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

ATAR course examination, 2019

Question/Answer booklet

PHYSICS

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of this box.

WA student number: In figures

In words

Number of additional answer booklets used (if applicable):

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Formulae and Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in this examination, drawing templates, drawing compass and a protractor

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Ref: 19-066

PHY

2020/2639
Web Version of 2019/53357

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Short response	11	11	50	55	30
Section Two Problem-solving	7	7	90	93	50
Section Three Comprehension	2	2	40	38	20
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

   In calculations, give final answers to three significant figures and include appropriate units where applicable.

   In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

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

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 50 minutes.

Question 1 **(4 marks)**

A straight conducting rod is placed in contact with, and at right angles to, two conducting rails 30 cm apart. A magnetic field of 0.4 T is perpendicular to both the rails and the rod, as shown in the diagram below. A current of 1.5 A flows from the supply through both the rails and the rod.

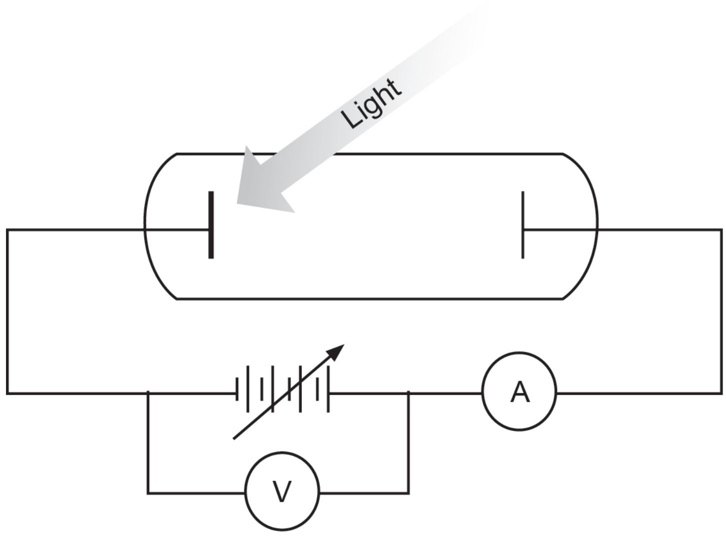
(a) (i) Draw an arrow showing the direction of the flow of conventional current in the circuit. (1 mark)

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

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

Question 2 **(4 marks)**

When light is shone on a metal plate, electrons may be emitted from the plate. This is called the 'photoelectric effect'. The apparatus below shows incident light of wavelength 450 nm striking a metal plate. The number of photons striking the plate per second can also be controlled by varying the brightness of the incident light. The current produced by the light is initially measured by the ammeter (A). Initially, the ammeter (A) reads a current. The stopping potential (V) is then adjusted until the ammeter reads 0 A.



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'.

	Change 1: wavelength is changed to 490 nm. Photons/second remains unchanged.	Change 2: wavelength is changed to 400 nm. Photons/second is increased.
Initial A		
Final V		

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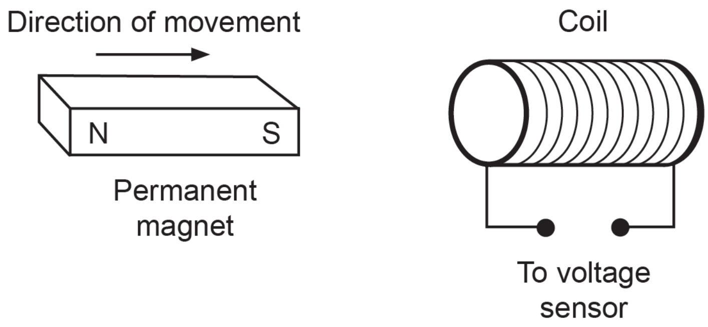
Question 3 **(4 marks)**

A permanent magnet is moved toward a coil at a constant velocity causing an emf to be induced across the ends of the coil.



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.

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}.

Planet	Mass (Earth masses)
Mercury	0.055
Venus	0.815
Earth	1.000
Mars	0.107
Jupiter	318
Saturn	95
Uranus	14.5
Neptune	17.2
Pluto	0.002

