



TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

2021

DO NOT REMOVE PAPER FROM EXAM ROOM

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Centre Number

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Student Number

Physics

Morning Session
Tuesday, 3 August 2021

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Use Multiple-Choice Answer Sheet provided
- NESAA-approved calculators may be used
- Data, formulae sheets and Periodic Table are provided SEPARATELY
- Write your Centre Number and Student Number on the top of this page

Total marks - 100

Section I Pages 2-13

20 marks

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

Section II Pages 14-32

80 marks

- Attempt Questions 21-34
- Allow about 2 hours and 25 minutes for this section

Disclaimer

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Section I

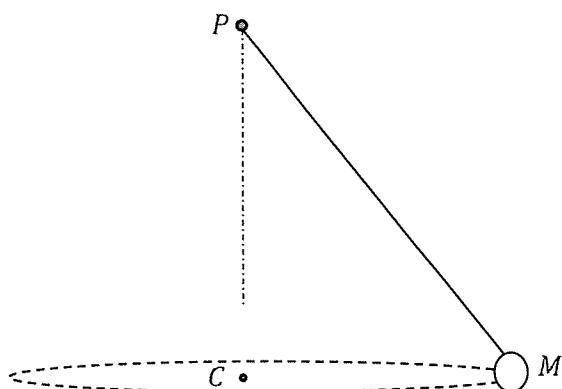
20 marks

Attempt Questions 1–20

Allow about 35 minutes for this part

Use the Multiple-Choice Answer Sheet for Questions 1–20.

- 1 A conical pendulum consists of a mass, M attached by a string to a point, P. The pendulum moves in a uniform circular motion around a point C.



The direction of the total force acting on M is always

- A. towards P.
- B. towards C.
- C. vertically downwards.
- D. at a tangent to the circular motion.

- 2 A proton moves into a magnetic field as shown in the diagram below.



The direction of the force on the proton is

- A. up the page.
 - B. into the page.
 - C. down the page.
 - D. out of the page.
- 3 The following images show the spectral lines of two stars.



Which choice below could correctly identify the stage in the stars' life cycle?

	Star X	Star Y
A.	Main sequence	Main sequence
B.	Main sequence	Red supergiant
C.	Red supergiant	Main sequence
D.	Red supergiant	Red supergiant

- 4 An electron bound to the nucleus of an atom may only possess certain discrete energies in what is now known as a quantum model for electron energy.

Which physical technique was the first to provide support for a quantum model of electron energy?

- A. Electron diffraction
- B. Emission spectroscopy
- C. Radioactive decay
- D. X-ray diffraction

- 5 An electrical substation uses a step-down transformer to convert a 13.2 kV supply to a 240 V supply for household usage. If the primary coil is 3850 turns, how many turns are in the secondary coil?

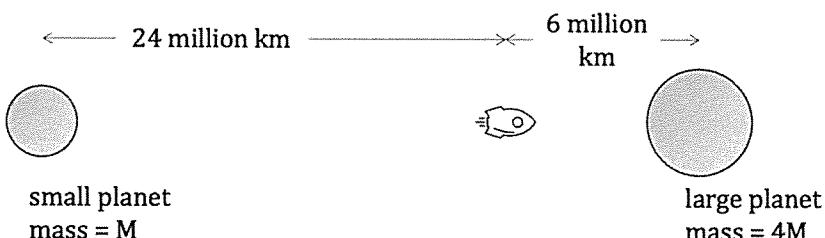
- A. 70
- B. 80
- C. 90
- D. 210

- 6 A space craft is travelling between two planets of mass M and $4M$.

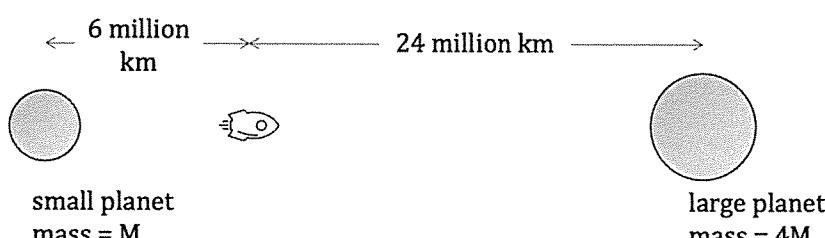
Which of the following diagrams represents the location of the space craft at which it will experience zero net gravitational force?

Diagrams are not drawn to scale.

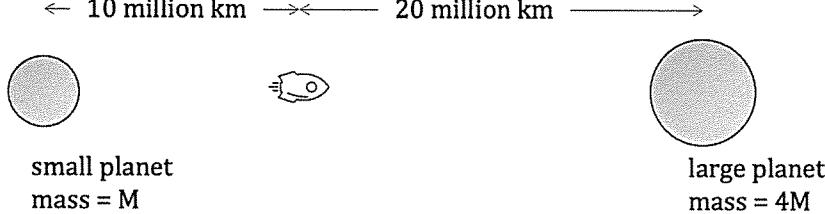
A.



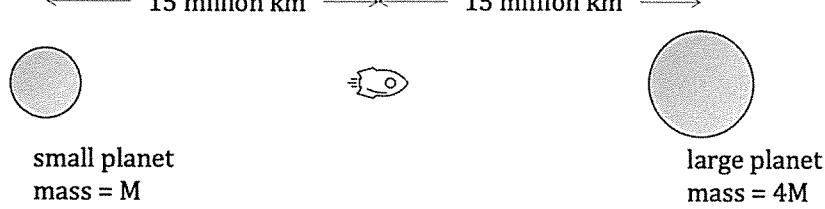
B.



C.



D.



- 7 Calculate the amount of energy released as a result of annihilation of an electron and positron.

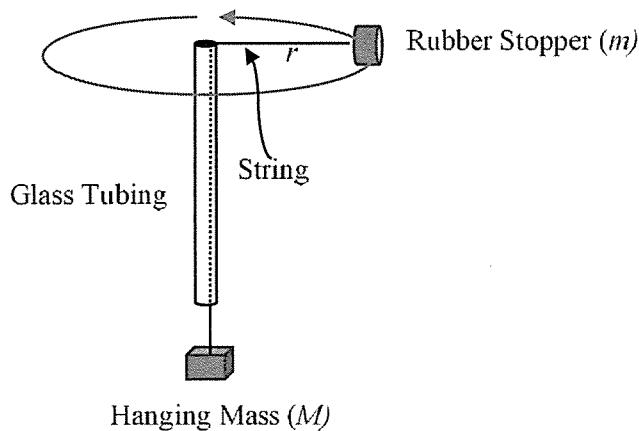
A. 0.0034 MeV

B. 0.511 MeV

C. 1.023 MeV

D. $3.400 \times 10^{-9} \text{ MeV}$

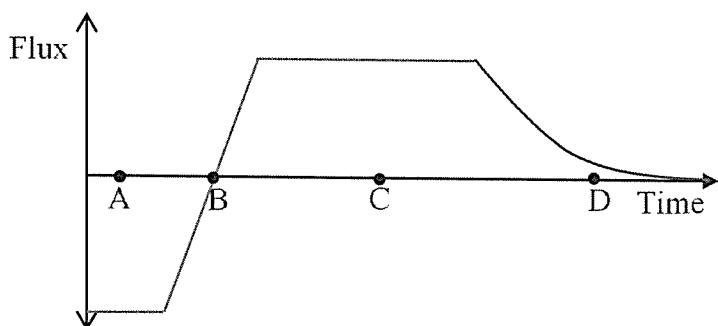
- 8 Nuclear fission is able to produce a large amount of energy because
- there is a large amount of energy required to refine uranium.
 - there is a mass defect where the mass of the products is greater than the mass of the reactants.
 - there is a mass defect where the mass of the products is less than the mass of the reactants.
 - although mass is conserved neutrinos are produced in the reaction.
- 9 A hanging mass of mass M is used to counteract the outward pull from a rubber stopper undergoing a horizontal circular motion as shown in the diagram. The rubber stopper has a mass m , and is travelling at a speed of v .



Assuming all friction is negligible, what expression could be used to find the hanging mass M ?

- $\frac{mv^2}{gr}$
- $\frac{mv}{gr}$
- $\frac{mv^2}{r}$
- $\frac{mv^2}{g}$

- 10** The graph below shows the variation of magnetic flux through a coil with time.



At which of the following times is the induced emf at a maximum?

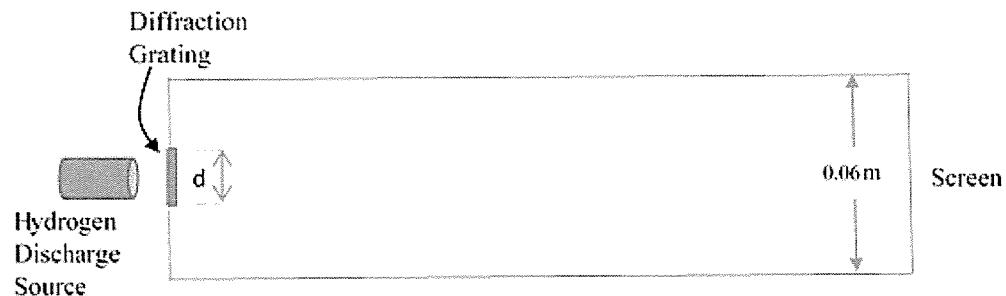
- A. A
 - B. B
 - C. C
 - D. D
- 11** An unstable nucleus has a half-life of 6.00 days when measured at rest. When moving at $0.9c$ relative to the observer, its half-life is equal to
- A. 1.89 days.
 - B. 2.62 days.
 - C. 13.76 days.
 - D. 18.97 days.

