CSSA

CATHOLIC SECONDARY SCHOOLS
ASSOCIATION OF NSW

Centre Number

Student Number

DO NOT REMOVE PAPER FROM EXAM ROOM

2020

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Morning Session
Tuesday, 25 August 2020

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Use Multiple-Choice Answer Sheet provided
- NESA-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 14-29

80 marks

- Attempt Questions 21-35
- Allow about 2 hours and 25 minutes for this section

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.

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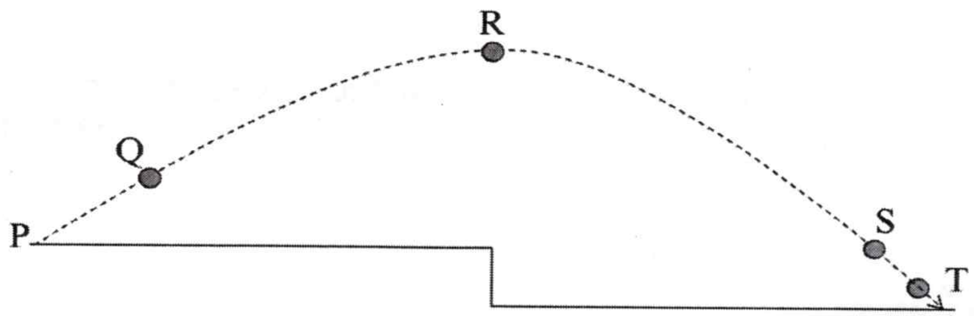
1 A ball undergoes projectile motion from point P to T as shown.



Ignoring air resistance, which statement below correctly describes the motion of the ball?

(A) The ball has no acceleration at point R.

(B) The ball has the greatest acceleration at point T.

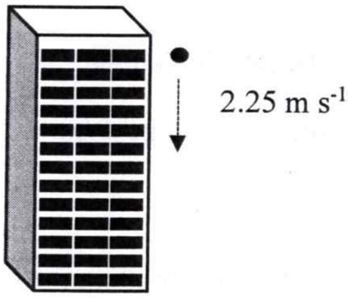
(C) The ball has the maximum acceleration at point R.

(D) The ball has the same acceleration at all the points marked.

2 A student throws a ball vertically downwards from the roof of a building.

The ball leaves her hand at 2.25 m s^{-1}.

If the ball takes 1.80 seconds to hit the ground, how high is the building?



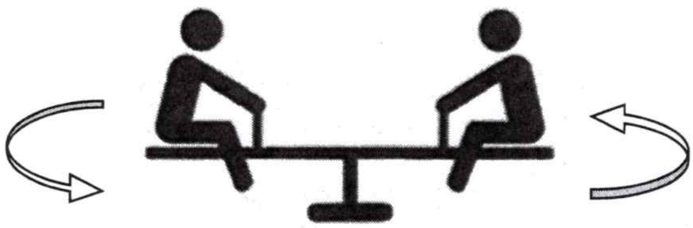
(A) 16 m

(B) 20 m

(C) 25 m

(D) 30 m

3 Two children sit on opposite ends of a small roundabout that is rotating horizontally.
They are both sitting 2.5 metres from the axis of rotation.
Child P has a mass of 36 kg and child Q has a mass of 45 kg.



Which statements correctly show the values for the centripetal acceleration and force experienced by each child?

	Centripetal acceleration	Centripetal force
(A)	P < Q	P < Q
(B)	P = Q	P < Q
(C)	P < Q	P = Q
(D)	P > Q	P > Q

4 Which list only contains fundamental particles from the Standard Model?

(A) Higgs boson, baryon, photon, neutron

(B) Up quark, electron neutrino, proton, tau

(C) Gluon, tau, z boson, strange quark, muon

(D) Proton, neutron, electron, electron neutrino

5 A small satellite with mass of 500 kg is orbiting the Earth at an altitude of 800 km. What is the magnitude of the satellite's centripetal acceleration?

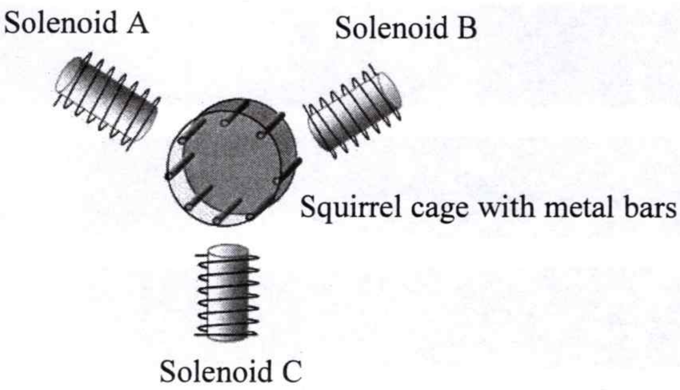
(A) 3.6 m s^{-2}

(B) 6.8 m s^{-2}

(C) 7.8 m s^{-2}

(D) 9.8 m s^{-2}

6 A student performed an experiment where a squirrel cage was surrounded by three solenoids.



The currents in the solenoids are varied so that they create a north magnetic pole first in A, then then in B and then in C, in a clockwise rotating cycle. Which statement correctly describes what happens in the squirrel cage?

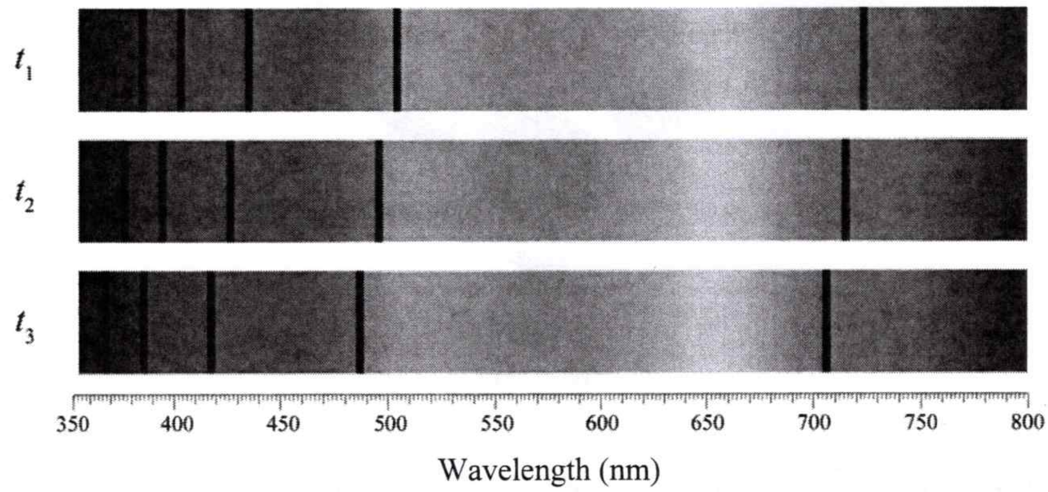
(A) Current is induced in the metal bars of the squirrel cage and will cause it to rotate in a clockwise direction.

(B) Current is induced in the metal bars of the squirrel cage and will cause it to rotate in an anticlockwise direction.

(C) The metal bars in the squirrel cage will become permanent magnets causing the squirrel cage to rotate in a clockwise direction.

(D) The metal bars in the squirrel cage will become permanent magnets causing the squirrel cage to rotate in an anticlockwise direction.

7 Three simplified absorption spectra from a distant star are shown below.



The spectra are recorded sequentially in time.

Which physics principle would be used to conclude that the star is moving relative to an Earth observer?

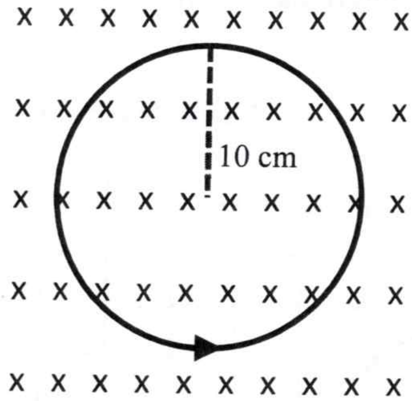
(A) Malus' law

(B) Wien's law

(C) Doppler effect

(D) Photoelectric effect

8 A charged particle with a mass of 6.692×10^{-27} kg and charge of 1.6×10^{-16} C follows a circular path of radius 10 cm, inside a uniform magnetic field of strength 0.10 T. Calculate the speed of the charged particle.



(A) 1.2×10^{6} m s^{-1}

(B) 2.4×10^{6} m s^{-1}

(C) 2.4×10^{8} m s^{-1}

(D) 2.4×10^{10} m s^{-1}

9 A transformer has a primary input power of 500 W and is 70 % efficient. If the secondary voltage of the transformer is 70 V. What is the current flowing in the secondary coil?