______________ N kg^{-1}

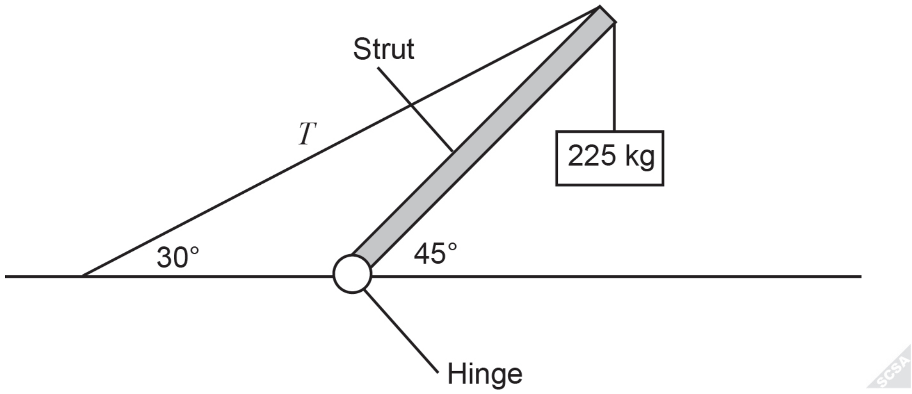
______________ m s^{-2}

Question 5 **(4 marks)**

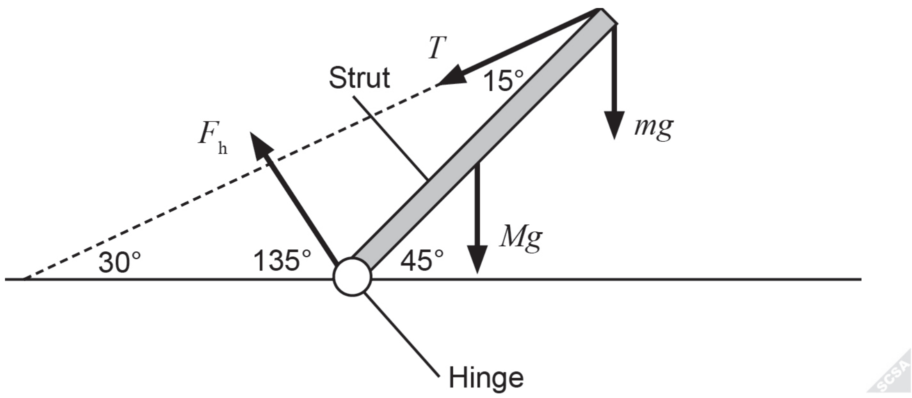
In 2012 scientists at the European Organisation for Nuclear Research (CERN) in Switzerland claimed to have found the Higgs boson. They measured its rest energy to be 126 GeV. Show that the mass of the Higgs boson is 2.24×10^{-25} kg.

Question 6 **(4 marks)**

The diagram below shows a system in equilibrium.

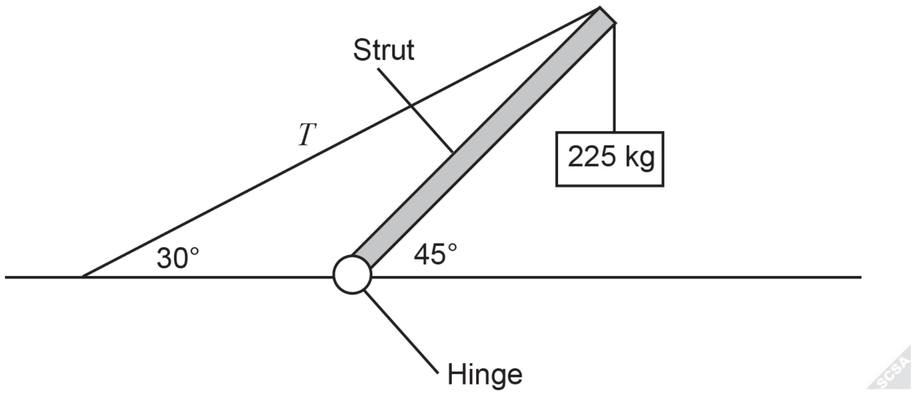


A student drew a diagram of the forces acting on the strut. That diagram is shown below. It is not drawn to scale.



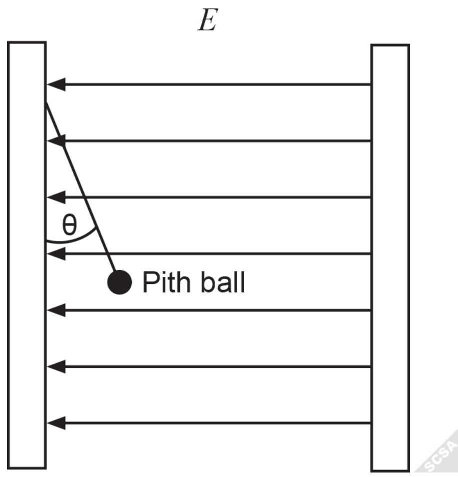
(a) With specific reference to the conditions required for equilibrium, explain why the diagram of the forces is incorrect. (2 marks)

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



Question 7 **(8 marks)**

A pith ball is a very small, lightweight object that readily picks up electric charge. A pith ball with a mass of 75.0×10^{-6} kg is suspended by a string attached to a charged plate. The pith ball has an excess of 2.00×10^{12} electrons on it and the electric field strength between the charged plates is 95.0 N C^{-1}.



(side view)

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

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

______ °

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.)