- 12** A small sample of the radioisotope Nitrogen-13 has a half-life of 10.0 minutes.

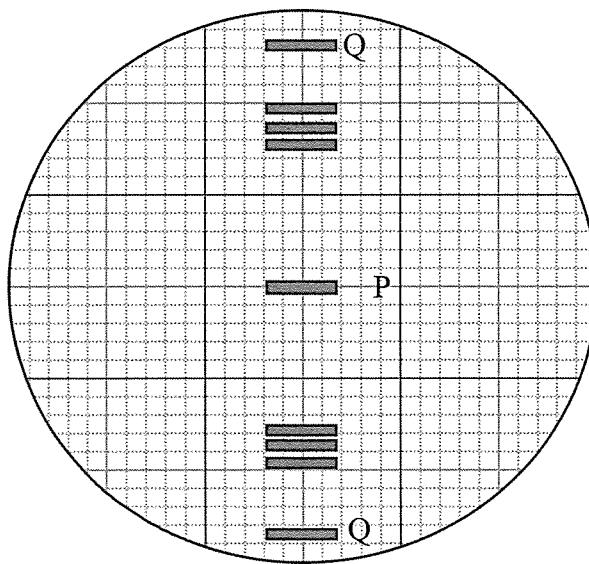
What percentage of undecayed nuclei are expected to remain after 5.50 minutes?

- A. 32%
- B. 44%
- C. 56%
- D. 68%

- 13 A student is using a spectroscope to observe the four smallest energy transitions in the Balmer Series of the hydrogen atom. A hydrogen lamp shines through a diffraction grating at one end of a tube, with a screen at the other end



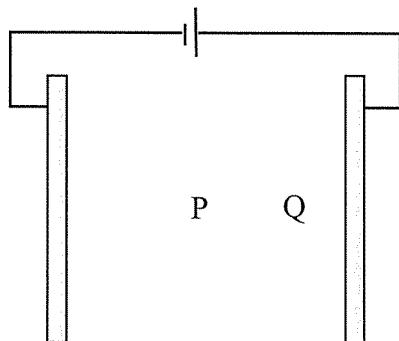
The student observes the following pattern on the screen. P is the central band.



What does the wavelength of light for bands Q represent?

- A. The jump from 3 to 2.
- B. The jump from 4 to 2.
- C. The jump from 5 to 2.
- D. The jump from 6 to 2.

- 14** Two metal plates are placed vertically in a vacuum aligned as shown below. Point P is midway between the plates. An electron is moving between the plates when the power is off.



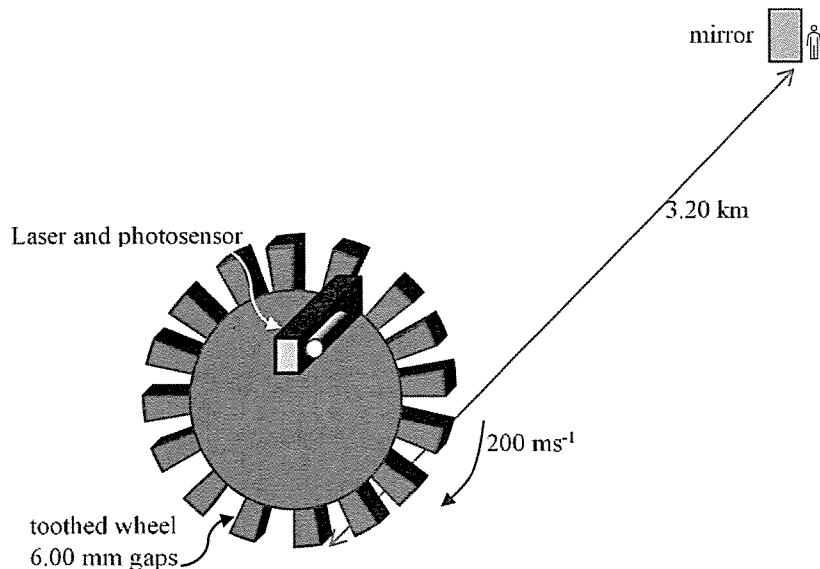
Which of the following options will result in the greatest particle acceleration when the potential difference between the plates is now switched on?

- A. An electron moving downwards from P
 - B. An electron moving to the left from P
 - C. An electron moving downwards from Q
 - D. All the choices result in the same acceleration
- 15** Technetium-99 is a medical radionuclide needed during certain bone scanning procedures. It is the result of parent radionuclide undergoing a single beta minus decay.

What is the name of the parent radionuclide?

- A. molybdenum-99
- B. molybdenum-97
- C. ruthenium-99
- D. ruthenium-97

- 16 A student is carrying out an experiment similar to Fizeau's experiment to measure the speed of light. He sets up a mirror on one headland and a laser and photosensor on another, 3.20 km away, positioned behind a toothed wheel, as shown. The laser light reflects off the mirror, passes between the teeth of the wheel and reaches the photosensor. The gaps between the teeth on the wheel are 6.00 mm wide.



During the night, the angular velocity of the toothed wheel is gradually increased from zero until the photosensor records no light. The student measures the speed of the teeth on the wheel to be 200 ms^{-1} at this point. Using this information, what should the student calculate the velocity of light to be?

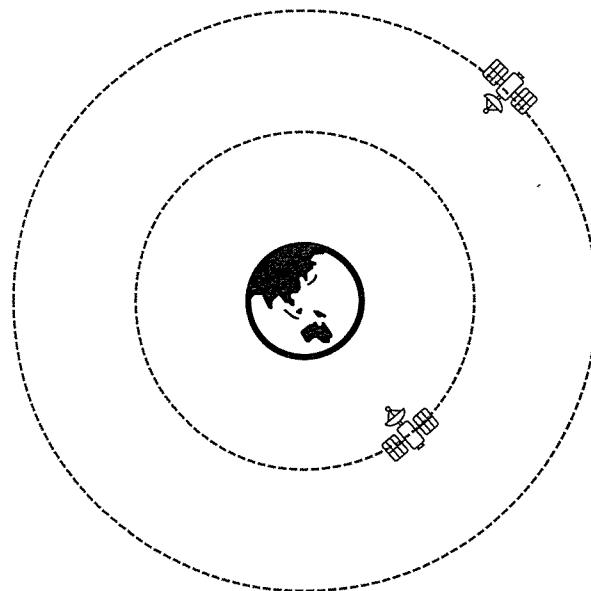
- A. $1.06 \times 10^5 \text{ ms}^{-1}$
- B. $2.13 \times 10^5 \text{ ms}^{-1}$
- C. $1.06 \times 10^8 \text{ ms}^{-1}$
- D. $2.13 \times 10^8 \text{ ms}^{-1}$

- 17** A student investigates the current flowing in a DC motor. Firstly, the power is switched on for one minute and the average current flowing through the coil is calculated. Secondly the power is continuously switched on and off for one minute. The student finds the average current in the first test was lower than the average current in the second test.

The best explanation is:

- A. The motor in test 2 is experiencing more friction as it speeds up and down. So more current is needed.
 - B. The motor in test 1 heats up more, this lowers the resistance in the coil of the motor. So less current is needed.
 - C. The motor in test 1 runs more smoothly and so experiences less changes in flux. This makes the current lower.
 - D. The motor in test 1 has a higher average angular speed and so experiences a greater change in flux. This makes the current lower.
- 18** A black body is heated to 5700 K and emits electromagnetic radiation. Determine the energy of the emitted photons of radiation with the wavelength of maximum intensity.
- A. 3.78×10^{-30} J
 - B. 3.91×10^{-19} J
 - C. 5.08×10^{-7} J
 - D. 5.90×10^{14} J

- 19 Two satellites, A and B, orbit the same planet with orbital periods T_A and T_B , respectively.



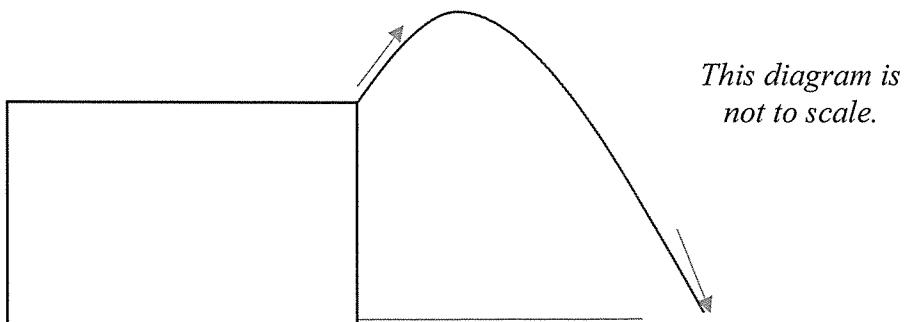
If the ratio of their orbital periods is given by:

$$\frac{T_A}{T_B} = 64$$

What is the ratio of the satellites' radii, $\frac{r_A}{r_B}$?

- A. $\frac{1}{16}$
- B. $\frac{1}{4}$
- C. 4
- D. 16

- 20** A spear is launched at 45° to the horizontal from a high cliff. The spear lands at 60° to the horizontal below the cliff. The spear reaches a maximum height after 1.5 seconds.



The total time of flight for the spear is

- A. 1.5 s.
- B. 3.0 s.
- C. 4.1 s.
- D. 4.7 s.

Section II

80 marks

Attempt Questions 21 - 34

Allow about 2 hours and 25 minutes for this section

- 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.
 - Section II extra writing space is provided on pages 33-34. If you use this space, clearly indicate which question you are answering.
 - SEPARATE writing booklets are available if required. If you use a SEPARATE writing booklet, clearly indicate which question you are answering by writing the question number before beginning the response.
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Question 21 (3 marks)

A space probe is in orbit around Mars at an altitude of 1200 km. To move to a higher orbit, small rocket engines are used to provide the energy required.