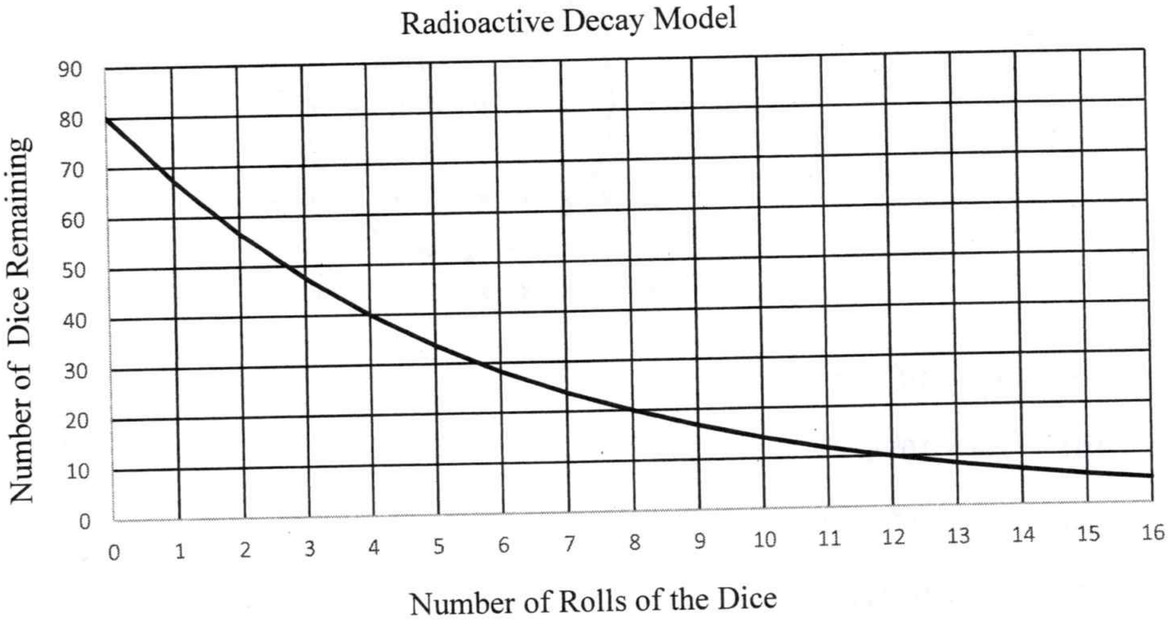
(A) 2.1 A

(B) 5.0 A

(C) 7.1 A

(D) 10.2 A

10 Students performed an experiment to model radioactive decay.
80 dice were rolled and the dice that showed a six were removed.
The procedure was repeated multiple times, with the sixes removed after each throw.
The graph shows the results of the student's experiment.



Identify the half-life of the radioactive decay that the student modelled.

(A) 1 roll

(B) 2 rolls

(C) 4 rolls

(D) 8 rolls

11 Two parallel conductors have their separation distance halved and both their currents halved. What effect will this have on the magnitude of force between the conductors?

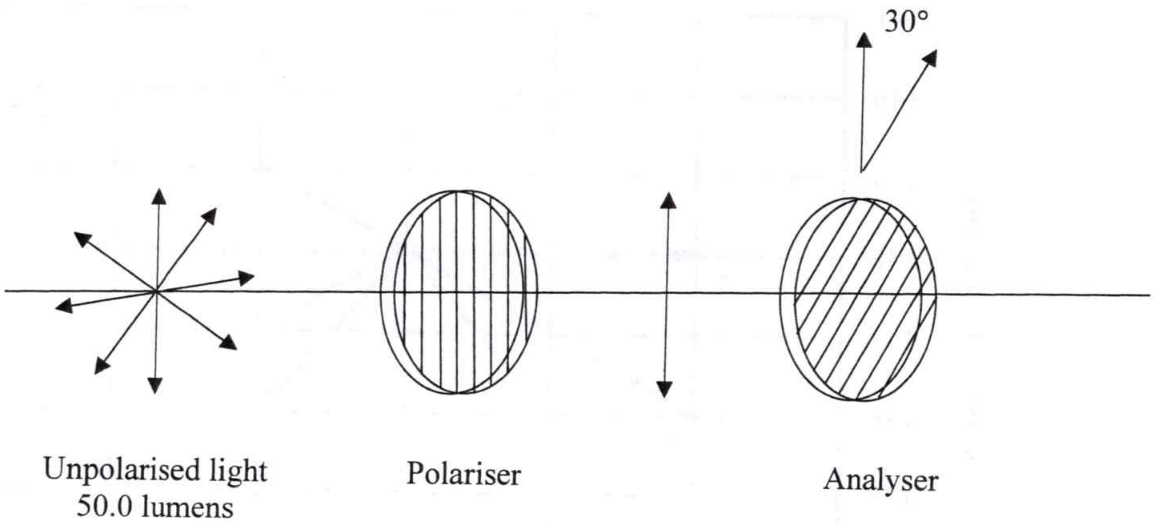
(A) The magnitude will be halved.

(B) The magnitude will be doubled.

(C) The magnitude will be 8 times larger.

(D) The magnitude will be 1/8 times smaller.

12 An unpolarised light with intensity of 50.0 lumens passes through a polariser and then an analyser as shown. The analyser is rotated by an angle of 30 degrees to the polariser. Calculate the intensity of the light after it passes through the analyser.



(A) 18.8 lumens

(B) 21.6 lumens

(C) 37.5 lumens

(D) 43.3 lumens

13 When comparing gamma and ultraviolet radiation, which statement is correct?

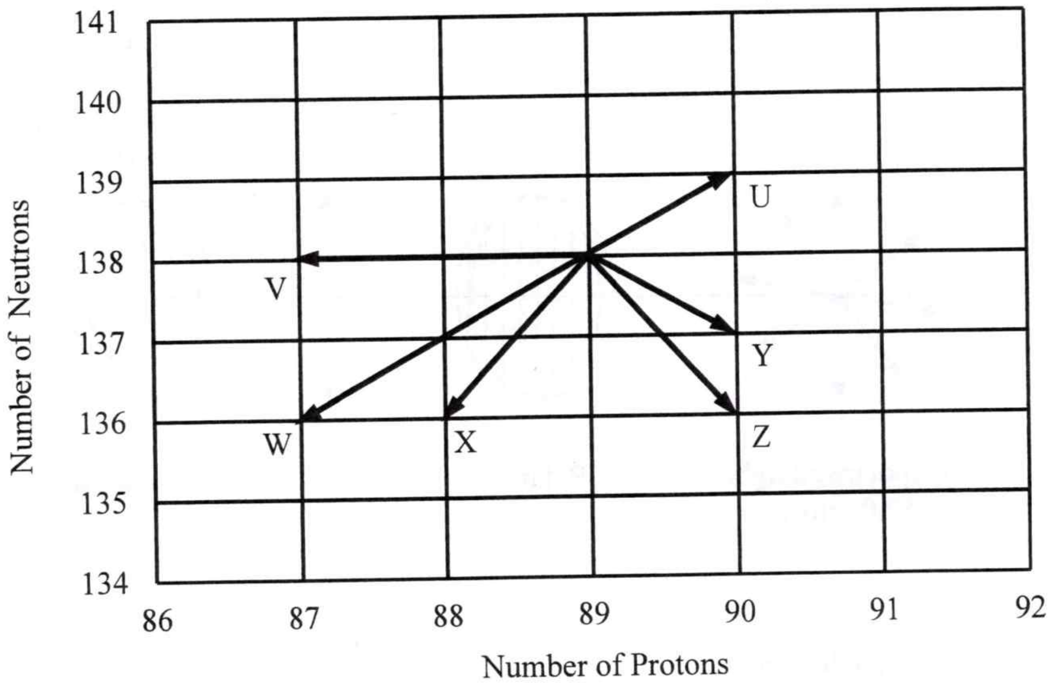
(A) Gamma radiation has a higher wavelength.

(B) Gamma radiation travels faster in a vacuum.

(C) Gamma radiation has less power to ionise molecular bonds.

(D) Gamma radiation produces photoelectrons with higher maximum kinetic energy.

14 An Actinium-227 isotope can naturally undergo either alpha, or beta-minus decay. Which arrows on the diagram would best represent an alpha and beta-minus decay respectively?