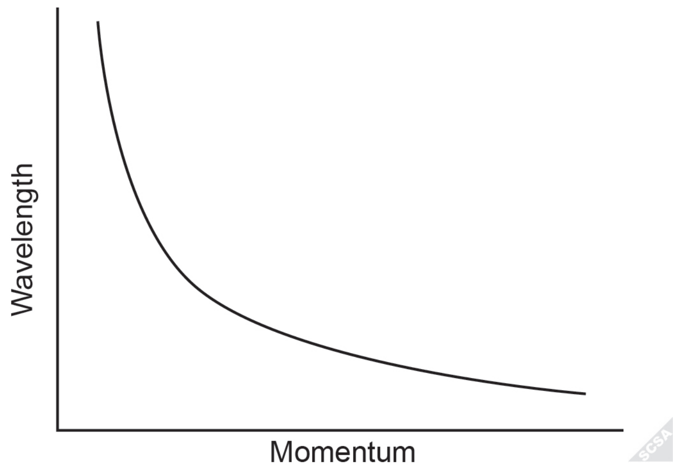
______________ N

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}.

Question 10 **(8 marks)**

If we plot the de Broglie wavelength of a subatomic particle against its momentum, we get the graph shown below. This applies to velocities less than 5% of the speed of light.



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

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

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

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

Unit:

Question 11 **(7 marks)**

Chloe is piloting the spaceship *Antilles*. It is 1.10 km long and travelling at $0.80c$ past a spaceport controlled by Zhang. Zhang needs to measure the speed of passing spaceships. Chloe steers the spaceship between two beacons 1000 m apart as measured by Zhang. The beacons are placed parallel to the *Antilles'* path. Both Chloe and Zhang start their timers when the front of the *Antilles* reaches the first beacon.

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

______________ s

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

______________ m

(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)

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End of Section One

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

This section has **seven** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

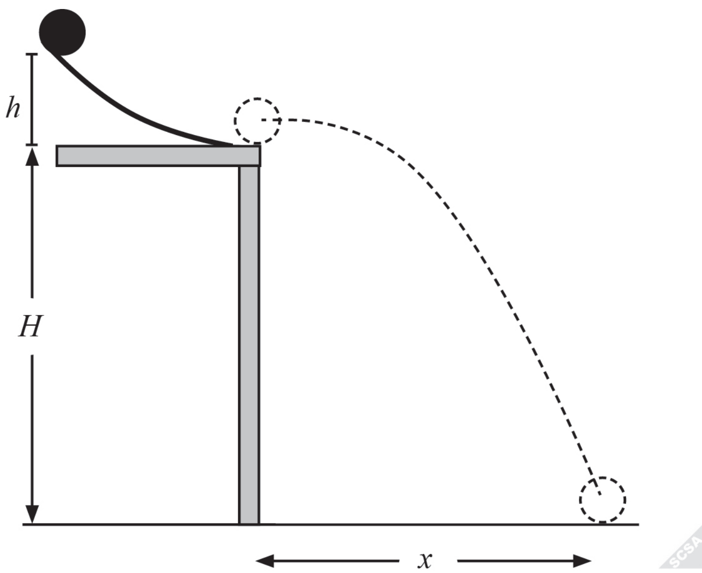
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 90 minutes.

Question 12 **(15 marks)**

A ball is rolled from rest down a curved slope, across a flat, smooth table leaving the table horizontally and falling to the floor.



If h = 30.0 cm and H = 1.20 m

(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)

______________ m s^{-1}

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

______________________ m

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

______________________ m s^{-1} Angle: ___________ ° above horizontal

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

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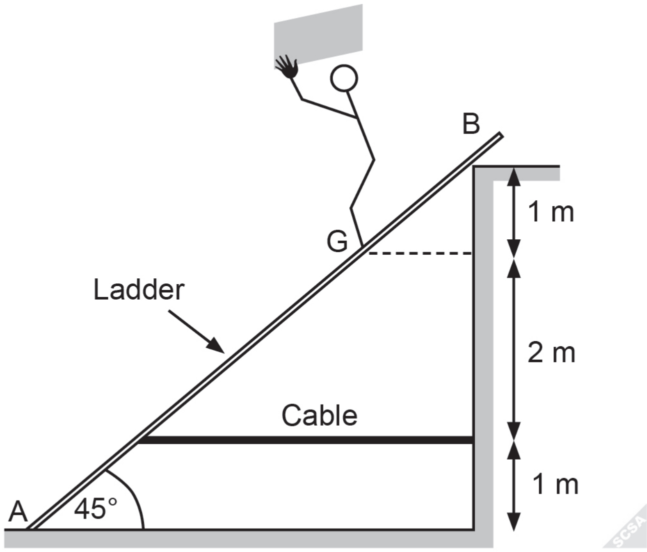
Question 13 **(10 marks)**

Workers at an ice skating venue use a ladder to fix a sign 5.0 m above the surface of the ice. To prevent the 6.00 m long ladder from slipping on the ice, they tie a cable between the ladder and the 4.00 m high wall. The cable is at right angles to the wall. The uniform 15.0 kg ladder is placed at an angle of 45° between the frictionless surfaces at A and B. A 90.0 kg worker is standing still on the ladder at G.



