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

Western Australian Certificate of Education Examination, 2012

Question/Answer Booklet

PHYSICS
Stage 3

Please place your student identification label in this box

Student Number: In figures

In words

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

Number of additional answer booklets used (if applicable):

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction tape/fluid, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, 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 notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Ref: 12-130

PHY3

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	11	11	50	54	30
Section Two: Problem-solving	7	7	90	90	50
Section Three: Comprehension	2	2	40	36	20
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2012*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. 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.

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

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

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

Section One: Short answers **30% (54 Marks)**

This section has **eleven (11)** questions. Answer **all** questions.

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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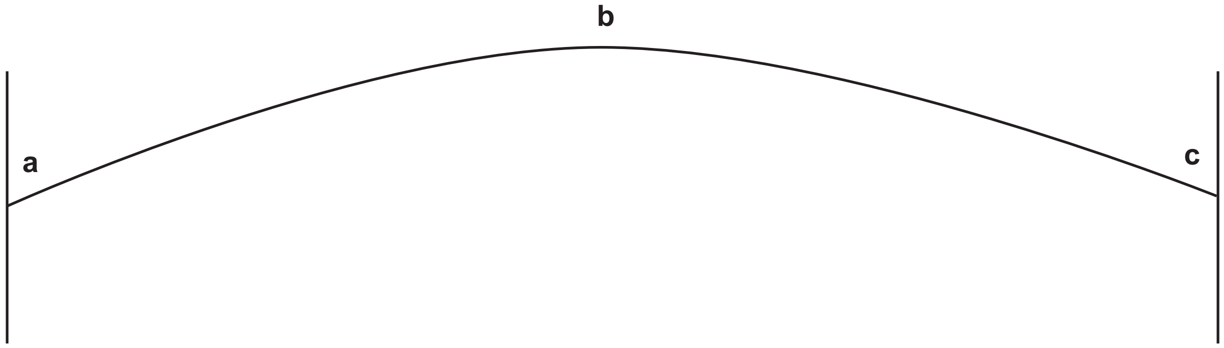
Suggested working time: 50 minutes.

Question 1 **(3 marks)**

The diagram below shows a string 250 cm long vibrating in its fundamental mode between two fixed points.



The string is vibrating with a frequency of 100 Hz.
For each of the positions **a**, **b**, and **c,** indicate whether these are nodes or antinodes, and calculate the speed of the wave.

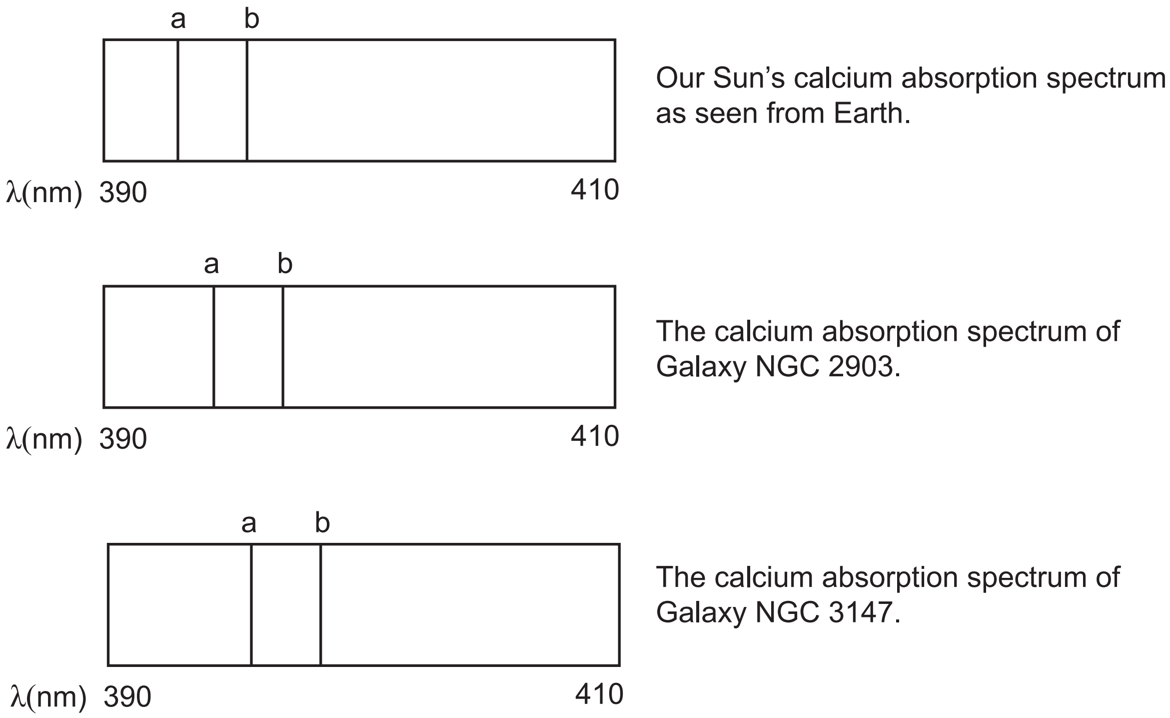
a: ______________________________

b: ______________________________

c: ______________________________

Question 2 **(6 marks)**

The figure below shows three simplified absorption spectra for ionised calcium. Many of the absorption lines and the background colour have been removed. In all three spectra the same two absorption lines, 'a' and 'b', are shown. The top spectrum is an example of a spectrum recorded in a laboratory on Earth; the lower two have been recorded from two different galaxies.

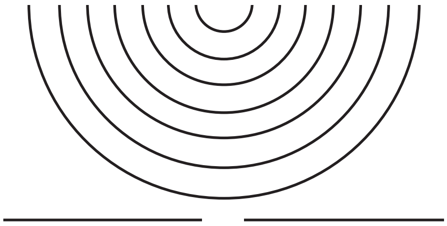


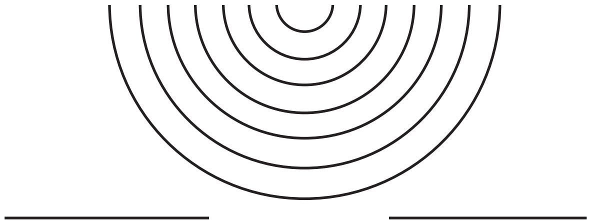
(a) Explain why absorption spectra appear as dark lines on an otherwise continuous electromagnetic spectrum. (3 marks)

(b) Which galaxy is further away from Earth? Justify your answer. (3 marks)

Question 3 **(4 marks)**

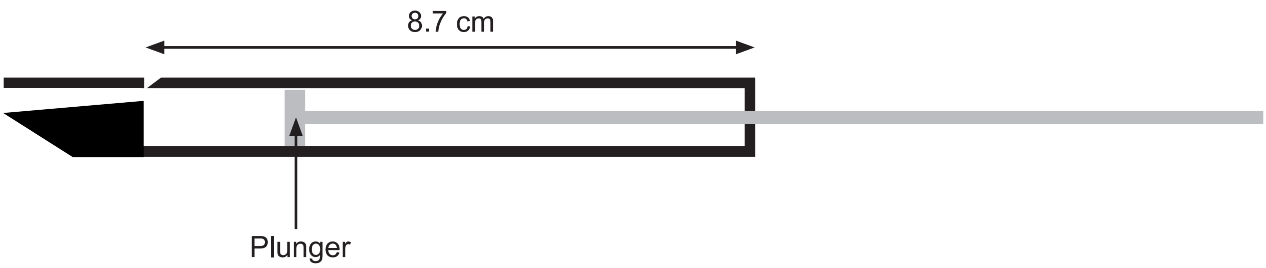
The two diagrams below show wavefronts incident on gaps of different width. On each diagram draw **five (5)** wavefronts to show how the waves behave after they have passed through the gap.