(A) W and Y

(B) W and Z

(C) X and Z

(D) Y and X

15 In a particle accelerator a proton has a momentum of 5.1×10^{-19} kg m s^{-1}. Calculate the proton's wavelength.

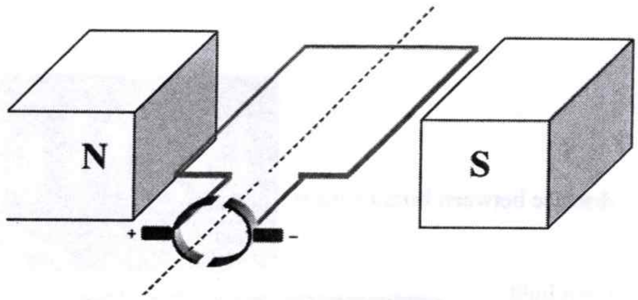
(A) 1.3×10^{-18} m

(B) 1.3×10^{-15} m

(C) 4.0×10^{-10} m

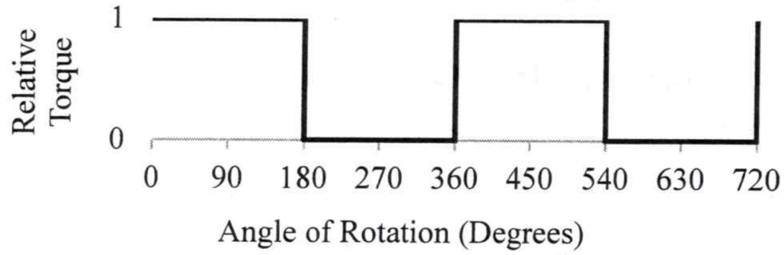
(D) 4.0×10^{-7} m

16 The diagram shows a simple D.C. motor.

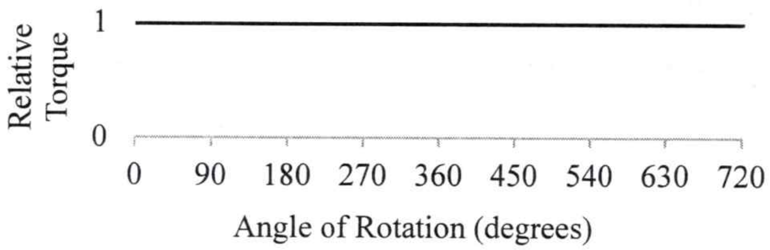


Which of the following graphs correctly shows the change in torque on the coil, as the motor rotates through two revolutions?

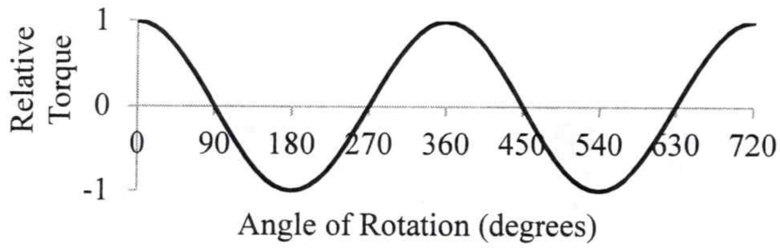
(A)



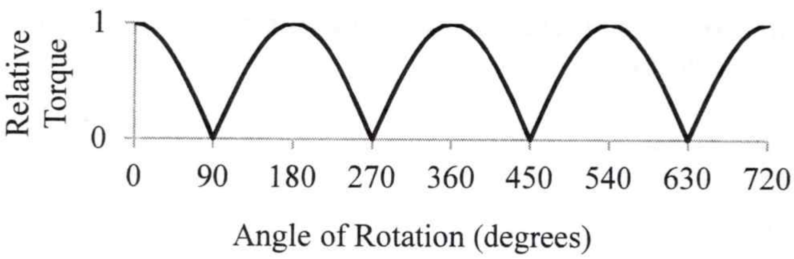
(B)



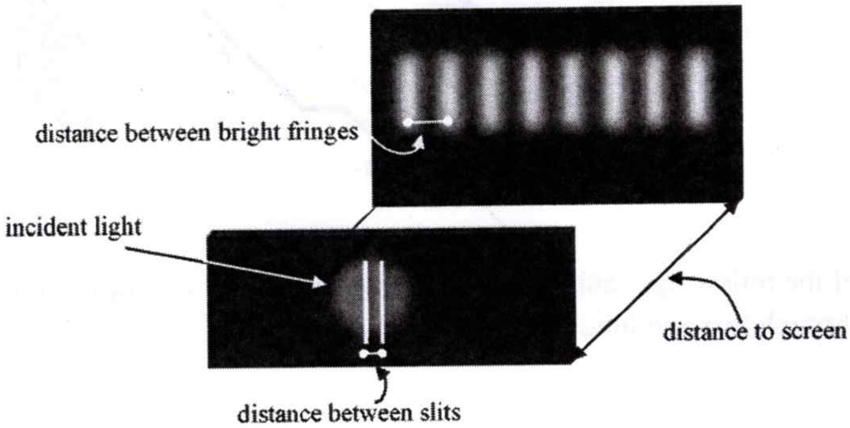
(C)



(D)



17 The diagram below shows the set-up for an investigation of double-slit diffraction.



Which of the following changes would increase the distance between the bright fringes appearing on the screen?

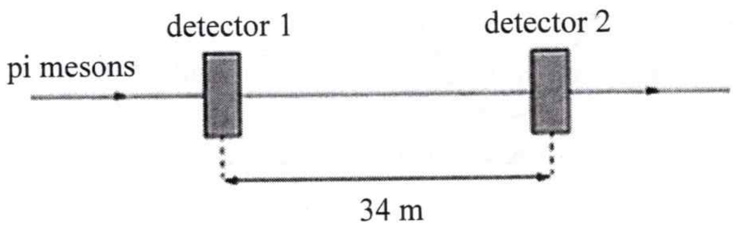
(A) Moving the screen closer to the double slits.

(B) Increase the wavelength of the incident light.

(C) Increasing the width of the slits, while keeping their separation distance the same.

(D) Increasing the separation distance between the slits, while keeping their width the same.

18 Two detectors are measured to be 34 m apart by an observer in a laboratory. A beam of pi mesons travels in a straight line at a speed of 0.95 c past the two detectors, as shown in the figure below.



What time difference would the observer measure in their reference frame for the pi meson to travel between the two detectors?

(A) 6.0×10^{-8} s

(B) 1.2×10^{-7} s

(C) 1.9×10^{-7} s

(D) 3.8×10^{-7} s

19 How would the spectra of the first stars that were formed after the Big Bang vary from recently formed stars, like the Sun?

(A) There would be no variation.

(B) They would not contain element lines heavier than lithium.

(C) They will contain many fewer lines, as the atoms will have no electrons.

(D) They would contain many more absorption lines, as they will be much hotter.

20 Two relativistc spacecraft travel away from each other, each at a speed of 0.6 c. What value would each spacecraft measure the others's speed?

(A) Less than 0.6 c

(B) 0.6 c

(C) Greater than 0.6 c, but less than c

(D) 1.2 c

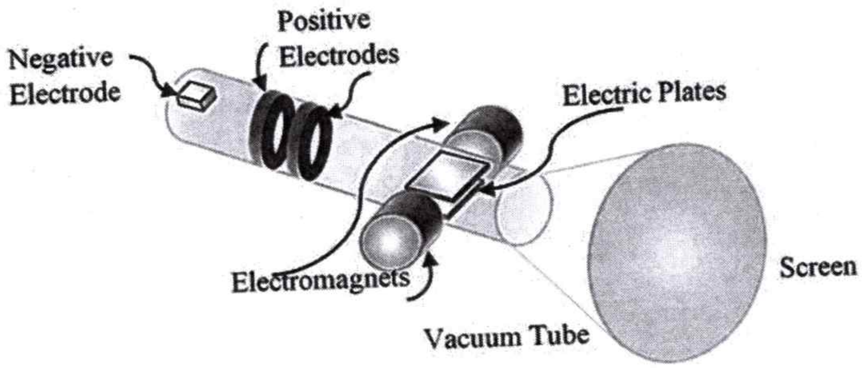
Section II

80 marks
Attempt Questions 21-35
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.
- Extra writing space is provided on page 30. If you use this space, clearly indicate which question you are answering.

Question 21 (3 marks)

The diagram shows an experiment that was used to discover more about the properties of electrons.



Outline the physics of this experiment and what it revealed about the electron. 3

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Question 22 (5 marks)

Kepler 186f, an exoplanet that orbits the red dwarf star Kepler 186, was discovered in 2014.

The planet has been proposed as an alternate place for human habitation.

The following data provides a comparsion of the Earth and Sun, to the exoplanet Kepler 186f and its star Kepler 186.

Mass of Sun 2.0×10^{30} kg = 1 solar mass	Mass of star Kepler 186 0.54 solar mass
Orbital radius of Earth 1.5×10^{8} km = 1 astronomical unit	Orbital radius of exoplanet Kepler 186f 0.41 astronomical units
	Mass of the exoplanet Kepler 186f 1.4 Earth's mass
Earth days in a year = 365	Radius of the exoplanet Kepler 186f 1.2 Earth's radius

(a) Calculate the orbital period for Kepler 186f, to the nearest day. **3**

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(b) Show by calculation if the gravity of Kepler 186f would be suitable for human life. **2**

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Question 23 (8 marks)

The International Space Station (ISS), with its crew of six astronauts, orbits the Earth at an altitude of 400 km. The ISS has been constructed utilising multiple space missions and now has a total mass of 420,000 kg.