(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)

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

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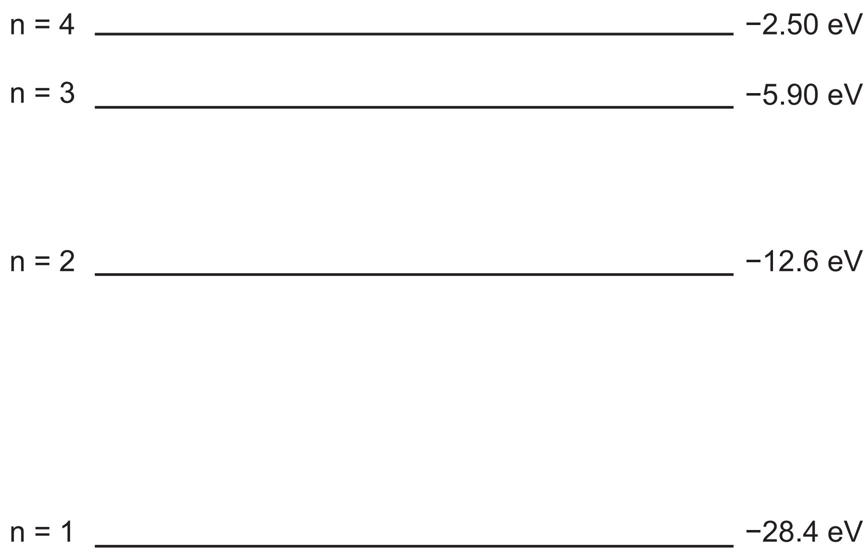
Question 14 **(15 marks)**

When gaseous mercury atoms are excited, they emit photons of varying wavelengths. Some of the energy levels in a mercury atom are shown in the diagram below.



A mercury lamp is used to produce light which is first fed through a filter that eliminates all wavelengths except those produced from the n = 2 to n = 1 transition. The resultant light is then shone onto a potassium metal plate whose work function is 2.00 eV.

(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)

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

______________ m

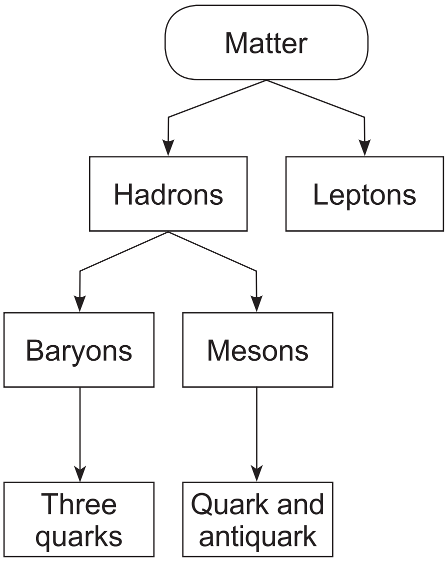
(c) Calculate the maximum velocity of any electrons liberated from the potassium metal plate. Ignore relativistic effects. (5 marks)

______________ $m\ s^{-1}$

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

Question 15 **(12 marks)**

The table below shows the classification of matter.



A kaon is a subatomic particle first detected in cosmic rays in 1947. There are four types:

K^-	a negatively-charged particle consisting of a strange quark and an up antiquark
K^+	a positively-charged antiparticle of the K^- kaon
K^0	a neutrally-charged particle consisting of a strange antiquark and a down quark
K^{0-}	the antiparticle of the K^0.

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

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

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

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(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)

______________ s

Kaons were produced in the Tevatron, a particle accelerator in the United States. Protons were accelerated in a linear accelerator (LINAC) containing a strong electric field. Then they were injected into the circular main injector ring to be accelerated to energies of up to 1 TeV.

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

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

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

Question 16 **(12 marks)**

A ball is being swung around in a vertical circle on a string.

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

Statement	A, B, C and/or D
point(s) where the centripetal acceleration is the greatest	
point(s) where the tension in the string is the lowest	
point(s) where the net force is not toward the centre of the circle	
point(s) where the ball's weight force is perpendicular to the tension	

(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)

____

(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)

______________ $m\ s^{-1}$

(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)

