Government of **Western Australia**
School Curriculum and Standards Authority

PHYSICS

ATAR course examination 2019

Marking key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

2019/62819

Section One: Short response **30% (55 Marks)**

Question 1 **(4 marks)**

(a) (i) Draw an arrow showing the direction of the flow of conventional current in the circuit. (1 mark)

Description	Marks
draws one arrow away from positive **or** draws one arrow towards the negative.	1
Total	**1**

(ii) Draw an arrow on the conducting rod to show the direction of the force acting on it. (1 mark)

Description	Marks
arrow pointing to the right	1
Total	**1**

(b) Calculate the magnitude of the force referred to in part (a) (ii). (2 marks)

Description	Marks
$F = BIl$	
$= 0.4 \times 1.5 \times 0.3$	1
$= 0.18$N	1
Total	**2**

Question 2 **(4 marks)**

Assume the frequency of the light remains above the threshold frequency of the metal. In the table below, describe what would happen to the initial reading on A and the final reading on V, if the following changes were made. Use the terms ‘increase’, ‘decrease’ or ‘unchanged’.

Description		Marks
unchanged	increases	1–2
decrease	increases	1–2
	Total	**4**

Question 3 **(4 marks)**

Using an appropriate equation from the Formulae and Data booklet, explain why a larger EMF would be detected if the magnet was moved at a greater velocity toward the coil.

Description	Marks
$EMF = -N(\Delta BA/\Delta t)$	1
EMF is proportional to rate of change of flux. N, B and A remain constant. As velocity increases, Δt decreases therefore EMF increases	1–3
Total	**4**

Question 4 **(5 marks)**

Titan is the largest of Saturn's moons. Its orbital radius is 1.22 × 10^6 km. Use the Formulae and Data booklet and the data in the table below to determine the strength of Saturn's gravitational field where Titan orbits. Give your answer in N kg^{-1} and m s^{-2}.

Description	Marks
$r = 1.22 \times 10^9$ m	1
$M = 95\ M_E = 5.67 \times 10^{26}$ kg	1
$g = MG/r^2$ $g = 5.67 \times 10^{26} \times 6.67 \times 10^{-11}/(1.22 \times 10^9)^2$ $g = 2.54 \times 10^{-2}$ N kg^{-1}	1–2
$g = 2.54 \times 10^{-2}$ m s^{-2}	1
Total	**5**

Question 5 **(4 marks)**

In 2012 scientists at the European Organisation for Nuclear Research (CERN) in Switzerland claimed to have found the Higgs boson. They measured its rest energy to be 126 GeV. Show that the mass of the Higgs boson is 2.24 × 10^{-25} kg.

Description	Marks
$m = E/c^2$	1
$= 126 \times 10^9 \times 1.6 \times 10^{-19} / 9 \times 10^{16}$ $= 2.24 \times 10^{-25}$ kg	1–3
Total	**4**

Question 6 **(4 marks)**

(a) With specific reference to the conditions required for equilibrium, explain why the diagram of the forces is incorrect. (2 marks)

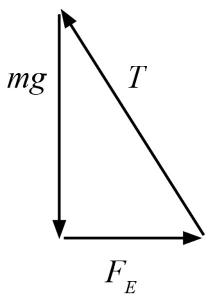
Description	Marks
Σ horizontal forces should = 0	1
No F_H to the right to counter component of T to the left: unbalanced	1
Total	**2**

(b) Using the diagram below, show what change(s) should be made to correct it. (Calculations are not required.) (2 marks)

Description	Marks
$\mathbf{F_{hinge}}$ must be to the right	1
and a vertical component	1
Total	**2**

Question 7 **(8 marks)**

(a) In the space below, draw a vector diagram of the forces acting on the pith ball. (3 marks)



Description	Marks
correct forces	1
closed right triangle	1
correct labels	1
Total	**3**

(b) Calculate the angle between the string and the charged plate. (5 marks)

Description	Marks
$\tan\theta = F_E / mg$	1
$F_E = Eq$ = 95 x 2 × 10^{12} x 1.6 × 10^{-19} = 3.04 × 10^{-5}	1–2
mg = 75 × 10^{-6} x 9.8 = 7.35 × 10^{-4}	1
$\tan\theta$ = 3.04 × 10^{-5} / 7.35 × 10^{-4} $\theta = 2.37^0$	1
Total	**5**

Question 8 **(4 marks)**

A cyclist is travelling at 6.0 m s^{-1} over a hump in the road that is part of a circle of radius 4.80 m. Calculate the magnitude of the total reaction force of the ground on the cyclist at the top of the hump. The total mass of the cyclist and bicycle is 72 kg.
(Note: diagram not to scale, ignore friction.)

