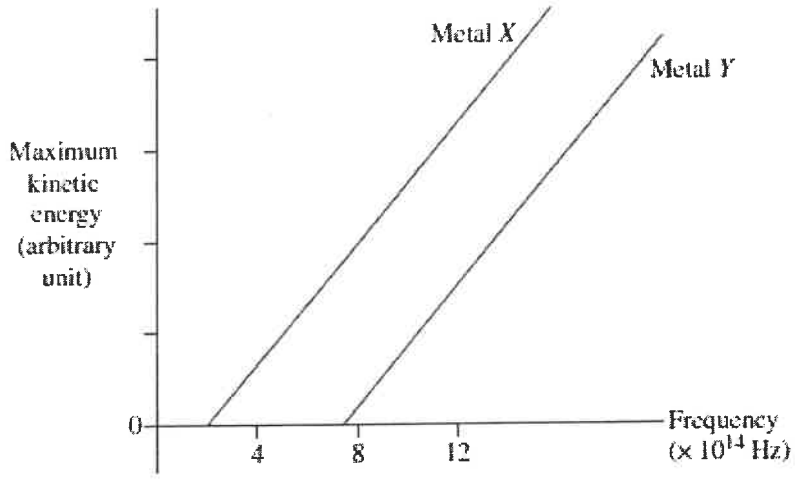
(B) 30 mm

(C) 45 mm

(D) 60 mm

Question 15

The graph shows the relationship between the frequency of light used to irradiate two different metals, and the maximum kinetic energy of photoelectrons emitted.



Suppose that light having a frequency of 8×10^{14} Hz is used to irradiate both metals.

Compared to the photoelectrons emitted from metal *X*, photoelectrons emitted from metal *Y* will

A) Take a shorter time to gain sufficient energy to be ejected
B) Have a lower maximum velocity
C) Have a higher maximum velocity
D) Take a longer time to gain sufficient energy to be ejected

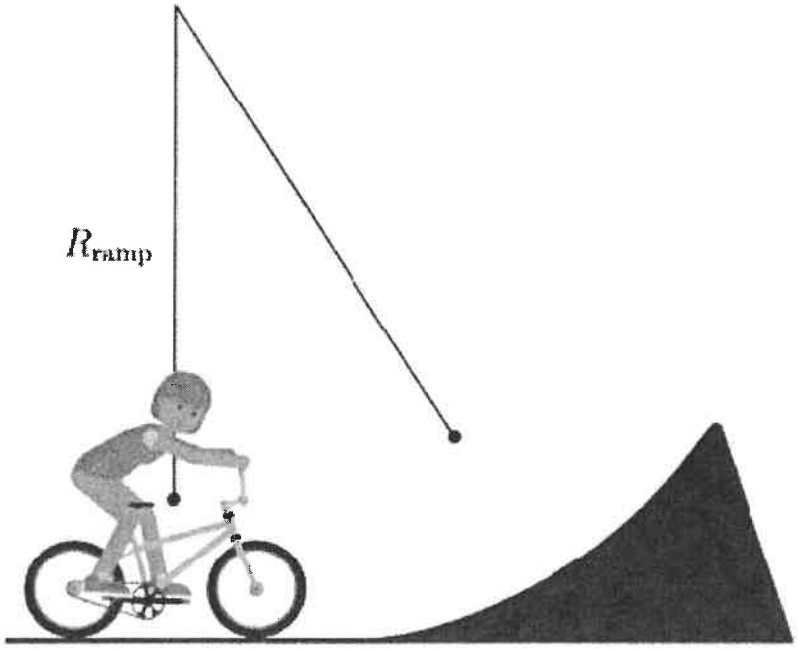
Question 16

What fundamental particle must be emitted from the nucleus of an atom as a net result of the process of fusion in which four protons are fused into a helium nucleus?

(A) quark
(B) electron
(C) hydrogen atom
(D) neutrino

Question 17

When a bike travels up a circular ramp as the cyclist goes up the ramp they apply a force parallel to the ramp to maintain a constant speed.



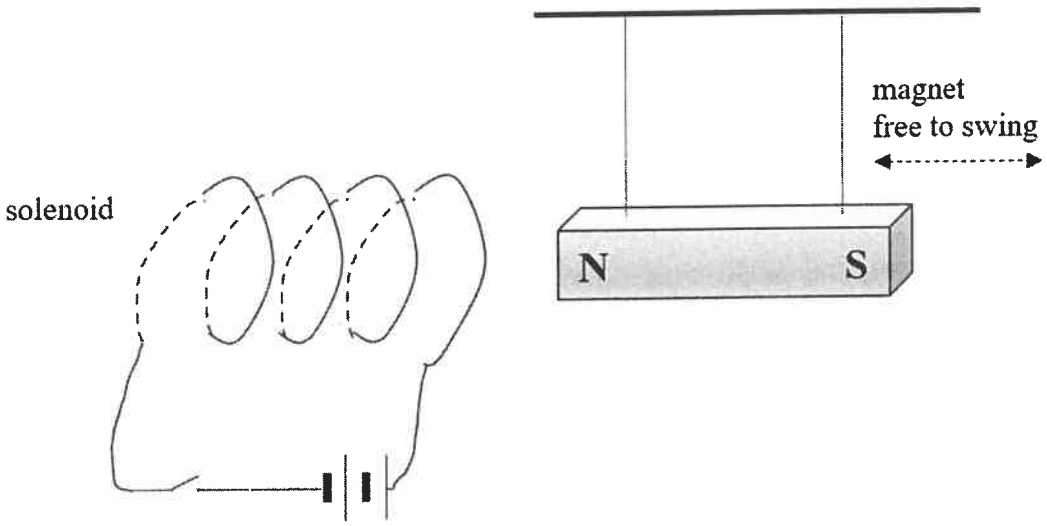
Which of the following statements is correct when the bike is on the ramp?

