CSSA

CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NSW

Centre Number

Student Number

DO NOT REMOVE PAPER FROM EXAM ROOM

2019

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Morning Session
Tuesday, 13 August 2019

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
- A data sheet and formulae sheets are provided SEPARATELY. Ensure you use the replacement Periodic Table sheet
- Write your Centre Number and Student Number on the top of this page

Total marks - 100

Section I Pages 2-10

20 marks

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

Section II Pages 11-26

80 marks

- Attempt Questions 21-33
- 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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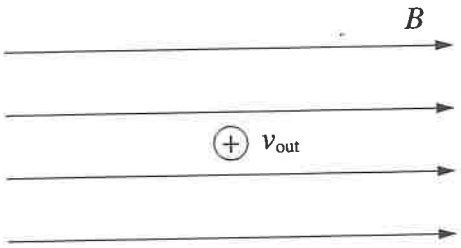
1 A positively charged particle is moving through a magnetic field with a velocity v.



If the charge is moving out of the page, what is the direction of the force F on the particle?

(A) to the right
(B) to the left
(C) downwards
(D) upwards

2 Diffraction is the name given to the:

(A) change of direction when waves cross the boundary between one medium and another.
(B) addition of two coherent waves to produce a stationary wave pattern.
(C) bending of waves round an obstacle.
(D) splitting of white light into colours.

3 Hertzsprung-Russell diagrams are used to classify stars using a variety of different characteristics.

Which of the following is NOT a characteristic that can be determined using a Hertzsprung-Russell diagram?

(A) surface temperature

(B) apparent brightness

(C) spectral class

(D) luminosity

4 What is the angular velocity of the Earth in its orbit around the Sun?

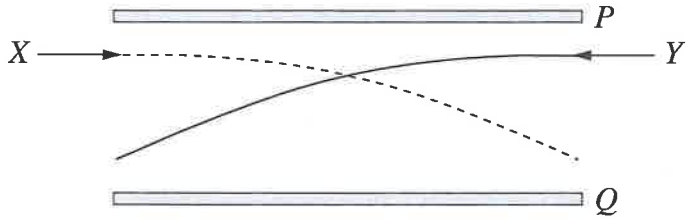
(A) 2.0×10^{-7} rad s^{-1}

(B) 7.2×10^{-5} rad s^{-1}

(C) 1.1×10^{-5} rad s^{-1}

(D) 4.1×10^{-3} rad s^{-1}

5 The diagram shows the paths of two charged particles, *X* and *Y*, during their passage between a pair of oppositely charged metal plates, *P* and *Q*.



The plates are charged such that the electric field between them is directed from *Q* to *P*.

Which charges on X and Y will produce the observed paths?

	X	*Y*
(A)	–	–
(B)	–	+
(C)	+	–
(D)	+	+

6 James Clerk Maxwell's revolutionary theory of electromagnetism was first proposed in 1865, it was not well accepted by the scientific community until some 20 years later.

What was the reason for this?

(A) There was little experimental evidence available at the time to support the theory.

(B) The photoelectric effect had shown that light had particle-like properties.

(C) The speed of light had not been measured experimentally.

(D) Spectroscopy had not yet been developed.

7 If a wave can be polarised, it must be:

(A) an electromagnetic wave.

(B) a longitudinal wave.

(C) a mechanical wave.

(D) a transverse wave.

8 In 1909, Robert Millikan and Harvey Fletcher conducted the oil drop experiment to determine the:

(A) charge to mass ratio on an electron.

(B) nature of cathode rays.

(C) charge on an electron.

(D) charge on a proton.

9 A satellite P orbits the Earth at a distance r between the two centres with a period T_P. Another satellite Q orbits at a distance of $6r$ in a time T_Q. The ratio of T_P to T_Q is:

(A) 1:15

(B) 1:6

(C) 6:1

(D) 15:1

10 Which of the following is NOT a function of transformers in the large-scale distribution of electrical energy?

(A) Transformers increase voltage across transmission lines for efficient power distribution.

(B) Transformers reduce energy losses in transmission lines by decreasing current.

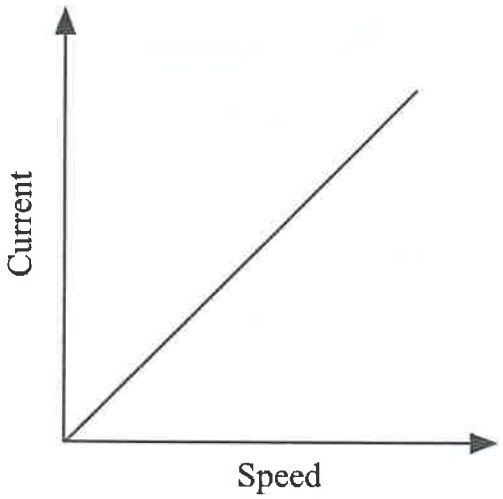
(C) Transformers reduce energy losses in transmission lines by increasing current.

(D) Transformers decrease voltage across household circuits for safety reasons.

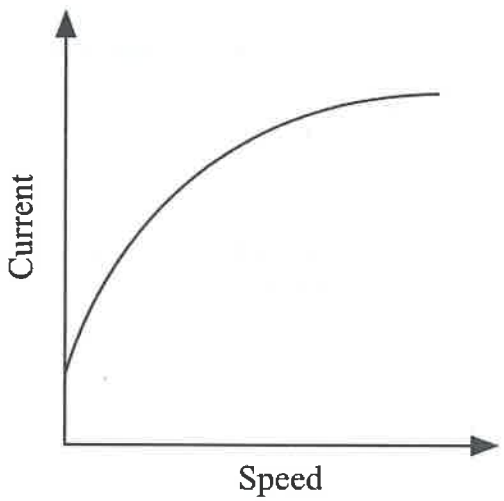
11 A DC electric motor is connected to a power supply operating at a constant voltage. The speed of the motor is varied by applying a friction brake to the axle.

Which graph correctly shows how the current through the motor windings varies with speed?

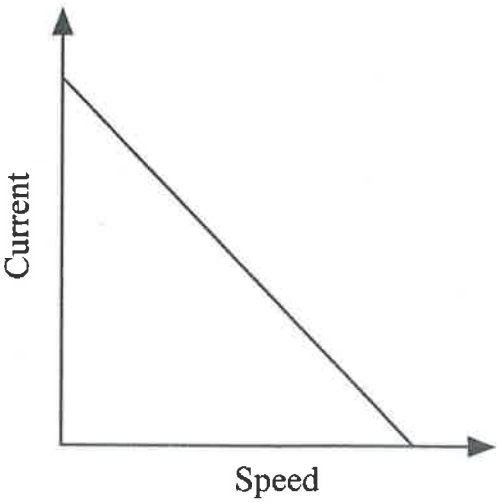
(A)



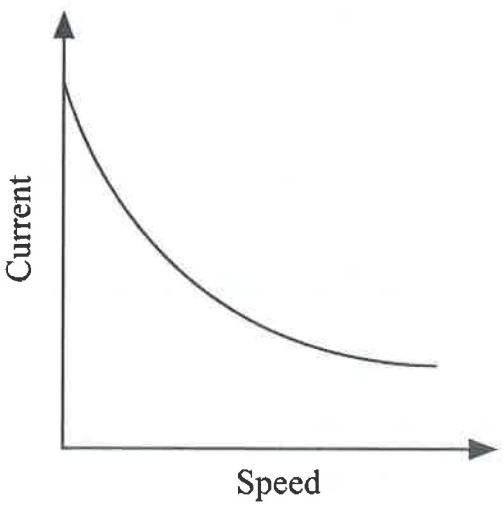
(B)



(C)



(D)



12 Which fundamental quantity required that its unit of measurement be redefined following acceptance of the theory of special relativity?

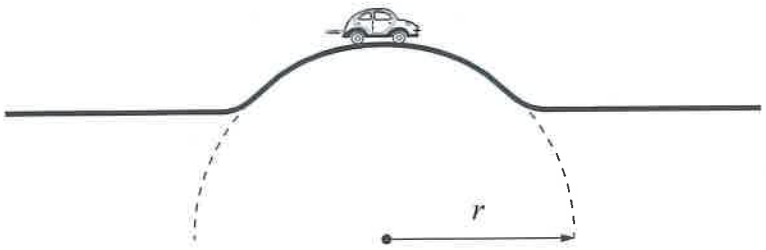
(A) luminous intensity

(B) length

(C) mass

(D) time

13 A car and driver with mass m moves at a speed v over a bridge which is the arc of a circle of radius r.



Which of these expressions represents the maximum speed of the car so that it remains in contact with the road?