(a) Calculate the amount of energy required to raise the total mass of the ISS to its 400 km altitude from the Earth's surface. **3**

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(b) Calculate the kinetic energy and the total energy of the ISS as it orbits the Earth. **3**

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(c) Explain why the total energy of the ISS is less than its kinetic energy. **2**

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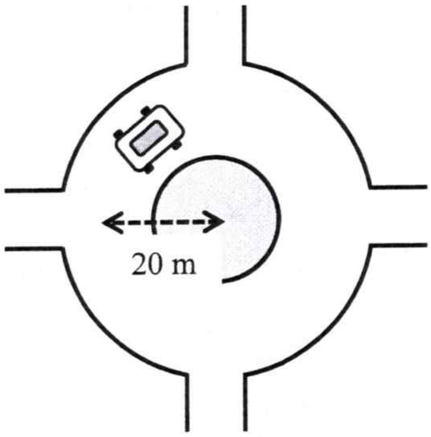
Question 24 (4 marks)

A student, sitting in a passenger seat of a car, was balancing a flat tray with a 50 g marble placed on the centre of the tray. As the car travelled around a roundabout of radius 20 metres at 30 km/h, the student angled the tray to stop the marble rolling off.



(a) What is the angle that the student needed to hold the tray to keep the marble in the centre of the tray, while travelling in the roundabout? Assume no friction acts on the marble. **3**

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(b) If the marble's mass was doubled to 100 g, what angle would the student now require? Justify your answer. **1**

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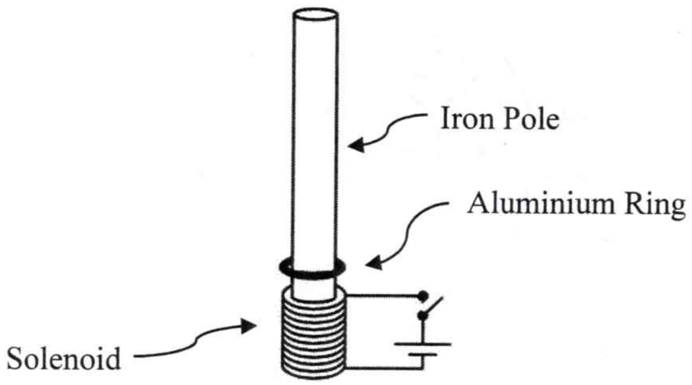
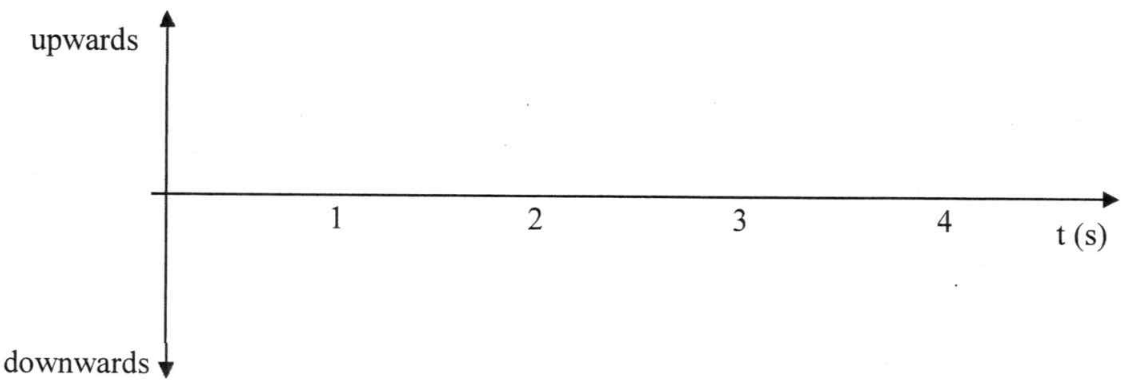
Question 25 (5 marks)

An aluminim ring is free to move up and down an iron pole (as shown).
Wound around the bottom of the pole is a high voltage solenoid.
At time t = 0 s, the ring is resting on the solenoid.
At time t = 1 s, a D.C. voltage is switched on by closing the switch shown.
At time t = 3 s, the D.C. voltage is switched off by opening the switch.



(a) Sketch a velocity versus time graph for the motion of the alumium ring for the first 4 s. **2**



(b) Using the appropriate physics, explain the motion of the aluminium ring, if the switch is closed and remains closed. **3**

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Question 26 (5 marks)

When a uranium-235 nucleus absorbs a slow-moving neutron, a possible outcome is the production of a strontium-90 and xenon-136 nucleus. The nuclear reaction also results in the release of a number of neutrons.

(a) Complete the nuclear equation to represent this fission. State how many neutrons must be released as part of this process. **2**

$^{235}_{92}U + ^{1}_{0}n \rightarrow$

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(b) Use the information in the table below to calculate the amount of energy released from a single Uranium-235 atom undergoing the fission reaction described above. **3**

Particle	**Mass (x 10^{-27} kg)**
neutron	1.675
U-235	390.989
Sr-90	149.301
Xe-136	225.687

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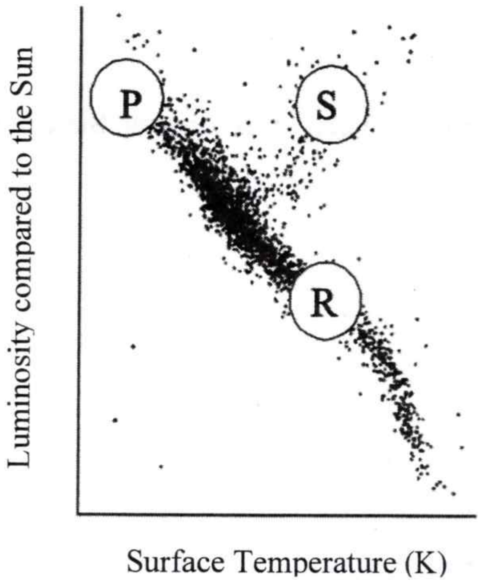
Question 27 (4 marks)

Three stars are positioned on the Hertzsprung Russell Diagram as shown.



(a) State the evolutionary stages of stars P, R and S. **1**

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(b) Compare the nucleosynthesis reactions that are occurring in the three stars. Include the reactants and products of the reactions. **3**

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Question 28 (3 marks)

Outline the important features of Edwin Schrödinger's model of the the atom and contrast one feature from earlier models. **3**

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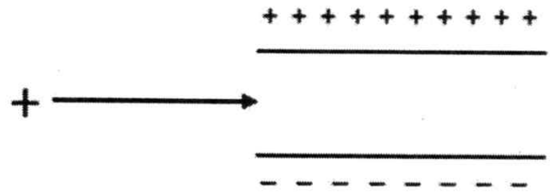
Question 29 (6 marks)

A particle of mass 0.01 g and charge +3 μC enters a uniform electric field as shown.
The voltage between the metal plates is 1000 V, and the plates are 5 cm apart.
The particle enters the field midway between the plates with a velocity of 50 m s^{-1}, perpendicular to the field.



(a) Calculate the horizontal distance travelled by the particle before it reaches one of the electric plates. **3**

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(b) Calculate the velocity of the particle when it reaches the same plate. **3**

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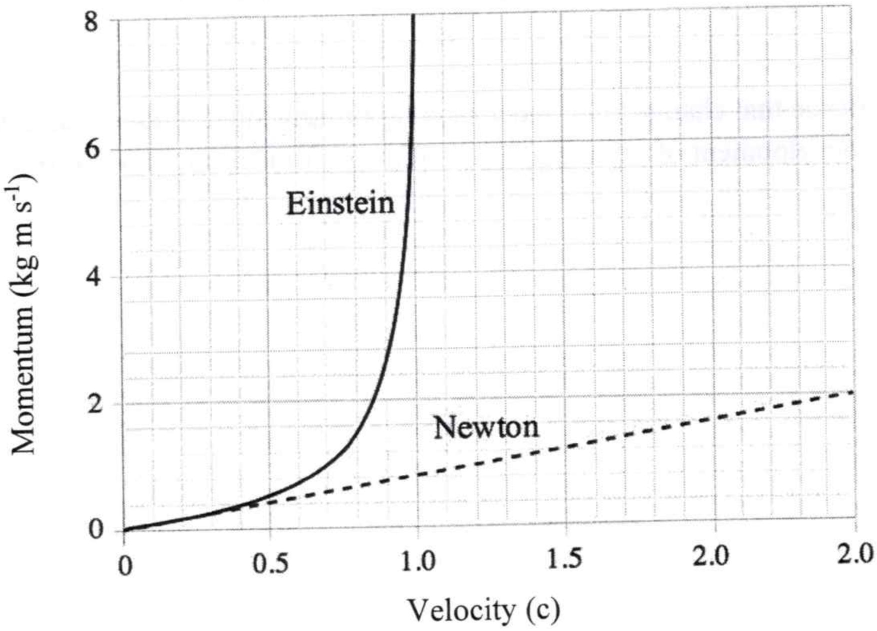
Question 30 (6 marks)

The graph below shows the relationship between the velocity of an object and its momentum as explained by Newton's laws of motion and Einstein's theory of special relativity.



(a) Justify the claim that the gradient of the line labelled Newton is equivalent to mass. **2**

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(b) Account for the differences in the shape of the two lines using Newton's classical mechanics and Einstein's theory of special relativity. **4**

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Question 31 (7 marks)

Thomas Young provided the first real experimental evidence for the wave nature of light in 1803 by demonstrating diffraction and interference for a beam of visible light. We now accept light as having either wave or particle properties, depending on the experiment conducted to measure those properties. **7**

Describe the evidence that changed our understanding of light since Young's discovery and explain how it led to the development of wave-particle duality as a model for all forms of electromagnetic radiation.