Question 4 **(4 marks)**

The diagram below shows a section lengthwise through a bird whistle capable of making sounds over a large range of frequencies. The frequency can be changed by moving the plunger inside the whistle. The longest length of the whistle is 8.7 cm.

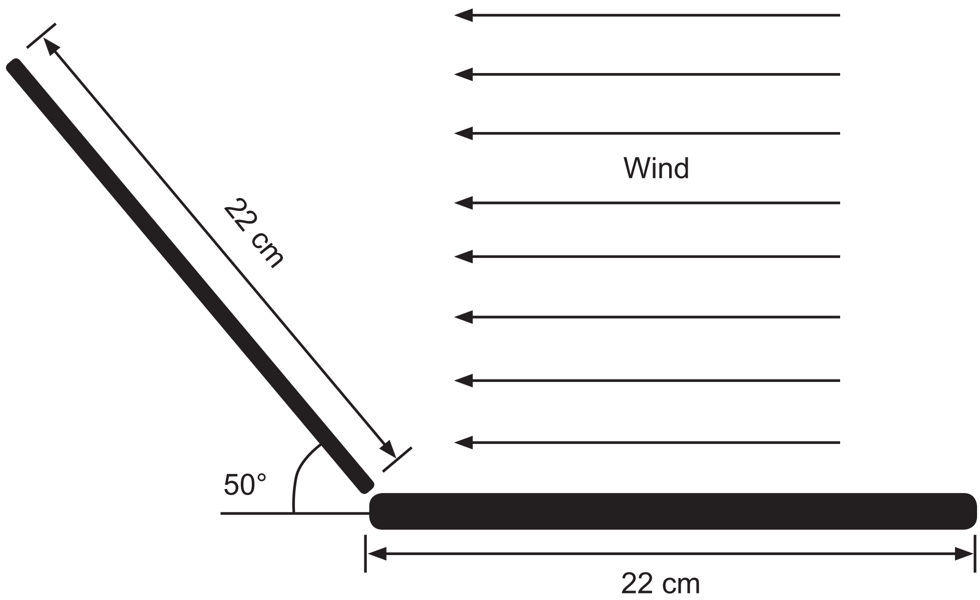


You should assume that air at 25°C is in the whistle.
Determine the distance moved by the plunger when changing the fundamental note from 18 kHz to 21 kHz, and draw a diagram of the fundamental wave in the whistle.

Question 5 **(4 marks)**

The diagram below shows a side view of a laptop computer resting on an outdoor table. The mass of the base of the laptop is 2.00 kg and the mass of the screen is 600 g. They are both 22.0 cm long. There is an angle of 50.0° between the horizontal and the screen. The computer is blown over by wind.

Assume that the base and screen both have a uniform mass distribution.

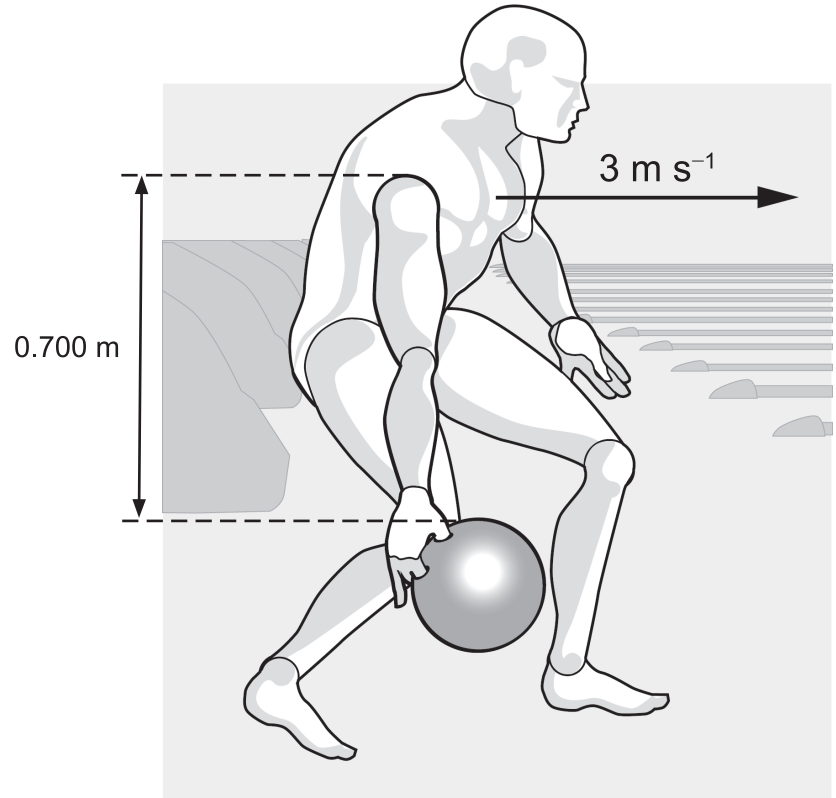


Calculate the minimum single equivalent wind force on the centre of the screen needed to tip the laptop over.

Question 6 **(5 marks)**

The diagram below shows a tenpin bowler propelling a bowling ball which has a velocity of 11.5 m s^{-1} when released. The distance from the bowler's shoulder to the top of the ball is 0.700 m and the ball has a diameter of 0.250 m. The ball has a mass of 6.00 kg.

The bowler approaches the lane at 3.00 m s^{-1}.

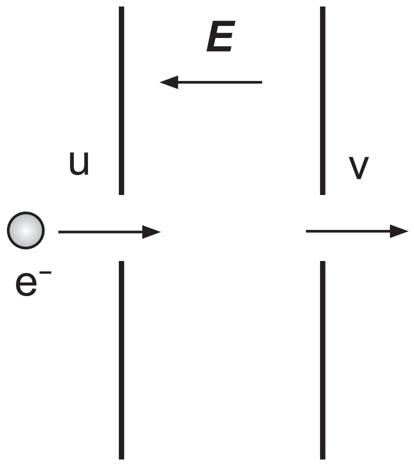


(a) Calculate the tension in the bowler's arm, due to the bowling ball, as the ball is released. You should assume the ball is released horizontally from the lowest point. (4 marks)

(b) Draw an arrow on the diagram to show the direction of the force exerted on the bowler's arm by the shoulder joint. (1 mark)

Question 7 **(4 marks)**

An electron moving with an initial velocity u, has initial kinetic energy E_{Ki} . It enters a uniform electric field with field strength ***E***, as shown in the diagram below. The electron's final kinetic energy E_{Kf} is equal to $4E_{Ki}$.



The electric field strength is now doubled. If another electron, having initial kinetic energy E_{Ki} enters the field, determine this electron's final kinetic energy in terms of E_{Ki}.

You should ignore the effects of gravity.

Question 8 **(7 marks)**

A GPS system uses the signals from four satellites to establish a position on the Earth's surface. The satellites have an orbital period of 12.0 hours but they are in different planes of orbit. Each satellite has an atomic clock that allows a signal to be emitted at prescribed intervals. The time difference between the four signals is used by the receiver to establish a position.

(a) By equating the relationship for centripetal force and gravitational force show that the orbital velocity of each satellite is close to 3.90×10^3 m s^{-1}. (5 marks)

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

Show all your workings.