(A) rg

(B) $\sqrt{rg}$

(C) mrg

(D) $\sqrt{mrg}$

14 An electron in a hydrogen atom transitions from a quantum state with number $n = 3$ to the ground state.

The wavelength of the emitted photon is closest to:

(A) 95 nm

(B) 100 nm

(C) 105 nm

(D) 110 nm

15 Which particles are the only constituents of hadrons?

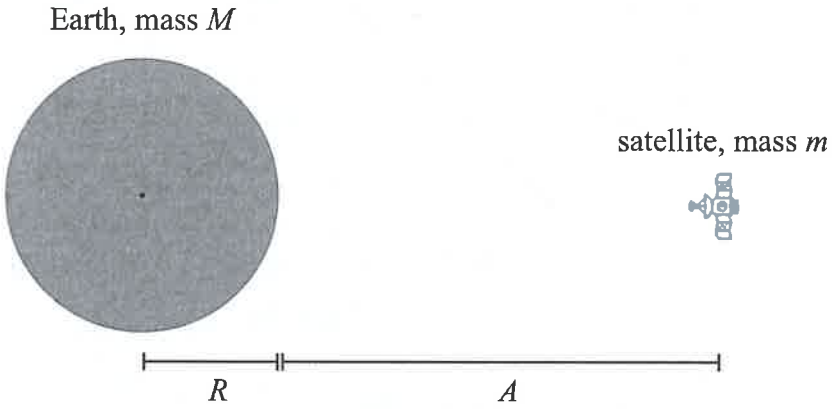
(A) neutrinos

(B) electrons

(C) quarks

(D) bosons

16 A satellite of mass m orbits the Earth at an altitude A with an orbital velocity v above the surface of the Earth as shown. The Earth has a mass M and a radius R.



Which expression represents the total energy of the satellite?

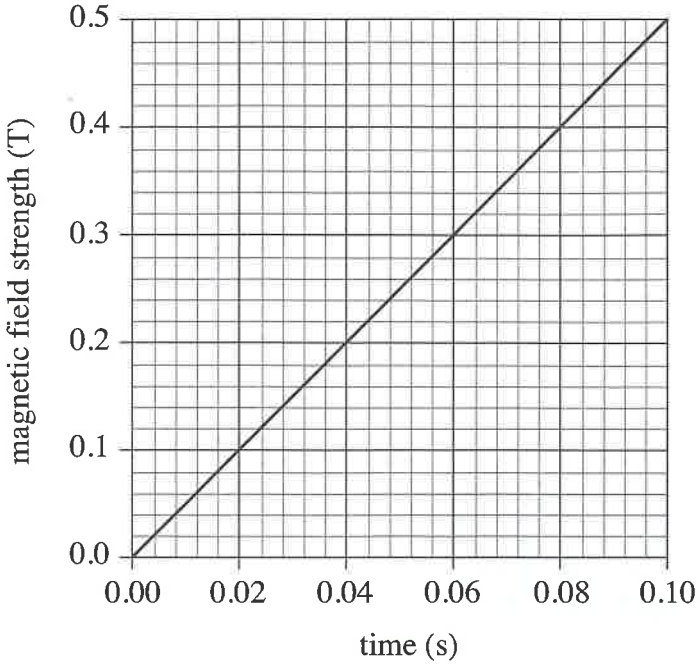
(A) $-\dfrac{GMm}{2(R+A)}$

(B) $-\dfrac{GM}{2(R+A)}$

(C) $-\dfrac{GMm}{(R+A)}$

(D) $-\dfrac{GMm}{R}$

17 A circular coil of 100 turns with a radius of 2.0 cm is placed in a changing magnetic field. The angle between the magnetic field lines and the plane of the coil is 60°. The graph below shows the variation with time of the magnetic field strength.



What is the magnitude of the *emf* induced in the coil?

(A) –0.63 V

(B) –0.54 V

(C) –0.31 V

(D) –0.16 V

18 A parallel beam of white light passes through a diffraction grating. Orange light of wavelength 600 nm in the fourth order diffraction maximum coincides with blue light in the fifth order diffraction maximum.

What is the wavelength of the blue light?

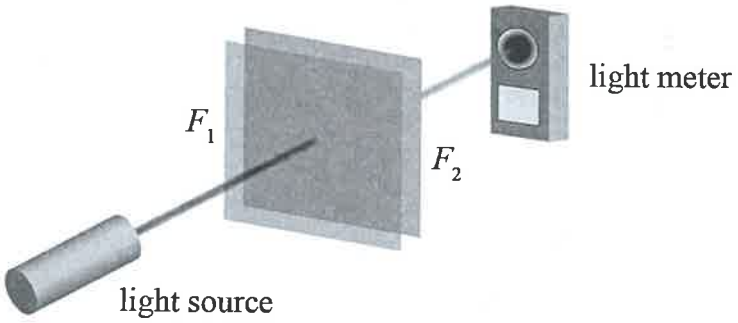
(A) 450 nm

(B) 480 nm

(C) 500 nm

(D) 750 nm

19 In an experiment to verify Malus' law, two students measured the intensity of monochromatic light passing through two polarising filters. One student rotated the second filter F_2 with respect to the axis of the first filter F_1. The other student held a light meter in front of F_2 to measure the intensity of the light that had passed through both filters.



Which of the following would most significantly improve both the accuracy and reliability of the experiment?

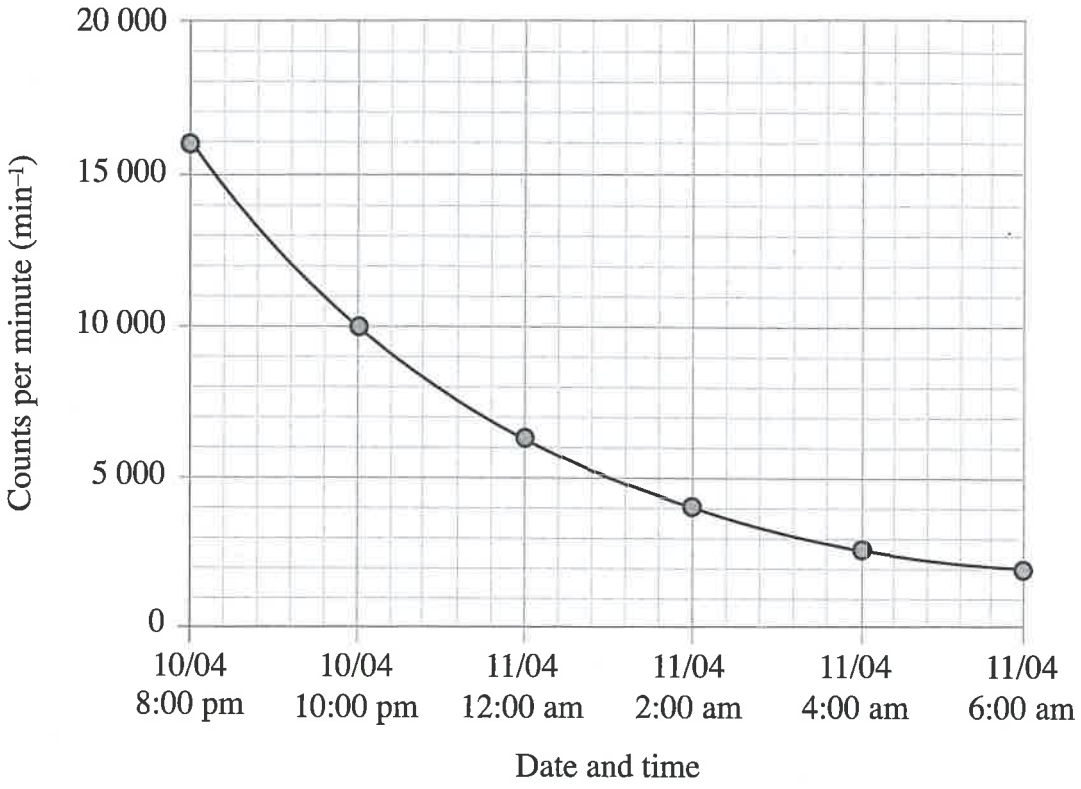
(A) taking many readings of light intensity for each angle of rotation

(B) using white light instead of monochromatic light

(C) decreasing the intensity of the incident light

(D) securing the light detector to the benchtop

20 The graph below shows the decay rate for a radioisotope in the blood of a patient after a nuclear medicine procedure.



What is the decay constant λ for technetium-99m?