Description	Marks
$F_c = mg - R$ $R = mg - mv^2/r$	1–2
= 72(9.8 – 36/4.8)	1
= 166 N	1
Total	**4**

Question 9 **(3 marks)**

With the use of a relevant formula, explain why time dilation is negligible at a speed of 100 km h^{-1}.

Description	Marks
$t = t_0 / \sqrt{1 - v^2 / c^2}$	1
As 100 km h^{-1} is considerably less than c, v^2/c^2 is close to zero so dilation is not noticeable.	1–2
Total	**3**

Question 10 **(8 marks)**

(a) Give a possible relationship between wavelength and momentum based upon the shape of the graph. (1 mark)

Description	Marks
$\lambda \alpha \frac{1}{p}$ $\left(\text{not } \lambda = \frac{1}{p}\right)$ or inverse relationship	1
Total	**1**

(b) Describe how the data used to generate the graph could be reorganised to produce a straight-line graph. (2 marks)

Description	Marks
plot λ vs 1/p or p vs 1/λ (must mention both variables)	1–2
Total	**2**

(c) What would the gradient of the straight-line from part (b) represent? (1 mark)

Description	Marks
Planck's constant for λ vs $1/p$	1
$1/h$ for p vs $1/\lambda$	
Total	**1**

(d) Ignoring relativistic effects, calculate the momentum of a particle with a wavelength of 2.50×10^2 nm. (4 marks)

Description	Marks
$p = h/\lambda$	1
$= 6.63 \times 10^{-34} / 2.5 \times 10^{-7}$	1
$= 2.65 \times 10^{-27}$	1
kg m s^{-1} or Ns or J s m^{-1}	1
Total	**4**

Question 11 **(7 marks)**

(a) Calculate the time elapsed on Zhang's clock (as observed by Zhang) when the front of *Antilles* reaches the second beacon. (1 mark)

Description	Marks
t = 1000/0.8 x 3.0 × 10^8 = 4.17 × 10^{-6} s	1
Total	**1**

(b) Calculate the distance Chloe observes between the beacons before she passes the first beacon. (2 marks)

Description	Marks
$l = 1000\sqrt{1 - 0.8^2}$	1
= 600 m	1
Total	**2**

(c) At one stage, Zhang observes *Antilles* fits completely between the two beacons. Chloe says that at no time did the spaceship completely fit between the beacons. Explain how they can both be correct, and why. (4 marks)

Description	Marks
• Observing the whole of *Antilles* between the beacons at a particular time requires you to measure the positions of the front and back simultaneously. • Simultaneity is not the same for each observer. • Due to length contraction, Zhang observes length of *Antilles* as 660 m so it fits easily between the beacons. • Chloe observes distance between the beacons contract to 600 m so *Antilles* does not fit.	1–4
Total	**4**

Section Two: Problem-solving 50% (93 Marks)

Question 12 (15 marks)

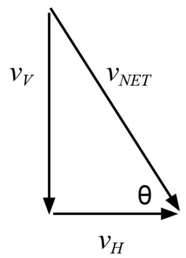
(a) Using conservation of energy, calculate the speed with which the ball leaves the table. Assume no energy is lost to friction, air resistance or is transferred to rotational energy. (2 marks)

Description	Marks
$mgh = mv^2/2$ $v = \sqrt{2\ gh} = \sqrt{2 \times 9.80 \times 0.3}$	1
$= 2.42$ m s^{-1}	1
Total	**2**

(b) Calculate the distance x. (4 marks)

Description	Marks
$s = 0.5\ a\ t^2$ $t = \sqrt{1.20/4.9}$	1
= 0.495 s	1
$x = v_H \times t$	1
= 2.42 × 0.495 = 1.20 m	1
Total	**4**

(c) Calculate the velocity of the ball when it hits the floor. (5 marks)