A) The magnitude of the normal force on the bike is constant
B) The normal force on the bike is the bikes centripetal force
C) The normal force on the bike is equal in magnitude to the bikes weight force
D) The direction of the net force on the bike is towards the centre of the circle

Question 18

A solenoid is connected to a DC power source with a switch connected in series.

A magnet is placed near the end of the solenoid, suspended by cotton threads and free to swing.



At the instant that the switch is closed:

(A) back EMF would begin to be generated in the solenoid and the magnet would swing to the left.
(B) a surge of current would flow through the solenoid and the magnet would not move.
(C) a back EMF would be generated in the solenoid and the magnet would not move.
(D) a surge of current would flow through the solenoid and the magnet would swing to the right.

Question 19

Laser light with a wavelength of 620 nm was passed through double slits with a separation of 60 μm. The screen was placed 2.00 m behind the slits. How far from the centre of the central maximum is the next bright spot in the interference pattern on the screen?

(A) 21 cm

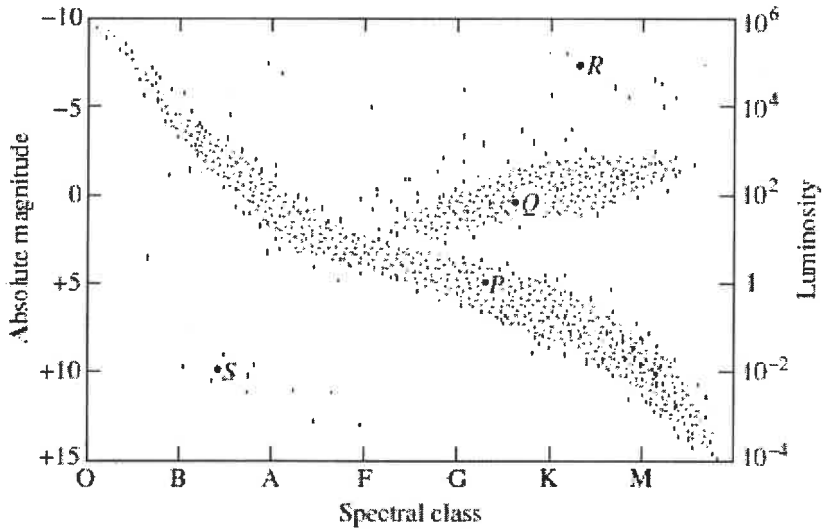
(B) 10 cm

(C) 1.0 cm

(D) 2.1 cm

Question 20

Four Stars PQRS are labelled on the Hertzsprung Russell Diagram



Which statement is correct?

A) R is a blue star whereas S is a red star

B) S has a greater luminosity than Q

C) P is at a more advanced state of its evolution than R

D) S has a higher surface temperature than R

Question 21 (5 marks)

(a) In the past, Earth's rotation was much faster than it is today.

Calculate the apparent weight of a 60.0 kg person standing on the equator if Earth's rotational period was 4 hours exactly. **3**

Marking Criteria	Marks
• Correct calculations made with correct answer supplied	3
• Calculations of F_c made OR • an error made in otherwise correct calculations	2
• one correct step shown	1

$$W = mg - F_c$$
$$= m(g - \frac{v^2}{r})$$
$$= 60(9.8 - \frac{(2.78\times10^3)^2}{6.371\times10^6})$$
$$= 515 \text{ N}$$

where $$v = \frac{2\pi r}{T}$$
$$= \frac{2\pi \times 6.371\times10^6 \text{ m}}{4\times60\times60 \text{ s}}$$
$$= 2.78\times10^3 \text{ m s}^{-1}$$

(b) Identify and describe the effects of two other factors which affect the gravitational field strength on the surface of the earth (2 marks)

2 marks: two factors identified and explained

1 mark: 2 identified or 1 identified and explained or 1 identified.

e.g. Elevation – higher ground means being further from the centre of the earth, and as $F_G = G\frac{Mm}{r^2}$ being further from the centre results in a lower gravitational field strength.
Being over more dense crust such as a mineral deposit may also increase the gravitational field strength due to the concentration of mass closer to that region of the surface.

While the question was asking for changes particular to the earth as it exists (eg local density and elevation) students who referred to the effect of mass of the earth or its radius AND also described the nature of that interaction were given a concessional mark (1 out of 2).

Question 22 (5 marks)

A proton entered a uniform magnetic field that had a magnitude of 0.80 T. The initial velocity of the proton was 3.3×10^{6} m s^{-1} perpendicular to the magnetic field.

(a) Explain why the proton travelled in a circular path at a constant speed after entering the magnetic field (2 marks)

Criteria	Marks
● Explains that the force exerted on the proton is always perpendicular to its velocity producing a centripetal acceleration with a constant rate of change in velocity directed to the centre of motion because the magnetic field is constant	2
● Applies a good understanding of the behaviour of the proton in a constant magnetic field to explain the resultant motion of the proton is circular with a constant rate of change in velocity directed to the centre of motion	1

Sample answer

Since the movement of the proton is always perpendicular to the force produced by the constant magnetic field on the proton, magnetic forces do no work and the particle's velocity stays constant. Since the force is F = qvB in a constant magnetic field, a charged particle feels a force of constant magnitude always directed perpendicular to its motion. That results in the proton undergoing a circular motion.