(A) $9.6 \times 10^{-5}\ s^{-1}$

(B) $6.4 \times 10^{-5}\ s^{-1}$

(C) $4.8 \times 10^{-5}\ s^{-1}$

(D) $3.2 \times 10^{-5}\ s^{-1}$

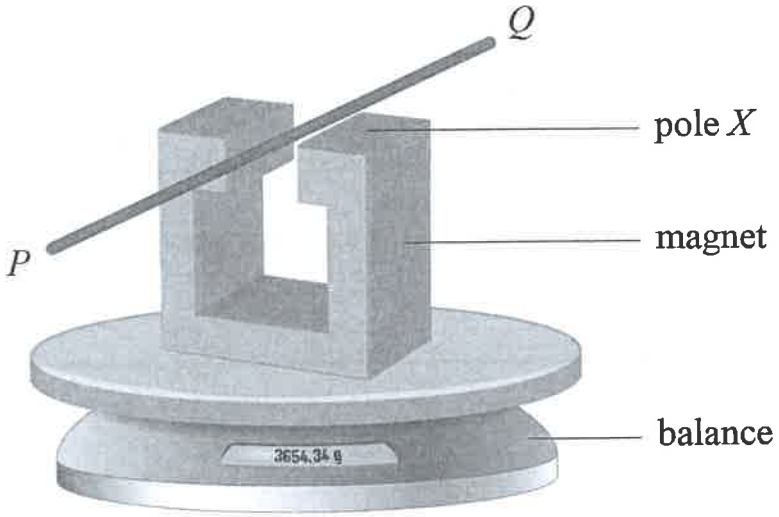
Section II

80 marks
Attempt Questions 21-33
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 27. If you use this space, clearly indicate which question you are answering.

Question 21 (5 marks)

A large horseshoe magnet produces a uniform magnetic field B between its poles. The magnet is placed on a digital balance and a secured copper rod placed between its poles as shown. The rod PQ is positioned perpendicularly to the magnetic field and horizontally to the pan of the balance. The length of the wire between the poles is 3.45 cm.



When a direct current of 3.2 A is passed through the rod from P to Q, the reading on the digital balance increases by 2.69 grams.

(a) Identify and explain the polarity of the magnet at pole X. **2**

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(b) Calculate the magnetic field strength between the poles of the magnet. **3**

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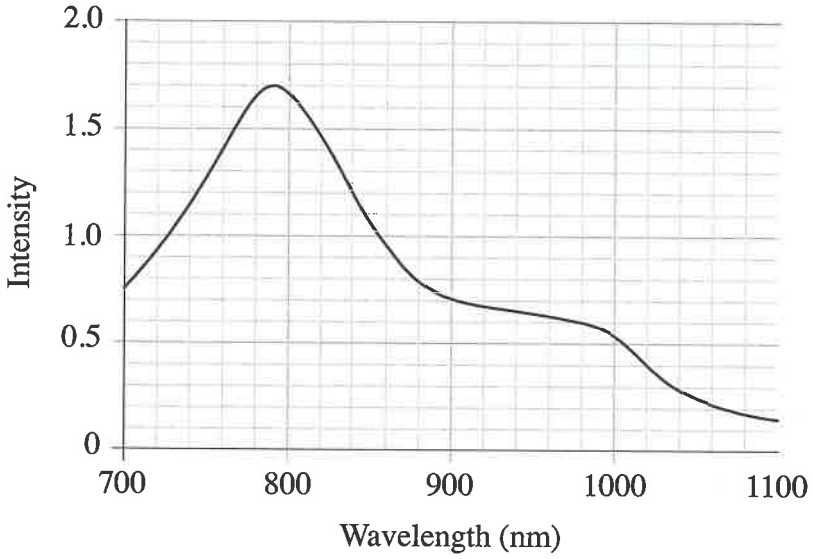
Question 22 (4 marks)

30 Piscium is a red giant star in the zodiac constellation of Pisces that is visible to the naked eye. The spectrum below was recorded by the Cassini space probe in 2006.



(a) Calculate the surface temperature of 30 Piscium. **2**

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(b) Explain how light from 30 Piscium can be used to provide evidence of its chemical composition. **2**

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Question 23 (7 marks)

If hydrogen gas is bombarded by neutrons, a neutron can be captured, forming a deuterium atom ${}^{2}_{1}\mathrm{H}$ with the emission of a gamma ray photon.

(a) Write a nuclear equation for this reaction. **2**

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(b) Complete the table below showing the number of protons and neutrons in hydrogen and deuterium. **2**

	Hydrogen ${}^{1}_{1}\mathrm{H}$	*Deuterium* ${}^{2}_{1}\mathrm{H}$
Proton number		
Neutron number		

(c) By referring to the datasheet, calculate the rest mass of a neutron in atomic mass units (u). **1**

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(d) Use the data in the table below to calculate the energy carried by the gamma ray photon in MeV. **2**

Particle	*Rest mass (u)*
Hydrogen	1.0079
Deuterium	2.0141

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Question 24 (7 marks)

In December 2018, the comet 46P/Wirtanten passed the Earth while orbiting the Sun at its closest distance of 11.6 million km from the centre of the Earth. The comet's mass was estimated to be 2.1×10^{11} kg and it passed the Earth at this distance with a velocity of about 10 km s^{-1}.

(a) Calculate the force between the comet and Earth at this distance. **2**

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(b) Calculate the theoretical orbital velocity at this distance required for a circular orbit around the Earth. **2**

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(c) Calculate the escape velocity from the Earth for the comet at this distance and use it to explain why the comet passes the Earth without being drawn into the Earth's orbit. **3**

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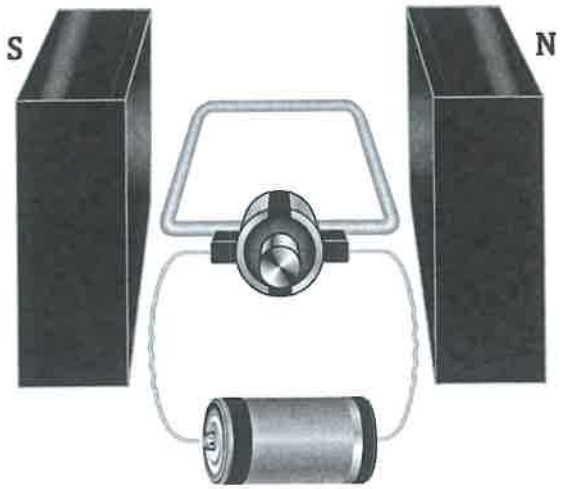
Question 25 (7 marks)

A student constructed a simple DC motor as shown in the simplified diagram below. The plane of the rotating coil has an area of 0.0036 m^2 and the armature has 80 turns. The coil is placed in a uniform magnetic field of flux density 0.41 T and when a supply current of 1.5 A flows, the armature begins to turn.



(a) Calculate the theoretical maximum torque produced by this motor. **1**

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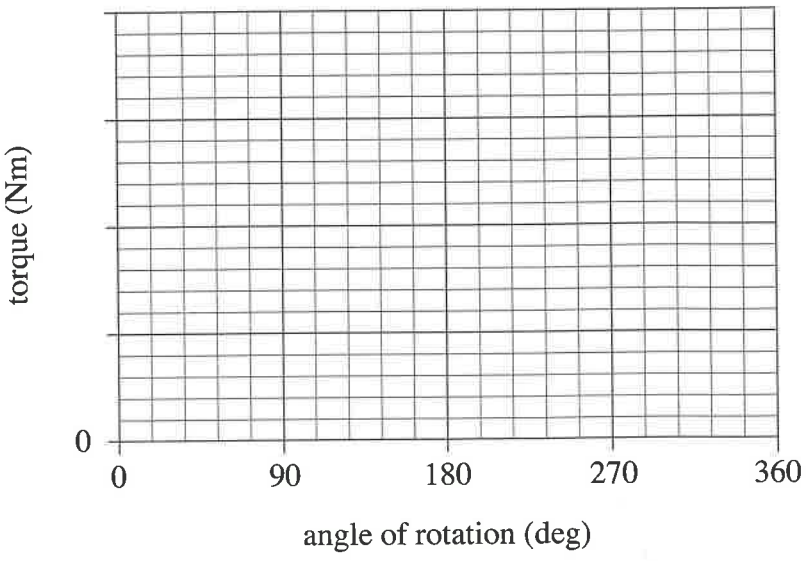
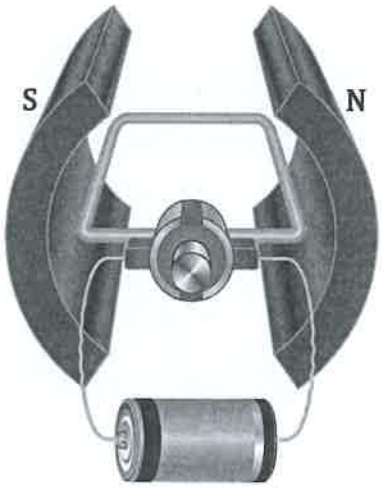
(b) Construct a graph to show how the torque varies through one revolution of the armature, from the starting position shown in the diagram. **3**



Question 25 continued

(c) To improve the torque, the student varied the construction of the motor by using radial magnets as shown. **3**



Use the grid in part (b) to show how this variation affects the torque and justify your answer below.