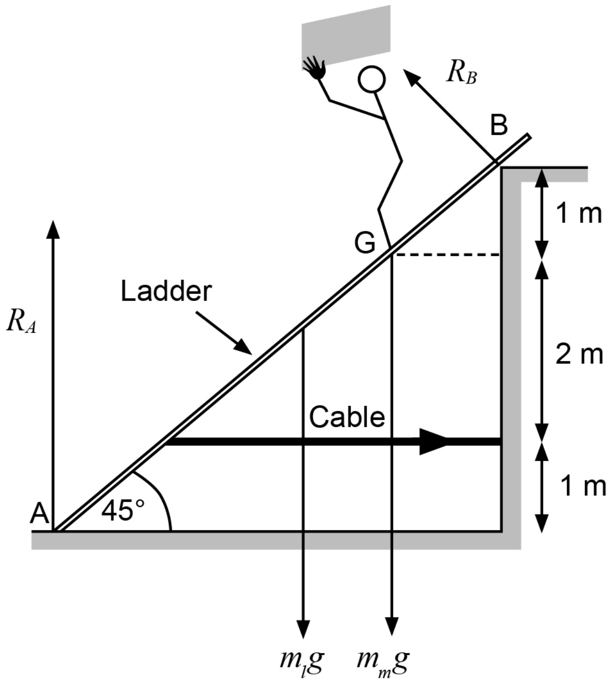


Description	Marks
$v_V = 0 + 9.8 \times 0.495$	1
$= 4.85$ m s^{-1}	1
$v_{N2} = v_V^{\ 2} + v_H^{\ 2}$ $v_N = \sqrt{4.85^2 + 2.42^2}$	1
$= 5.42$ m s^{-1}	1
tan θ = 4.85/2.42 θ = 63.5°	1
Total	**5**

(d) Derive an expression for x in terms of h and H only. (Note: may include numbers.) (4 marks)

Description	Marks
$v_H = \sqrt{2\ g\ h}$	1
$t = \sqrt{2\ H / g}$	1
$x = v_H \times t$ $= \sqrt{2 \times g \times h} \times \sqrt{2H / g}$	1
$= 2\ \sqrt{h \times H}$	1
Total	**4**

Question 13 **(10 marks)**



(a) On the diagram above, draw and label the forces acting on the ladder. Assume the reaction force at B acts at right angles to the ladder. (4 marks)

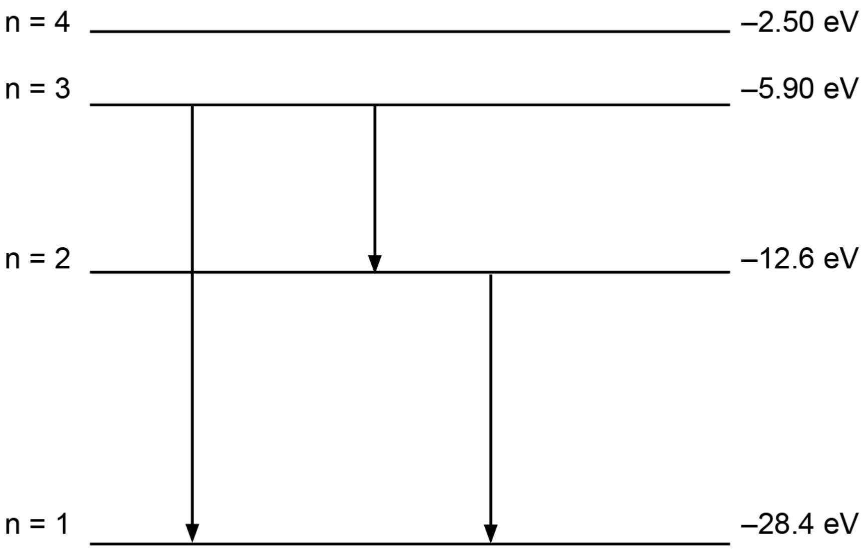
Description	Marks
forces: R_A, R_B, T, m_lg and m_mg	
all five correctly labelled with directions	4
all five, one incorrectly labelled or directed	3
four correctly labelled	3
four, one incorrectly labelled or directed or all five, two incorrectly labelled or directed	2
three correct	1
Total	**4**

(b) By taking moments around A, calculate the tension in the cable. (6 marks)

Description	Marks
$\Sigma F_H = 0$ $T = R_B$ cos 45 $R_B = T$/cos 45	1–2
Taking moments at A: (T × 1) + (90 × 9.8 × 3) + (15 × 9.8 × 3 cos 45) = R_B × 4/cos 45	1–2
Sub for R_B: T + 2650 + 312 = $4T/(\cos 45)^2$	1
2960 = 8T – T T = 423 N	1
Total	**6**