(b) Determine the radius of the circular path taken by the proton. (3 marks)

Criteria	Marks
● A correct response showing relevant calculations	3
● An incorrect response with one incorrect substitution	2
● A response that equates the centripetal and magnetic forces	1

Sample answer

The magnetic force is F = qvB in a constant magnetic field,

The centripetal force is produced by that magnetic force. $F = \frac{mv^2}{r}$

Equating the two forces

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

$$r = \frac{1.673 \times 10^{-27} \times 3.3 \times 10^{6}}{1.602 \times 10^{-19} \times 0.8}$$

$$r = 4.31 \times 10^{-2} m$$

Question 23 (2 + 3 + 4 = 9 marks)

Question 23 Part 1 (2 marks)

The Earth can be modelled as a black body. The average surface temperature of Earth is about 15 °C.

(a) What is the peak wavelength of the radiation emitted by Earth? (1 mark)

(a) What is the peak wavelength of the radiation emitted by Earth?

$$\lambda_{max} = \frac{b}{T} = \frac{2.89 \times 10^{-3}}{273+15} = 1.0 \times 10^{-5}\ m$$

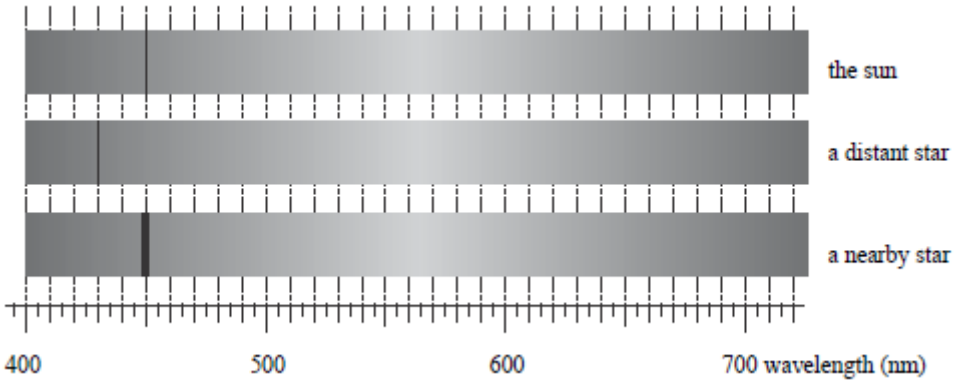
or 10 μm

(b) To which part of the electromagnetic spectrum does this peak wavelength correspond? (1 mark)

infrared

Question 23 Part 2 (3 marks)

Light from the sun is passed through a spectroscope to produce a visible spectrum. A student views this spectrum and observes a number of dark lines as shown below. In the diagram only one of these dark lines due to hydrogen is shown.



The position of this hydrogen line in the visible spectrum is shown for the sun, a distant star and a nearby star.

(a) Explain why the line is in a different position for the distant star compared to the sun and give possible reasons for the line from the nearby star having a different shape from that of the sun. (3 marks)

The light has a shorter wavelength, that is a blue shift which means that it is travelling towards us.

The star may be rotating on its own axis or have a high density.

For part (a) concessional marks were awarded if the spectral shift referred to a doppler shift (even if the shift were in the wrong direction). Since star density may also affect the width of observed spectra answers referring to a greater concentration of fuel (H) may have also been awarded a concessional mark).

Question 23 Part 3 (4 marks)

The experiment showing interference of light passing through two narrow slits is known as Young's double slit experiment. Young carried out the experiment in 1801 and the presence of the light and dark banded interference pattern was regarded as strong evidence to support the wave model of light.

For a maximum:

$d\sin\theta = m\lambda = \frac{dx}{L}$ where:

λ = wavelength
L = distance from slits to screen
d = distance between the two slits
x = distance from the central maximum
θ = the angle from the central maximum
m = integer: 0 for the central maximum, 1 for the first maximum, etc.

For a minimum:

$d\sin\theta = \left(m - \frac{1}{2}\right)\lambda = \frac{dx}{L}$ where:

m = 1 is the first dark band, m = 2 is the second dark band, etc.

Laser light of wavelength 650 nm is used in a double slit experiment. The distance between the double slits and the screen is 38.5 cm. The double slits are 0.085 mm apart.

(a) What is the angle of the first order bright band. (1 marks)

$$(a)\ d\sin\theta = m\lambda = \frac{dx}{L} \quad 0.085 \times 10^{-3} \times \sin\theta = 1 \times 650 \times 10^{-9} \quad \sin\theta = 7.65 \times 10^{-3} \quad \theta = 0.44^{0}$$

(b) What is the distance from the central band to the first order bright band. (1 marks)

$$(b)\ \sin\theta = \frac{x}{L} \qquad \sin 0.44 = \frac{x}{0.385} \quad x = 2.96\ mm$$

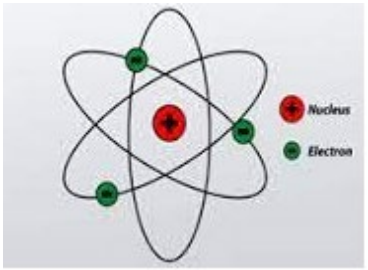
(c) How would the pattern change if a laser of wavelength 550 nm was used? Justify your response. (2 marks)

(c) If a shorter wavelength laser is used then the separation of the bands would change.

$$\frac{dx}{L} = \frac{0.085 \times 10^{-3} \times X}{0.385} = 1 \times 550 \times 10^{-9}.$$ *This gives a separation of 2.49 mm.*

Concessional marks were awarded ofr a correct identification of what would happen to the spectral pattern together with a justification. E.g. closer together as the separation angle would decreas since it is linearly related to wavelength.

Question 24 (3 + 5 = 8 marks)

Rutherford's Model of the Atom Characteristics & Features	
The labelled diagram shows the model of the atom proposed by Rutherford.	