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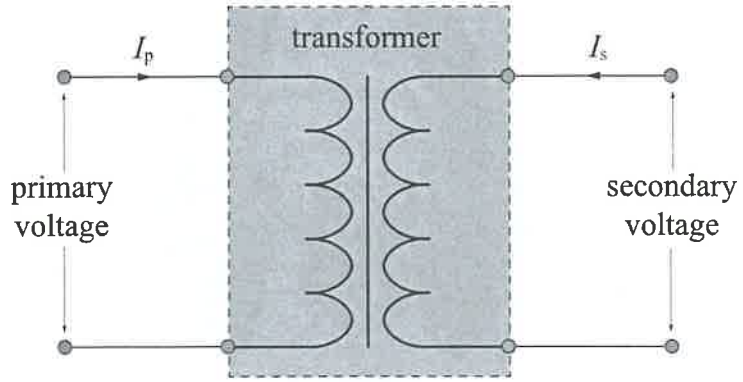
Question 26 (4 marks)

In the electricity grid, a transformer is used to reduce voltage to 240 V for household use. The specifications of the transformer are shown below. **4**



In routine testing, a technician measures the input and output voltage and current for the transformer over a number of trials. The average results are shown in the table below.

	average voltage (V)	*average current (A)*
primary coil	7540	0.35
secondary coil	240	9.98

Account for these results in terms of the law of conservation of energy.

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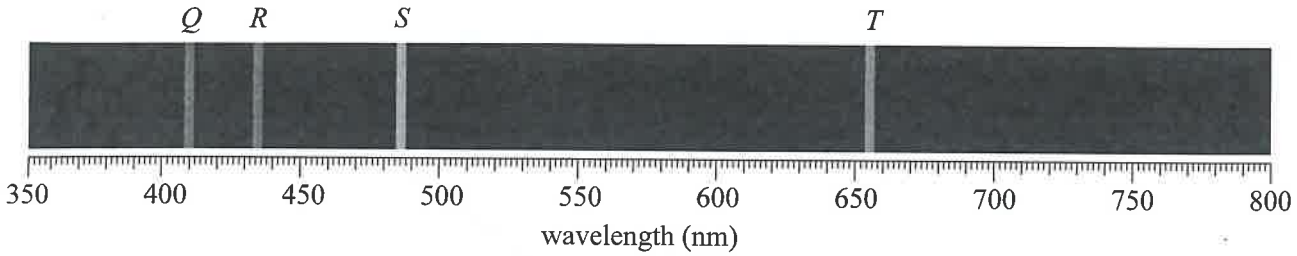
Question 27 (7 marks)

A student researching the spectra of the various elements found the image below showing the Balmer series in a spectrum of hydrogen.



(a) Outline how this spectrum might have been obtained experimentally. **3**

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(b) Interpret and compare the lines *Q*, *R*, *S* and *T* in terms of electron transitions and energy. **4**

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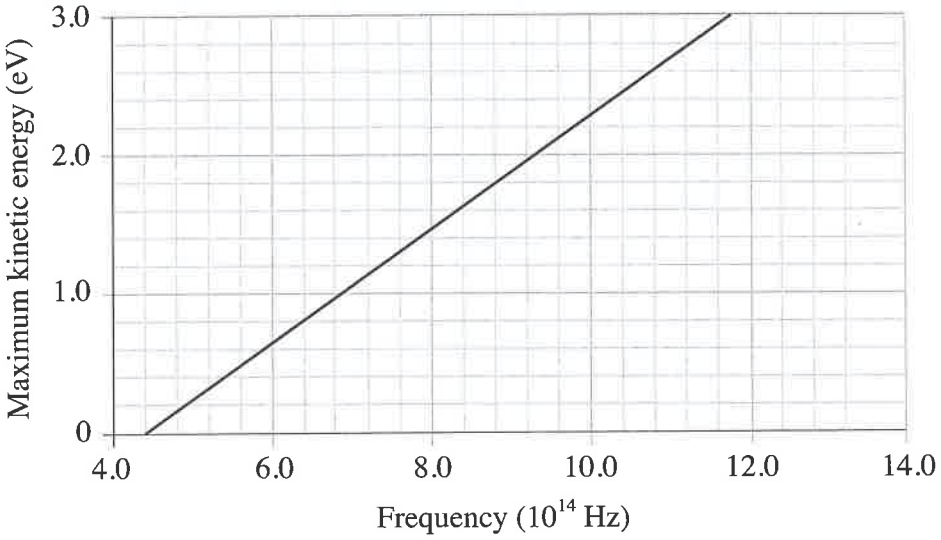
Question 28 (7 marks)

In early experiments to investigate the photoelectric effect, a beam of monochromatic light was directed at a clean surface of potassium metal. By applying a stopping voltage to reduce the photocurrent to zero, the maximum kinetic energy of the ejected electrons was measured.

When the experiment was repeated with different frequencies of light, the maximum kinetic energy of electrons depended on the frequency of the light as shown below.



(a) Calculate the wavelength of light required to begin photoemission. **2**

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(b) In another experiment, the potassium metal surface was replaced with aluminium metal with a work function of 4.2 eV. **3**

Calculate the threshold frequency for the aluminium surface.

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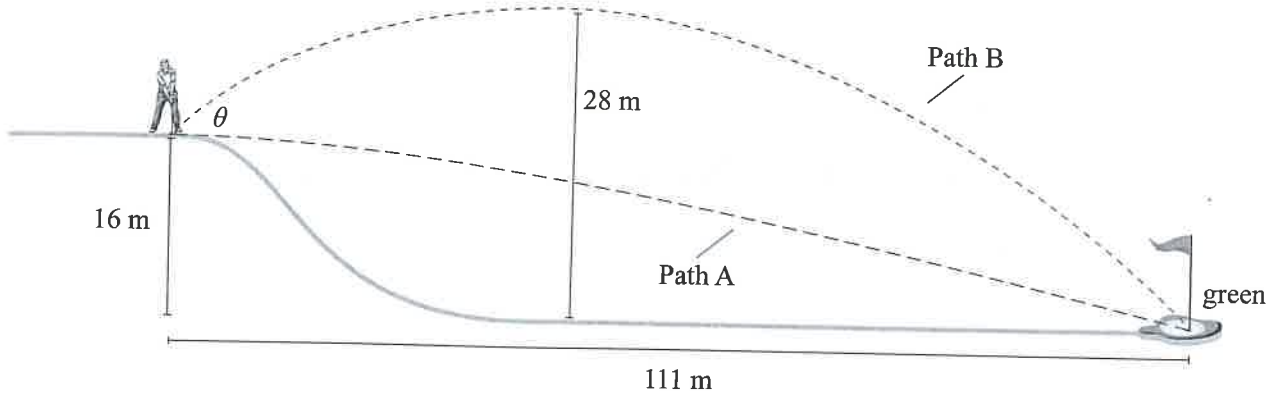
(c) On the graph above, draw a line to show the relationship between the maximum kinetic energy of ejected electrons and the frequency of incident light for the aluminium surface. **2**

Question 29 (6 marks)

A golfer launches a golf ball at a height of 16 metres vertically above the green which is 111 metres away. When launched horizontally, the golf ball follows Path A and when launched at an angle θ to the horizontal, it follows Path B.



(a) Calculate the initial velocity of the golf ball when launched horizontally following Path A. **2**

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(b) Calculate the total time of flight when the golf ball is launched at an angle to the horizontal following Path B. **2**

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(c) Calculate the launch angle θ required for the ball to follow Path B. **2**

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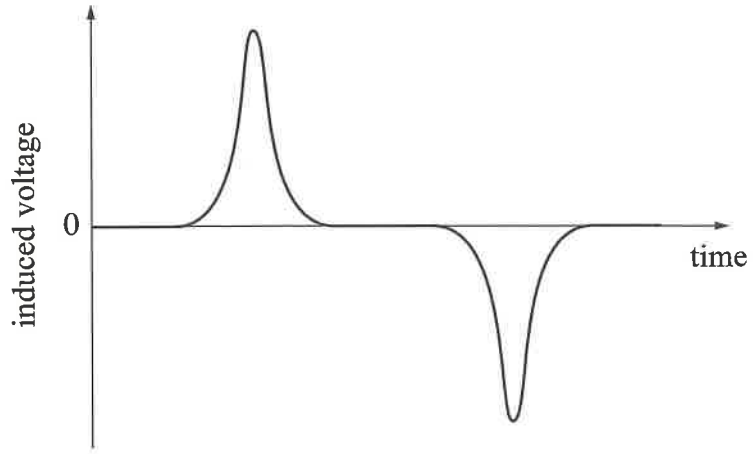
Question 30 (5 marks)

A student conducted an investigation to verify Faraday's law of electromagnetic induction and presented some of the results in the graph shown below. **5**



Identify equipment, and describe and justify a procedure that would produce these results.