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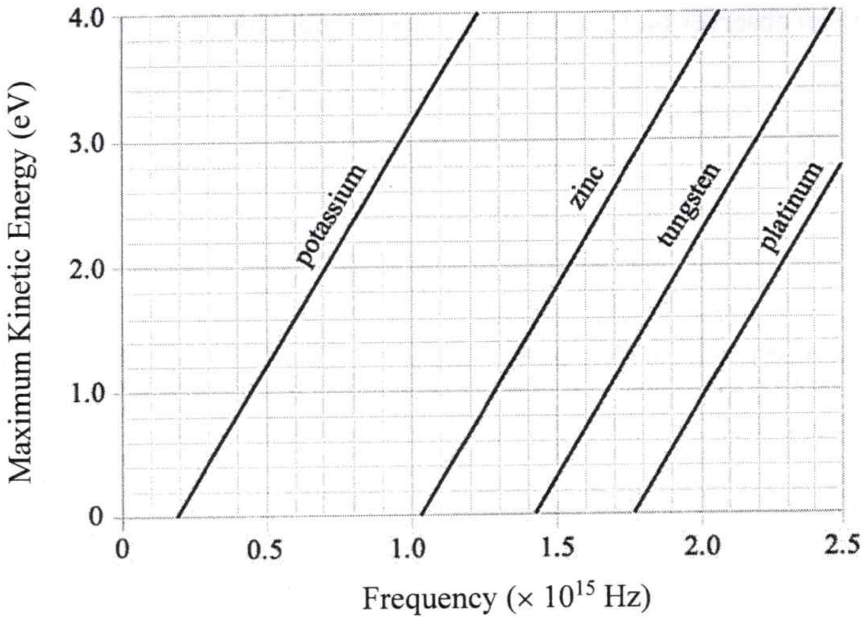
Question 32 (5 marks)

The graph below shows how the relationship between the frequency of incident light and the maximum kinetic energy of emitted photoelectrons varies for different metals.



(a) Explain the relationship of maximum kinetic energy and frequency as shown on the graph. **3**

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(b) Explain why the line for each of the metals shown on the graph has the same gradient. **2**

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Question 33 (3 marks)

Light takes 4.3 years to reach the Earth from the nearby star Alpha Centauri.

(a) A space probe is to be sent from the Earth to Alpha Centauri to arrive 5.0 years later, according to an observer on Earth. At what speed would the space probe need to travel? **1**

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(b) Calculate the time taken for this journey in years measured by a clock inside the space probe. **2**

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Question 34 (7 marks)

An experiment is performed to measure the charge of the electron. A potential difference of 2041.7 V is applied between two horizontal parallel metal plates which are 20.0 mm apart. As a result, an oil droplet with mass of 5.0×10^{-15} kg is suspended stationary in the field.

(a) Calculate the charge of this oil droplet. **3**

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(b) The experiment was repeated 7 times and the results are shown in the table below. **2**

Trial number	Charge on the oil droplet ($\times 10^{-19}$ C)
1	19.2
2	12.8
3	9.6
4	6.4
5	38.4
6	16.0
7	28.8

What value for the charge on an electron would these results produce?
Justify your answer.

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(c) Electrons are classified as leptons in the Standard Model of matter. Name two other lepton particles. **2**

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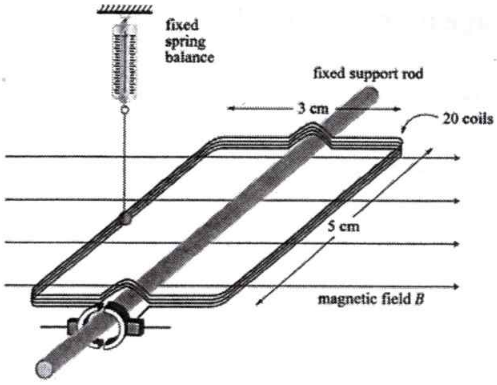
Question 35 (9 marks)

A simple D.C. motor is placed in a magnetic field (B). The rectangular coil has sides 3 cm and 5 cm with 20 turns. A spring balance is attached to one side of the winding to measure the force required to prevent the motor from rotating. The current in the winding is increased and the force on the spring balance recorded.

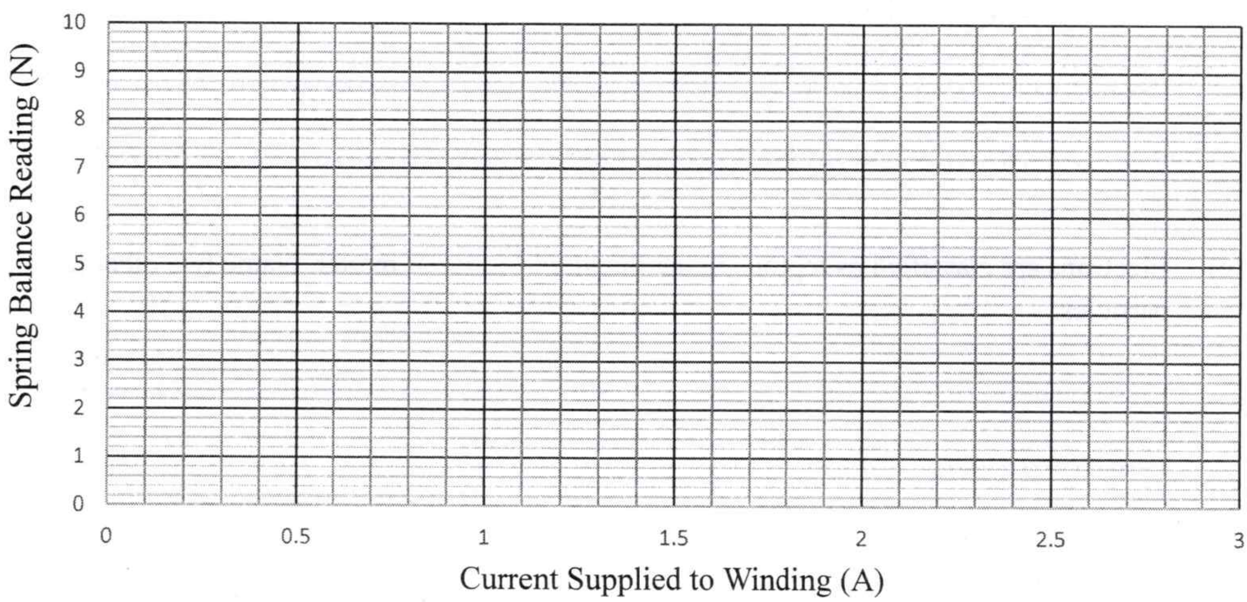


The results are shown in the table.

Current Supplied to Winding (A)	Spring Balance reading (N)
0.0	0
0.5	1.8
1.0	3.3
1.5	5.3
2.0	6.3
2.5	8.5

(a) Indicate the direction the current is flowing on the diagram above. **1**

(b) Graph the results and include a line of best fit. **3**



Question 35 continued

(c) How can the reading on the spring balance be used to determine the torque produced by the motor? **1**

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(d) Use the line of best fit to determine the strength of the magnetic field in this DC motor. **2**

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(e) A student completing this experiment notices that when the motor is running it stays cool, but when the spring balance prevents the motor from turning it gets hot. Explain why this is the case. **2**

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End of paper

Section II extra writing space

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EXAMINERS

Tony Walsh (Convenor)	Freeman Catholic College, Bonnyrigg Heights
Janet Pemberton (Convenor)	Roseville College, Roseville
Jonathon Saurine	All Saints Grammar School, Belmore
Alex Conolly	Santa Sabina College, Strathfield
Lily Okati	Christian Brothers' High School Lewisham

CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NSW
2020 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION
PHYSICS – MARKING GUIDELINES

Section I

20 marks

Questions 1-20 (1 mark each)

Question	Answer	Content	Outcomes Assessed	Targeted Performance Bands
1	D	Projectile motion	12-12	2-3
2	B	Equations of uniform motion	12-12	2-3
3	B	Centripetal motion	12-12	2-3
4	C	Standard model	12-15	2-3
5	C	Gravitational field strength	12-12	3-4
6	A	Induction motor	12-13	3-4
7	C	Stellar spectra	12-13	3-4
8	C	Charge in magnetic field	12-13	3-4
9	B	Transformers	12-13	3-4
10	C	Modelling radioactive decay	12-15	3-4
11	A	Parallel conductors	12-13	4-5
12	A	Malus's law	12-14	4-5
13	D	Light quantum	12-14	3-4
14	A	Alpha and beta decay	12-15	4-5
15	B	De Broglie wavelength	12-15	4-5
16	D	Motor graphs	12-13	4-5
17	B	Double slit diffraction	12-14	4-5
18	B	Relativity	12-12	4-5
19	B	First star spectra	12-15	4-5
20	C	Special relativity	12-14	4-5

Section II
80 marks

Question 21 (3 marks)
Outcomes Assessed: 12-15
Targeted Performance Bands: **3-4**

Criteria	Marks
• Explains the physics of Thomson's experiment that produced an electron beam and was directed by electric and magnetic fields • Identifies that the electron charge to mass ratio was measured	3
• Explains the magnetic and electric field interaction • Describes the properties of cathode rays	2
• Describes the properties of cathode rays	1

Sample answer:

- The negative electrode produces a beam of cathode rays, that we now call electrons.
- They are concentrated into a beam that accelerates to the anode, then travels at a constant speed before hitting the screen.
- The beam was able to be deflected by both an electric (E) and magnetic (B) field.
- Thomson adjusted the strength of electric and magnetic fields to eliminate any beam deflection.
- Equating the forces caused by the two fields, the speed of the beam could be determined by $v = E/B$.
- Using the magnetic field only produced a centripetal force on the beam.
- Equating $F = qvB$ with mv^2/r, an expressing for the charge to mass ratio can be derived. $q/m = E/B^2r$.
- The q/m ratio was measured to be very large. The conclusion being that the electron has a very small mass relative to a large charge.