Outline the evidence or conclusions forming or supporting the basis of his model

State observations or features Rutherford's model could not account for.

3 marks: links multiple points of evidence supporting Rutherford's model and gives multiple observations or features not accounted for.

2 marks links to evidence supporting Rutherford's model and a feature unaccounted for

To be awarded multiple marks it was not enough to simple describe the diagram

Sample answer:

Geiger and Marsden bombarded thin layers of gold foil with alpha particles and determined the scattering pattern of the particles by counting and measuring the scintillations on a fluorescent screen through a microscope. The results did not agree with the predictions based on the Thomson model. Rutherford proposed a model with most of the atom being empty space, based on the large number of alpha particles that passed straight through with no deflection. Some of the α-particles were deflected by very small angles and a very small number were deflected by 180°. Rutherford stated that the positive charge in an atom could not be uniformly distributed but had to be concentrated in a very small volume in the centre of the atom to produce the deflection pattern obtained by Geiger and Marsden. Only a concentration of both positive charge and mass could have resulted in any alpha particles being reflected back to the source.

Not accounted for: isotopes, atomic mass not correct (resolved by Chadwick and the neutron), specific spectral lines, becquerel predicament (EMR emission and collapse of electron into nucleus)

Q 24 (5 marks)

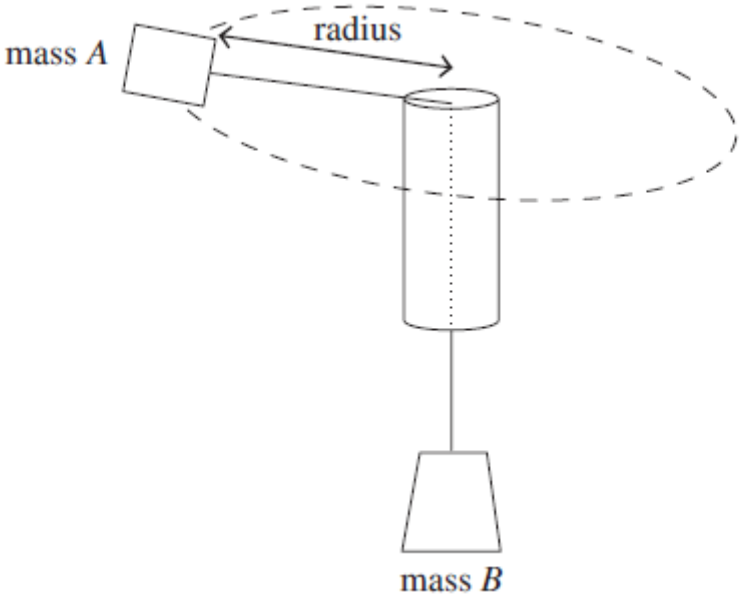
The work of Bohr, de Broglie and, later, Schrödinger demonstrated that the quantum mechanical nature of matter was a better way to understand the structure of the atom. How does the nature of the electron proposed in each of the three models developed by Bohr, de Broglie and Schrödinger differ and what were the post deBroglie views on the physical nature of the electron? (5 marks)

Marking Criteria	**Marks**
• Shows a comprehensive understanding of how the nature of the electron differs between the THREE models and incorporates uncertainty or definitional inconsistency into the reality of wave – particle duality (Heisenberg Uncertainty Principle & its inferential consequences or some significant reference to probabilistic views and difficulties in their interpretation).	5
Describes the nature of the electron in each model showing a sound understanding of the differences	4
• Outlines the nature of the electron in TWO models OR • Identifies a feature of the electron in each of the THREE models showing some understanding of the differences	3
• Identifies features of the electron in the model(s)	2
• Provides some relevant information	1

Bohr proposed that the electron a negatively charged particle orbits the nucleus at quantised energy levels. De Broglie's model subsequently proposed that the electron instead had a dual wave/particle nature, and existed in stable standing waves around the nucleus. In contrast, Schrödinger's model described the electron as having a wave nature with properties that could be predicted by his wave equation. The dual wave particle nature of the electron (a quantum entity) inevitably leads to definitional inconsistencies between particle and wave properties when interpreted in individual circumstances. Heisenberg dealt with this in contemplation of his uncertainty principle which precludes ultimate knowledge of certain paired variables. Schrodinger acknowledged some philosophical paradoxes arising from thought experiments such as the 'cat in a box' problem.

Question 25 (9 marks)

A student conducted several tests on circular motion in accordance with the diagram



Mass A was swung on a circular path and mass B provided the necessary weight force

The student measured the time for mass *A* to make 10 rotations. Averaged results after conducting three trails for each of the test conditions are presented in each row of the table.

Table: Average measured time for mass A to make 10 rotations

Test	Mass of A (g)	Mass of B (g)	Radius of circle (m)	Average Time for 10 rotations (s)
1	50	50	0.125	10
2	50	50	0.200	13
3	50	50	0.250	14
4	50	50	0.375	17
5	50	75	0.125	8
6	50	100	0.125	7
7	50	200	0.125	5
8	125	50	0.125	16
9	250	50	0.125	22
10	750	50	0.125	27

(a) Outline THREE different experiments conducted using the information from the table. (3 marks)

(a)	Experiment 1: Examining the relationship between the mass of mass B and the period of rotation when keeping the mass of mass A and the radius of the circle constant (Data taken from Tests 1, 5, 6 and 7). Experiment 2: Examining the relationship between the mass of mass A and the period of rotation when keeping the mass of mass B and the radius of the circle constant (Data taken from Tests 1, 8, 9 and 10). Experiment 3: Examining the relationship between the period of rotation and the radius when keeping the mass of mass A and the mass of mass B constant (Data taken from Tests 1, 2, 3 and 4).	Mod 5 Advanced Mechanics PH12–6, PH12–12 Band 3 • Outlines THREE experiments . . . . .3 • Outlines TWO experiments. . . . . .2 • Outlines ONE experiment 1