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Question 31 (7 marks)

An observer on Earth sees a spacecraft moving across the sky parallel to the horizon with a uniform speed of 2.3×10^8 m s^{-1}. The spacecraft fires a missile of rest length 1.8 metres in the direction of its motion which is observed from Earth to be travelling across the sky with speed of 2.4×10^8 m s^{-1}.

(a) Calculate the length of the missile after it leaves the spacecraft as measured by the observer on Earth. **2**

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(b) The spacecraft now fires a laser in the direction of the missile. **5**

A physics student assumes that an observer on Earth would measure the speed of the photons in the laser as the sum of the speed of light and the speed of the spacecraft.

Evaluate this claim.

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Question 32 (8 marks)

A car rounds a bend on a road that follows the arc of a circle with radius 25.6 metres. The car has a mass of 885 kg and the force of kinetic friction between the tyres and the road is 9420 N.

(a) At what maximum speed should the car be moving so as to stay on the road while taking the bend? **1**

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(b) Using physics principles and your answer to part (a), quantitatively explain why motorists are advised to drive at slower speeds during wet weather. **3**

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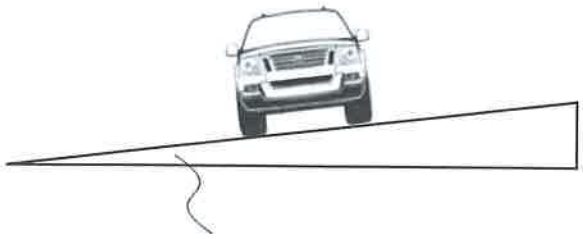
Question 32 continued

(c) For safety reasons, when building roads, corners are sometimes banked so they form an angle to the horizontal as shown in the diagram below. **4**



banking angle θ

If the bend in part (a) were banked at 8.0° to the horizontal, show quantitatively how this increases the maximum speed that allows the car to remain on the road.

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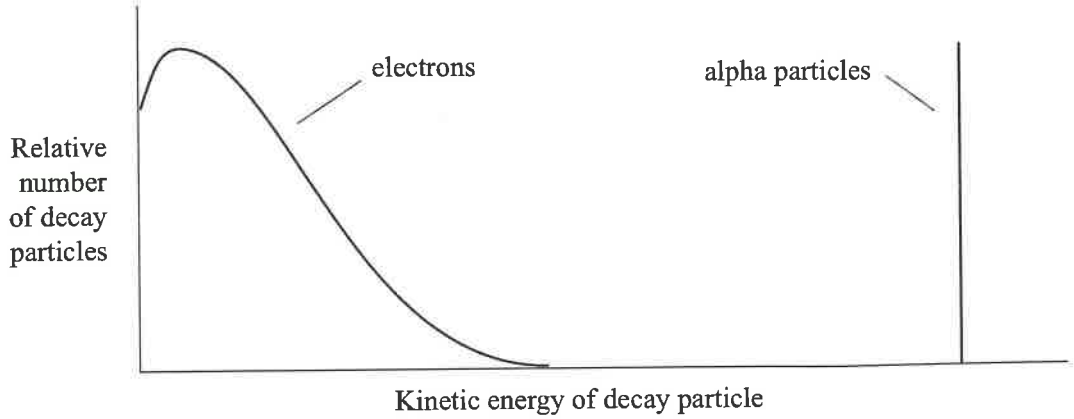
Question 33 (6 marks)

The graph below compares the kinetic energy of alpha decay in platinum-190 and beta decay in cobalt-60 particles with respect to the relative number of decay particles with these energies. **6**



x-axis not to scale

Account for the differences in energies of these alpha and beta radioactive decay particles.

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End of paper

Section II extra writing space

EXAMINERS

Jonathan Saurine (Convenor)	All Saints Grammar School, Belmore
Lara Tyler	All Saints Grammar School, Belmore

CSSA

CATHOLIC SECONDARY SCHOOLS ASSOCIATION
TRIAL HSC EXAMINATION

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^6 m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}
Wien's displacement constant, b	2.898×10^{-3} m K

3700-4

FORMULAE SHEET

Motion, forces and gravity

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

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\Delta U = mg\Delta h$$

$$W = F_{||}s = Fs\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$K = \frac{1}{2}mv^2$$

$$P = F_{||}v = Fv\cos\theta$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$a_{\text{c}} = \frac{v^2}{r}$$

$$\omega = \frac{\Delta\theta}{t}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$F = \frac{GMm}{r^2}$$

$$v = \frac{2\pi r}{T}$$

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

$$U = -\frac{GMm}{r}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f = \frac{1}{T}$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

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

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

$$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$$

$$I = I_{\max}\cos^2\theta$$

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

3700-4

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

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

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

$$\lambda = \frac{h}{mv}$$

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

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

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

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

$$N_t = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

CSSA

CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NSW

2019 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	6.1	PH12-6, PH12-13	2-3
2	C	7.2	PH12-14	2-3
3	B	8.1	PH12-15	2-3
4	A	5.1	PH12-4, PH12-12	2-3
5	A	6.1	PH12-6, PH12-13	2-3
6	A	7.1	PH12-14	2-3
7	D	7.2	PH12-14	2-3
8	C	8.2	PH12-15	2-3
9	A	5.3	PH12-4, PH12-6, PH12-12	3-4
10	C	6.3	PH12-6, PH12-13	3-4
11	D	6.3	PH12-6, PH12-13	3-4
12	C	7.4	PH12-14	3-4
13	B	5.1	PH12-6, PH12-12	3-4
14	C	8.3	PH12-15	4-5
15	C	8.5	PH12-15	4-5
16	A	5.3	PH12-6, PH12-12	4-5
17	B	6.3	PH12-4, PH12-13	4-5
18	B	7.2	PH12-14	5-6
19	D	7.2	PH12-14	5-6
20	B	8.4	PH12-15	5-6

Section II
80 marks

Question 21 (5 marks)
(a) (2 marks)
Outcomes Assessed: PH12-6, PH12-13
Targeted Performance Bands: 3-4

Criteria	Marks
• Recognises the direction of force due to the increase in the balance reading • Accounts for the correct pole at X by determining the direction of the magnetic field	2
• Recognises the direction of force due to the increase in the balance reading OR • Deduces the correct direction of the magnetic field	1

Sample answer:

When current flows from P to Q, the force on the magnet is downwards as the reading on the balance increases. Given the perpendicular relationship between the direction of the magnetic field, current and force, the magnetic field lines are directed away from pole X, making it the south pole of the magnet.

(b) (3 marks)

Outcomes Assessed: PH12-6, PH12-13

Targeted Performance Bands: 4-5

Criteria	Marks
• Calculates the correct force on the rod using the balance reading • Substitutes the correct quantities into the equation • Calculates the correct magnetic field strength	3
• Substitutes some incorrect quantities • Calculates a magnetic field strength based on incorrect quantities	2
• Calculates the correct force on the rod using the balance reading	1

Sample answer:

The force on the rod is calculated using the reading on the balance:

$$\begin{aligned} F &= mg \\ &= 2.69 \times 10^{-3} \times 9.8 \\ &= 0.026 \text{ N} \end{aligned}$$

The magnetic field strength is calculated using $F = BIL\sin\theta$:

$$\begin{aligned} B &= \frac{F}{IL\sin\theta} \\ &= \frac{0.026362}{\left(\sin 90 \times 3.2 \times 0.0345\right)} \\ &= 0.24 \text{ T (2 sf)} \end{aligned}$$

Question 22 (4 marks)
(a) (2 mark)
Outcomes Assessed: PH12-4, PH12-14
Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly determines the peak wavelength from the graph • Calculates the surface temperature in Kelvin	2
• Calculates the surface temperature using an incorrect peak wavelength OR • Correctly determines the peak wavelength from the graph	1

Sample answer:

Wien's law ($\lambda_{max} = \frac{b}{T}$) can be used to calculate the surface temperature of a star from its spectral intensity:

$$T = \frac{b}{\lambda_{max}}$$
$$= \frac{2.898 \times 10^{-3}}{790 \times 10^{-9}}$$
$$= 3668 \text{ K}$$

(b) (2 marks)
Outcomes Assessed: PH12-7, PH12-14
Targeted Performance Bands: 3-4

Criteria	Marks
• Refers to the unique spectrum of each element • Relates the spectrum of stars to the spectra of the elements	2
• Refers to the unique spectrum of each element	1

Sample answer:

Each of the known elements produces a unique spectrum showing a series of lines at specific wavelengths. Comparing the measured spectrum of 30 Piscium to those of the known elements will allow for the identification of the elements that compose the star.