______________ $m\ s^{-1}$

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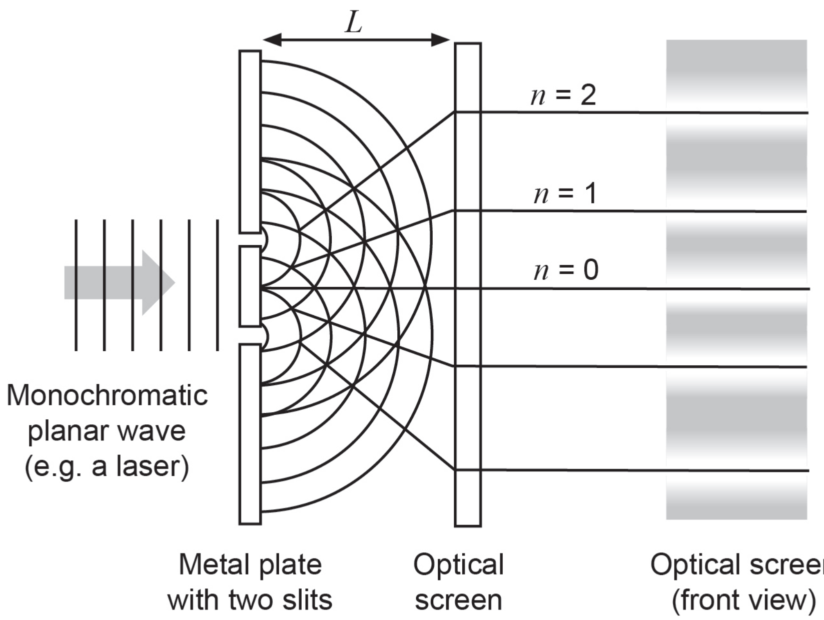
Question 17 **(17 marks)**

The first serious challenge to the particle theory of light was made by the English scientist Thomas Young in 1803. Young reasoned that if light were actually a wave phenomenon, as he suspected, then a similar interference effect observed with sound waves should occur for light. This line of reasoning led Young to perform an experiment which is nowadays referred to as 'Young's double-slit experiment'.

In Young's double-slit experiment, two very narrow parallel slits, separated by a distance d, are cut into a plate made of thin metal. Monochromatic light, from a distant light source, passes through the slits and eventually hits an optical screen a comparatively large distance L from the slits. The experimental setup is shown in the diagram below.



Young observed a series of alternating parallel light and dark bands on the screen, with the central band being bright.

From his research, he established the following relationship between L, the distance between the slits and the screen; d, the distance between the two slits; λ, the wavelength of the monochromatic light and x, the distance between the centres of adjacent light bands in the interference patterns:

$$\frac{x}{L} = \frac{n\lambda}{d}$$

A group of students set up an experiment to measure the wavelength of light produced by a laser pointer. Using a commercially-produced metal plate where $d = 2.19 \times 10^{-5}$ m, they varied the distance from the slits to the optical screen (L) and measured the distance between the centre light band and the one closest to it ($n = 1$). Their results are shown in the table below.

L (m) ± 0.002 m	0.400	0.800	1.200	1.300	1.400	1.500
x (m × 10^{-2}) ± 0.002 m	1.12	2.21	3.06	3.76	4.28	4.38

(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)

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A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and clearly indicate that you have redrawn it on the spare page.

Question 17 (continued)

(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)

____

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

______________________ nm

The students were disappointed when they found their answer was 10% different from the wavelength supplied by the manufacturers of the laser pointer. When the teacher helped them use the uncertainties associated with their experiment, they found the manufacture's value fell within the accepted range of uncertainty.

(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)

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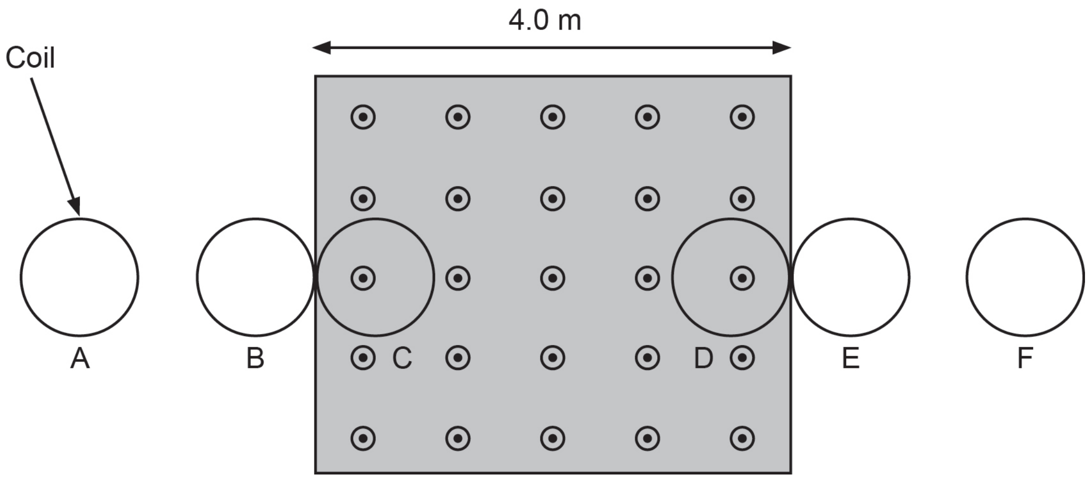
Question 18 **(12 marks)**

A coil with a radius of 50.0 cm and 25 turns is moved at a constant velocity of 0.80 m s^{-1} to the right of the page into, through and out of a uniform magnetic field of strength 0.28 T.