(b) The manufacturers of the satellites deliberately build in a correction to the rate at which the clocks tick so that they run a little fast before they are put into orbit. Explain why they do this. (2 marks)

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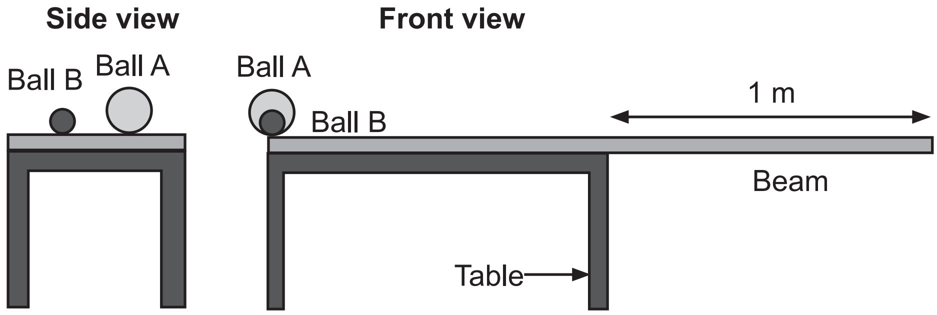
Question 9 **(5 marks)**

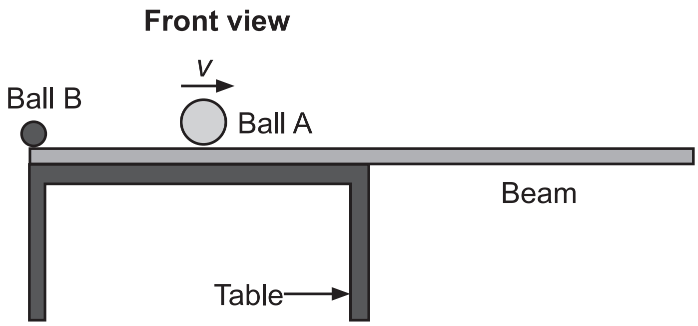
A uniform beam of length 2.00 m and mass 1.00 kg sits horizontally on a table. Two balls, A and B, are initially stationary on the left edge of the beam. Ball A has a mass of 2.00 kg and Ball B has a mass of 0.250 kg. This is summarised in Diagram 1 below.

Diagram 1



Ball A is pushed to the right and begins to move toward with a constant velocity, *v*. This is shown in Diagram 2 below.

Diagram 2



Determine, in terms of *v*, the time at which Ball B begins to move.

Hint: Consider the positions of the balls at the moment that Ball B begins to move.

Question 10 **(6 marks)**

Your use of appropriate significant figures will be assessed in this question.

The photograph shows a motorcyclist riding around a roundabout on a flat road.

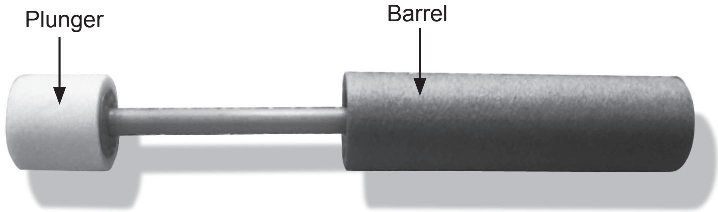
(a) Show that the angle between the motorcyclist and the road is independent of the mass of the motorcyclist. Draw a vector diagram to assist your answer. (3 marks)

(b) Using an appropriate calculation, estimate the velocity of the motorcyclist in the photograph. Use the photograph as a guide. (3 marks)

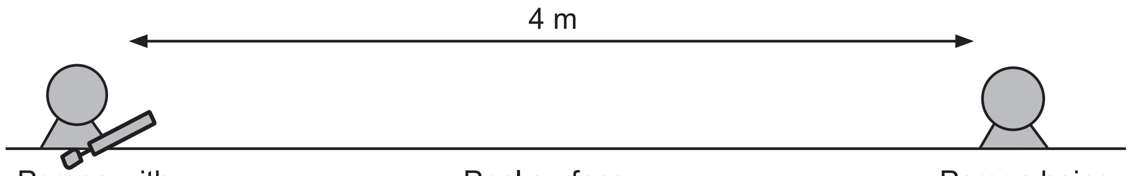
Question 11 **(6 marks)**

Your use of appropriate significant figures will be assessed in this question.

The photograph shows a swimming pool toy that sprays water when the plunger is pressed into the barrel containing water. A boy, using the toy, sprays water vertically from a height of 1 m and counts the time from the last drop of water leaving the barrel to it hitting the ground and finds it to be 3 s.



Estimate the angle at which the toy should be held if it is to be used to spray water from the surface of a swimming pool onto a person 4 m away. Assume that air resistance is negligible and show **all** your workings.



Hint: You may need to use the trigonometric identity $\sin 2\theta = 2 \sin\theta \cos\theta$ to answer this question.

End of Section One

Section Two: Problem-solving **50% (90 Marks)**

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

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Suggested working time: 90 minutes.

Question 12 **(11 marks)**

Photovoltaic cells are used to generate electricity from sunlight. Photons in sunlight hit the cell and are absorbed by a semiconducting material and electrons are raised to a higher energy level and become conducting electrons. A common material in photovoltaic cells is monocrystalline silicon, which has a band gap energy of 1.1 eV.

A solar panel consists of 72 photovoltaic cells each with dimensions of 0.125 m × 0.125 m. Under test conditions the panel generates electricity at a rate of 190 W. During a test, 1000 W m^{-2} falls on a panel, and the energy includes a full range of solar wavelengths.

(a) Calculate the wavelength of electromagnetic radiation absorbed by the silicon, which causes electrons to become conducting electrons. State which part of the electromagnetic spectrum this wavelength belongs to. (3 marks)

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(b) Calculate the efficiency of the solar panel. Assume that there is no gap between the cells on the panel. (3 marks)

A wind turbine generates electricity at a rate of 2000 kW at a voltage of 690 V. The turbine is connected to a transformer which increases the voltage to 33 kV before connecting it to the electricity grid.