Question 23 (7 marks)

(a) (2 marks)

Outcomes Assessed: PH12-6, PH12-15

Targeted Performance Bands: 4-5

Criteria	Marks
• Correctly represents each species using atomic notation • Includes all reactants and products	2
• Correctly represents some species using atomic notation	1

Sample answer:

$${}^{1}_{0}\mathrm{n} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \gamma$$

(b) (2 marks)

Outcomes Assessed: PH12-6, PH12-15

Targeted Performance Bands: 3-4

Criteria	Marks
• Assigns the correct numbers to hydrogen and deuterium sub-atomic particles	2
• Assigns correct numbers to hydrogen OR • Assigns correct numbers to deuterium	1

Sample answer:

	Hydrogen ${}^{1}_{1}\mathrm{H}$	*Deuterium* ${}^{2}_{1}\mathrm{H}$
Proton number	1	1
Neutron number	0	1

(c) (1 mark)
Outcomes Assessed: PH12-6, PH12-15
Targeted Performance Bands: 3-4

Criteria	Mark
• Converts the mass of a neutron to atomic mass units	1

Sample answer:

$$m_n = \frac{1.675 \times 10^{-27}}{1.661 \times 10^{-27}}$$
$$= 1.0084 \text{ u}$$

(d) (2 marks)
Outcomes Assessed: PH12-6, PH12-15
Targeted Performance Bands: 4-5

Criteria	Marks
• Determines the difference in mass of reactants and products • Calculates the energy in the gamma ray photon	2
• Calculates energy without including the neutron mass	1

Sample answer:

$$E = \Delta mc^2$$
$$= \left(\left(1.0084 + 1.0079\right) - 2.0141\right) \times 931.5$$
$$= 2.05 \text{ MeV}$$

Question 24 (7 marks)

(a) (2 marks)

Outcomes Assessed: PH12-4, PH12-6, PH12-12

Targeted Performance Bands: 3-4

Criteria	Marks
• Calculates the correct gravitational force	2
• Uses the equation for gravitational force and substitutes values incorrectly	1

Sample answer:

The force can be determined using the equation for the law of universal gravitation:

$$F = \frac{GMm}{r^2}$$

$$= \frac{\left(6.67\times10^{-11}\right)\times\left(6.0\times10^{24}\right)\times\left(2.1\times10^{11}\right)}{\left(11.6\times10^{9}\right)^2}$$

$$= 625 \text{ N}$$

(b) (2 marks)

Outcomes Assessed: PH12-4, PH12-6, PH12-12

Targeted Performance Bands: 4-5

Criteria	Marks
• Calculates the correct orbital velocity	2
• Uses the equation for orbital velocity and substitutes values incorrectly	1

Sample answer:

$$v_o = \sqrt{\frac{GM}{r}}$$

$$= \sqrt{\frac{\left(6.67\times10^{-11}\right)\times\left(6.0\times10^{24}\right)}{11.6\times10^{9}}}$$

$$= 186 \text{ m s}^{-1}$$

$$= 0.186 \text{ km s}^{-1}$$

(c) (3 marks)

Outcomes Assessed: PH12-4, PH12-6, PH12-12

Targeted Performance Bands: 3-5

Criteria	Marks
• Calculates the correct escape velocity • Provides an explanation that relates the calculated value for escape velocity	3
• Calculates the correct escape velocity • Provides a plausible explanation that does not relate to escape velocity	2
• Calculates escape velocity OR • Provides a plausible explanation that does not relate to escape velocity	1

Sample answer:

The velocity required to escape the gravitational pull of the Earth at this distance is about 40 times smaller than the actual velocity of the comet. The comet will continue past Earth almost completely unaffected by the Earth's gravitational pull.

$$v_e = \sqrt{\frac{2GM}{r}}$$

$$= \sqrt{\frac{2\times\left(6.67\times10^{-11}\right)\times\left(6.0\times10^{24}\right)}{11.6\times10^{9}}}$$

$$= 263 \text{ m s}^{-1}$$

$$= 0.263 \text{ km s}^{-1}$$

Question 25 (7 marks)
(a) (1 mark)
Outcomes Assessed: PH12-6, PH12-13
Targeted Performance Bands: 2-3

Criteria	Mark
• Calculates the theoretical maximum torque	1

Sample answer:

The maximum torque is produced when the plane of the coil is parallel to the magnetic flux ($\cos\theta$) or, the normal to the coil is perpendicular to the magnetic flux ($\sin\theta$):

$$\tau = nBIA\sin\theta$$
$$= 80 \times 0.41 \times 1.5 \times \sin 90$$
$$= 0.18 \text{ Nm}$$

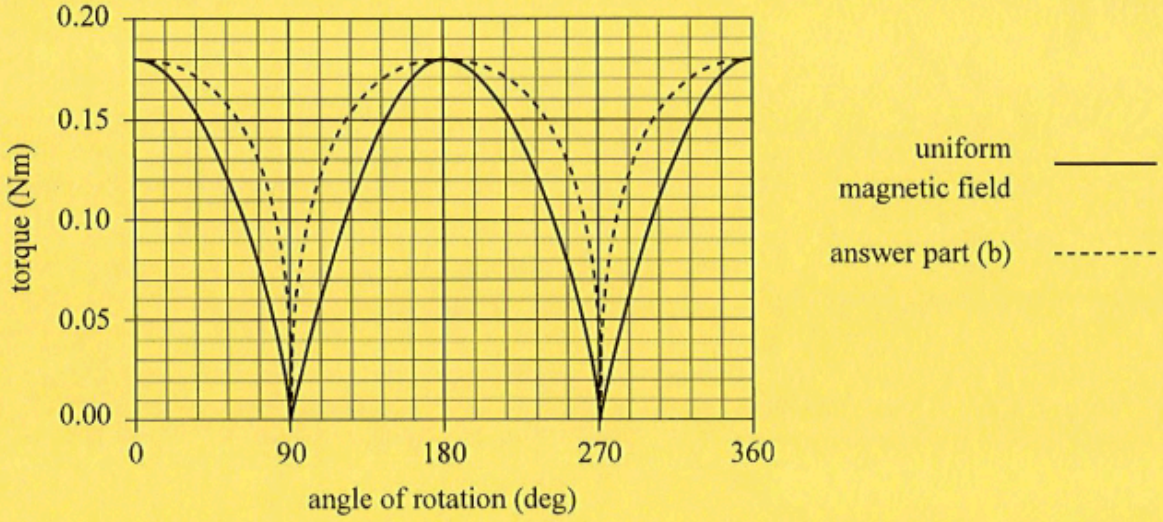
(b) (3 marks)

Outcomes Assessed: PH12-4, PH12-6, PH12-13

Targeted Performance Bands: 3-4

Criteria	Marks
• Draws a curve with the correct shape • Aligns y-axis with maximum torque • Aligns x-axis with correct angles for torque	3
• Any TWO of the above	2
• Any ONE of the above	1

Sample answer:



(c) (3 marks)

Outcomes Assessed: PH12-6, PH12-13

Targeted Performance Bands: 4-6

Criteria	Marks
• Draws a correct curve showing higher torque for each half rotation • Describes the field produced by the radial magnets • Relates the radial field to the maximisation of torque	3
• Describes the field produced by the radial magnets • Relates the radial field to the maximisation of torque	2
• Draws a correct curve showing higher torque for each half rotation OR • Describes the field produced by the radial magnets	1

Sample answer:

The radial magnetic field produces flux lines that curve towards the axle of the motor creating a concave or convex path. This ensures that the angle between the normal to the coil and the flux lines is kept as near as possible to 90° during each rotation. Since maximum torque occurs when $\sin 90 = 1$, this helps to produce less variation in the torque during a full rotation, keeping it as close as possible to the maximum torque for a greater proportion of the rotation.

Question 26 (4 marks)
Outcomes Assessed: PH12-6, PH12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Provides a quantitative comparison of power in the primary and secondary • Relates power loss to the law of conservation of energy • Describes the cause of the lost electrical energy	4
• Provides a qualitative comparison of power in the primary and secondary • Relates power loss to the law of conservation of energy • Describes the cause of the lost electrical energy	2-3
• Provides a comparison of power in the primary and secondary OR • Relates power loss to the law of conservation of energy OR • Outlines the cause of the lost electrical energy	1

Sample answer:

In order to obey the law of conservation of energy, the power provided to the transformer must be the same as the power produced by the transformer. Considering electrical energy alone:

$$P_p = V_p I_p \qquad P_s = V_s I_s$$
$$= 7540 \times 0.35 \quad \text{and} \quad = 240 \times 9.98$$
$$= 2639 \text{ W} \qquad = 2395 \text{ W}$$

As the electrical energies are not equivalent, 2639 – 2395 = 244 W of electrical energy is being converted to other forms of energy in the transformer. The iron core of the transformer ensures most of the flux is transferred from the primary to the secondary coil. However, eddy currents induced there produce resistive heat losses and this is the most likely cause of the energy loss.