Question 22 (5 marks)
(a) (3 marks)
Outcomes Assessed: 12-12
***Targeted Performance Bands:* 4-6**

Criteria	Marks
• Calculates period in days	3
• Calculates period in seconds	2
• Correct substitution into Kepler's Third Law Equation	1

Sample answer:

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

$$T = \sqrt{\frac{4\pi^2 \times (0.41 \times 1.5 \times 10^{11})^3}{6.67 \times 10^{-11} \times 0.54 \times 2.0 \times 10^{30}}} = 11{,}291 \text{ s} = 131 \text{ days}$$

OR

$$\frac{r^3}{T^2 M} \text{ (Kepler 186f)} = \frac{r^3}{T^2 M} \text{ (Earth)}$$

$$\frac{T_{\text{Kepler 186f}}}{T_{\text{Earth}}} = \sqrt{\frac{0.41^3}{0.54}} = 0.36$$

$$T_{\text{Kepler 186f}} = 365 \times 0.36 = 131 \text{ days}$$

(b) (2 marks)
Outcomes Assessed:* *12-12
***Targeted Performance Bands:* 3-4**

Criteria	Marks
• Calculates acceleration due to gravity • Suitable conclusion	2
• Calculates acceleration due to gravity OR • Correct substitution and suitable conclusion based on incorrect calculation	1

Sample answer:

Combining $F = \frac{GMm}{r^2}$ with weight equation $W = mg$

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 1.4 \times 6.0 \times 10^{24}}{(1.2 \times 6.371 \times 10^6)^2} = 9.6 \text{ m s}^{-2}$$

OR

$$g_{\text{Kepler 186f}} = g_{\text{Earth}} \times \left(\frac{1.4}{1.2^2}\right) = 9.5 \text{ m s}^{-2}$$

This is within 3% of the Earth's surface gravity of 9.8 m s^{-2}, which is suitable for human life.

Question 23 (8 marks)

(a) (3 marks)

Outcomes Assessed: 12-12

***Targeted Performance Bands:* 4-5**

Criteria	Marks
• Calculates required energy	3
• Correct method of calculating required energy, with one substitution error	2
• Correct method of calculating required energy, with more than one substitution error	1

Sample answer:

$\Delta U = U_{orbit} - U_{ground}$

$U_{orbit} = -\frac{GMm}{(r_e + \text{altitude})} = -\frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 4.2 \times 10^5}{(6.371 + 0.4) \times 10^6} = -2.4824 \times 10^{13}\ \text{J}$

$U_{ground} = -\frac{GMm}{(r_e)} = -\frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 4.2 \times 10^5}{(6.371 \times 10^6)} = -2.6383 \times 10^{13}\ \text{J}$

$\Delta U = (-2.4824 \times 10^{13}) - (-2.6383 \times 10^{13}) = 1.56 \times 10^{12}\ \text{J}$

(b) (3 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands 4-6

Criteria	Marks
• Calculates kinetic and total energies	3
• Correct substitution kinetic and total energies OR • Calculates kinetic or total energy	2
• Correct substitution for kinetic or total energy	1

Sample answer

$$v = \sqrt{\frac{GM}{r}}, K = \frac{1}{2}mv^2 = \frac{GMm}{2r} = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 4.2 \times 10^5}{2 \times (6.371 + 0.4) \times 10^6} = 1.24 \times 10^{13} \text{ J}$$

OR

$$K = -\frac{1}{2}U_{orbit} = \frac{1}{2} \times 2.482 \text{ x } 10^{13} = 1.24 \times 10^{13} \text{ J}$$

$$E = U + K = -\frac{GMm}{2r} = -\frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 4.2 \times 10^5}{2 \times (6.371 \times 10^6 + 4 \times 10^5)} = -1.24 \times 10^{13} \text{ J}$$

(c) (2 marks)
Outcomes Assessed: 12-12
Targeted Performance Bands 4-5

Criteria	Marks
• Explains the mathematical negative value of gravitational potential energy and the corresponding smaller value for total energy	2
• States that total energy is the sum of the kinetic and gravitational potential energies	1

Sample answer

The total energy is the sum of the kinetic and gravitational potential energy (U).

As U is mathematically defined as a negative value, increasing to zero at infinite distance, the sum of K ($\frac{GMm}{2r}$) and U (- $\frac{GMm}{r}$), yields a smaller mathematical value.
A higher orbit equates to a lower kinetic energy, with a higher potential and total energies.

Question 24 (4 marks)

(a) (3 marks)

Outcome assessed: 12-12

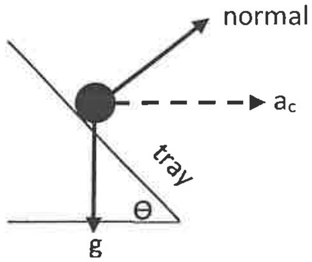
Target Performance Bands 4-6

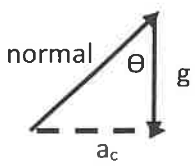
Criteria	Marks
• Calculates required angle	3
• Calculates centripetal acceleration • Correct drawing of vector diagram	2
• Calculates centripetal acceleration OR • Attempts vector diagram	1

Sample answer

30 km/h = 8.33 m s^{-1}

Centripetal acceleration a_c required is $\frac{v^2}{r} = \frac{8.33^2}{20} = 3.47 \text{ m s}^{-2}$ towards the centre of curve





$\theta = \tan^{-1}\left(\frac{a_c}{g}\right) = \tan^{-1}\left(\frac{3.47}{9.8}\right)$ = 19.5° to the horizontal

(b) (1 mark)

Outcomes Assessed: 12-12

Targeted Performance Bands 3-4

Criteria	Mark
• Identifies that the angle does not change	1

Sample answer

As the angle is independent of the mass of the marble, it will not change.

Question 25 (5 marks)

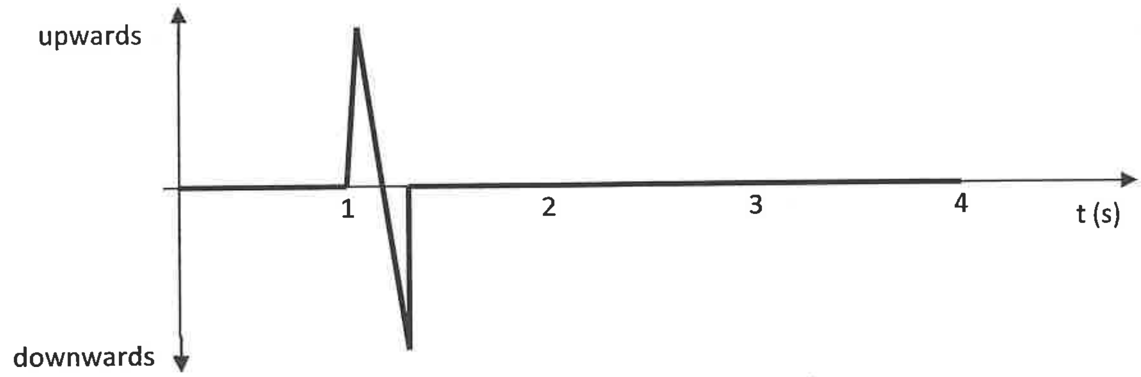
(a) (2 marks)

Outcomes Assessed: 12-12/13

Targeted Performance Bands 3-6

Criteria	Marks
• Upwards velocity spike at 1 s • Downward velocity gradient after 1 s • Followed by no motion	2
• Any one feature above	1

Sample answer



(b) (3 marks)
Outcomes Assessed: 12-12
Targeted Performance Bands 3-4

Criteria	Marks
• Explains the motion of the ring • Explains Lenz's law and induced eddy currents	3
• Describes the motion of the ring • Demonstrates some understanding of Lenz's law	2
• Describes the motion of the ring OR • Demonstrates some understanding of Lenz's Law	1

Sample answer

- When the switch is closed, current will flow through the solenoid.
- Initially a change in electric and magnetic field will result.
- The change in magnetic flux will induce an EMF and current in the aluminium ring.
- The current will produce a magnetic field to oppose the change in flux. Lenz's Law.
- The opposing magnetic fields will propel the ring upwards.
- As the closed switch causes a constant current to flow, no change in flux results, so there is no repelling force on the ring.
- The ring will fall, under gravity back down to the solenoid.