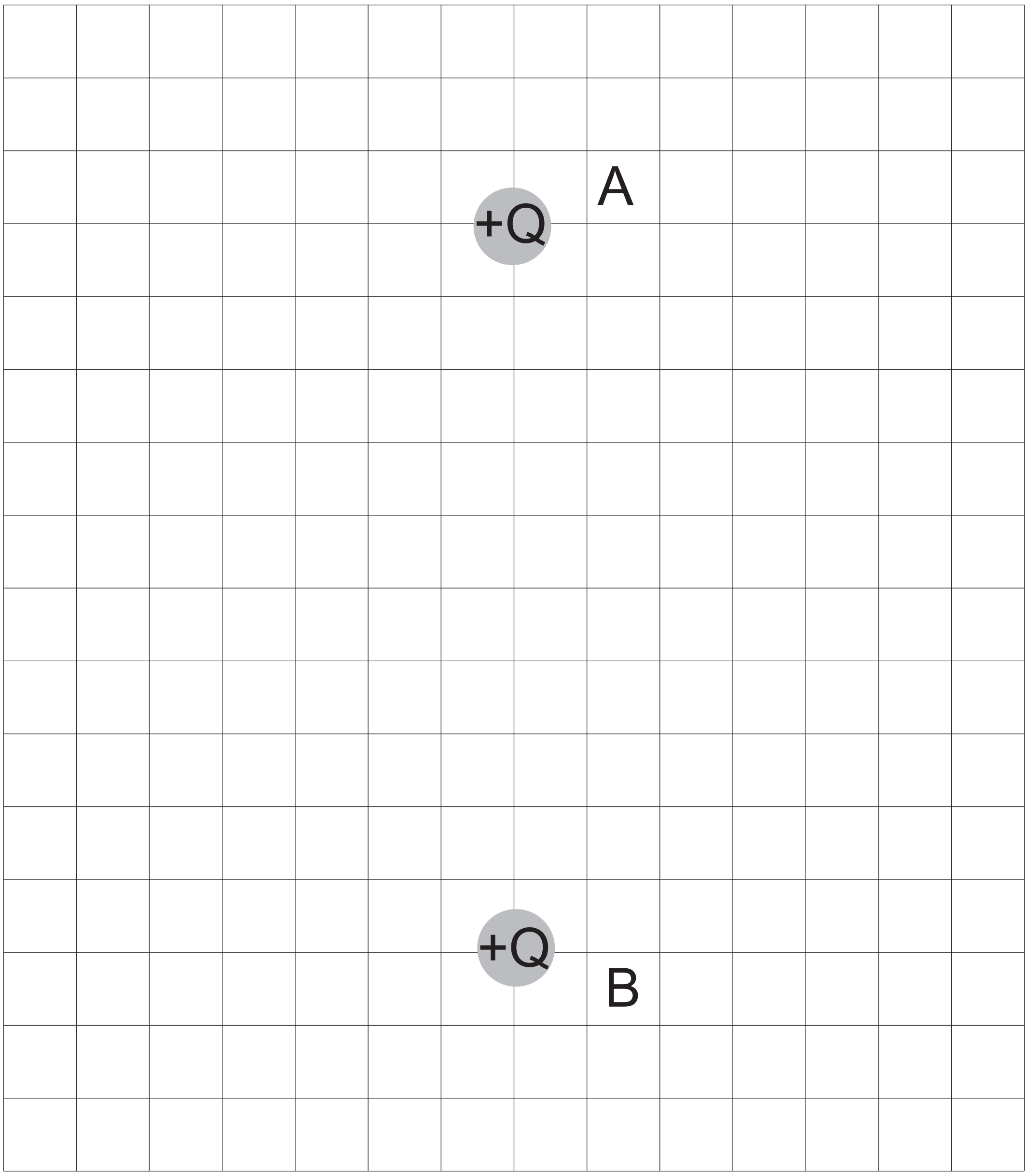
(c) Determine the turns ratio for the transformer connected to the wind turbine. (2 marks)

(d) Explain why the voltage is increased before it is transmitted. (3 marks)

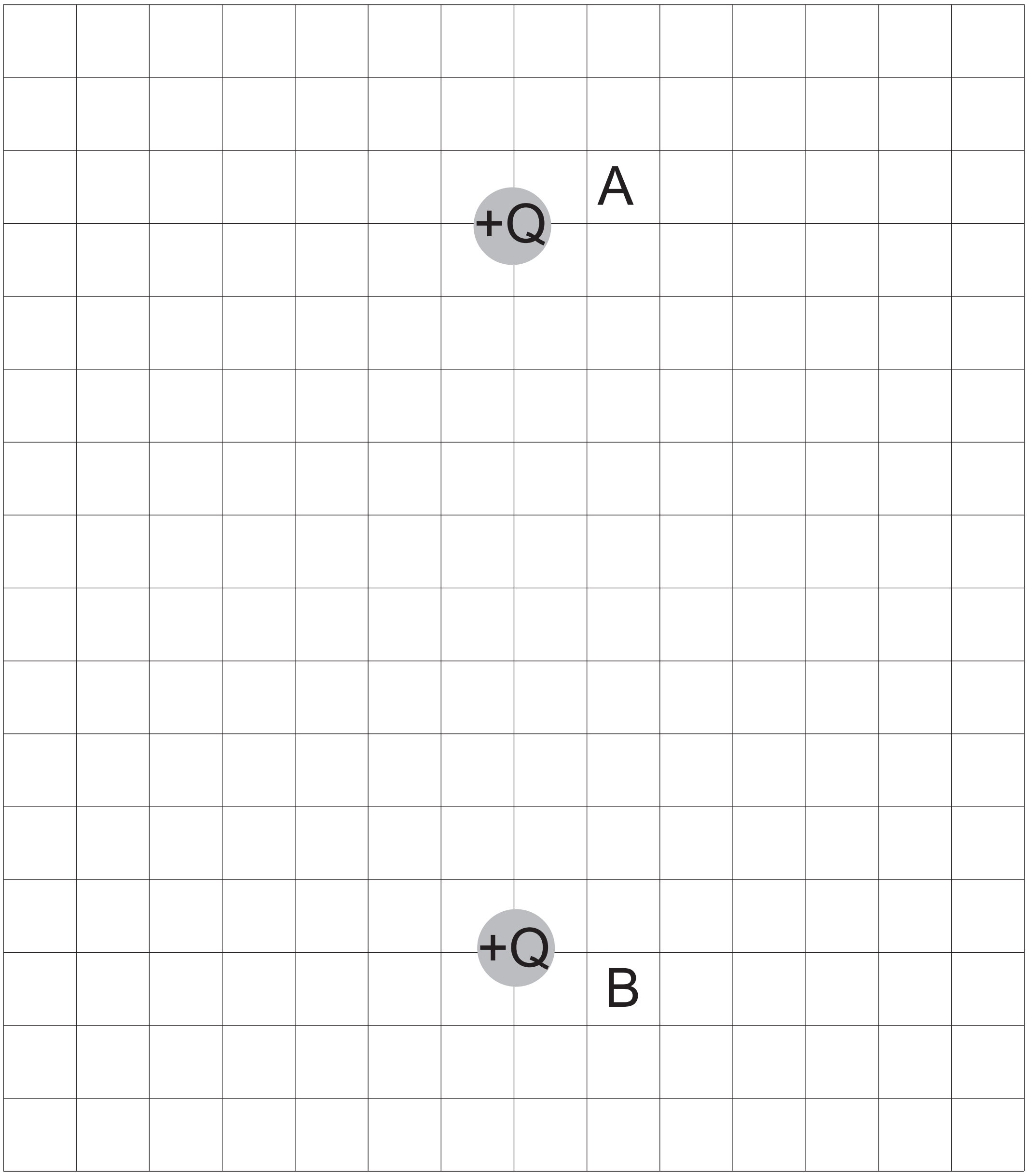
Question 13 **(9 marks)**

A and B are two identical very small particles. They are both positively charged with charge + Q. They are fixed in position 10 units apart.

(a) On the diagram below draw the resultant electric field around the charged particles. You should draw at **least five (5)** field lines around each particle. (3 marks)



(b) C and D are two particles with identical mass and volume to A and B but they have charge –Q. Draw particles C and D on the diagram below so that the four particles will be in static equilibrium. (3 marks)



(c) On the diagram above draw and label **three (3)** arrows on particle C to indicate the forces acting on particle C due to the other three particles. (3 marks)

Question 14 **(15 marks)**

The Kepler NASA mission aims to search for planets orbiting stars in other solar systems. The star named Kepler 20 has been observed to have several planets orbiting it. Kepler 20 is 950 light-years from Earth.

Information about Kepler 20 and some of the planets orbiting it is summarised in the table below.