Question 27 (7 marks)
(a) (3 marks)
Outcomes Assessed: PH12-2, PH12-15
Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies the spectrum as an emission spectrum • Outlines a suitable procedure for obtaining an emission spectrum	3
• Outlines a procedure for obtaining an emission or absorption spectrum	2
• Identifies the spectrum as an emission spectrum OR • Identifies apparatus and equipment	1

Sample answer:

The spectrum shown is an emission spectrum showing bright (coloured) lines against a black background. It is produced by exciting hydrogen gas in a discharge tube by passing a large potential difference across the ends of the tube. The emitted light is viewed with a spectroscope and the lines shown are seen at various wavelengths that can be determined using the scale.

(b) (4 marks)
Outcomes Assessed: PH12-5, PH12-7, PH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Describes the representation of the lines in terms of photon energy and electron transitions • Deduces the relative photon energies of the lines based on their wavelengths • Correctly identifies n_f for the Balmer series (n=2) • Relates the photon energy of each line to electron transitions in terms of quantum numbers	4
• Outlines the representation of the lines in terms of photon energy and electron transitions • Relates photon energies to wavelengths • Relates the photon energy to electron transitions	2-3
• Any ONE of the above	1

Sample answer:

The Balmer series for hydrogen shows lines at wavelengths that correspond to the energy released when electrons in hydrogen transition from higher energy levels to the energy level with principal quantum number n=2. Line T has the largest wavelength and from Planck's equation $E = \frac{hc}{\lambda}$, will produce a photon with the smallest energy. Line T, therefore, represents a transition from n=3 to n=2 and is seen as lower energy red light. Using the same reasoning, Line S represents the energy of a photon transitioning from n=4 to n=2, line R from n=5 to n=2 and line Q from n=6 to n=2. Line Q represents a photon with the smallest wavelength and the largest frequency, so it will carry the largest energy representing the largest energy transition from n=6 to n=2, seen as higher energy blue-violet light.

Question 28 (7 marks)
(a) (2 marks)
Outcomes Assessed: PH12-6, PH12-14
Targeted Performance Bands: 3-4

Criteria	Marks
• Identifies the threshold frequency as the start of photoemission • Converts frequency into wavelength	2
• Identifies the threshold frequency as the start of photoemission	1

Sample answer:

The wave equation ($c = f\lambda$) can be used to calculate the wavelength of the threshold frequency:

$$\lambda = \frac{c}{f}$$
$$= \frac{3.00 \times 10^{8}}{4.4 \times 10^{14}}$$
$$= 682 \text{ nm}$$

(b) (3 marks)
Outcomes Assessed: PH12-6, PH12-14
Targeted Performance Bands: 4-5

Criteria	Marks
• Converts electron volts to joules • Calculates the correct threshold frequency	2-3
• Calculates a threshold frequency using electron volts for energy	1

Sample answer:

The threshold frequency is the minimum energy needed to cause photoemission:

$$f = \frac{E}{h}$$
$$= \frac{4.2 \times (1.6 \times 10^{-19})}{6.626 \times 10^{-34}}$$
$$= 1.0 \times 10^{15} \text{ Hz}$$
$$= 10 \times 10^{14} \text{ Hz}$$

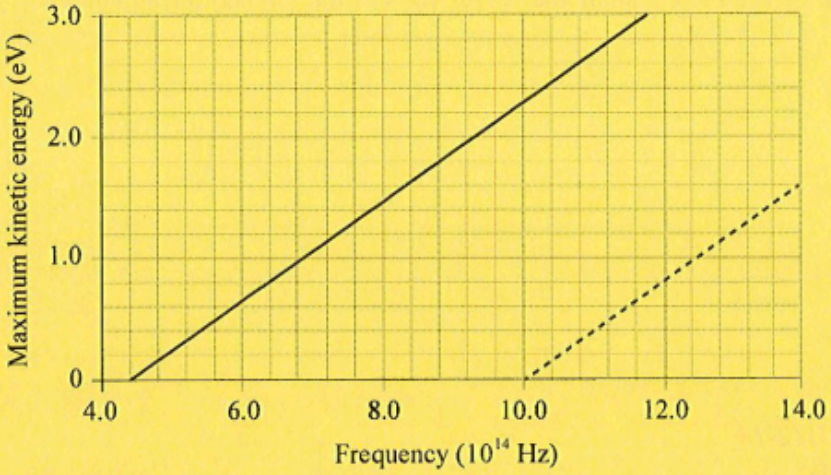
(c) (2 marks)

Outcomes Assessed: PH12-4, PH12-14

Targeted Performance Bands: 5-6

Criteria	Marks
• Line drawn is parallel to the line for potassium • Line intersects with the x-axis at the correct threshold frequency	2
• Line intersects with the x-axis at the correct threshold frequency	1

Sample answer:



Question 29 (6 marks)
(a) (2 marks)
Outcomes Assessed: PH12-4, PH12-6, PH12-12
Targeted Performance Bands: 3-4

Criteria	Marks
• Calculates the correct initial horizontal velocity of the golf ball	2
• Calculates the correct time of flight	1

Sample answer:

The initial velocity for Path A has a horizontal component only and can be calculated using the range:

$$s_y = u_y t + \tfrac{1}{2} a t^2$$
$$16 = 0 + \tfrac{1}{2} \times 9.8 \times t^2$$
$$t = \sqrt{\frac{2 \times 16}{9.8}}$$
$$= 1.81 \text{ s}$$

$$u_x = \frac{s_x}{t}$$
$$= \frac{111}{1.81}$$
$$= 61.4 \text{ m s}^{-1}$$

(b) (2 marks)

Outcomes Assessed: PH12-4, PH12-6, PH12-12

Targeted Performance Bands: 4-5

Criteria	Marks
• Calculates the total time of flight	2
• Calculates the time of flight for only one of the two segments	1

Sample answer:

Without knowing the launch angle, time of flight is determined by separating the trajectory to the left and right of maximum height:

Calculated as if the motion was from right to left:

$$s_y = u_y t + \frac{1}{2}at^2$$

$$(28-16) = 0 + \frac{1}{2} \times 9.8 \times t^2$$

$$t = \sqrt{\frac{2 \times 12}{9.8}}$$

$$= 1.56 \text{ s}$$

Calculated from maximum height:

$$s_y = u_y t + \tfrac{1}{2}at^2$$

$$28 = 0 + \tfrac{1}{2} \times 9.8 \times t^2$$

$$t = \sqrt{\frac{2 \times 28}{9.8}}$$

$$= 2.39 \text{ s}$$

Sum of both times:

$$t_{total} = 1.56 + 2.39$$

$$= 3.95 \text{ s}$$

(c) (2 marks)
Outcomes Assessed: PH12-4, PH12-6, PH12-12
Targeted Performance Bands: 4-5

Criteria	Marks
• Calculates the launch angle correctly	2
• Recognises that that the launch angle can be determined using the horizontal component of velocity	1

Sample answer:

The launch angle can now be determined using the horizontal component of the motion:

$$u_x = \frac{s_x}{t}$$

$$61.4 \times \cos\theta = \frac{111}{3.95}$$

$$\cos\theta = \frac{111}{61.4 \times 3.95}$$

$$\theta = \cos^{-1}\left(\frac{111}{61.4 \times 3.95}\right)$$

$$= 63^\circ \text{ (2sf)}$$

Question 30 (5 marks)
Outcomes Assessed: PH12-2, PH12-4, PH12-5, PH12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies suitable apparatus for this experiment • Describes a procedure that would produce the result shown in the graph • Justifies the procedure with reference to features of the graph • Accounts for the similarity of amplitude of the voltage peaks	5
• Identifies suitable apparatus for this experiment • Describes a procedure that would produce the result shown in the graph • Justifies the procedure with reference to features of the graph	4
• Describes a procedure that would produce the result shown in the graph • Justifies the procedure with reference to features of the graph	3
• Identifies suitable apparatus for this experiment • Outlines a procedure that would produce the result shown in the graph	2
• Identifies suitable apparatus for this experiment OR • Outlines a procedure that would produce the result shown in the graph	1

Sample answer:

The following equipment could be used for this investigation:

- solenoid with at least 250 turns
- a strong bar magnet
- a data logger with a voltage probe

The voltage probe should be connected across the solenoid so as to measure the induced voltage when the bar magnet is moved with respect to the solenoid. When the magnet is moved towards the solenoid from rest, the flux into the coil is increased and a positive voltage is induced as shown by the first positive peak in the graph. The voltage falls to zero as the magnet comes to rest and stays at zero until the motion of the magnet begins again as it is moved away from the solenoid. The flux into the solenoid is now decreasing so a voltage with reversed polarity is induced in the solenoid as shown by the second inverted peak on the graph. As the magnet comes to rest, the induced voltage returns again to zero. The amplitude of both peaks looks to be the same indicating the same induced voltage when moving the magnet toward and away from the solenoid. As such, the rate of change of flux would have been the same made possible by moving the magnet towards and away from the solenoid over the same distance in equal time periods.