Question 26 (5 marks)
(a) (2 marks)
Outcomes Assessed: 12-15
Targeted Performance Bands 3-4

Criteria	Marks
• Correct nuclear equation including the production of 10 neutrons	2
• Correct nuclear equation with incorrect number of produced neutrons OR • Incorrect nuclear equation with a relevant neutron number	1

Sample Answer

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{38}Sr + ^{136}_{54}Xe + 10^{1}_{0}n$$

10 neutrons produced

(b) (3 marks)

Outcomes Assessed: 12-15

Targeted Performance Bands 4-5

Criteria	Marks
• Correct energy calculation	3
• One error in calculation or substitution	2
• Two errors in calculations or substitutions	1

Sample Answer

Combined reactants' mass = $390.989 + 1.675 = 392.664 \text{ x } 10^{-27}$ kg

Combined products' mass = $149.301 + 225.687 + 10 \times 1.675 = 391.738 \times 10^{-27}$ kg

Mass deficit = $392.664 \times 10^{-27} - 391.738 \times 10^{-27} = 0.926 \text{ x} 10^{-27}$ kg

Energy created $E = mc^2 = 0.926 \times 10^{-27} \times (3 \times 10^8)^2 = 8.334 \times 10^{-11}$ J

OR

$0.926 \times 10^{-27} \div 1.66 \times 10^{-27} = 0.5578$ amu

Convert to energy using factor 931.5 MeV x 0.5578 = 519.620 MeV = 8.313×10^{-11} J

Question 27 (4 marks)

(a) (1 mark)

Outcomes Assessed: 12-15

Targeted Performance Bands 2-3

Criteria	Mark
• Identifies all three evolutionary stages for stars P, R and S	1

Sample Answer

Stars P and R are main sequence. Star S is a red giant or supergiant.

(b) (3 marks)

Outcomes Assessed: 12-15

Targeted Performance Bands 2-4

Criteria	Marks
• Identifies the dominant reactions in each star • Describes the reactants and products of each reaction	3
• Identifies 2 of the nucleosynthesis reactions	2
• Identifies 1 nucleosynthesis reaction	1

Sample Answer

- All the stars have the production of helium by the fusion of hydrogen.
- Star P mainly fuses helium via the CNO cycle (carbon, nitrogen, oxygen cycle).
- Star R predominately fuses hydrogen to helium via the proton-proton chain reaction.
- Star S fuses hydrogen to helium in the hydrogen burning shell around the core. The synthesis of heavier elements such as carbon will occur in layers of the core.

Question 28 (3 marks)
Outcomes Assessed: 15
Targeted Performance Bands 3-5

Criteria	Marks
• Describes Schrodinger's model with features such electron probability curves or clouds • Includes at least ONE significant difference to earlier models	3
• States some features of Schrodinger's model • Contrast one feature of Schrodinger's model to earlier models	2
• Identifies one feature of Schrodinger's model	1

Sample Answer

Schrodinger's Model

Schrodinger's model was a further advancement on de Broglie with the advancement in knowledge of wave particle duality leading to the blurring of the division between matter and waves and by the quantum physics discovery that the position of particles like electrons can only be determined as a probability not as a certainty.

The electrons exist in a series of orbitals (or clouds) which have particular shapes. These clouds are shaped according to Schrodinger's wave functions and agreement with Pauli's exclusion principle.

Earlier Models

When the electrons first appeared in the Atomic Model. Rutherford considered them to be particles with mass circling the nucleus like planets around the Sun. There was no though of particles having wave properties.

Question 29 (6 marks)
(a) (3 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands 5-6

Criteria	Marks
• Calculates electric field strength • Calculates horizontal distance • Calculates acceleration	3
• Two correct steps	2
• One correct step	1

Sample answer

Electric field between the plates $E = \frac{V}{d} = \frac{1000}{0.05} = 20\ \text{kV/m}$

Force on the charge $F = qE = 20 \times 10^3 \times 3 \times 10^{-6} = 6 \times 10^{-2}$ N towards negative plate

Downward acceleration $a = \frac{F}{m} = \frac{6 \times 10^{-2}}{0.01 \times 10^{-3}} = 6{,}000\ \text{m s}^{-2}$

Using projectile motion formulae

$$s = ut + \frac{1}{2}at^2$$

$$0.025 = 0 + \frac{1}{2} \times 6000 \times t^2$$

t = 2.89 ms

$x = u_x t = 50 \times 2.89 \times 10^{-3} = 14.4$ cm, or 0.144 m

(b) (3 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands 4-5

Criteria	Marks
• Calculates velocity of charge at plate	3
• Calculates magnitude of velocity of charge at plate	2
• Calculates vertical velocity component	1

Sample answer

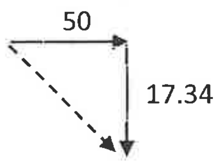
Finding vertical component of velocity at 2.89×10^{-3} s

$v = u + at = 0 + (6000 \times 2.89 \times 10^{-3}) = 17.34 \text{ m s}^{-1}$

Horizontal velocity is 50 m s^{-1}

Using Pythagoras and $\tan^{-1}$ (17.34 / 50)

$v = 53$ m s^{-1} at 19° below the horizontal.



Question 30 (6 marks)

(a) (2 marks)

Outcomes Assessed: 12-14

Targeted Performance Bands 3-4

Criteria	Marks
• Relates the formula for momentum to the gradient of the graph	2
• States the formula for momentum	1

Sample answer

The Newtonian relationship between momentum (p) and velocity (v) is given by the formula p = mv. A graph of momentum versus velocity, for a constant mass (m) yields a straight line with gradient p/v, which equates to mass.

(b) (4 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands 4-5

Criteria	Marks
• Justifies how the gradient of each line correspond to momentum using the appropriate Newtonian and Einstein equations	4
• Relates the gradient of each line to the appropriate Newtonian and Einstein equations	3
• Identifies the appropriate Newtonian and Einstein equations	2
• States a relevant Newtonian or Einstein equation	1

Sample answer

The lines match with the two formulae for momentum for Newton and Einstein.
The Newtonian relationship $p = mv$ states that mass can remain constant for all velocities, yielding a straight line.
However, Einstein proposed that at relativistic speeds the observed mass and momentum of an object is dilated as shown by the formula:

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

As v approaches c, the denominator of the formula for relativistic momentum approaches zero.
Therefore, the momentum approaches infinity.
The graph shows that it is not possible to have a velocity greater than c.

Question 31 (7 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands 4-6

Criteria	Marks
• Describes three pieces of evidence and explains in detail how this led to the wave particle duality model for all EM waves	7
• Describes three pieces of evidence and links to the wave particle model OR • Describes two pieces of evidence and explains in detail how this led to the wave particle model	6-5
• Identifies two pieces of evidence related to the wave particle model	4-3
• Gives some examples of light properties OR only discusses Young and Newton Huygens debate	2-1

Sample answer

Intro

When Thomas Young completed his double slit experiment, it seemed that the light was definitely a wave not a particle as Newton had suggested. A particle could not demonstrate constructive and destructive interference.

Evidence that changed the model

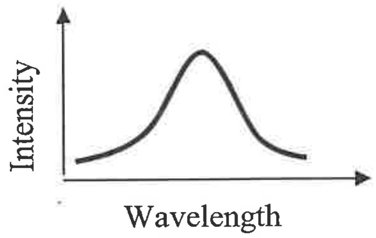
1 Maxwell

In the latter half of the 19th century, James Clark Maxwell theorised that light was an electromagnetic wave made up of oscillating electric and magnetic fields and that there were other forms of electromagnetic radiation with varying wavelengths and frequencies that all travelled at the speed of light. His theories were confirmed by Hertz and others when other electromagnetic waves were generated, and their speed measured to be the same as light.

But, in the 20th century new observations were made that challenged our understanding of electromagnetic radiation as a wave.

2 Black Body Radiation

It was observed that hot bodies released EM radiation and that a distinct graph could be constructed showing the Intensity of light being released for each wavelength.



This could not be explained using a wave model approach. Planck suggested that these hot bodies were releasing light energy in packets he called quanta. Each packet having energy E=hf stating that the higher the frequency the higher the energy of the quanta.

3 The Photoelectric Effect

It was well known that light hitting a metal would cause the metal to release electrons (called photoelectrons), but it was not clear why a very intense red beam of light might produce no photoelectrons where as a weak beam of ultraviolet light could produce many of high energy electrons.