- (a) Compare the kinetic energy of the space probe in the lower and higher orbit. 1

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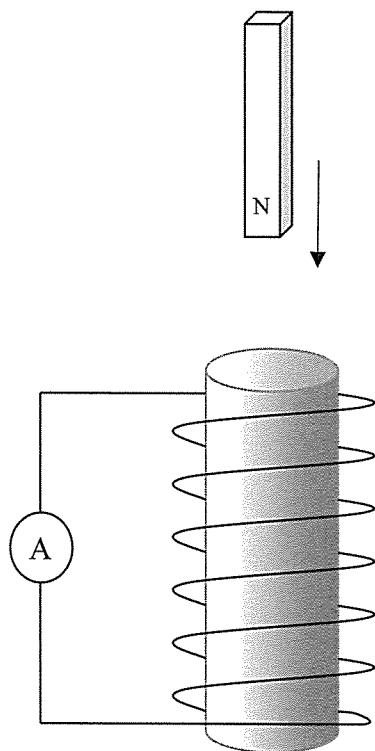
- (b) Explain why energy is required to move the space probe from a lower to a higher orbit. In your answer refer to the total energy of the satellite. 2

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Question 22 (5 marks)

- (a) A bar magnet enters a solenoid as shown in the figure below.

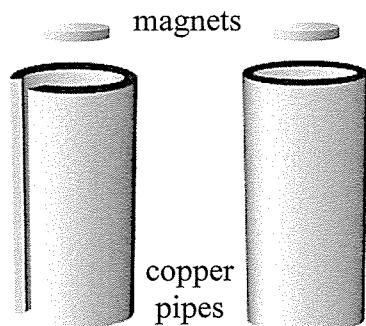
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Draw arrows on the diagram above to show the direction of the current induced in the coil **AND** the magnetic field produced as the magnet approaches.

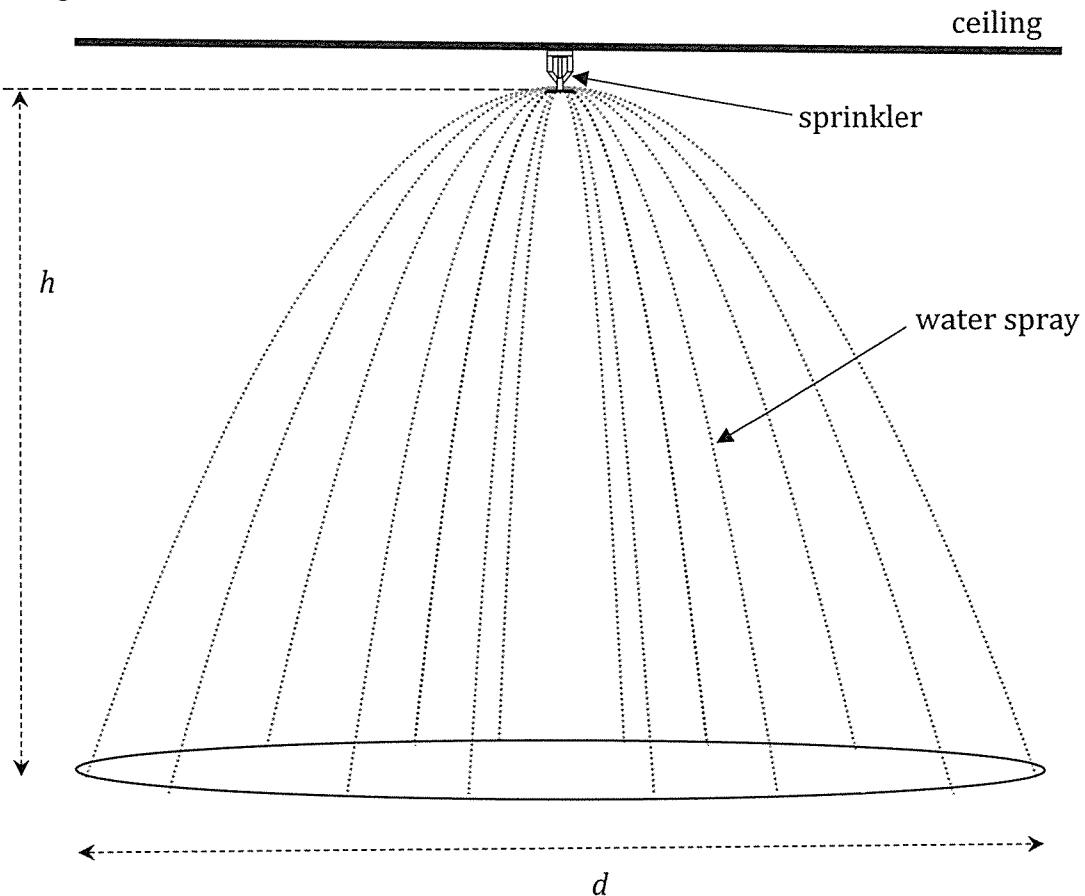
- (b) A cylindrical magnet is dropped through two copper pipes, one with a vertical slit, as shown in the diagram below. Describe and explain the difference in the motion of the TWO magnets.

3



Question 23 (7 marks)

A sprinkler is used to spray water over a fire to stop it from spreading. The fire sprinkler has a spray pattern that covers a circular section of diameter d on the floor. The sprinkler is mounted at height h above the floor as shown below.

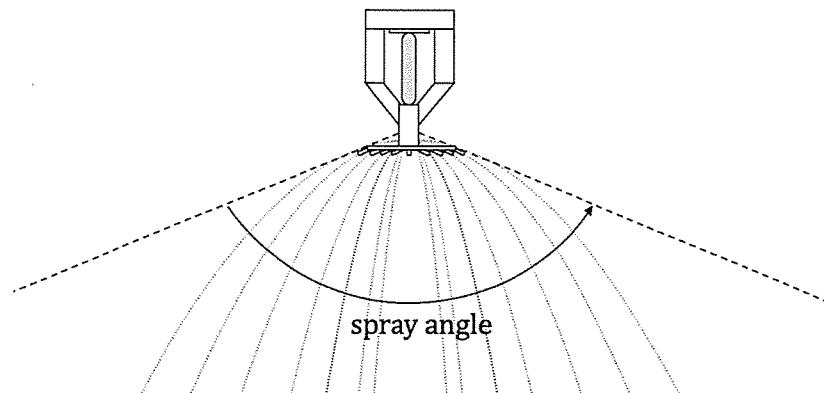


- (a) Assuming the water is initially directed horizontally, explain how the diameter of the spray pattern, d , changes with the speed of the water leaving the sprinkler. 3

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- (b) The sprinkler design can be modified to direct more water to a fire. This is done by reducing the spray angle of the sprinkler.

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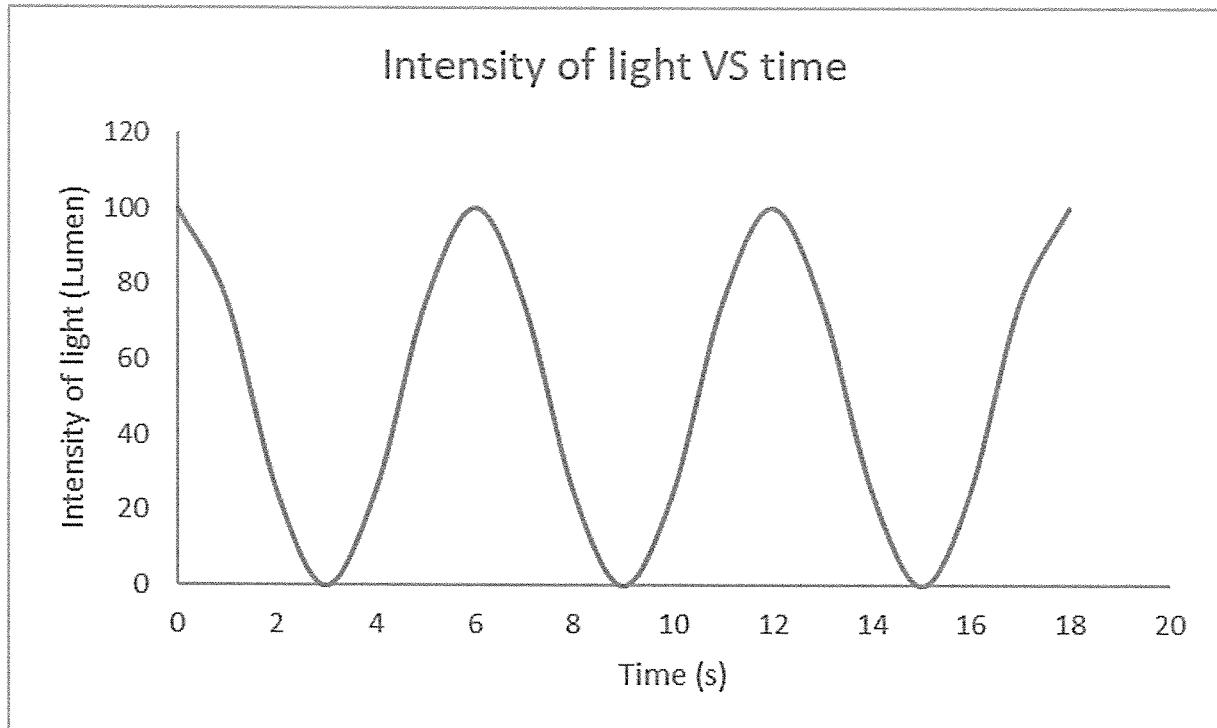


A sprinkler system is designed for a room where $h = 3.0$ m and $d = 4.0$ m. Water takes 0.65 s to fall 3.0 m to the floor while producing a spray pattern with a diameter of 4.0 m.