Question 31 (7 marks)
(a) (2 marks)
Outcomes Assessed: PH12-6, PH12-14
Targeted Performance Bands: 4-5

Criteria	Marks
• Applies the principle of relativity to determine speed • Calculates the observed speed	2
• Attempts to use the principle of relativity to determine speed	1

Sample answer:

The missile's speed is observed on Earth as the sum of the speed of the spacecraft and the speed of the missile:

$$\begin{aligned} v_o &= v_s + v_m \\ &= \left(2.3\times10^8\right) + \left(1.9\times10^7\right) \\ &= 2.5\times10^8 \text{ m s}^{-1} \\ &= 0.83\text{c} \end{aligned}$$

(b) (5 marks)
Outcomes Assessed: PH12-6, PH12-7, PH12-14
Targeted Performance Bands: 4-6

Criteria	Marks
• Distinguishes between Galilean and special relativity • Applies both types of relativity to refute the claim • Explains how the claim would violate the second postulate	4-5
• Outlines relativity in BOTH contexts	2-3
• Outlines the application of relativity to ONE context	1

Sample answer:

The claim made by the student is incorrect as they are using Galilean relativity alone and not both postulates of the theory of special relativity. The second postulate states that the speed of light is constant and is unchanged by the motion of the source of light or the receiver of the light. All observers in all reference frames will, therefore, measure the speed of light to have the same value of 3.00×10^8 m s^{-1}.
The speed of the missile is observed from Earth to be the sum of the speeds of the spacecraft and the missile relative to the spacecraft:

$$v_o = v_s + v_m$$
$$2.4 \times 10^8 = \left(2.3 \times 10^8\right) + v_m$$
$$v_m = 1.0 \times 10^7 \text{ m s}^{-1}$$

This calculation is made using Galilean relativity, that is, the observer sees the missile moving with a speed equal to the sum of its initial speed relative to the spacecraft as it exits, and the speed of the spacecraft. This calculation is valid as the missile is not itself a form of electromagnetic radiation. Photons produced by the laser, however, are a form of electromagnetic radiation and according to the theory of special relativity, the observed speed of the photons is independent of the speed of the spacecraft. Performing Galilean relativity calculations on the photons would also render an observed speed greater than the speed of light, violating the laws of the universe as we currently understand them.

Question 32 (8 marks)
(a) (1 mark)
Outcomes Assessed: PH12-4, PH12-12
Targeted Performance Bands: 3-4

Criteria	Mark
• Calculates the centripetal force	1

Sample answer:

The centripetal force is provided by friction:

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

$$v = \sqrt{\frac{Fr}{m}}$$

$$= \sqrt{\frac{9420 \times 25.6}{885}}$$

$$= 16.5 \text{ m s}^{-1}$$

(b) (3 marks)
Outcomes Assessed: PH12-4, PH12-6, PH12-7, PH12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Provides a detailed explanation that incorporates mathematical reasoning	3
• Provides a qualitative explanation without mathematical reasoning	2
• Includes a correct idea relating to the question	1

Sample answer:

When a car moves along the arc of a circle while rounding a bend, the frictional force between the tyres and the road must not exceed the required centripetal force. Centripetal force is proportional to the square of the velocity ($F \propto v^2$) so, doubling the speed of the car will require four times the centripetal force to keep the car on the road. During wet weather, the force of friction between the tyres and the road is significantly reduced, sometimes by up to one-half of the value on dry roads. As such, the centripetal force has to be reduced to the same value and to halve it would require the velocity be reduced by a factor of $\sqrt{0.5}$ or 0.7. In other words, the car taking the corner in part (a) with a maximum velocity of 16.5 m s^{-1} would have to reduce that velocity to 0.7 x 16.5 = 11.7 m s^{-1} in wet weather in order to stay on the road and remain in control of the vehicle.

(c) (4 marks)

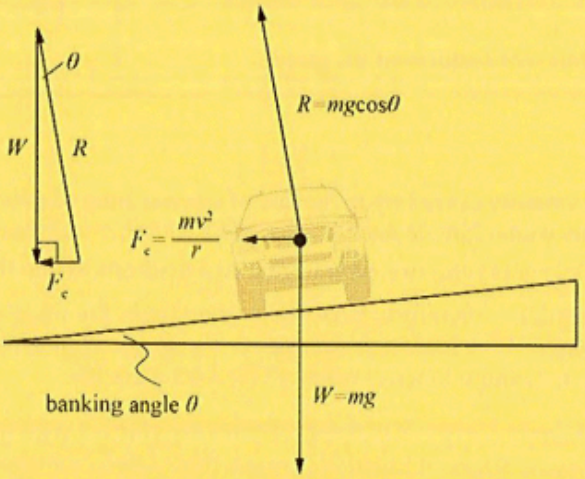
Outcomes Assessed: PH12-4, PH12-6, PH12-7, PH12-12

Targeted Performance Bands: 4-6

Criteria	Marks
• Provides a detailed explanation that incorporates mathematical reasoning and calculations of speed	4
• Provides a qualitative explanation with some mathematical reasoning	2-3
• Provides a qualitative explanation with little or no mathematical reasoning	2
• Includes a correct idea relating to the question	1

Sample answer:

When a corner is banked, some of the centripetal force required is provided by the horizontal component of the normal reaction force, reducing the force of friction needed and allowing motorists to take corners safely at higher speeds. The centripetal force required on a banked corner is the vector sum of the normal reaction force and the car's weight as shown. Using the values form part (a):



$$\left(F_c\right)^2 = \left(mg\cos\theta\right)^2 + \left(mg\right)^2$$

$$\frac{mv^2}{r} = \sqrt{\left(mg\cos\theta\right)^2 + \left(mg\right)^2}$$

$$\frac{885\times v^2}{25.6} = \sqrt{\left(885\times 9.8\times\cos 8\right)^2 + \left(885\times 9.8\right)^2}$$

$$v^2 = \frac{\left(\sqrt{\left(8589\right)^2 + \left(8673\right)^2}\right)\times 25.6}{885}$$

$$v = 18.8 \text{ m s}^{-1}$$

Therefore, banking the road to 8.0° would increase the maximum safe speed by $18.8 - 16.5 = 2.3$ m s^{-1}, showing that banking corners makes a contribution to improving road safety.

Question 33 (6 marks)
Outcomes Assessed: PH12-4, PH12-7, PH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Outlines radioactive decay in terms of mass defect and kinetic energy • Defines alpha and beta decay in terms of the number and type of particles produced • Explains why alpha decay produces more kinetic energy than beta decay per particle • Relates the production of only one particle in alpha decay to the features of the graph • Relates the production of an electron and a neutrino in beta decay to the features of the graph	5-6
• Outlines radioactive decay in terms of mass defect and kinetic energy • Defines alpha and beta decay in terms of the number and type of particles produced • Explains why alpha decay produces more kinetic energy than beta decay per particle OR • Relates the production of only one particle in alpha decay to the features of the graph • Relates the production of an electron and a neutrino in beta decay to the features of the graph	3-4
• Outlines radioactive decay in terms of mass defect and kinetic energy • Defines alpha and beta decay in terms of the number and type of particles produced OR • Relates some aspect of alpha and/or beta decay to relevant features of the graph	1-2

Sample answer:

Radioactive decay is an exothermic process that produces energy according to the law of conservation of mass-energy. Unstable nuclei release particles from the nucleus with a kinetic energy associated with their mass and velocity ($E_k = \frac{1}{2}mv^2$). Alpha particles are helium nuclei containing two protons and two neutrons, while the beta particle shown on the graph is an electron. Alpha particles, therefore, have about 7000 times the mass of electrons and, therefore, significantly more kinetic energy. This feature is shown on the graph with alpha particles having much more kinetic energy than even the maximum kinetic energy of the beta particles.

The other difference shown on the graph also relates to kinetic energy. All alpha particles are emitted with the same kinetic energy while beta particles are shown to have a range of kinetic energies. Every alpha emission produces the same helium nucleus with the same mass and speed, shown by a single vertical line on the graph indicating that all alpha particles are emitted with the same kinetic energy. In beta decay, two particles are produced: an electron and a antineutrino. While the antineutrino has an imperceptibly small mass compared with the electron, these particles are emitted with significant speeds. In each decay, the energy released from the nucleus as lost mass is the same, however, the kinetic energy carried by the decay particles can be apportioned differently. Since the graph shows only electrons (and not antineutrinos), a range of kinetic energies is observed. If the graph were to show the combined energy of electrons and antineutrinos, it would look the same as the line for alpha particles, however, the line would occur at a much lower kinetic energy.