Question 14 **(15 marks)**

(a) On the diagram above, show all the possible downward electron transitions that can occur in a mercury atom after a successful collision with an incoming electron with an energy of 23.0 eV. (4 marks)



Description	Marks
3 to 1: 22.5 eV (possible) 4 to 1: 25.9 eV not possible	1
diagram three lines with downward arrows: 1 mark each	1–3
Total	**4**

(b) Calculate the wavelength of the photon from part (a) that strikes the potassium metal plate. (3 marks)

Description	Marks
28.4 – 12.6 = 15.8 eV	1
$\lambda = ch/E = 3.0 \times 10^{8} \times 6.63 \times 10^{-34} / 15.8 \times 1.6 \times 10^{-19}$	1
$= 7.87 \times 10^{-8}$ m	1
Total	**3**

(c) Calculate the maximum velocity of any electrons liberated from the potassium metal plate. Ignore relativistic effects. (5 marks)

Description	Marks
$E_K = hf - W$ = (28.4 – 12.6) – 2 = 13.8 eV	1–2
$v = \sqrt{2 E_K/m}$	1
$= \sqrt{2 \times 13.8 \times 1.6 \times 10^{-19} / 9.11 \times 10^{-31}}$	1
$= 2.20 \times 10^{6}$ m s^{-1}	1
Total	**5**

Question 14 (continued)

(d) State a formal definition of the term 'work function' and explain why part (c) refers to maximum velocity. (3 marks)

Description	Marks
Work function is the minimum amount of work required to remove an electron from the (surface) of a metal.	1
Maximum velocity is attained when liberated electrons have the maximum kinetic energy. Not all electrons have this as they are liberated from atoms below the surface and expend energy getting to the surface or other electrons collide with other electrons and lose energy.	1–2
Total	**3**

Question 15 **(12 marks)**

(a) Are kaons classified as baryons or mesons? (1 mark)

Description	Marks
meson/s	1
Total	**1**

(b) Justify your answer to part (a). (2 marks)

Description	Marks
meson are comprised of two quarks, one quark and one antiquark	1
kaons are made up of a strange and an up antiquark: meson	1
Total	**2**

(c) Name the quarks that make up the K^{0-} particle. (2 marks)

Description	Marks
strange quark	1
down antiquark	1
Total	**2**

(d) K^- particles have a mean lifetime of 1.238×10^{-8} s in their own frame of reference. Kaons produced in a particle accelerator were found to be moving at 0.850c. Calculate their mean lifetime in the frame of reference of a stationary observer. (3 marks)

Description	Marks
$t = t_0 / \sqrt{1 - v^2 / c^2}$ $= 1.2380 \times 10^{-8} / \sqrt{1 - 0.85^2}$	1–2
$= 2.35 \times 10^{-8}$ s	1
Total	**3**

(e) With the use of appropriate equations, explain how the protons were:

(i) accelerated to high speeds in the linear accelerator. (2 marks)

Description	Marks
Charged particles are accelerated to higher speeds using electric fields.	1
$F = Eq = ma$	1
Total	**2**

(ii) held in circular paths in the main ring. (2 marks)

Description	Marks
Charged particles are held in circular paths by strong magnetic fields.	1
$r = mv/Bq$	1
Total	**2**

Question 16 **(12 marks)**

(a) In the table below, match the statements with A, B, C and/or D. (4 marks)

Description		Marks
point(s) where the centripetal acceleration is the greatest	A	1
point(s) where the tension in the string is the lowest	C	1
point(s) where the net force is not toward the centre of the circle	B and D (no mark for just one)	1
point(s) where the ball's weight force is perpendicular to the tension	B	1
	Total	**4**

(b) Write an expression for the net force acting on the string at point C in terms of the weight force and the tension in the string. (1 mark)

Description	Marks
$F_C = T + mg$ (could use F_{net})	1
Total	**1**

(c) Calculate how fast the 500 g ball can be moving at point A for the 1.20 m long string not to break, if the maximum tension it can withstand at point A is 172 N. (4 marks)