Find the spray angle of the sprinkler for this design.

Question 24 (4 marks)

A group of students shone a plane polarised beam of light on a polarising filter which was rotating at angular velocity of 30 degrees/s. They measured the intensity of light passing through the filter and showed their results on the graph below.



- (a) Explain the change in intensity of light shown on the graph.

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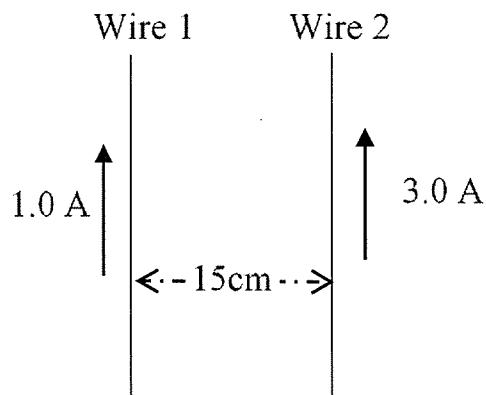
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- (b) Sketch on the graph above how the intensity will change with time if the plane polarised light is replaced with an unpolarised light source of equal intensity.

1

Question 25 (5 marks)

Two parallel wires of length 1m are set up such that both currents are travelling in the same direction and are separated by a distance of 15cm.



- (a) Determine the magnitude and direction of the magnetic force acting on both Wire 1 3 and Wire 2.

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- (b) What is the direction and strength of the magnetic field midway between the wires? 2

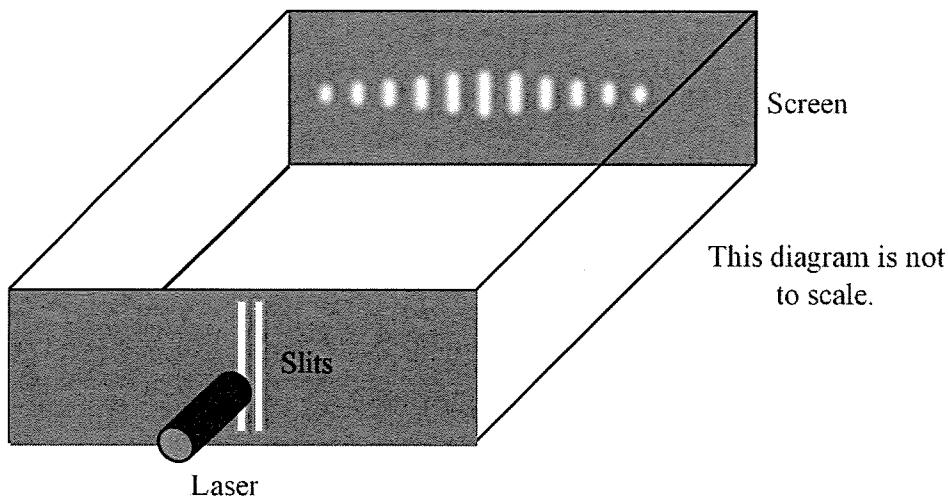
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Question 26 (5 marks)

A DC motor is being designed to drive a winch which is lifting an elevator. Explain the factors affecting the rotational speed of a DC motor. Use mathematical models to support your answer.

Question 27 (7 marks)

A laser beam of coherent monochromatic light with the wavelength of 700 nm was shone on double slits shown below:



The distance between two slits is 1.50 mm and the distance of the slits to the screen is 2.00 m

- (a) Circle both fifth order maxima on the diagram above and explain why there is a bright band of light at these positions. 3

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- (b) Calculate the angle of diffraction for the fifth order maxima. 2

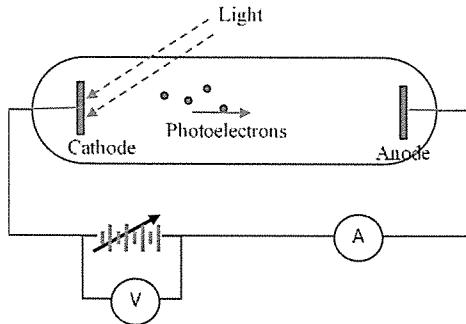
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- (c) Describe how the pattern above will be altered if the air between the slits and the screen is replaced by glass with a refractive index of 1.50. Justify your answer. 2

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Question 28 (7 marks)

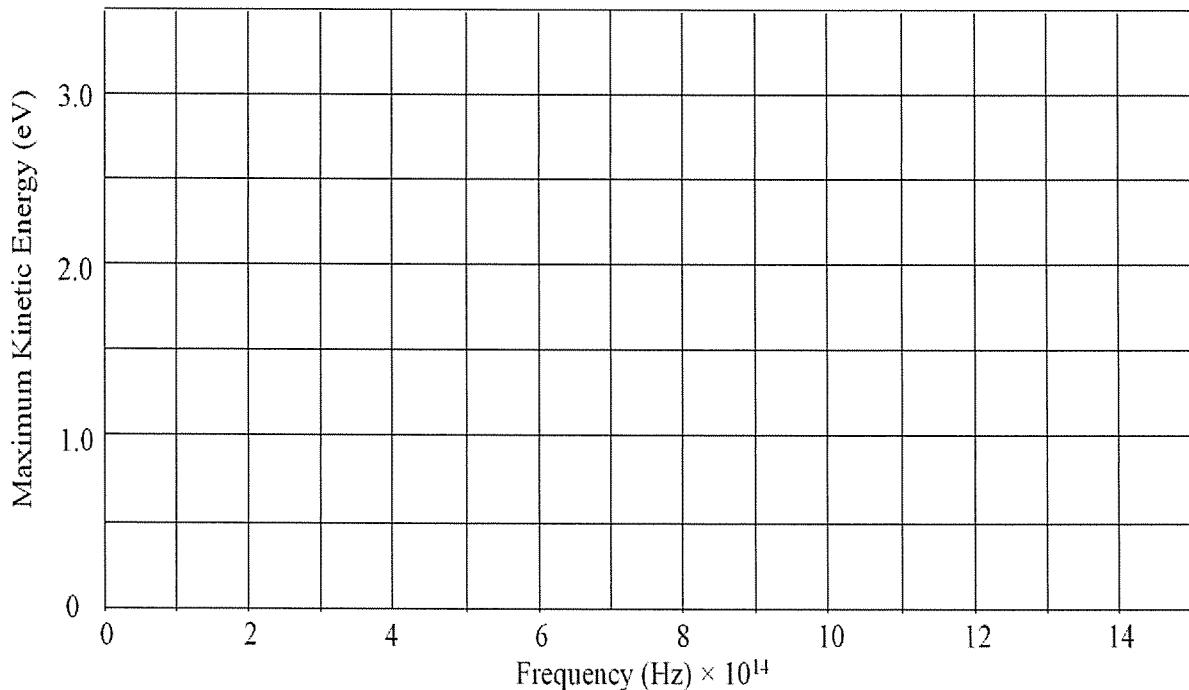
A group of students performed an investigation on the photoelectric effect using the following set-up.



When light is shone onto cathode, the photoelectrons produced set up a current which is recorded on the ammeter. The variable power supply is then increased from zero until the current is reduced to zero and the voltage is recorded. This voltage is called the stopping voltage and used to calculate the maximum energy of the photoelectrons released from the cathode. 1 volt of stopping voltage indicates 1eV of kinetic energy. The students varied the colour of light that was used to illuminate the cathode and recorded the stopping voltage in the table below:

Frequency of light (Hz) $\times 10^{14}$	Stopping voltage (V)
6.67	-0.33
7.50	-0.72
8.57	-1.18
10.0	-1.79
12.0	-2.62

- (a) Use the above data to draw a graph of maximum kinetic energy versus frequency. 2



- (b) Use the graph in part (a) to determine the threshold frequency.

1

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- (c) Use the graph in part (a) to calculate Planck's constant. Show your calculation process clearly.

2

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- (d) Explain how the law of conservation of energy applies in the photoelectric effect to produce the straight-line graph you have plotted.

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Question 29 (6 marks)

When a Uranium-235 nucleus absorbs a neutron in a nuclear reactor, Krypton-92, Barium-141 and several neutrons are common products of the reaction.

- (a) Name this type of nuclear reaction.

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- (b) Write a nuclear equation for this reaction.

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- (c) With reference to this process, justify the use of a moderator like graphite in nuclear reactors that produce these radioisotopes.

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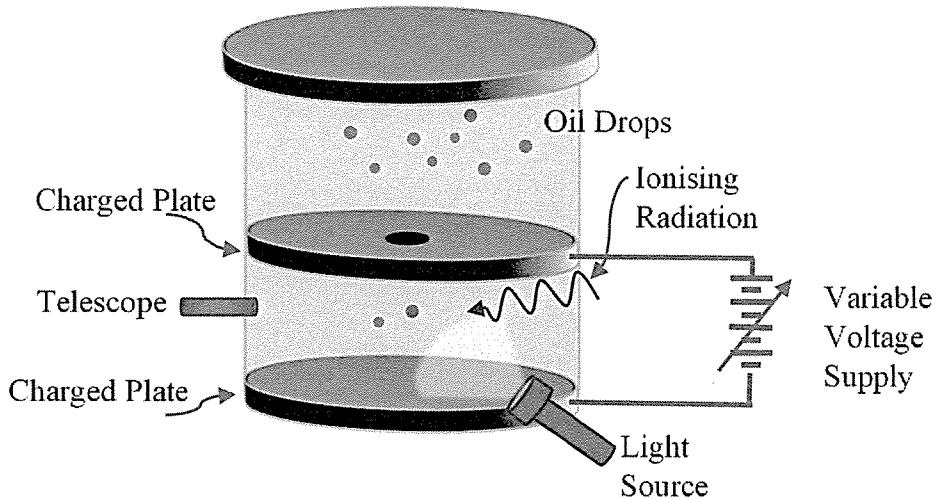
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Question 30 (6 marks)

Between 1909 and 1910 the American physicist Robert Millikan conducted a series of experiments with charged oil drops. By comparing the applied electric force to the weight of each oil drop, he was able to determine the electric charge on each oil drop.