The quanta approach of Planck (E = hf) could explain this. The quanta (or photons) of high frequency light could be absorbed individually by electrons on the surface of the metal and hence get enough energy to escape the metallic lattice. Whereas low frequency photons would not supply the energy to the electrons.

Hence Einstein proposed that all light, not just light from hot bodies, has particle properties.

Conclusion

Since the interference effects of light are also evident in diffraction and other effects which are now put to use in radio signals and optical fibre technology, Scientists now conclude that light can have either wave or particle properties and the measured properties actually depend on the type of experiment that is conducted to measure them. An experiment designed to measure wavelength via interference effects will show that light behaves as though it were a wave. An experiment designed to measure photocurrent via the photoelectric effect will show that light behaves as though it were a particle.

Question 32 (5 marks)
(a) (3 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands 4-5

Criteria	Marks
• Explains how the maximum kinetic energy of photoelectrons relates to the frequency of incident light for differing metals	3
• Discusses the maximum kinetic energy of photoelectrons and the frequency of incident light for differing metals	2
• Identifies the photoelectric effect	1

Sample answer

When a photon of light of sufficient energy is absorbed by a metal, an electron is released.
This is called the photoelectric effect.
The amount of energy of the photon is proportional to its frequency $E = hf$.
Any additional energy above the required amount (work function) results in kinetic energy of the photoelectron.
Each metal has a different work function, so the maximum kinetic energy of the released electron will differ.

(b) (2 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands 4-5

Criteria	Marks
• Explains Relates graph to the formula $K_{max} = hf - \phi$ Relates slope to Planck's constant	2
• Relates slope to Planck's constant without detail	1

Sample answer

The equation $K_{max} = hf - \phi$ shows the relationship of the kinetic energy (K_{max}) of a released photoelectron from a metal when impacted by incident light of frequency (f).
Graphing K_{max} versus f yields a gradient of h (Planck's constant).
The gradient (h) is the same for all metals.

Question 33 (3 marks)

(a) (1 mark)

Outcomes Assessed: 12-14

Targeted Performance Bands 2-3

Criteria	Mark
• Correct calculation of speed	1

Sample answer

Distance is 4.3 ly; time is 5 years.

$$v = \frac{d}{t} = \frac{4.3}{5} = 0.86\ c$$

(b) (2 marks)

Outcomes Assessed: 12-14

Targeted Performance Bands 3-4

Criteria	Marks
• Correct calculation of time of journey	2
• Correct substitution into a relevant equation	1

Sample answer

The space probe would observe a contraction in the journey length

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)} = \ = 4.3\sqrt{\left(1 - \frac{0.86c^2}{c^2}\right)} \ = 2.19 \text{ ly}$$

The time measured by the space probe

$$t = \frac{d}{v} = \frac{2.19}{0.86} = 2.55 \text{ years}$$

Question 34 (7 marks)

(a) (3 marks)

Outcomes Assessed: 12-13

Targeted Performance Bands 3-5

Criteria	Marks
• Calculates charge	3
• Calculates electric field	2
• Correct substitution into a relevant equation	1

Sample answer

Electric field between plates $E = \frac{V}{d} = \frac{2041.7}{0.02} = 102{,}085 \text{ V m}^{-1}$

$qE = mg$, as the weight and electric field force are balanced

$$q = \frac{mg}{E} = \frac{5 \times 10^{-15} \times 9.8}{102{,}085} = 4.8 \times 10^{-19} \text{ C}$$

(b) (2 marks)

Outcomes Assessed: 12-15

Targeted Performance Bands 3-4

Criteria	Marks
• Identifies the value of the charge • Justifies the value of the charge	2
• Identifies the value of the charge	1

Sample answer

The charge of each droplet needs to be a whole number of electrons.
The smallest charge difference between oil droplets is = 3.2
Checking other charge values confirms they are multiples of 3.2
The charge on an electron based on this data is therefore 3.2×10^{-19} C.

(c) (2 mark)

Outcomes Assessed: 12-15

Targeted Performance Bands 2-3

Criteria	Marks
• Identifies two additional leptons	2
• Identifies one additional lepton	1

Sample answer

Leptons include electron neutrinos, muon, muon neutrino, tau and tau neutrino

Question 35 (9 marks)

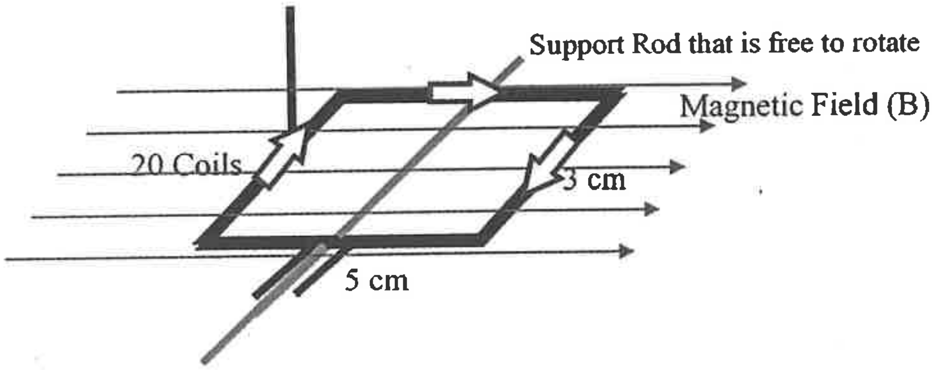
(a) (1 mark)

Outcomes Assessed: 12-13

Targeted Performance Bands 3-4

Criteria	Mark
• Illustrates correct current direction	1

Sample answer.



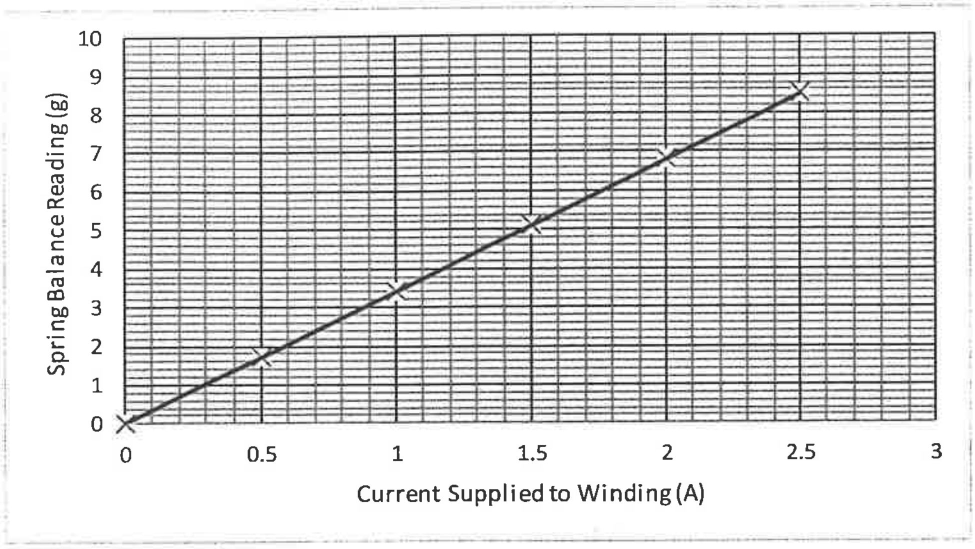
(b) (3 marks)

Outcomes Assessed: 12-4

Targeted Performance Bands 2-3

Criteria	Marks
• Accurate plotting of points • Suitable line of best fit	3
• Error in plotting of points • Suitable line of best fit	2
• Error in plotting of points • No line of best fit	1

Sample answer



(c) (1 mark)

Outcomes Assessed: 12-12

Targeted Performance Bands 3-4

Criteria	Mark
• States that the force by radius distance yields a value for torque	1

Sample answer

Torque $\tau = r \perp F$

Multiplying the force reading on the spring balance by 1.5×10^{-2} will yield a torque reading.

(d) (2 marks)

Outcomes Assessed: 12-5&13

Targeted Performance Bands 5-6

Criteria	Marks
• Calculation of magnetic field strength	2
• Calculates gradient of graph OR • Equates rF = nIAB	1

Sample answer

Gradient of Line = 3.3

Torque = $r_{\perp}F = nIA_{\perp}B$

rF = nIAB   slope of line of graph = $\frac{F}{I}$

$$\frac{F}{I} = \frac{nAB}{r} = 3.3$$

$$\frac{20 \times (0.05 \times 0.03) \times B}{0.025} = 3.3$$

B = 2.75 T

(e) (2 marks)

Outcomes Assessed: 12-13

Targeted Performance Band 4-5

Criteria	Marks
• Explains the effect of back EMF, current in the winding and subsequent heat for both situations	2
• Identifies that a back EMF is induced in the winding	1

Sample answer

When the motor is running a voltage (back EMF) is induced in the windings to oppose the change in flux. A resultant reduction in the current flowing in the windings occurs. As current in the windings produces heat, a reduction is noticed by the student.
When the motor is prevented from rotating, no back EMF is induced, causing the supply voltage to deliver a higher current to the windings. This produces heat in the motor.