Astronomical object	**Radius**	**Mass**	**Orbital period around Kepler 20**
Star – Kepler 20	$0.944 \times \text{radius}_{SUN}$	$0.912 \times \text{mass}_{SUN}$	
Planet – Kepler 20b	$2.40 \times \text{radius}_{EARTH}$		290 days
Planet – Kepler 20e	$0.87 \times \text{radius}_{EARTH}$		6.1 days
Planet – Kepler 20f	$1.03 \times \text{radius}_{EARTH}$		19.6 days

(a) A light-year is an astronomical unit of distance. It is defined as the distance travelled by light in one year. Calculate the distance from Kepler 20 to Earth in kilometres. (2 marks)

(b) Astronomers express the mass of Kepler 20 as $(0.912 \pm 0.035) \times \text{mass}_{SUN}$. Calculate the maximum value astronomers expect for the mass of Kepler 20. (2 marks)

(c) Calculate the orbital radius of Kepler 20e around Kepler 20. You should use the mass for Kepler 20 quoted in the table and assume the orbit is circular. (4 marks)

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(d) The mass of Kepler 20b is unknown but it has been speculated that it may have a density similar to that of Earth, 5520 kg m^{-3}. Calculate the surface gravity of Kepler 20b if its density is 5520 kg m^{-3}. (4 marks)

Reminder:

$$density = \frac{mass}{volume}$$

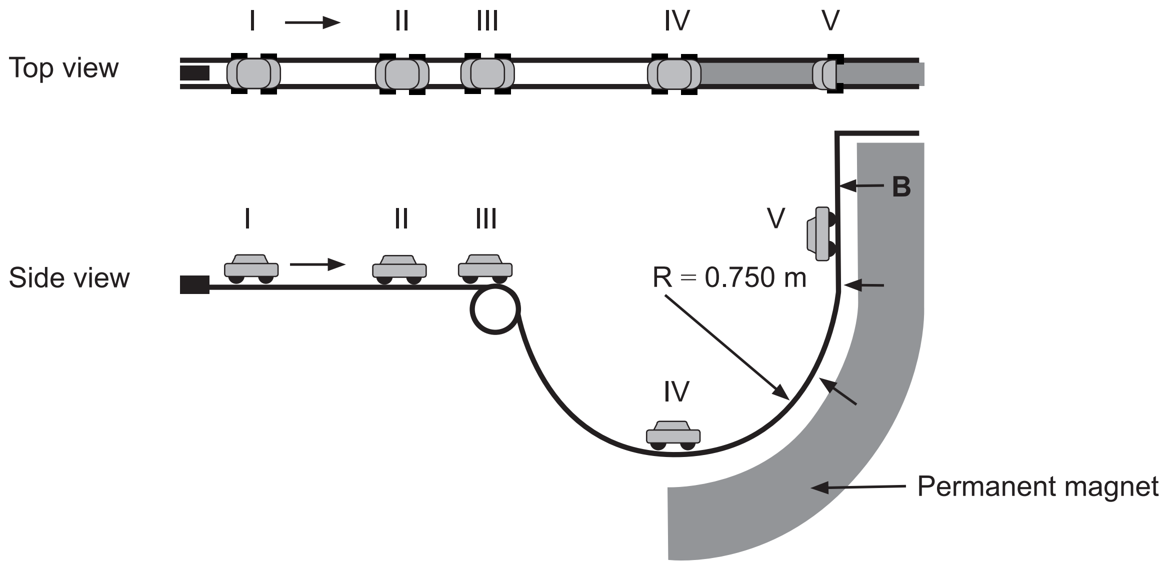
$$volume\ of\ a\ sphere = \frac{4}{3}\pi r^3$$

The Kepler mission is particularly concerned with finding planets that lie within the habitable zones of stars. A planet in a star's habitable zone receives the right amount of energy from the star to maintain liquid water on its surface, provided it also has an appropriate atmosphere.

(e) By comparing the Kepler 20 system and our own solar system, suggest which planet in the Kepler 20 system is most likely to lie in the habitable zone. Explain your answer. (3 marks)

Question 15 **(13 marks)**

Two parallel metal rails are connected by a resistor. A vehicle made of copper allows current to flow between the rails and moves from rest at Position I to Position V.



(a) The vehicle moves between Position I and Position II in 3.00 s, driven by a 3.00 V, 20.0 mA motor. The energy conversion efficiency of the vehicle is 70.0% and the mass of the vehicle is 120 g. Ignore air resistance and frictional forces.

Show that the velocity of the vehicle at Position II is 1.45 m s^{-1}. (3 marks)

(b) The motor is switched off at Position II and the vehicle continues to move from Position II to Position V, and then back through Position IV. The metal rails are 0.170 m apart and have a radius of curvature of 0.750 m as shown in the diagram. A magnetic field, B, is arranged so that the field strength acting anywhere between Position IV and Position V is perpendicular to the rails, and has magnitude 0.550 T.

Calculate the magnitude of the emf induced across the vehicle as it first passes through Position IV. (4 marks)

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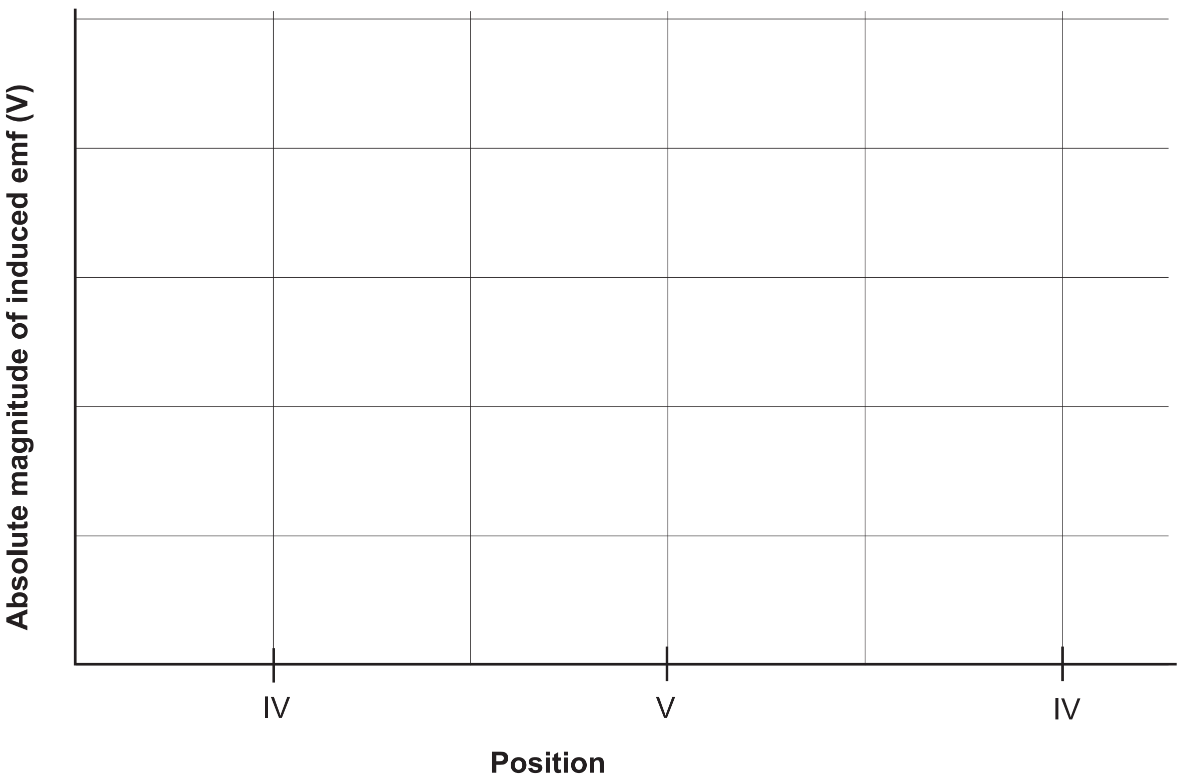
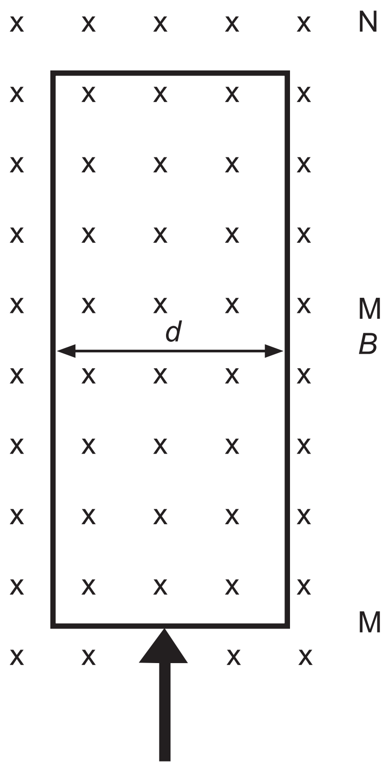
(c) Draw a labelled free body diagram to show the forces acting on the vehicle at Position IV. (3 marks)