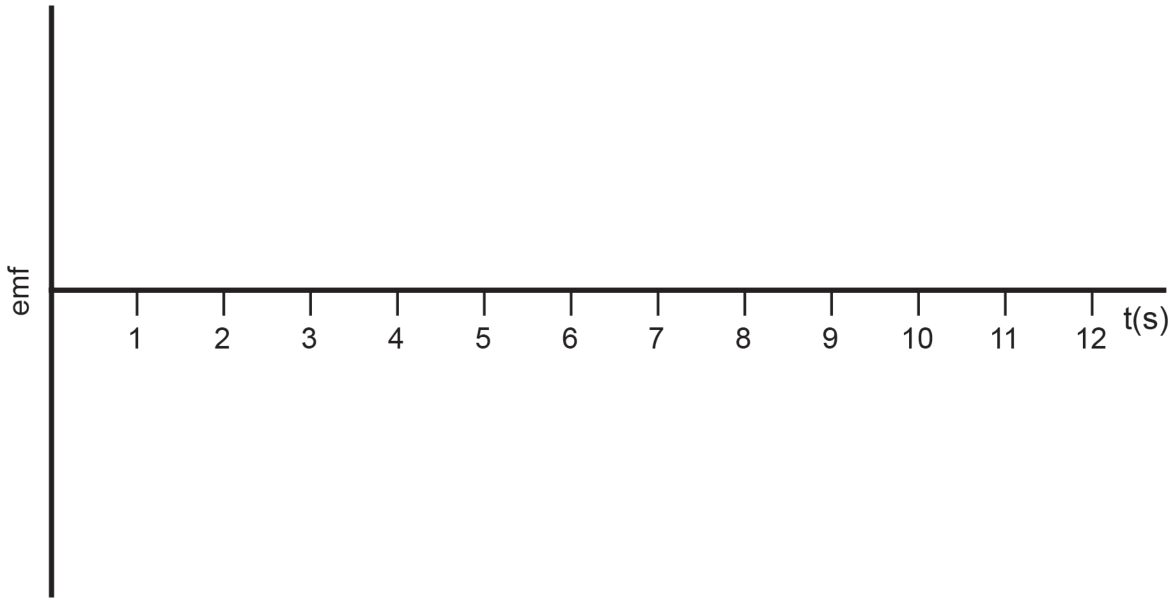
The total distance from the centre of the coil at A to the centre of the coil at F is 8.00 m and the distance from A to B is the same as E to F.



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

______________ V

(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)



Spare axes are provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate clearly that you have drawn it on the spare axes.

End of Section Two

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

This section has **two** questions. You must answer **both** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

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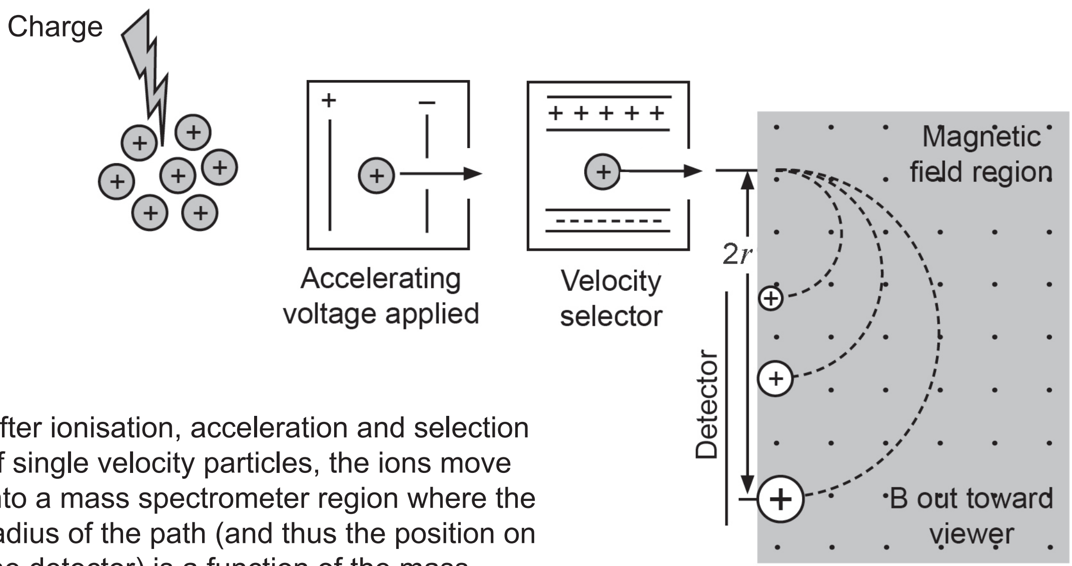
Suggested working time: 40 minutes.

Question 19 **(20 marks)**

Mass spectrometer

The mass spectrometer is an instrument that can measure the masses and relative concentrations of atoms in a mixed sample. It makes use of the magnetic force on a moving charged particle.

