CSSA

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

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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:

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

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

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

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

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

OR

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

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

(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

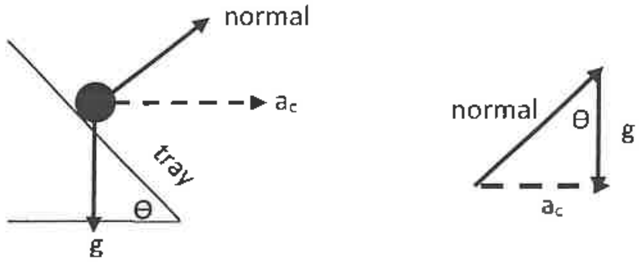
Target Performance Bands 4-6

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)

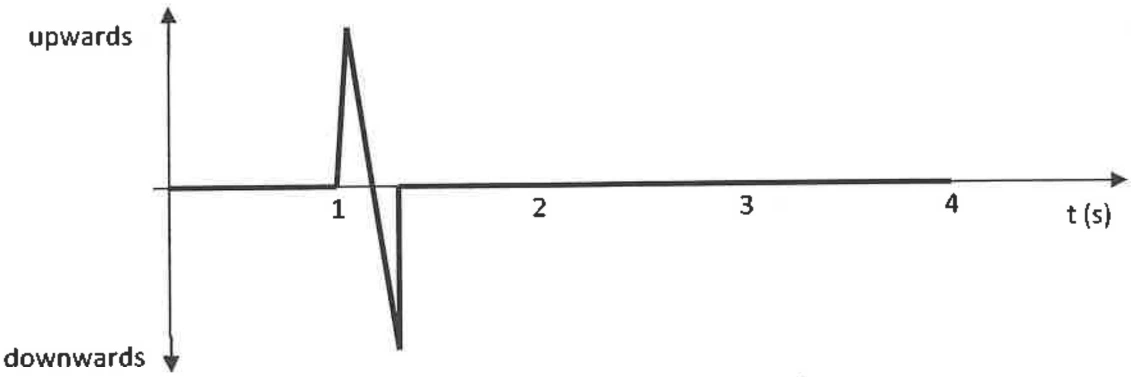
(a) (2 marks)

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 = $390.989 + 1.675 = 392.664 \times 10^{-27}$ kg

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

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

$x = u_x t = 50 \times 2.89 \text{ x } 10^{-3} = 14.4$ 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

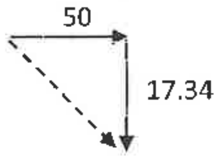
Finding vertical component of velocity at 2.89×10^{-3} s

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

Horizontal velocity is 50 m s^{-1}

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

$v = 53 \text{ m s}^{-1}$ 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

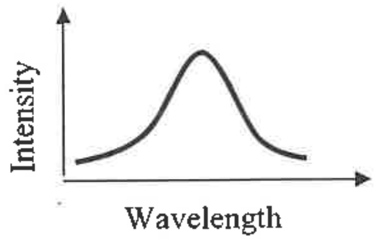
1 Maxwell

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)

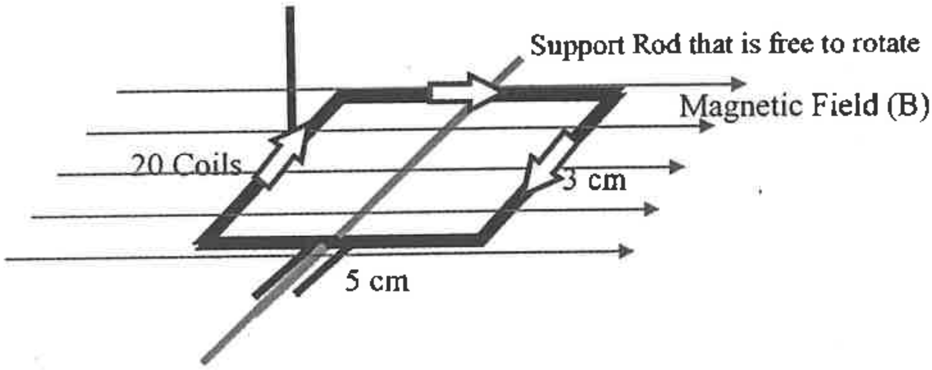
(a) (1 mark)

Outcomes Assessed: 12-13

Targeted Performance Bands 3-4

Criteria	Mark
• Illustrates correct current direction	1

Sample answer.



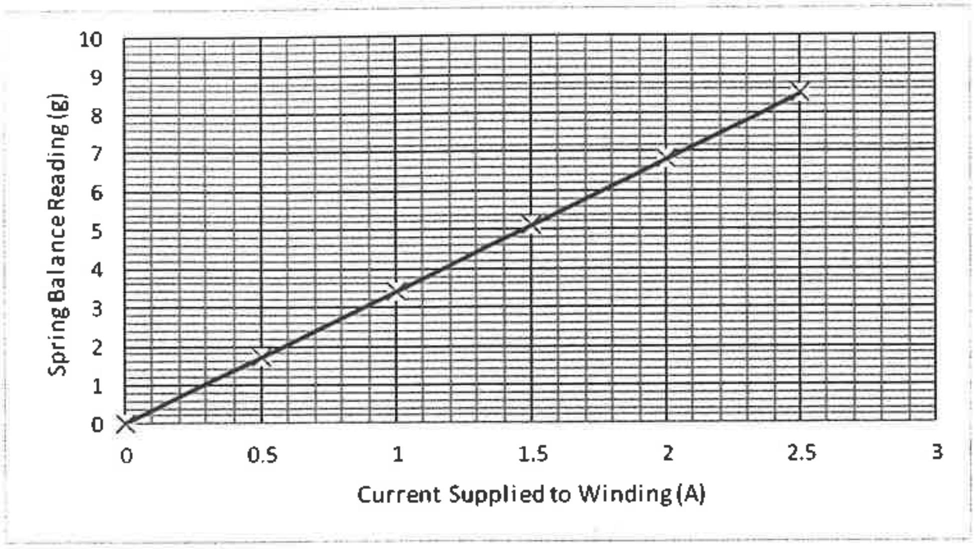
(b) (3 marks)

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.