(d) Sketch a graph of the magnitude (absolute value) of induced EMF versus position as the vehicle moves from Position IV to Position V and then back again to IV. (3 marks)



Question 16 **(10 marks)**

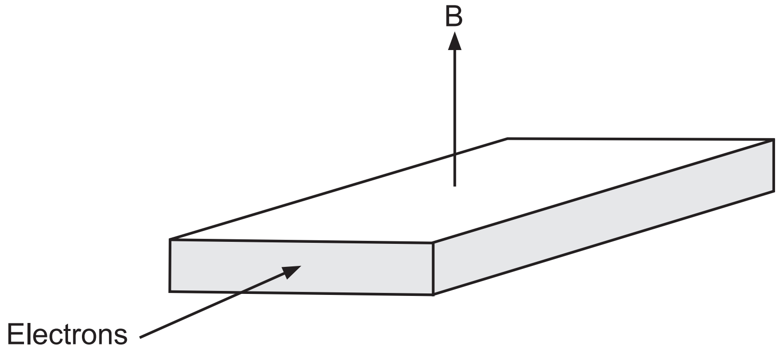
In the diagram below, the arrow represents a stream of electrons, moving with velocity *v*, entering a solid copper strip. The electrons are moving in the direction M to N. A magnetic field of strength *B*, perpendicular to the strip is switched on.



(a) Explain why electrons will begin to collect on the right hand edge of the strip and why an electric field develops across the strip. Express the voltage (*V*) due to the electric field in terms of the electric field strength (*E*) and the distance across the strip (*d*). (4 marks)

The phenomenon of a voltage being produced across a current carrying conductor due to the presence of a magnetic field is called the Hall effect, and the voltage is termed the Hall voltage. It is utilised in probes used to measure magnetic field strength.

(b) For the probe in the diagram below draw an arrow to indicate the direction of the electric field in the strip. (1 mark)



(c) The Hall voltage can be calculated using the equation $V = \frac{IB}{tne}$

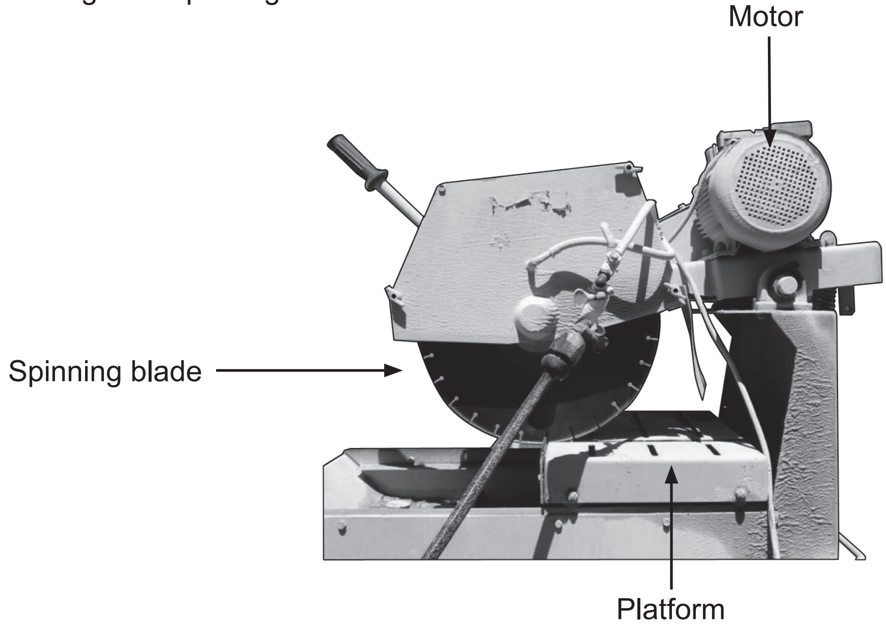
where
I = electric current
B = magnetic field strength
t = thickness of the strip
n = number of electrons per m^3
e = charge on an electron

Calculate the magnetic field strength when V = 2.25 mV, I = 1.80 A, $t = 1.25 \times 10^{-4}$ m and $n = 1.52 \times 10^{25}$ m^{-3}. (3 marks)

(d) Calculate the magnetic force exerted on the electrons if they are moving with velocity 1.17 m s^{-1}. (2 marks)

Question 17 **(14 marks)**

Below is a photograph of a brick saw on a stand. The saw is powered by a 2.2 kW single phase AC electric motor that draws current from the 240 V and 50 Hz mains supply. There is a very tight belt around the shaft of the blade and the shaft of the electric motor and this is how the spinning motor makes the blade spin. Bricks are cut by placing them on the platform and pushing them through the spinning blade.



(a) Calculate the current used by the saw when it is operating normally. (2 marks)

(b) Calculate the size of the EMF generated by the coil if the supply is exactly 240 V and the losses due to inefficiency are 28 V. (2 marks)

(c) When the motor is switched on, it speeds up until it reaches a maximum. Explain how the EMF generated in the coil restricts the speed of the motor. (4 marks)

(d) While the saw is operating it suddenly stops spinning because it gets stuck in a brick. The current through the saw will (3 marks)