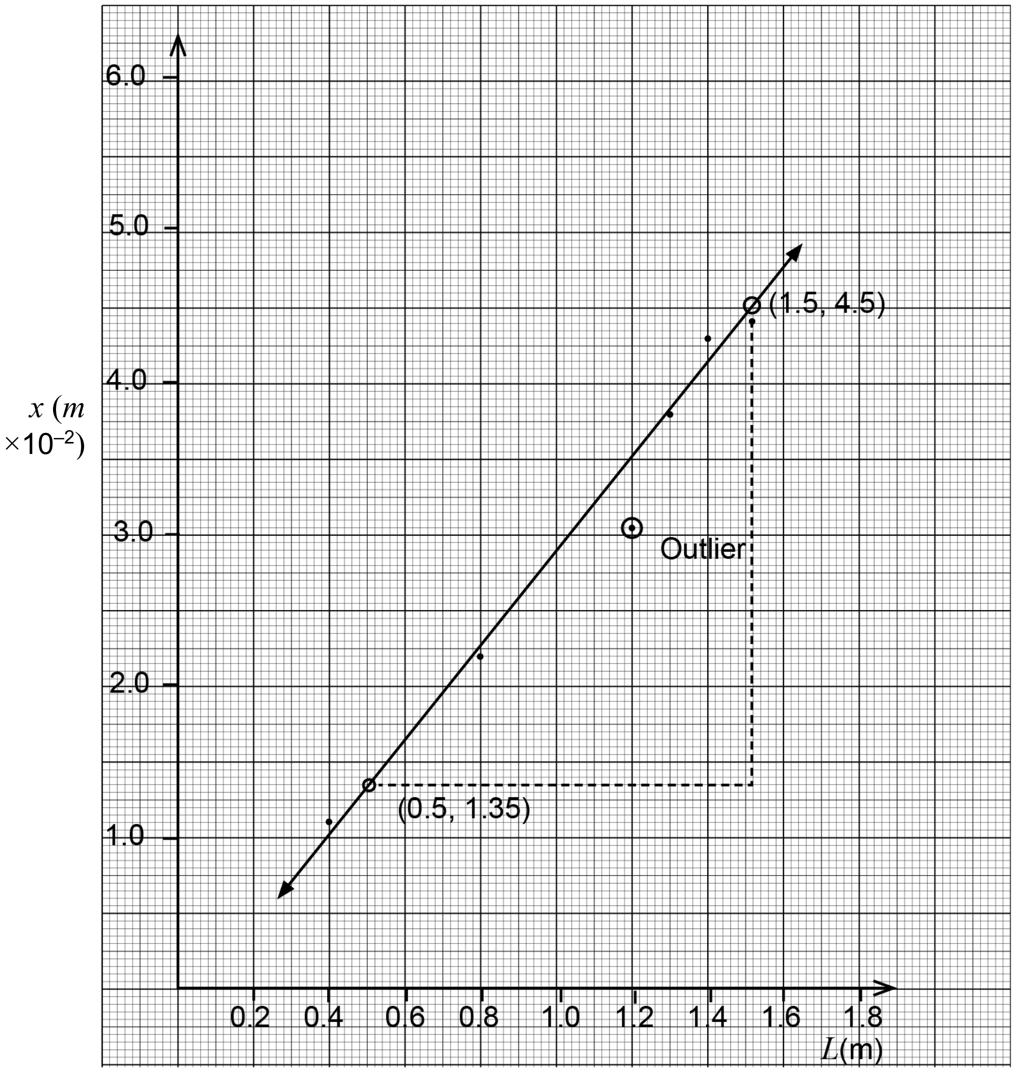
Description	Marks
At A: $T = Fc + mg$	1
$T = 0.5(v^2/1.2 + 9.8)$	1
$172/0.5 - 9.8 = v^2/ 1.2$ $v = 20.0 \text{ m s}^{-1}$	1–2
Total	**4**

(d) Calculate the maximum speed at which the ball can be moving at point C for the string not to break at point A. (3 marks)

Description	Marks
At C: $E_{total} = 0.5mv_C^2 + mg \text{ x } 2.4 = m20^2/ 2$	1
$v_C = \sqrt{2(200 - 23.5)}$	1
$= 18.8 \text{ m s}^{-1}$	1
Total	**3**

Question 17 **(17 marks)**

(a) Graph x vs L on the grid paper provided on page 23. Include the line of best fit. Do **not** include uncertainties. (5 marks)