Different elements are ionised so they all have a charge of +1. They are then accelerated across a potential difference that increases their velocities. They move through a velocity selector and are then fired into a magnetic field where they undergo circular motion and land on a detector. The different masses of the elements will determine where they land on the detector. The concentration of each element can be determined by how many ions land in the one place.



After ionisation, acceleration and selection of single velocity particles, the ions move into a mass spectrometer region where the radius of the path (and thus the position on the detector) is a function of the mass.

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Velocity selector

In many experiments involving moving charged particles, it is important that the particles all move with essentially the same velocity. This can be achieved by applying a combination of an electric field and a magnetic field oriented as shown in the diagram above. A uniform electric field is directed vertically downward, and a uniform magnetic field is applied in the direction perpendicular to the electric field and into the page. For positive particles, the magnetic force is equal to qvB upward and the electric force (qE) is downward.

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

$r =$

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

Question 19 (continued)

(c) Below is a table of ions and their masses in kg.

An unknown ion enters the detector at 9.24×10^4 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)

________________ kg Particle: ________________

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

________________ V

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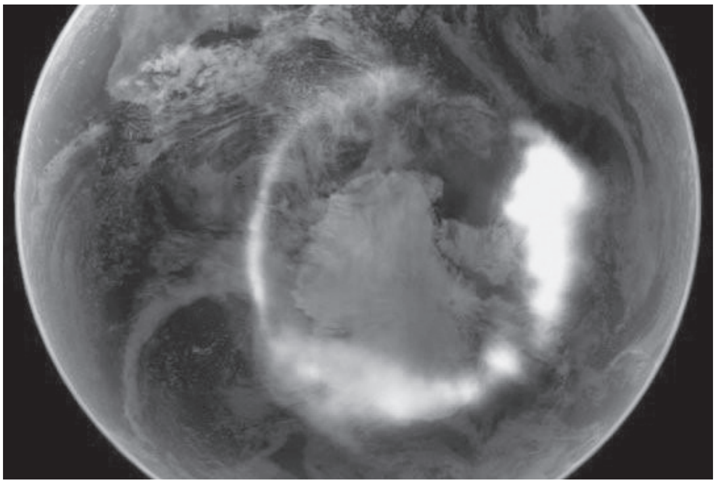
(e) The velocity selector shown on page 29 uses a combination of electric and magnetic fields to select only ions with a specific velocity to enter the detector. These ions travel directly across the selector parallel to the charged plates. Derive an expression for the selected velocity in terms of B and E. (3 marks)

(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)

Question 20 **(18 marks)**

Auroras: What are they and how are they created?



The Aurora Australis, captured by NASA's IMAGE satellite and overlaid onto a photograph of the earth. (NASA: public domain)

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

________________ hours

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

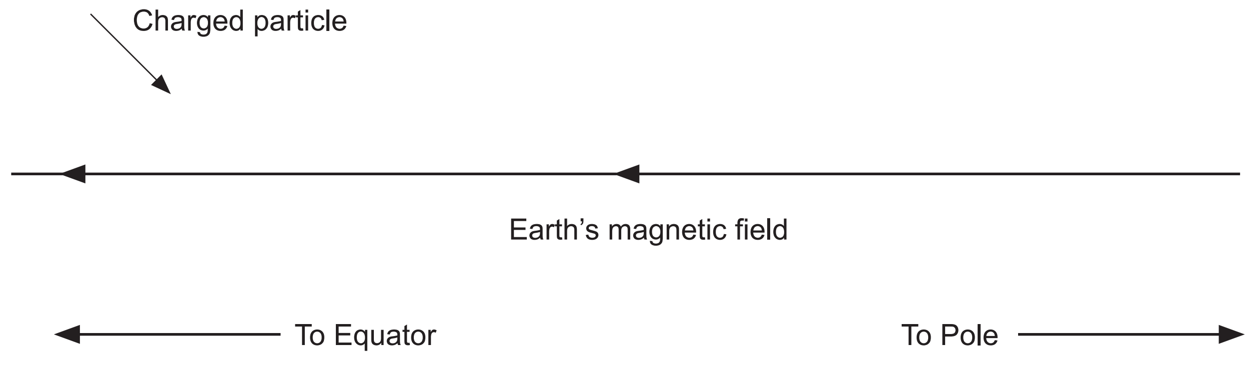
One: ____

____

Two: ____

____

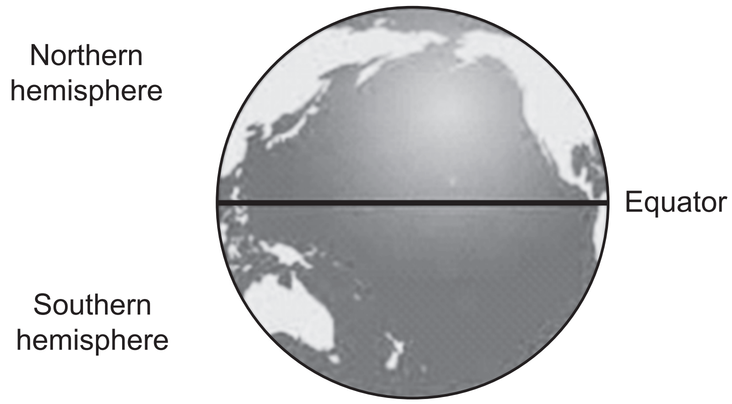
(b) Draw the possible path of a charged particle travelling along a magnetic field line after approaching it at an angle other than 90°. The field strength increases as the particle moves toward the pole. (3 marks)