(b) For Tests 5, 6 and 7, identify the dependent, independent and TWO controlled variables. (3 marks)

(b)	Dependent variable: time to complete 10 rotations Independent variable: mass of B Controlled variables: mass of A, radius of circle *Note: The dependent variable is the thing that is measured, the independent variable is the thing that changes and the controlled variables are the things that are kept the same.*	Mod 5 Advanced Mechanics PH11, PH12–12 Bands 3–4 • Identifies the independent variable. AND • Identifies the dependent variable. AND • Identifies TWO controlled variables . . . . . .3 • Identifies THREE variables. . . . . .2 • Identifies TWO variables. 1

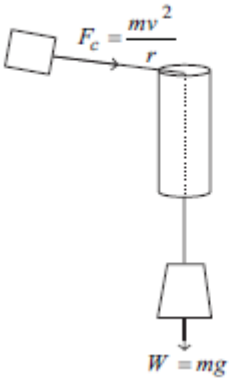
(c) If the student repeated all of the tests with 20 rotations would the experiment that used 10 rotations or the experiment that used 20 rotations be more accurate and reliable? Justify your answer. (1 mark)

1 mark – identifies the more accurate experiment and gives an appropriate reason

The experiment that measured 20 rotations would be more reliable and accurate than the experiment that measured 10 rotations. This is because 20 rotations provides for more circular trips and divides out timing errors thus yielding a more accurate average measurement.

(d) Assuming there are no frictional forces, derive an equation for the orbiting radius of mass *A* in terms of *v* and *g*. Justify your answer. (2 marks)

(d) From a free-body diagram, the centripetal force required is due to the hanging mass.



Mod 5 Advanced Mechanics
PH12–12 Bands 4–5

- Accurately derives an equation from the correct formulas.

AND

- Gives a justification for the derivation 2

- Any ONE of the above points 1

$F_{ucm} = m_A v^2/r$ $Fw = m_B g$

$F_{ucm} = Fw$

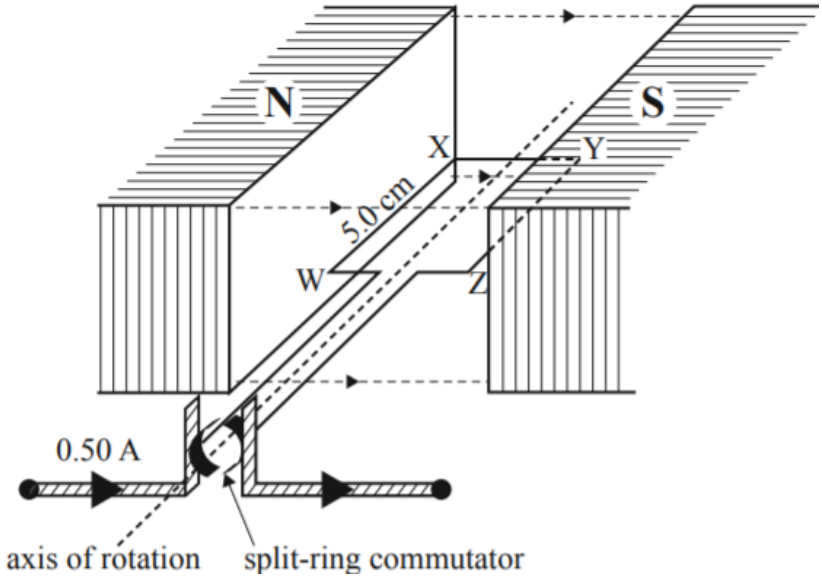
$m_A v^2/r = m_B g$

$r = m_A v^2/ m_B g$

$r = m_A/m_B\, v^2/ g$ (if the masses are equal then $r = v^2/ g$)

Question 26 (4 marks)

A model representing a motor is shown below.



(a) What type of motor is it? (1 mark)

DC MOTOR

(b) While in the position shown in the diagram, a current of 0.50 A is flowing in the rotating coil. The coil has 10 turns and the magnetic field across the coil has a strength of 1T. The side WX of the rectangular coils has a length of 5.0 cm and the side XY is 3 cm. Calculate the magnitude of the maximum torque on the coil and the direction of its rotation. (3 marks)

Criteria	Marks
• A correct calculation of the maximum torque and a correct determination of the direction of coil rotation	3
• A correct calculation of the maximum torque and an incorrect determination of the direction of coil rotation or an incorrect calculation of the maximum torque due to a substitution error with a correct determination of the direction of coil rotation	2
• A correct determination of the direction of coil rotation	1

Sample answer

$$\tau_{max} = nIAB = 10 \times 0.5\text{x } (0.05\ x\ 0.03)\text{ x1 } = 7.5 \times 10^{-3} Nm$$

$$\tau_{max} = nIAB = 10 \times 0.5 \times 0.05 \times 0.03 = 7.5 \times 10^{-3} Nm$$

From the right hand rule the coil will rotate in an anticlockwise direction.

Question 27 (5 marks)

UV light of frequency 2.4 x 1015 Hz strikes magnesium whose work function is 3.7 eV.