Description	Marks
correct orientation of axes	1
correct labelling of axes including units	1
accurate plotting	1
line of best fit.(LOBF) (not through origin)	1
outlier clearly identified	1
Total	**5**

(b) From your graph, calculate the gradient of the line of best fit. Show construction lines on your graph. Use correct significant figures. (3 marks)

Description	Marks
using points (0.50,1.35) and (1.50, 4.50) (must be on LOBF not data points)	1
m = $(4.50 - 1.35) \times 10^{-2} / (1.50 - 0.50) = 3.2 \times 10^{-2}$	1
appropriate significant figures	1
Total	**3**

Question 17 (continued)

(c) Using the gradient from part (b), calculate the wavelength of the monochromatic light used. Use correct significant figures. (4 marks)

Description	Marks
$x = \lambda L / d$ but λ / d = gradient (m) $So\ \lambda = d \times m$	1–2
= 2.19 × 10^{-5} × 3.15 × 10^{-2} = 6.90 × 10^{-7} m = 690 nm	1
appropriate significant figures	1
Total	**4**

(d) Using the same values as in part (b), recalculate your gradient including uncertainties to show that a 10% difference falls within the accepted range. (5 marks)

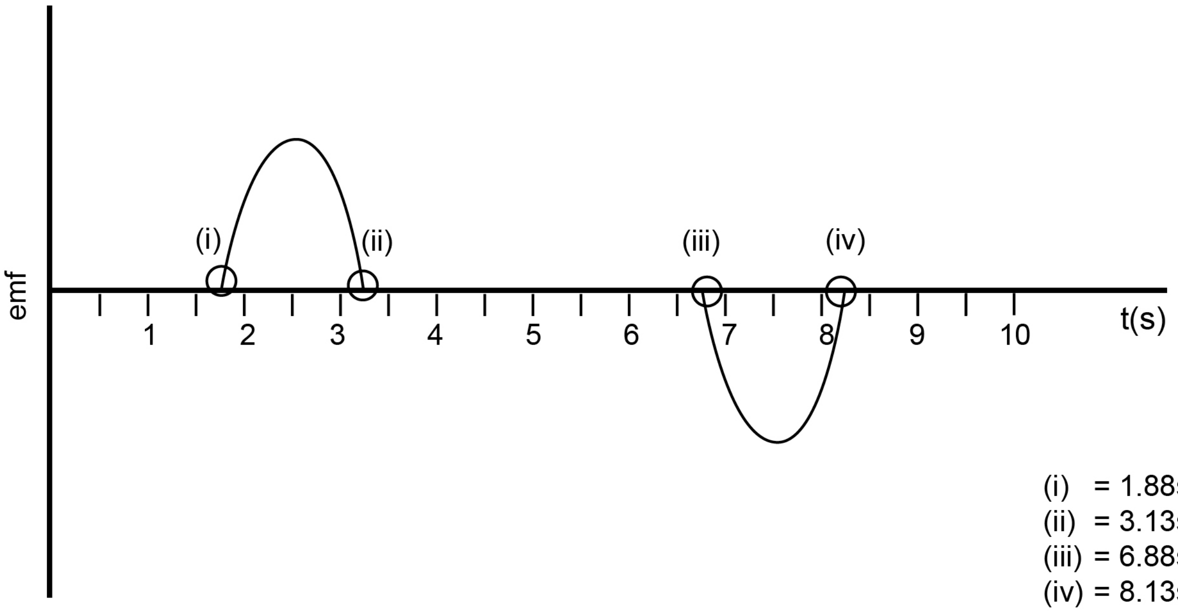
Description	Marks
using points (0.50, 1.35) and (1.50, 4.50) (must be same points as part (b).) Δy = 3.15 × 10^{-2} ± 0.004m	1
% uncertainty = (0.004 / 0.0315) × 100 = 12.7 %	1
Δx = 1.50 – 0.50 = 1.00 ± 0.004 m	1
% uncertainty = (0.004 / 1.0) × 100 = 0.4) × 100 = 0.4%	1
(Assuming value of gradient is the same) Total uncertainty of gradient = 13.1% so 10% is OK	1
Total	**5**

Question 18 **(12 marks)**

(a) Calculate the average emf induced as the coil moves from B to C. (4 marks)

Description	Marks
Area of coil = $\pi r^2 = \pi (0.5)^2 = 0.785$ m^2	1
Δt = 1.0/0.8 = 1.25 s	1
Average emf = 25 × 0.28 × 0.785/1.25	1
= 4.40 V	1
Total	**4**