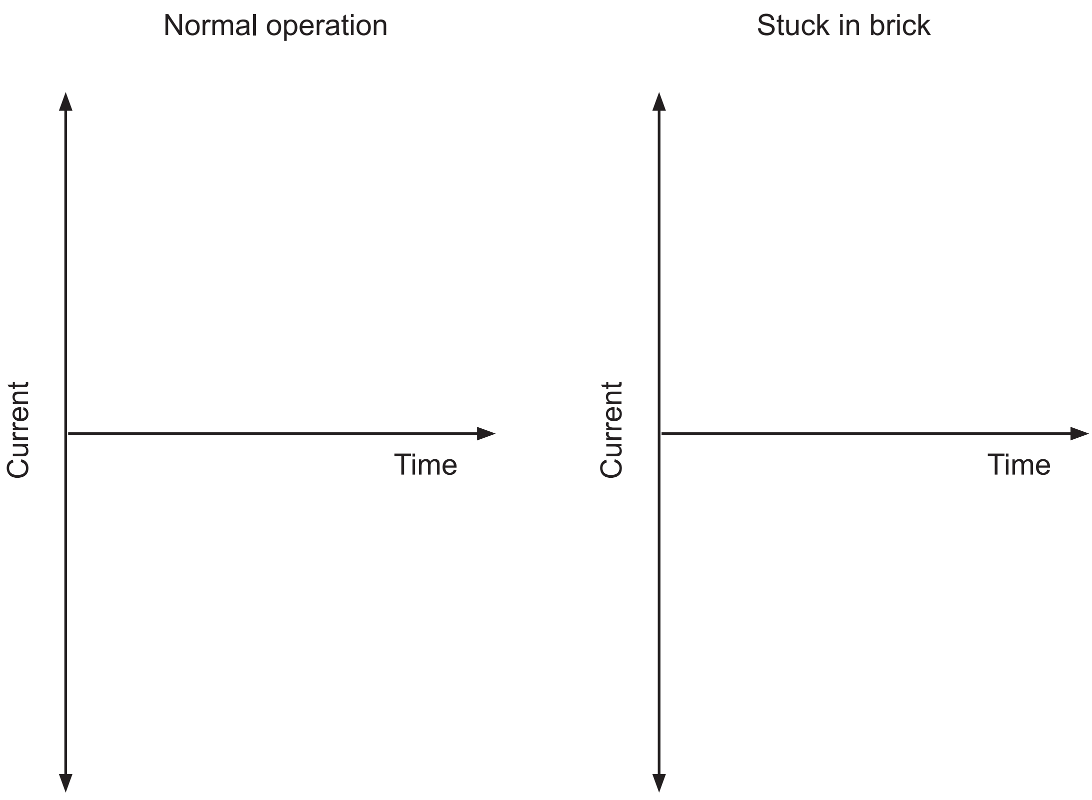
(i) increase.

(ii) decrease.

(iii) remain the same.

Circle your answer and explain your reasoning.

(e) On the axes below sketch the current in the saw when the saw is operating normally and when it gets stuck in a brick. (3 marks)



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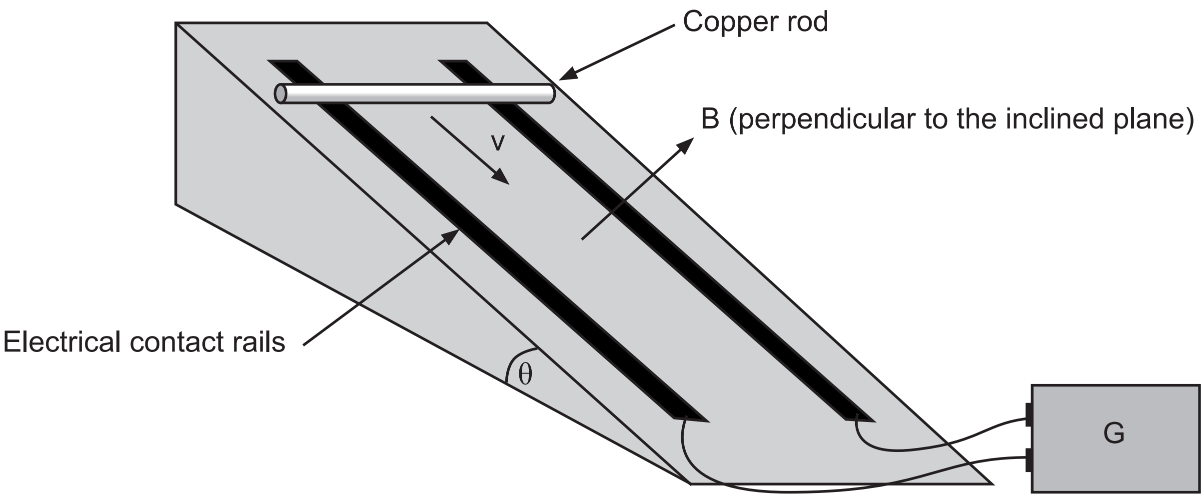
Question 18 **(18 marks)**

In the diagram below a copper rod is free to slide down two parallel electrical contact rails which are mounted on an inclined plane. The inclined plane is a strong magnet. The angle, θ, between the inclined plane and the horizontal can be changed. The electrical contact rails are connected to a galvanometer.



As the rod slides, it first accelerates but eventually reaches a constant, terminal speed.

(a) Explain why a current is detected by the galvanometer when the copper rod moves. (2 marks)

(b) Explain why there is a force opposing the rod's motion down the rails. (2 marks)

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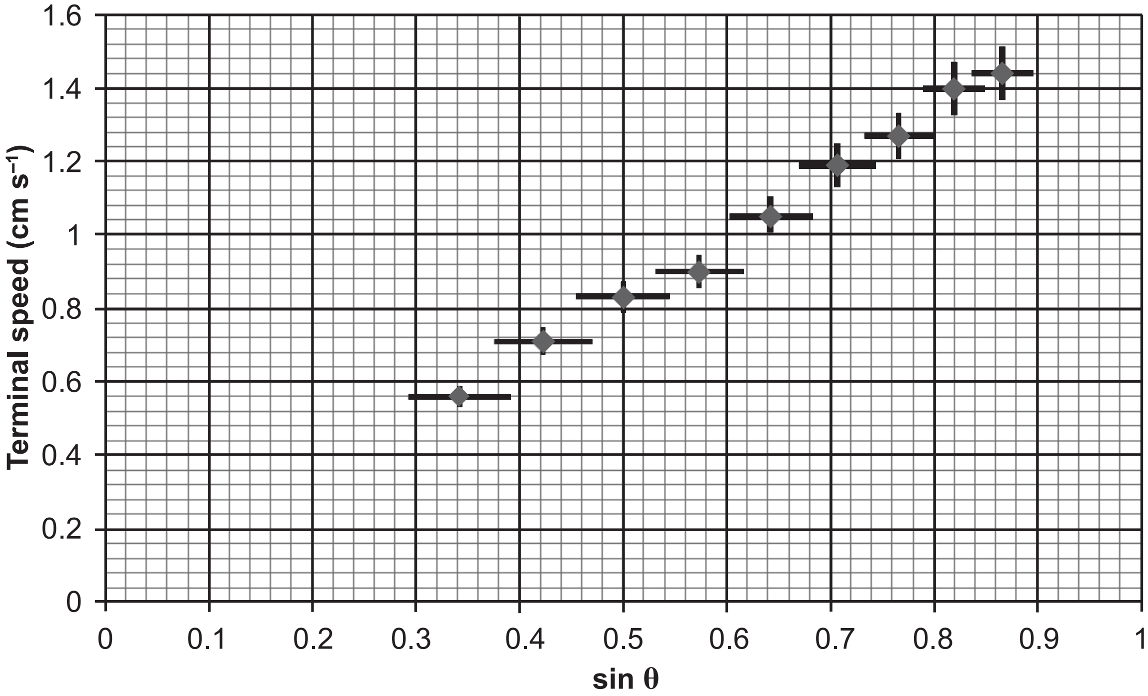
A group of students investigate the relationship between the terminal speed of the rod and the angle of inclination. They measure the terminal speed of the rod using data logging equipment and the angle of inclination with a protractor. They plot their data on a graph. This graph is reproduced below.