The apparatus Millikan used is shown below.



- (a) Why was the radius of the observed oil drops measured? 1

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- (b) Outline how Millikan determined the electric charge on the oil drops he observed. 2

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- (c) It was known at the time that electric charge was a quantum property of matter. 3

How did Millikan use this assumption to determine the charge on a single electron?

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Question 31 (6 marks)

A plank of wood is fixed to a wall using a hinge.

When the angle between the plank and the wall is 45° , a spring is attached to the wood 25cm from the hinge and fixed to the wall so that it is horizontal (Diagram A).

The wood is then pushed downwards until it is perpendicular to the wall (Diagram B).

Diagram A

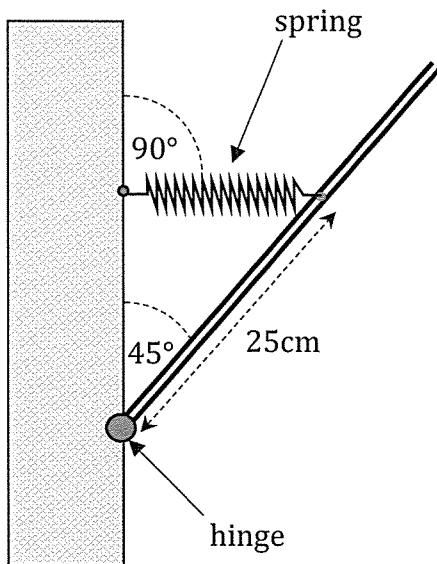
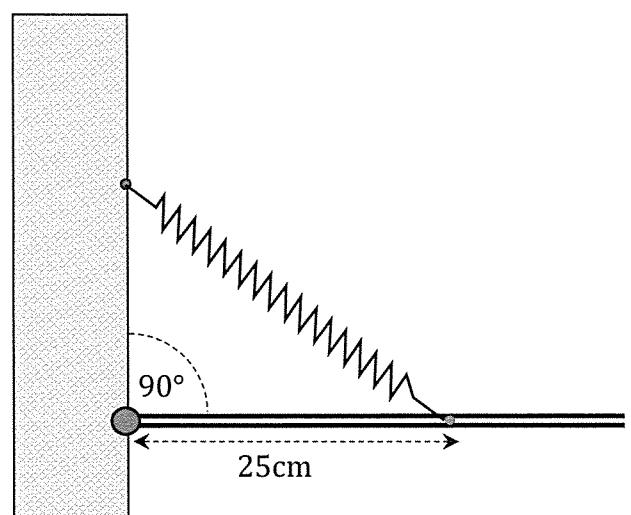
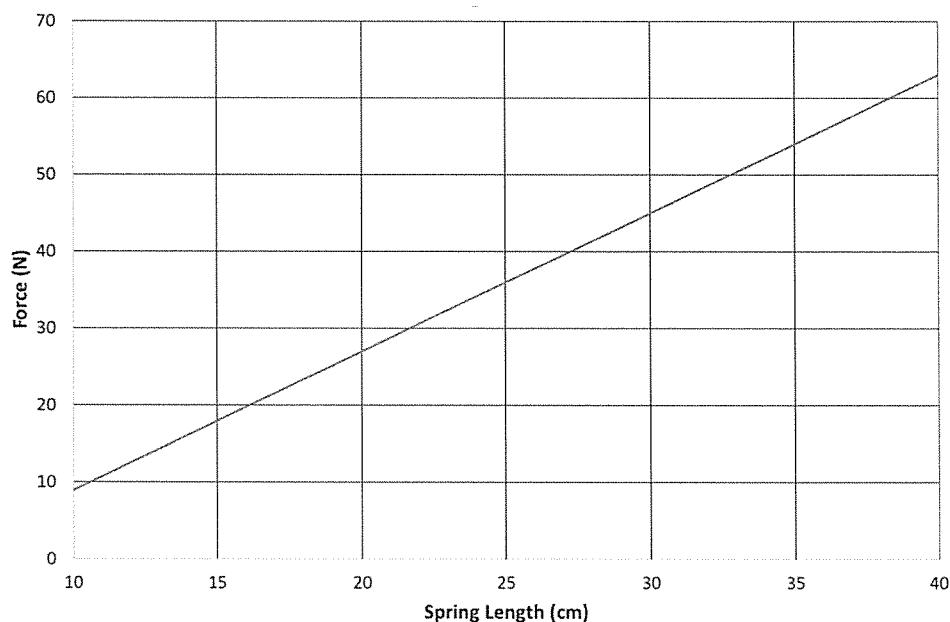


Diagram B



The force exerted by the spring, depends on its length. As the spring stretches, the force it exerts increases. A graph showing this relationship is below.



Question 30 continues on the next page

- (a) Calculate the length of the spring in Diagrams A and B.

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- (b) Calculate the torque produced by the spring on the plank of wood around the hinge in both Diagrams A and B and compare the values.

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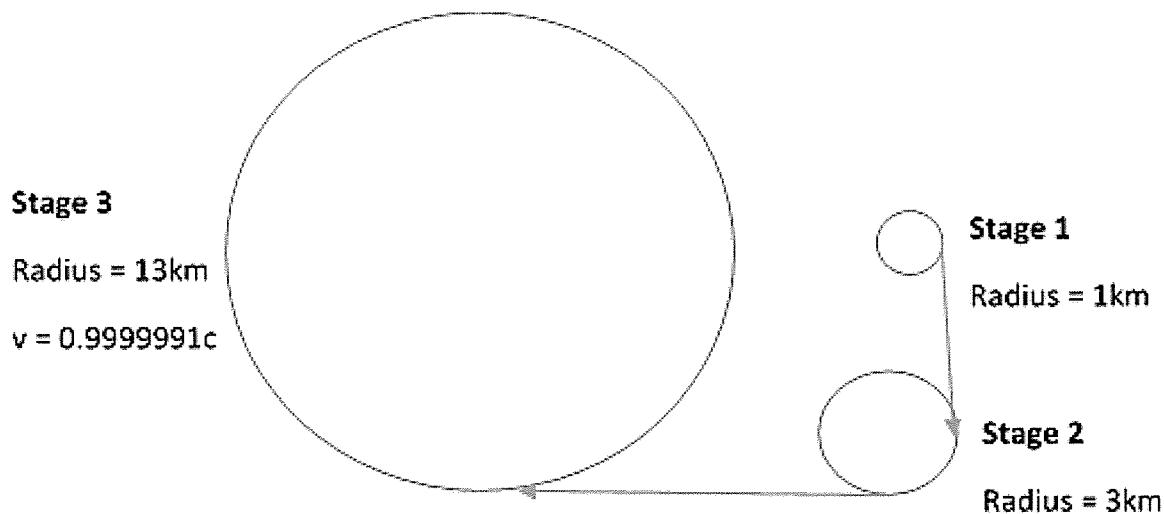
Question 32 (4 marks)

When the Bohr model of the atom was proposed in 1913, some atomic properties could not be fully explained using classical mechanics alone. 4

Explain how subsequent contributions to our understanding of atomic structure from Louis de Broglie supported the establishment of an improved quantum-mechanical model for the atom.

Question 33 (9 marks)

A particle accelerator is being proposed. It will consist of three stages of circular rings containing proton beams. The protons will be accelerated by electric fields and directed by powerful magnetic fields. The protons will reach relativistic speeds at Stage 3. Each stage will have an identical magnetic field and protons will travel in a clockwise direction.



- (a) Justify the use of particle accelerators in investigating the Standard Model of matter. 3

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Question 33 continues on the next page

- (b) Explain why the THREE rings have different radii. 3

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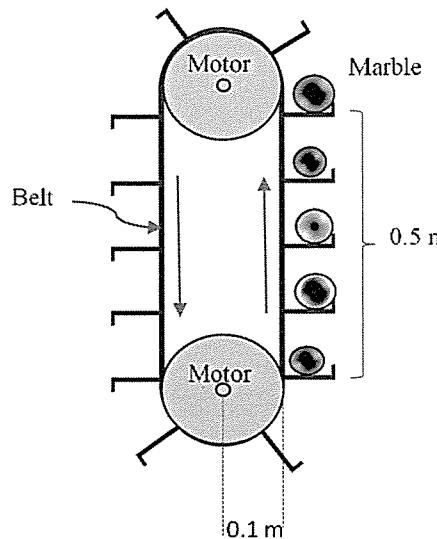
- (c) Calculate the magnitude and direction of the magnetic field in Stage 3 where the protons reach a velocity of $0.9999991c$. 3

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Question 34 (6 marks)

A toy engineer is designing an elevator to lift a maximum of five marbles over a height of 0.50 m. It consists of two identical motors. The coil of each motor has 100 turns, a 0.50 T magnetic field and a coil area of $1 \times 10^{-4} \text{ m}^2$. The motors are connected to a pulley with a radius of 0.10 m and connected via a belt with platforms of negligible mass.

The engineer adds one marble at a time and measures the smallest current passing through each motor that allows the marbles to be stationary. The following data is recorded:



Number of marbles	Current in each motor (A)
1	0.64
2	1.27
3	1.91
4	2.55
5	3.19

- (a) Explain how the engineer can calculate the torque exerted by a marble mass m .