(b) On the axes below, show the induced emf versus time as the coil moves from A to F. (Note: only include specific values on the time axis.) (8 marks)



(i) = 1.88s
(ii) = 3.13s
(iii) = 6.88s
(iv) = 8.13s

Description	Marks
one mark per correct time i, ii, iii and iv	1–4
graph: same size curves	1
curves not straight lines	1
opposite sides of x-axis	1
flat line between at zero	1
Total	**8**

Section Three: Comprehension **20% (38 Marks)**

Question 19 **(20 marks)**

(a) Give an expression for the radius of a charged particle's path when fired into a uniform magnetic field. (1 mark)

Description	Marks
$r = mv/Bq$	1
Total	**1**

(b) Explain why it is important to make sure that all the ions that enter the detector have the same velocity. (3 marks)

Description	Marks
the purpose of the mass spectrometer is to identify particles by their mass	1
this is done by measuring r therefore all variables except m must be kept constant	1
q and B are constant therefore v must be also	1
Total	**3**

(c) An unknown ion enters the detector at 9.24 x 10^4 m s^{-1}. It strikes the detector plate 12.38 cm from the entrance point. If the magnetic field strength is 3.50 T, calculate the mass of the unknown particle and identify it from the table above. (5 marks)

Description	Marks
$m = rBq/v$	1
$= 0.1238 \times 3.5 \times 1.60 \times 10^{-19} / 2 \times 9.24 \times 10^4$	1–2
$= 3.75 \times 10^{-25}$ kg	1
Ra^+	1
Total	**5**

(d) Calculate the accelerating voltage needed for the ion to attain a velocity of 9.24 x 10^4 m s^{-1} when entering the velocity selector. If you could not obtain an answer to part (c), use 3.11 x 10^{-25} kg. (4 marks)

Description	Marks
$W = Vq = mv^2/2$	1
$V = mv^2/2q$	1
$= 3.75 \times 10^{-25} \times (9.24 \times 10^4)^2 / 2 \times 1.60 \times 10^{-19}$	1
$= 1.0 \times 10^4$ V	1
Total	**4**

(e) The velocity selector shown on page 27 uses a combination of electric and magnetic fields to select only ions with a specific velocity to enter the detector. These ions travel directly across the selector parallel to the charged plates. Derive an expression for the selected velocity in terms of B and E. (3 marks)

Description	Marks
$F_B = F_E$ $Bvq = Eq$	1
$Bv = E$	1
$v = E/B$	1
Total	**3**

(f) Explain in detail why an ion travelling at a velocity greater than the selected velocity would not enter the detector. Use the diagram below to show the path the ion would take. (4 marks)

Description	Marks
if v is too great, F_B is too large	1
F_B exerts an upward force on the ion	1
particle will hit the barrier above the opening	1
path shown on diagram must be curved, not linear	1
Total	**4**

Question 20 **(18 marks)**

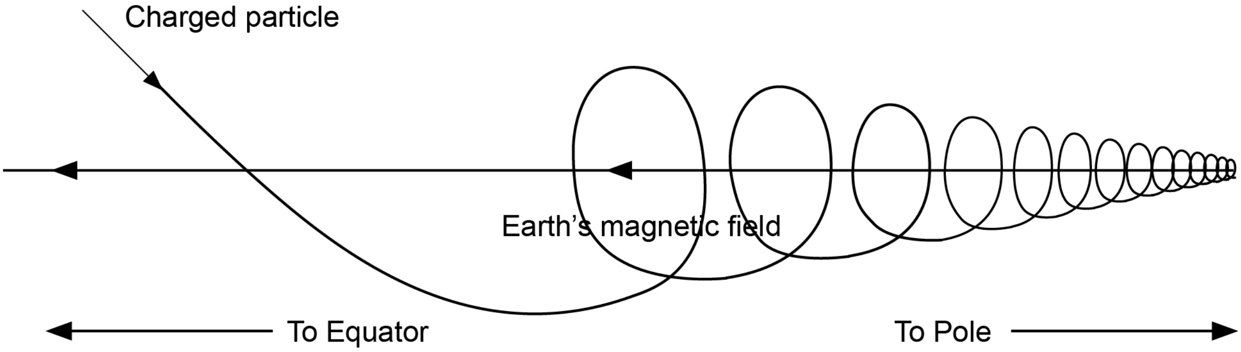
(a) (i) Estimate how much time it takes for the plasma from a typical CME to reach the Earth's magnetic field. (2 marks)