(a) What is the energy transferred by each photon? (1 marks)

$E = hf = 6.626 \times 10^{-34} \times 2.4 \times 10^{15} = 1.6 \times 10^{-18}\ J$ (if the calc done in ev then 9.93 eV)

(b) Calculate the maximum kinetic energy of the ejected electrons. (1 marks)

$K_{max} = hf - \phi = 1.6 \times 10^{-18} - 3.7 \times 1.6 \times 10^{-19}\ J = 1.0 \times 10^{-18}\ J$

(if calc done in ev then 6.226 eV)

(c) Calculate the maximum speed of the electrons. (1 marks)

$K_{max} = \frac{1}{2} mv^2$
$1.0 \times 10^{-18} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$
$v = 1.5 \times 10^{6}\ m\ s^{-1}$

(d) Calculate the stopping voltage for the electrons. (2 marks)

$eV_s = K_{max}$
$1.6 \times 10^{-19} \times V_s = 1.0 \times 10^{-18}$
$V_s = 6.25\ V$

NOTE if the calcs were done in eV then this final set is trivial (see part (b))

(a) What is the energy transferred by each photon? (1 marks)

$E = hf = 6.626 \times 10^{-34}\ Js \times 2.4 \times 10^{15}\ s = 1.59024 \times 10^{-18}\ J$

$E = hf = 4.136 \times 10^{-15}\ eVs \times 2.4 \times 10^{15}\ s = 9.93\ eV.$

(b) Calculate the maximum kinetic energy of the ejected electrons. (1 marks)

$9.93\ eV - 3.7\ eV = 6.226\ eV$

$1.59024 \times 10^{-18}\ J - 3.7 \times 1.6 \times 10^{-19} = 9.98 \times 10^{-19}\ J.$

(c) Calculate the maximum speed of the electrons. (1 marks)

$KE = \frac{mv^2}{2} \Rightarrow v = \sqrt{\frac{2 \times KE}{m}} = \sqrt{\frac{2 \times 9.98 \times 10^{-19}}{9.1 \times 10^{-31}}}$

$= \sqrt{2.19 \times 10^{12}} = 1481015$

$= 1.5 \times 10^{6}\ ms^{-1}$

(d) Calculate the stopping voltage for the electrons. (2 marks)

$eV_s = KE_{max}$

$KE_{max} = 6.226\ eV$

$V_{stop} = 6.226\ eV$

$KE_{max} = 9.98 \times 10^{-19}\ J$

6.3 V.

6.25 V.

Question 28 (6 marks)

(a) Account for the release of energy in both the processes of fission and fusion. Support your answer with examples. (3 marks)

Criteria	Marks
• Describes clearly the process of fission and fusion • Provides an example for each • Explains the source of the energy released	4–5
• Outlines the process of fission and fusion with examples or with identification of energy source	2–3
• Indicates difference between fission and fusion	1

Sample answer: In both fission and fusion reactions, the products have more binding energy than the reactants. Binding energy per nucleon is greatest for element 56, iron after which it decreases to uranium. In fusion, small elements join to form larger nuclei, increasing binding energy. This occurs in the Sun where hydrogen atoms become helium. In fission, large nuclei break apart to form smaller "daughter" nuclei, also with more binding energy. Uranium isotopes bombarded with neutrons break up, producing the energy used in atom bombs and nuclear reactors.

The binding energy change is equivalent to the mass decrease of the products compared to the reactants multiplied by c^2 as $E = mc^2$. This is the energy released in the reactions.

(b) When 2 protons fuse to form a deuterium nucleus, a positron and a neutrino are released. Calculate the binding energy per deuterium nucleus formed, assuming the mass of a neutrino to be negligible. (Assume the mass of a deuterium nucleus to be 3.3435 x 10-27 kg). (3 marks)

Marking Criteria	Marks
• Energy calculated correctly	3
• $E=mc^2$ identified • That a difference in mass exists is identified	2
• A correct step towards the answer is provided	1

Mass deficit = (mass of 2 protons) – (mass of a deuterium nucleus + positron)
$= 2 \times 1.673 \times 10^{-27}$ kg) – (3.3435×10^{-27}kg + 9.109×10^{-31} kg)
$= 1.589 \times 10^{-30}$ kg

Binding energy: $E = mc^2$
$= 1.589 \times 10^{-30} \times (3.00 \times 10^{8})^2$
$= 1.430 \times 10^{-13}$ J per nucleus

Question 29 (6 marks)

(a) Two projectiles are launched with the same initial speeds and angles to the horizontal. Projectile A has a mass of m, while projectile B has a mass of 2m. Explain why the two projectiles will have the same range. (2 marks)

Marking Criteria	Marks
• complete explanation provided	**2**
• some relevant information provided, e.g. mass not included in motion eqns	**1**

The horizontal component of the projectiles' speed will remain constant for the flight, as a_x = 0.
The vertical acceleration of a projectile is equal to their acceleration due to gravity, regardless of the mass, thus they will have the same path and therefore the same range.

(b) The train line between Sydney and Newcastle is designed so that it can take slow moving freight trains as well as much faster passenger trains at speeds up to 100 km h^{-1}. The track has many tight curves along the route. For a section of track banked at 20° to the horizontal around a curve with a radius of 400 m, what is the design speed for a train?