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- (b) Calculate the average mass of the marbles used.

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End of examination

Section II extra writing space

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

Section II extra writing space

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

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Physics

Section I
20 marks

Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	B	PH12-12	2-3
2	A	PH12-13	2-3
3	C	PH12-14	2-3
4	B	PH12-15	2-3
5	A	PH12-12	3-4
6	C	PH12-13	3-4
7	C	PH12-14	3-4
8	C	PH12-15	3-4
9	A	PH12-12	3-4
10	B	PH12-13	3-4
11	C	PH12-14	3-4
12	D	PH12-15	3-4
13	A	PH12-15	4-5
14	D	PH12-13	3-4
15	A	PH12-15	4-5
16	D	PH12-14	4-5
17	D	PH12-13	5-6
18	B	PH12-14	5-6
19	D	PH12-12	4-5
20	C	PH12-12	5-6

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Section II

80 marks

Questions 21 - 30

Question 21 (3 marks)

(a) (1 mark)

Outcomes Assessed: 12-12

Targeted Performance Bands: 2-4

Criteria	Marks
• Indicates that the kinetic energy is less in the higher orbit	1

Sample answer:

At the higher orbit the velocity is lower and so the Kinetic Energy is lower. $K=GMm/2r$

(b) (2 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 2-4

Criteria	Marks
• Relates gain in GPE to the need for onboard propulsion.	2
• Identifies the reduction in kinetic energy of the satellite in a higher orbit being less than required gain in GPE.	
• Identifies the satellite has a higher energy at the new orbit.	1

Sample answer:

The total energy of a satellite in orbit is the sum of its gravitational potential and kinetic energy. In moving to the new orbit, the gain in gravitational potential energy is higher than the reduction in kinetic energy. As a result, there is a net increase in the energy of the satellite and work must be done to move it to a higher orbit. The energy for this is provided by the onboard propulsion.

Mathematically:

In each orbit $T=U+K = -GMm/r + GMm/2r = -GMm/2r$

The higher the orbit the bigger the value for r and the less negative the total energy.

So the total energy has increased overall, even though the kinetic energy has decreased.

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Question 22 (5 marks)

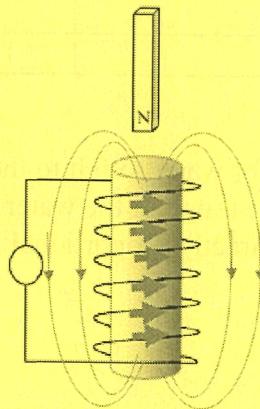
(a) (2 marks)

Outcomes Assessed: 12-13

Targeted Performance Bands: 2-4

Criteria	Marks
• Both Field AND current direction correct	2
• Field direction OR current direction correct	1

Sample answer:



(b) (3 marks)

Outcomes Assessed: 12-13

Targeted Performance Bands: 3-5

Criteria	Marks
• Correct description of the motion of the magnet through both pipes AND demonstrates a good understanding of Lenz's Law, Faraday's Law and Induced Eddy Currents and how it applies to this situation.	3
• Correct description of the motion of the magnet through both pipes AND demonstrates some understanding of Lenz's Law, Faraday's Law and induced Eddy currents.	2
• Correct description of the motion of the magnet through both pipes OR demonstrates some understanding of Lenz's Law and Faraday's Law	1

Sample answer:

No slit

As the magnet falls through the copper pipe without a slit, its acceleration is reduced.

Throughout the movement towards, through and leaving the full pipe the changing magnetic flux around the pipe will induce an emf in the pipe, (Faraday's law). The direction is described by Lenz's law as eddy currents will be induced to oppose the change in flux caused by the falling magnet.

This results in the magnet falling more slowly than in the other pipe.

Pipe with slit

As the magnet falls through the pipe with a slit it will fall with acceleration due to gravity. Due to the slit in the pipe, eddy currents are unable to form as the loop would be incomplete and will therefore not act to oppose the changing flux. Small eddy currents may form within the walls of the pipe, with size limited by the thickness of the walls, but the effect of these will be negligible.

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Question 23 (7 marks)

(a) (3 marks)

Outcomes Assessed: 12-12**Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"> Relates the increase in speed to greater coverage with reference to principles of projectile motion Identifies the directly proportional relationship between speed of water and the radius of the coverage 	3
<ul style="list-style-type: none"> Relates the increase in speed to greater coverage with reference to principles of projectile motion 	2
Describes the increase in speed to a greater coverage on the floor.	1

Sample answer:

The initial vertical component of the velocity is zero and so the time taken for water to fall to the floor is unaffected by the initial speed of the water leaving the sprinkler. The range of the water is given by $s_x = u_x t$. Since t is constant, the diameter of the spray pattern is directly proportional to u_x (initial speed of the water).

(b) (4 marks)

Outcomes Assessed: 12-12**Targeted Performance Bands: 3-5**

Criteria	Marks
Correctly calculates the spray angle	4
Correct calculation of both components of the initial velocity of the water	3
Correct calculation of one of the components of the initial velocity of the water.	2
Provides some relevant information interpreted from the question.	1

Sample answer:

Horizontal component of initial velocity

$$\begin{aligned}
 s_x &= u_x t \\
 2.0 &= u_x \times 0.65 \\
 \therefore u_x &= 3.08 \text{ ms}^{-1} \text{ (to 2 sig figs)}
 \end{aligned}$$

Find vertical component of the initial velocity

$$\begin{aligned}
 s_y &= u_y t + \frac{1}{2} a_y t^2 \\
 -3.0 &= u_y \times 0.65 - \frac{1}{2} \times 9.81 \times 0.65^2 \\
 u_y &= -1.43 \text{ ms}^{-1}
 \end{aligned}$$

Angle of initial velocity (to the vertical)

$$\begin{aligned}
 \tan \theta &= \frac{3.08}{1.43} \\
 \theta &= 65^\circ
 \end{aligned}$$

Spray angle (2θ) 130° **Disclaimer**

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Question 24 (4 marks)

(a) (3 marks)

Outcomes Assessed:

Targeted Performance Bands:

Criteria	Marks
<ul style="list-style-type: none"> Defines Malus's law Explains the change in intensity of light by time using Malus's law Supports their answer by some examples from the graph 	3
<ul style="list-style-type: none"> Defines Malus's law and explains the change in intensity of light by time using Malus's law <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Explains the change in intensity of light by time using Malus's law and supports their answer by some examples from the graph 	2
<ul style="list-style-type: none"> Defines Malus's law <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Explains the change in intensity of light by time using Malus's law 	1

Sample answer:

- a) According to Malus's law $I=I_{\max} \cos^2\theta$ when a plane polarised light pass through an analyser (polarising filter). The intensity of light passing through the analyser is proportional to $\cos^2\theta$. When the polarisation plane and analyser are perpendicular I is equal zero and when they are parallel I is equal to the maximum amount. As we can see in the graph by rotating the analyser the angle between the polarisation plane and analyser changes and as a result the intensity of light changes. for example, at times 0, 6, 12, 18 seconds the polarisation plane and analyser are parallel, and I is equal 100 lumen (maximum amount). And at times 3, 9, 15 seconds, the polarisation plane and analyser are perpendicular and I is equal zero. In other times it also agrees with Malus's law.

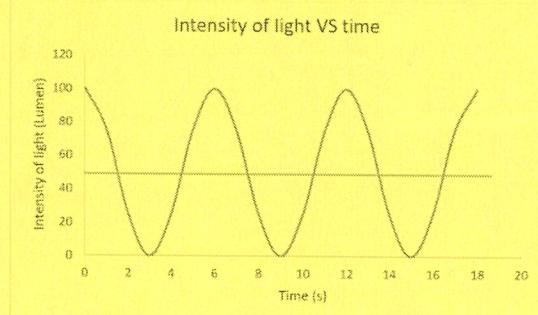
(b) (1 mark)

Outcomes Assessed: 12-14

Targeted Performance Bands: 3-5

Criteria	Marks
<ul style="list-style-type: none"> Correctly sketches a graph for an unpolarised light at 50 % 	1

Sample answer:



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Question 25 (5 marks)

(a) (3 marks)

Outcomes Assessed: 12-13

Targeted Performance Bands: 3-5

Criteria	Marks
• Recognises force acting on both wires will be the same	3
• Correctly calculates force on wires including units	
• Correctly determines direction of force on each wire (attractive force is sufficient)	
• Any two points above	2
• Any one point above	1

Sample answer:

From the Right Hand Grip rule we can determine the magnetic force between the two wires to be attractive. i.e. Wire 1 will experience a force to the right and Wire 2 will experience a force to the left.

From Newton's Third Law the magnitude of the force acting on each wire will be the same.

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

$$\frac{F}{1} = \frac{4\pi \times 10^{-7} \times 1 \times 3}{2\pi \times 0.15}$$

$$F = 4 \times 10^{-6} \text{ N}$$

(b) (2 marks)

Outcomes Assessed: 12-13

Targeted Performance Bands: 3-5

Criteria	Marks
• Correct calculation AND direction	2
• Correct calculation OR direction.	1

Sample answer:

$$B = \frac{\mu_0 I}{2\pi r}$$

Combining for both wires

$$= \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 0.075} - \frac{4\pi \times 10^{-7} \times 3}{2\pi \times 0.075}$$

$$= 5.33 \times 10^{-6} \text{ T Out of the page.}$$

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Question 26 (5 marks)**Outcomes Assessed: 12-13****Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"> Covers internal and external parts of the motor. Correctly uses equations to reinforce the answer Includes the role of back EMF in terms of limiting the velocity of the motor. Covers the essential aspects of Torque ($nIAB$) and Load including 4 factors that affect speed 	4-5
<ul style="list-style-type: none"> Gave 2 -3 factors that affect speed. Included a formula which helped the answer. 	2-3
<ul style="list-style-type: none"> Gave a factor that affects speed. 	1

Sample answer:

Rotational speed of a DC motor is affected by torque acting on the current carrying loop AND the load on the motor. Friction may also be a factor.