Description	Marks
$s = vt$, $t = s/v$	1
t = 150 x 10^6/6 x 10^6 = 25 hours	1
Total	**2**

(ii) Give **two** reasons why your answer to part (a) (i) is only an estimate. (2 marks)

Description	Marks
varying speeds of more than six million kilometres per hour	1
around 150 million kilometres	1
Total	**2**

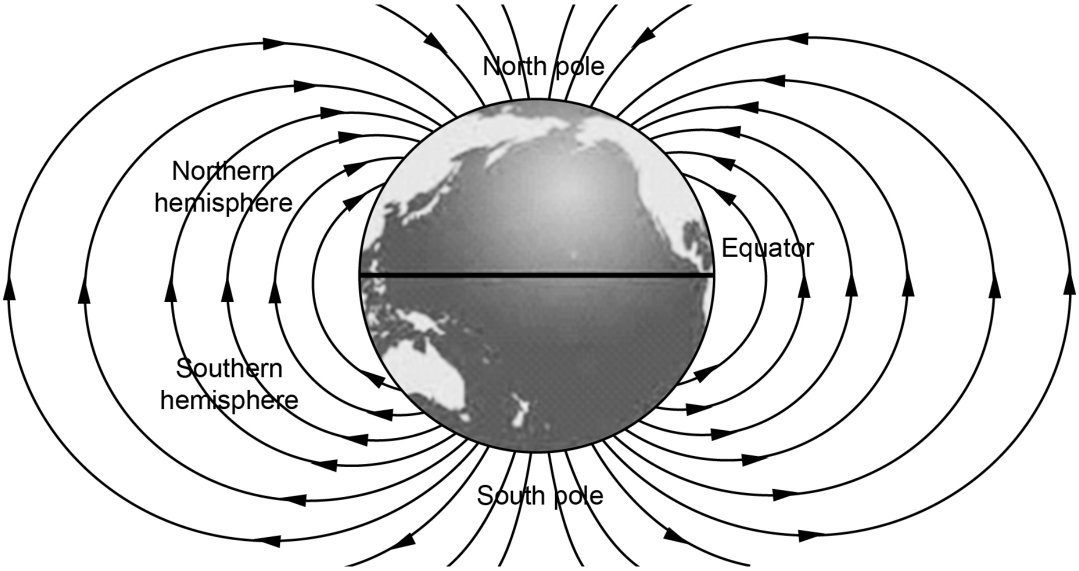
(b) Draw the possible path of a charged particle travelling along a magnetic field line after approaching it at an angle other than 90°. The field strength increases as the particle moves toward the pole. (3 marks)



Description	Marks
spiral-shaped	1
radius decreasing as it approaches pole	1
loops closer together as it approaches pole	1
Total	**3**

(c) (i) Draw the magnetic field around the earth on the diagram below before any distortion occurs due to a CME. (3 marks)

Description	Marks
direction	1
shape	1
relative intensity	1
Total	3



(ii) Using information from the text, suggest a reason why auroras are usually seen at the north and south poles but not at the equator. (3 marks)

Description	Marks
the plasma travels along our planet's magnetic field lines towards the poles	1
the maximum altitude above the Earth's surface where auroras occur is 300 km	1
particles only enter the atmosphere below 300 km when the field lines turn downwards towards the Earth's surface at the poles	1
Total	3

(d) Using specific information from the passage, explain why the same photon-producing electron transition produces red light in neutral molecular nitrogen and blue light in ionised molecular nitrogen. (5 marks)

Description	Marks
the electrons are more tightly bound due to ionisation	1
more energy is needed to excite an electron to a higher level due to being more tightly bound	1
when excited electrons fall back down in an excited ionised nitrogen molecule, they give off more energy	1
if energy difference is greater the wavelength is shorter	1
blue light has a shorter wavelength than red	1
Total	5

ACKNOWLEDGEMENTS

Question 20(c)(i) Diagram adapted from: University of Hawaii. (n.d.). *Exploring our fluid earth: Teaching science as inquiry (TSI).* Retrieved June, 2019, from https://manoa.hawaii.edu/exploringourfluidearth/physical/world-ocean/locating-points-globe

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