Marking Criteria	Marks
• Design speed correctly calculated	**2**
• A step taken towards the correct calculation of the ideal speed	**1**

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

$$\tan 20° = \frac{v^2}{gr}$$

$$v = \sqrt{gr\tan 20°}$$

$$= 38 \text{ m s}^{-1}$$

Or 136.8 km/hour

(c) If a rocket is launched at 100 ms^{-1} at 45^{O} from its position on top of a 150 m high cliff determine its time of flight (2 marks)

Marking Criteria	Marks
• Correct TOF determined	**2**
• Some consistent application of quadratic formula or significantly correct working	**1**

$s = ut + \frac{at^2}{2}$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$s_x = u_x t - 4.9t^2$

$-150 = 50\sqrt{2}\, t - 4.9t^2$

$4.9t^2 - 50\sqrt{2}\, t - 150 = 0$

$t = \frac{50\sqrt{2} \pm \sqrt{(50\sqrt{2})^2 - 4(4.9)(-150)}}{2 \times 4.9}$

$$t = \frac{70.7107 \pm \sqrt{5000 + 2940}}{9.8}$$

$$= \frac{70.7107 \pm \sqrt{7940}}{9.8}$$

$$= \frac{70.7107 \pm 89.107}{9.8}$$

$$= \frac{159.82}{9.8}$$

$$= 16.31 \text{ seconds.}$$

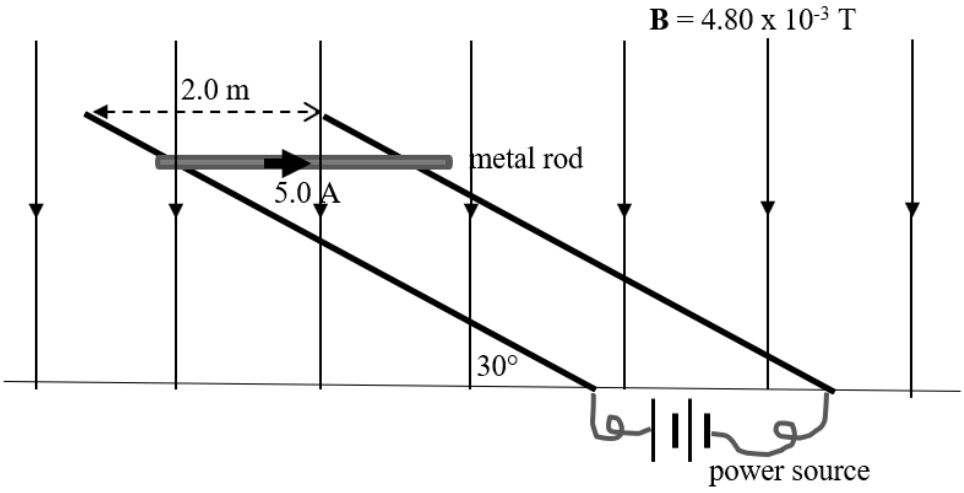
SOME CONSISTENT APPLN OF QUADRATIC FORMULA.

NOTE: it was possible to solve this via v = u + at yielding climb time to the maximum height and then then determine fall time off total fall distance – a couple of students correctly did that.

Question 30 (11 marks)

A straight metal rod sits on parallel metal tracks spaced 2.0 m apart which are angled at 30° to the horizontal. The apparatus exists within a vertical magnetic field of strength 4.80 x 10^{-3} T, as shown.

A current of 5.0 A flows through the metal rod.



(a) Neglecting the effects of gravity, what force would act on the metal rod as it sits motionless on the rails? (2 marks)

Marking Criteria	Marks
• Correct magnitude and direction of force provided	**2**
• Magnitude of force only OR • magnitude and direction of force given with an error made	**1**

$F = lI \cdot B$
$= 2.0 \times 5.0 \times 4.80 \times 10^{-3}$
$= 4.80 \times 10^{-2}$ N horizontally to the left (or similar statement of direction)

(b) Suggest a procedure that could be used to find the mass of the metal rod, given that gravity is taken into account but friction is ignored. (3 marks)

Marking Criteria	Marks
• Appropriate procedure outlined with reference to the forces involved	**3**
• Several appropriate steps outlined with reference to some of the forces involved	**2**
• An aspect of an appropriate procedure outlined, a reference to a force included	**1**

The component of the metal rod's weight acting down the inclined rails is $mg\sin\theta = 4.9m$ (as $\theta = 30°$)
By varying the current flowing through the rod, the force $F = lI \cdot B$ opposes the force down the rails until the rod does not slide. The component acting against the motion is $lIB\cos\theta$ where θ is the angle of inclination of the rails, so: $m = lIB\cos30°/4.9$ where l= 2.0 m and B is 4.80 x 10^{-3}T

C) Discuss the validity of this statement and illustrate its meaning with reference to specific examples:

"Lenz's law is simply a consequence of the conservation of energy."

(4 marks)

Marking Criteria	Marks
• Lenz's law is explained clearly with at least 2 specific examples cited • Conservation of energy used to explain Lenz's law in examples used	**4**
• Lenz's law is explained with reference to a specific example • Conservation of energy linked to outcome predicted by Lenz's law	**3**
• Lenz's law is identified and one example cited	**2**
• An aspect of Lenz's law is referenced	**1**

Answers may include:
Lenz's law stated that the direction of an induced current is such that it opposes the change that is inducing the current. When a bar magnet is approaching an end of a solenoid, the induced EMF in the coils of the solenoid cause a current to flow in the coils if an electric circuit exists. The direction of this current produces a magnetic field that repels the approaching magnet. The direction of this current is predicted by Lenz's law. The electric energy produced in the solenoid's coils originated from the work done in pushing the bar magnet towards the coil. If the current flowed in the other direction, the magnet would be drawn towards the solenoid and obtain kinetic energy with no other energy input into the system, violating the conservation of energy. Electromagnetic braking is also predicted by Lenz's law – if it were the other way, the braked disc would not brake but rotate faster, again obtaining energy with no other energy input.