The formula $\tau = nIA_{\perp}B = nIAB \sin\theta$ indicates the variables that can affect the size of the torque that will speed up the motor. So the size of the current in the winding, the area of the winding and the strength of the magnetic field. Increasing the number of coils in the winding will also increase the rate at which the motor can spin.

The faster the motor turns the greater the back EMF in the coils and reduces the current in the coil and this slows the motor down.

However the speed is also affected by the job the motor is doing. A bigger load to lift will slow the movement of the motor. This is an example of the conservation of energy.

Frictional effects within the commutator may also affect the speed of the motor.

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Question 27 (7 marks)

(a) (3 marks)

Outcomes Assessed: 12-14**Targeted Performance Bands: 2-4**

Criteria	Marks
• Identifies both maxima and explains path difference clearly and relates to the maxima	3
• Identifies both maxima and explains path difference partially	2
• Identifies both maxima OR explains path difference partially	1

Sample answer:

On the diagram the two smallest outer bands should be circled.

The 5th bright band shown in the diagram above is there because the distance between slit one and that spot on the screen is exactly 5 wavelengths shorter or longer than the distance between slit two and that point on the screen. So at these spots both waves are at the same stage and so constructively interfere producing a maximum light.

(b) (2 marks)

Outcomes Assessed: 12-14**Targeted Performance Bands: 2-4**

Criteria	Marks
• Correctly calculates the angle of diffraction	2
• Provides some relevant information	1

Sample answer:

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

$$1.5 \times 10^{-3} \times \sin \theta = 5 \times 700 \times 10^{-9}$$

$$\theta = 0.134^\circ$$

(c) (2 marks)

Outcomes Assessed: 12-14**Targeted Performance Bands: 3-5**

Criteria	Marks
• Correct answer with correct justification for wavelength decreases and therefore smaller angle θ	2
• Correct answer OR correct inference on wavelength decrease	1

Sample answer:

$$d \sin\theta = m \lambda \quad \text{therefore } \sin \theta = m \lambda / d$$

With an increase in refractive index we have a decrease in wavelength. Thus as λ is smaller, and all the other variables are the same, the angle will be reduced.

The pattern will show the maxima closer together.

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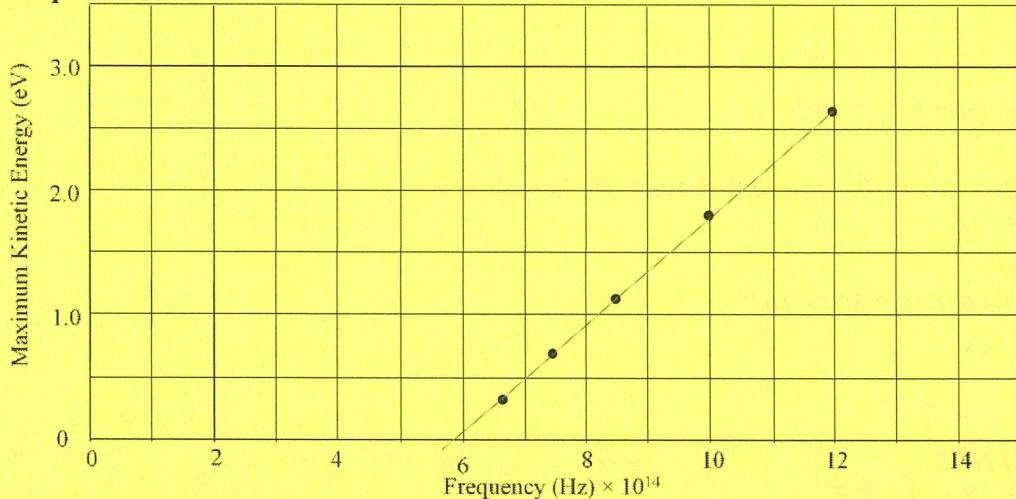
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Question 28 (7 marks)

(a) (2 marks)

Outcomes Assessed: 12-14**Targeted Performance Bands: 3-5**

Criteria	Marks
• Correctly plots data	2
• Draws a sensible line of best fit	1
• One of the above	1

Sample answer:

(b) (1 mark)

Outcomes Assessed: 12-14**Targeted Performance Bands: 2-4**

Criteria	Marks
• Identifies the x intercept with correct units.	1

Sample answer: $f_0 = 5.8 \times 10^{14} \text{ Hz}$ [NB: This depends on the student's graph so may vary]**Disclaimer**

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(c) (2 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates Planck's constant using gradient of the graph.	2
• Identifies Planck's constant is equal to the gradient of the graph and attempts to calculate it using the gradient.	1

Sample answer:

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

$$\text{Gradient of the above graph} = h$$

$$\text{Gradient} = \text{rise/run}$$

$$= ((1.79 - 0.72) \times 1.6 \times 10^{-19}) / ((10.0 - 7.50) \times 10^{14}) \\ = 6.68 \times 10^{-34} \text{ Js}$$

$$\text{OR Gradient} = \text{rise/run}$$

$$= ((1.79 - 0.72) / ((10.0 - 7.50) \times 10^{14})) \\ = 4.28 \times 10^{-15} \text{ eV s}$$

(d) (2 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies that photon energy is then shared to the kinetic energy and work function.	2
• Relates this to the graph.	
• Correctly identifies two of the parts of the energy process.	1

Sample answer:

The law of conservation of energy states that energy cannot be created or destroyed but can be changed from one form to another.

The photons of light hitting the cathode have an energy related to the frequency of the light. ($E=hf$)

If an electron absorbs a photon then it uses some of the energy to overcome the bonds holding it to the metallic lattice (the smallest needed energy is called the work function).

The rest of the energy is then used in the kinetic energy of the electron as it leaves the cathode.

The formula $K_{max} = hf - \phi$ is a statement of the conservation of energy in the photoelectric effect.

In the graph above f is the X axis, K_{max} is the Y axis and ϕ is the Y intercept.

As the work function does not vary and h is a constant we see that the frequency will produce a straight line graph with the kinetic energy.

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Question 29 (6 marks)

(a) (1 mark)

Outcomes Assessed: 12-15**Targeted Performance Bands: 2-4**

Criteria	Marks
• Correctly names the reaction type using the word ‘fission’	1

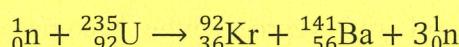
Sample answer:

Nuclear fission reaction

(b) (2 marks)

Outcomes Assessed: 12-15**Targeted Performance Bands: 2-4**

Criteria	Marks
• Recognises, represents and distinguishes between reactant and product species through the correct placement and direction of an arrow.	2
• Represents a balanced nuclear equation using atomic notation for each species	
• Recognises, represents and distinguishes between reactant and product species through the correct placement and direction of an arrow.	1

Sample answer:

(c) (3 marks)

Outcomes Assessed: 12-15**Targeted Performance Bands: 2-4**

Criteria	Marks
• Explains the purpose of the moderator in terms of neutron energies/velocities	3
• Describes the consequence of operating this type of reactor without a moderator	
• Outlines the purpose of the moderator by referring to neutron energies/velocities	2
• Identifies the purpose of the moderator	1

Sample answer:

In a fission reactor of this type, the moderator reduces the kinetic energy and velocity of neutrons. The neutrons produced are known as fast neutrons with kinetic energies close to 1 MeV. Collisions with a moderator such as graphite slows neutron velocities and kinetic energies into a category known as thermal neutrons. Thermal neutrons have kinetic energies of about 0.025 MeV and are suitable for initiating the fission process. Without this reduction in energy, the neutrons move too fast to be absorbed by the uranium nuclei and tend to pass right through the fuel rods without initiating fission of the nucleus.

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Question 30 (6 marks)

(a) (1 mark)

Outcomes Assessed: 12-15**Targeted Performance Bands: 3-4**

Criteria	Marks
• Correct answer relating to mass.	1

Sample answer:

The radius enabled Millikan to find the mass of each droplet.

(b) (2 marks)

Outcomes Assessed: 12-15**Targeted Performance Bands: 3-5**

Criteria	Marks
• Outlines an experimental observation consistent with Newton's first law	2
• Relates the weight of the oil drop to the electric force and Newton's first law with an expression for charge	
• Outlines an experimental observation consistent with Newton's first law	1

Sample answer:

When the sum of all forces on an oil drop is zero, it either becomes stationary, suspended in the chamber, or falls with uniform velocity. Millikan was able to focus on a single oil drop and adjust the potential difference to balance the weight of the drop (mg) with the force in the electric field (Eq) until the drop had zero acceleration. Millikan determined the electric field E using the formula $E = \frac{V}{d}$ [He knew the distance between the plates and found V using a voltmeter]. Equating the weight of the drop with the electric force provided an expression for the charge on the oil drop $q = \frac{mg}{E}$.

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Question 30 continued..