A spare diagram is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and clearly indicate that you have redrawn it on the spare page.

Question 20 (continued)

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



(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)

(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)

End of questions

Supplementary page

Question number: ____________

Supplementary page

Question number: ____________

Supplementary page

Question number: ____________

Supplementary page

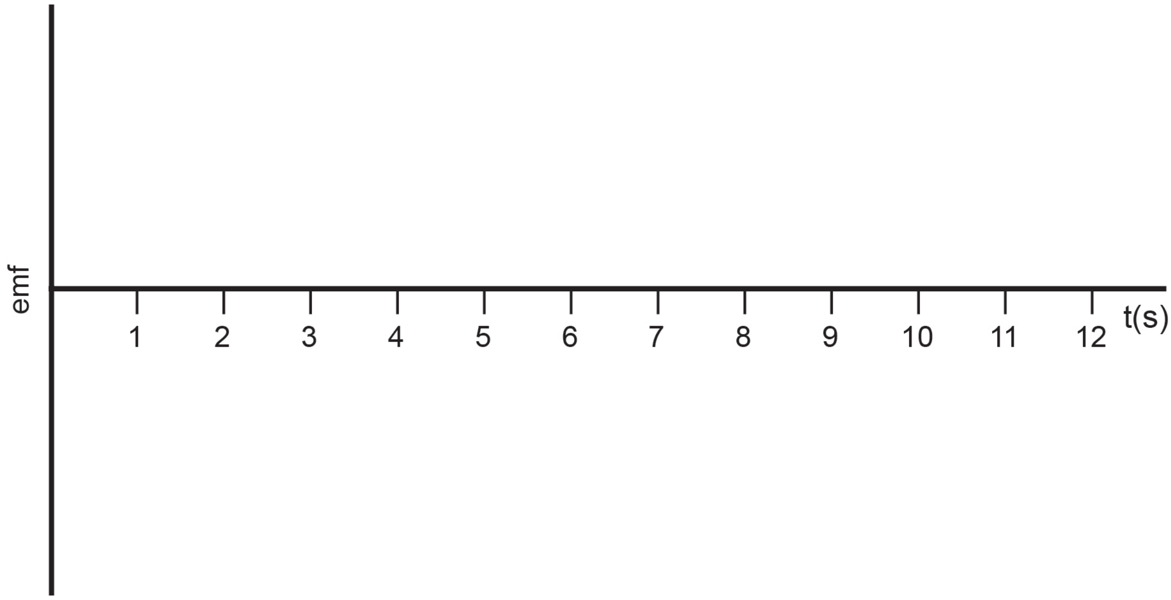
Question number: ______________

Supplementary page

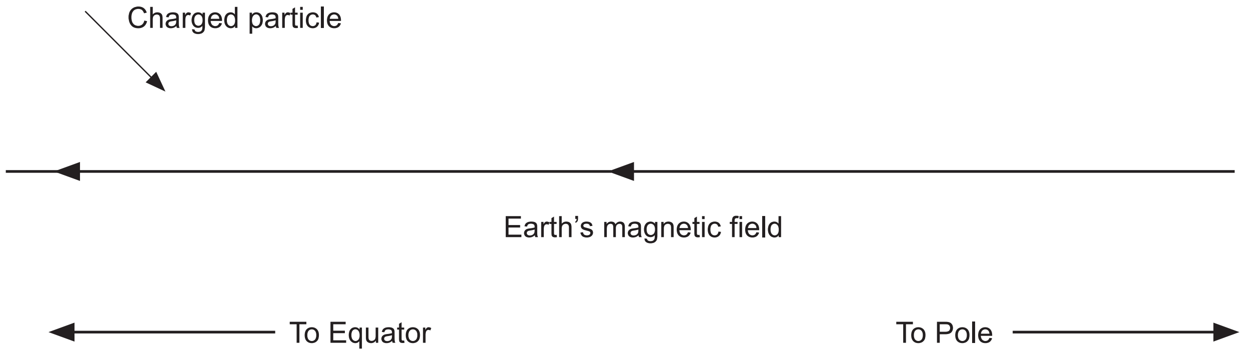
Question number: ____________

Spare grid

Spare axes



Spare diagram



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