(d) Describe magnetic flux and identify whether is it a vector or a scalar? (2 marks)

1 mark correct definition of magnetic flux

1 mark identifies it as a vector

Magnetic Flux is defined as the total amount of magnetism (typically crossing a surface). It is a vector as magnetic fields have magnitude and direction

Question 31 (6 marks)

(a) A spacecraft is travelling at 0.87c between Earth and Teegarden's Star, a distance of 12.51 lightyears from Earth's frame of reference. Calculate the distance of the journey in the spacecraft's frame of reference. (2 marks)

$$L_v = L_0\sqrt{1-\frac{v^2}{c^2}}$$

$L_v = 12.51\sqrt{1-0.87^2}$ =6.168077035 or 6.2 light-years

(some unnecessarily converted 1 light-year = 9.4607×10^{15} m so answer is 5.8×10^{16} m)

Criteria	Mark
Correct answers	2
Single mistake: Answer must still be a distance • Length contraction equation is wrong equation, but right data used. • Right equation but error in calculation like missing square/square root	1

(b) Outline how special relativity imposes a limitation on the maximum velocity of the spaceship. (1 mark)

1 mark: Relativistic momentum would approach infinity as v approaches c. This means that an infinite force would be required to accelerate it further, limiting the velocity.

(c) A muon is an elementary particle which decays into an electron. When at rest the decay time of a muon is 2.2 μs, but when observed moving at a relativistic velocity its decay time is measured as 8.8 μs. Explain how these muons provide evidence for Einstein's theory of special relativity and hence calculate the speed of the muons. (3 marks)

Explain: Relate cause and effect; make the relationships between things evident; provide why and/or how
Note: There is no mention of muons created in the atmosphere reaching the surface. You are just comparing two different decay times. Many answers are assuming information with no context that they should be explaining or excluding.

The question is asking you to show how the observation

- that muons decaying slower when moving

supports Einstein's special theory of relativity

- where he predicts that time dilation will occur as a consequence of his postulate that light will travel the same velocity in all inertial reference frames
- The moving muons are experiencing slower time (to external observer)
- Einstein's equation relates the time dilation to the speed, and it can be calculated using

$$t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

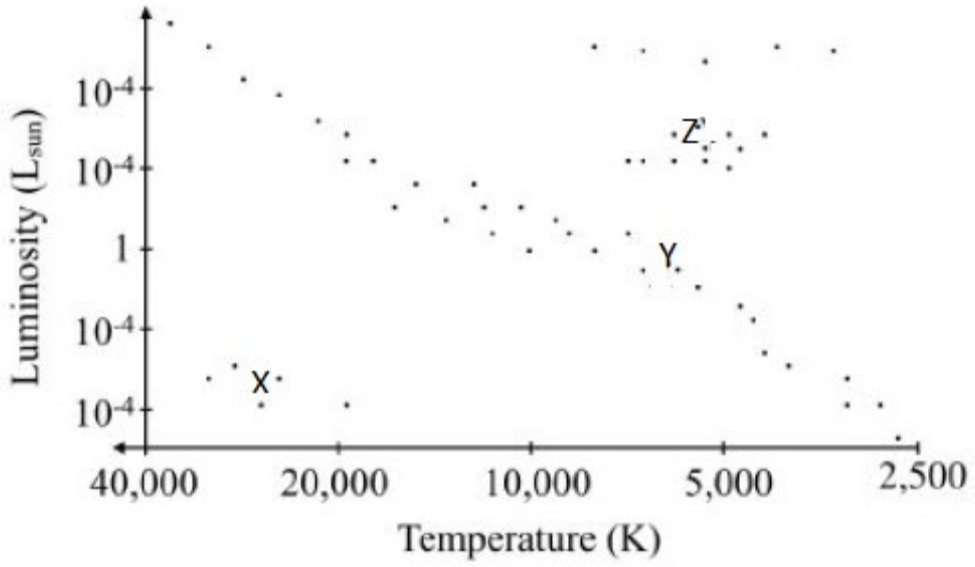
$\left(\frac{t_0}{t_v}\right)^2 = 1-\frac{v^2}{c^2}$ and $\left(\frac{v}{c}\right)^2 = 1-\left(\frac{t_0}{t_v}\right)^2$ and $\frac{v}{c} = \sqrt{1-\left(\frac{t_0}{t_v}\right)^2} = \sqrt{1-\left(\frac{2.2}{8.8}\right)^2} = \sqrt{0.9375}$

So $v = 0.968245837c$ or $v = 0.968c$ or $v = 290473751\ \text{ms}^{-1}$ or $2.9 \times 10^8 \text{ms}^{-1}$

Criteria	Mark
Identify that the decay time difference is a prediction of Einstein and is therefore evidence for it (i.e. identifying it is because of time dilation). Must be more than what is given in question. AND A more detailed explanation directly stating what Einstein's prediction is (moving clocks run slower) and linking to how the moving muons will be observed (by external observer) to be experiencing less time (increasing decay time). Must be clear about which frame of reference or observer is being referred to. Better answer link this to consequences of postulates. AND Being able to correctly calculate the velocity using Einstein's time dilation equation	3
TWO of the above (i.e. not specifying slowing time of moving observer)	2
ONE of the above	1

Question 32 (6 marks)

Question 32 refers to the HR Diagram: WARNING BELOW DIAGRAM VERTICAL SCALE MISTAKENLY PRINTED AS 10^{-4} REPEATING – DO NOT REUSE DIAGRAM (BHZ)



(a) Identify what star luminosity is and also describe and justify the nature of the numerical scales adopted on the axes shown (2 marks)

Luminosity is power output measured in watts. (1 marks OWTTE)

The scales adopted are log scales to accommodate the very wide range in values observed. (1 marks OWTTE)

(b) Identify the types of stars characteristically at the locations marked X, Y and Z in the H-R Diagram. Also outline the most likely dominant nucleosynthesis reactions at Y (4 marks)

X – WHITE DWARFS

Y – MAIN SEQUENCE

Z – GIANT (or Red Giant will do)

X – fusion of hydrogen to helium