(c) (3 marks)

Outcomes Assessed: 12-15

Targeted Performance Bands: 3-5

Criteria	Marks
• Outlines why charge is a quantum property of matter	
• Links charge as a quantum property to the total charge on an oil drop	3
• Explains how Millikan's experimental results allowed for the determination of charge on an electron	
• Describes the procedure used by Millikan to determine the charge on an electron	2
• Identifies a correct aspect of the procedure used by Millikan to determine the charge on an electron	1

Sample answer:

At the time, electrons and protons were considered fundamental particles in that they could not be broken down into anything simpler. Being fundamental meant that these two particles carried the smallest possible quantity of charge q (now known to be 1.602×10^{-19} C). All charged bodies must, therefore, carry an integer multiple of q and this is what makes electric charge a quantum property of matter. Millikan used this concept in determining the charge on a single electron. Each oil drop contained a certain (very large) number of electrons and when the charge on a single electron was multiplied by this number, it would equal the charge on the oil drop such that $q_{\text{oil-drop}} =$

$n_{\text{electrons}} \times q_{\text{electron}}$ where the number of electrons had to be an integer. By looking at the measured charge on thousands of oil drops Millikan was able to find this fundamental value of charge because all charged oil drops were a multiple of that value and because the difference between the charges on all drops was a multiple of that value.

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Question 31 (6 marks)

(a) (2 marks)

Outcomes Assessed: 12-15

Targeted Performance Bands: 3-6

Criteria	Marks
• Correct calculation of lengths using trigonometric means for both diagrams.	2
• One length correct.	1

Sample answer:

Length of spring in Diagram A

$$= 25 \text{ cm} \times \sin 45^\circ$$

$$= 17.68 \text{ cm}$$

Length of spring in Diagram B

$$= \sqrt{17.68^2 + 25^2}$$

Note distance along wall from hinge to spring is also 17.68cm

$$= 30.62 \text{ cm}$$

(b) (4 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 3-6

Criteria	Marks
• Correct comparison of the torque produced by the spring. (Ignore direction)	4
• Correct calculation of torque produced in either Diagram A or B	3
• Single error leading to incorrect answer for other situation.	
• Correct use of torque equation, but with minor errors in interpreting geometry or graph in either Diagram A or B	2
• Appropriate interpretation of the graph for either situation	
• Attempt at use of torque equation	1

Sample answer

Force exerted by spring

From graph = 23N (approx.)

Torque produced by spring

$$\tau_A = 23 \times 0.25 \times \sin 45^\circ$$

$$= 4.1 \text{ Nm}$$

Note distance along wall from hinge to spring is also 17.68cm

Force exerted by spring

From graph = 46N (approx.)

Angle between wood and spring

$$= \cos^{-1}\left(\frac{25}{30.6}\right) = 35.3^\circ$$

Torque produced by spring

$$\tau_B = 46 \times 0.25 \times \sin 35.3^\circ$$

$$= 6.6 \text{ Nm}$$

Comparison

$\tau_B = 1.6\tau_A$ in the same direction

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Question 32 (4 marks)

(a) (i) (2 marks)

Outcomes Assessed: 12-15**Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"> • Describes the classical mechanical features of the Bohr model of the atom • Relates de Broglie's electron standing waves to the quantisation of angular momentum proposed by Bohr • Distinguishes classical and quantum mechanical features of each model of the atom 	4
<ul style="list-style-type: none"> • Describes the classical mechanical features of the Bohr model of the atom • Describes de Broglie's contribution to the understanding of atomic structure 	2-3
<ul style="list-style-type: none"> • Outlines the features of the Bohr model of the atom OR • Outlines the features of de Broglie's contribution to the understanding of atomic structure 	1

Sample answer:

After observing the nature of Hydrogen spectral lines, Bohr developed a model of the atom that assumed that electrons moved around the nucleus in circular motion with only certain allowed radii and energies. At these radii the electrons did not give off EM radiation. Bohr did not have an explanation for this. Bohr's model of the atom relied almost entirely on principles derived from classical mechanics such as circular motion and angular momentum. There was a quantum component in that Bohr's model hypothesised that the angular momentum of electron orbits was quantised and that only certain values for momentum and orbital radius were allowed. However, at the time, classical mechanics provided no convincing reason as to why orbits were quantised in this way. In 1923, Louis de Broglie made a quantum leap(!) and proposed matter waves for particles whose wavelength could be calculated using the formula $\lambda = \frac{h}{mv}$. If an electron were assumed to be a wave, its wavelength could be calculated from its mass and the velocity of its orbit. De Broglie proposed that standing wave orbits were possible for electrons that corresponded to Bohr's quantised orbitals where their circumference had an integral multiple of electron wavelengths. Standing electron waves could thus be possible where no energy was lost and this was Bohr's second postulate that the angular momentum of electrons was quantised. De Broglie's proposal solved the problem of why some orbits were stable and introduced a quantum explanation for quantisation of angular momentum proposed by Bohr.

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Question 33 (9 marks)

(a) (3 marks)

Outcomes Assessed: 12-15**Targeted Performance Bands: 4-6**

Criteria	Marks
<ul style="list-style-type: none"> • Describes the ability for accelerators to validate a model predicted by mathematics • Outlines the operation of an accelerator (accelerates and collides high speed particles.) • Justifies the requirement for large amounts of energy to discover massive, exotic particles by using $E = mc^2$ and how these energies are required to isolate individual particles 	3
<ul style="list-style-type: none"> • Outlines the operation of an accelerator (accelerates and collides high speed particles.) • Identifies the ability for accelerators to validate a model predicted by mathematics • Describes the large amounts of energy are required to discover new particles 	2
<ul style="list-style-type: none"> • Outlines the operation of an accelerator (accelerates and collides high speed particles,) OR • Identifies the ability for accelerators to validate a model predicted by mathematics OR • Describes the large amounts of energy are required to discover new particles 	1

Sample answer:

New particles not previously observed in experiments were being discovered after witnessing the interaction of highly energetic cosmic rays with particles in the upper atmosphere. Physicists determined that new particles would arise due to even higher energy collisions ($E = mc^2$). They devised ways to accelerate known particles (protons, etc.) using electric and magnetic fields. After colliding them with each other with very large kinetic energies, they found new particles. As they increased the kinetic energy of the colliding particles, new more exotic and more massive particles were being discovered, forming the standard model of matter.

Using this model, physicists were able to predict the existence of more massive particles, requiring huge amounts of energy. Once built, these particle accelerators were able to validate the mathematical predictions of the standard model of matter. The standard model of matter is still incomplete with predicted particles not yet found.

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Question 33 continued

(b) (3 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 4-6

Criteria	Marks
<ul style="list-style-type: none"> Describes the perpendicular force of charged particles in a magnetic field Demonstrates the relationship between radius and velocity by equating $F = \frac{mv^2}{r} = qvB\sin\theta$ 	4
<ul style="list-style-type: none"> Explains the very large radius due to the increased relativistic momentum Describes the perpendicular force of charged particles in a magnetic field Demonstrates the relationship between radius and velocity by equating $F = \frac{mv^2}{r} = qvB\sin\theta$ 	3
OR	
<ul style="list-style-type: none"> Explains the very large radius due to the increased relativistic momentum Identifies the perpendicular force of charged particles in a magnetic field 	
OR	
<ul style="list-style-type: none"> Uses one equation to show how velocity will affect radius Identifies relativistic momentum will affect radius size 	2
OR	
<ul style="list-style-type: none"> Identifies relativistic momentum will affect radius size 	1

Sample answer:

In circular accelerators (synchrotrons) a powerful magnetic field is required to direct the particles in a circular path. As protons are charged particles, the radius of their deflection is given by

$$F = \frac{mv^2}{r} = qvB\sin\theta$$

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

As the velocity increases, the radius of its path increases if all other variables are kept constant. In this particle accelerator, there will be relativistic momentum dilation which further increases the radius required.

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Question 33 continued

(c) (3 marks)

Outcomes Assessed: 12-12 and 12-13 and 12-14

Targeted Performance Bands: 4-6

Criteria	Marks
• Correctly uses centripetal force, force of magnetic field on charged particle and momentum dilation to correctly calculate magnetic field strength and direction	3
• Shows some correct steps	2
• Provides some relevant information	1

Sample answer:

$$p_v = \frac{1.673 \times 10^{-27} \times 0.9999991 \times 3 \times 10^8}{\sqrt{1 - 0.9999991^2}}$$

$$p_v = 3.741 \times 10^{-16} \text{ kgms}^{-1}$$

$$qvB\sin\theta = mv^2/r \text{ so } qB\sin\theta = mv/r \text{ so } B = mv/qrsin\theta = p_v/qrsin\theta$$

Substituting into

$$B = \frac{mv}{qrsin\theta}$$

$$B = \frac{3.741 \times 10^{-16}}{1.602 \times 10^{-19} \times 13 \times 10^3}$$

$$B = 0.18 \text{ T out of the page.}$$

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Question 34 (6 marks)

(a) (2 marks)

Outcomes Assessed: 12-12 & 12-13**Targeted Performance Bands: 4-6**

Criteria	Marks
• Chooses the correct expression AND uses mg as the Force value	2
• One of the above	1

Sample answer:Using the expression $\tau = Fd$ Where $F=mg$ so $\tau = mgd$

(b) (4 marks)

Outcomes Assessed: 12-12 & 12-13**Targeted Performance Bands: 4-6**

Criteria	Marks
• Average mass of marbles is correctly calculated using both motors and the largest number of marbles	4
• Equates torque from mass of marbles with torque from motors	
• Calculates the mass of a marble with one error OR uses current for one marble	3
• Equates torque from mass of marbles with torque from motors	
• Calculates torque of the two motors OR the torque provided by a marble	2
• Provides some relevant information	1

Sample answer:

$$\tau = Fd = nIAB \times 2$$

$$\tau = mgd = 2nIAB$$

use the current with 5 marbles

$$5m = \frac{2nIAB}{gd}$$

$$m = \frac{2 \times 100 \times 3.19 \times 1 \times 10^{-4} \times 0.5}{9.8 \times 0.1 \times 5}$$

$$m = 6.51 \times 10^{-3} \text{ kg}$$

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