(c) Express the value of terminal speed, when sin θ = 0.5 in the form y ± Δy, where y is the value of terminal speed and Δy is the uncertainty in the measurement. (2 marks)

(d) Describe the trend in uncertainty for the terminal speed and for the sin of the angle θ. (4 marks)

(e) When drawing the line of best fit the students chose not to include the two largest terminal speed measurements from their data because they thought these two measurements were less reliable. Refer to the graph to explain why they thought this. (3 marks)

(f) Draw a line of best fit onto the graph and determine the gradient of the line. (3 marks)

(g) The rod's terminal speed can be calculated from the equation $v_{ts} = \frac{(mg\ sin\theta)R}{l^2B^2}$ where m = 44.0 g, R = 1.4 × 10^{-4} Ω and l = 20.0 cm. Use your value of the gradient to calculate a value of the magnetic field strength B. If you were unable to determine a value for the gradient you should use 1.57 cm s^{-1}. (2 marks)

End of Section Two

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Section Three: Comprehension **20% (36 Marks)**

This section has **two (2)** 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.

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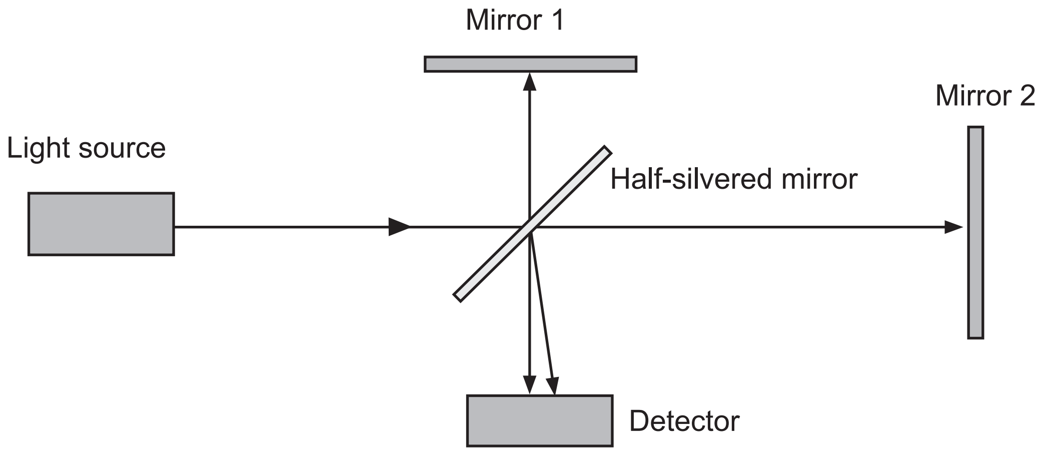
Suggested working time: 40 minutes.

Question 19 **(15 marks)**

Radio Telescopes and Interferometry

Light Interferometry
An interferometer is a device that can split a light beam into two parts and recombine them to form an interference pattern after they have travelled over different paths. A light interferometer can be used to accurately determine wavelengths or distance.
A simplified diagram of an interferometer is shown below. A beam of light is incident on a half-silvered mirror. Some of the light is reflected from this mirror and is incident on Mirror 1. The remaining light is transmitted through the half silvered mirror and is incident on Mirror 2. Light from both mirrors is then reflected back and received at the detector.
An observer at the detector may see an interference pattern consisting of a series of bright and dark lines. The spacing of the lines depends on the distances the two light beams, arriving at the detector, have travelled.



Resolving Power
The resolving power of a telescope is a measure of its ability to distinguish between objects separated by a small angular distance. Point like sources that are separated by an angle smaller than the resolving power of the telescope will not be seen as separate.

The angular resolution of a telescope can be approximated to $R = \frac{57.3 \times \lambda}{D}$

where λ is the wavelength of the observed radiation, D is the diameter of the aperture or lens used in the telescope and R is the distance between the objects being observed in degrees.

A way of increasing the resolving power of a telescope is to use interferometry. An array of telescopes arranged in a grid can all look at the same region of the sky. The signals from the telescopes are combined and the interference pattern can be interpreted to determine the exact location of a source in the sky.

The resolution of an array of telescopes can be calculated using $R = \frac{57.3 \times \lambda}{B}$

where B is the distance between telescopes in the array.

The Square Kilometre Array is a radio telescope that will be built in southern Africa and Western Australia. It is thought that both of these regions offer the best opportunity for observing without interference from other radio sources. When it is complete it will have a total collecting area of more than 1 square kilometre and the maximum distance between the central core of receivers and the most distant will be approximately 3000 km.

(a) Explain why a series of dark and light fringes may be observed at the detector of an interferometer. (3 marks)

(b) In an interferometer the distance from the half-silvered mirror to Mirror 1 is 1.5 m. The distance from the half-silvered mirror to Mirror 2 is 1.85 m. The light used in the interferometer has a wavelength of 694 nm. Calculate the difference in path length between the light beams arriving at the detector in terms of number of wavelengths. You should express your answer to 1 significant figure. (2 marks)

(c) Two stars, separated by an angle of 0.5°, are both emitting radio waves with a frequency of 1×10^6 Hz. Can they be seen as separate sources by a telescope with a diameter of 76 m? You should show the calculations you have used to justify your answer. (4 marks)

(d) Determine the resolution of two telescopes, 5 km apart receiving radio waves with a wavelength of 1.71 m. (2 marks)

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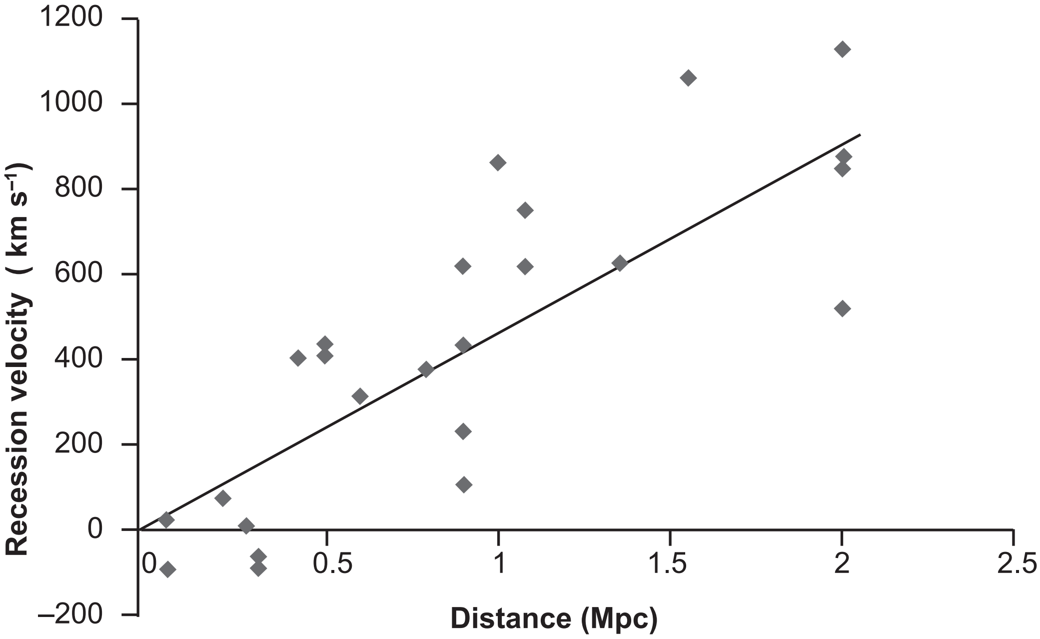
(e) Give **three (3)** reasons why radio waves are used to explore very distant regions of the Universe instead of visible light by comparing the characteristics of the two regions of the electromagnetic spectrum. (4 marks)

Question 20 **(21 marks)**

Measuring the age of the Universe

In 1929 Edwin Hubble published a claim that the recession velocities of galaxies are proportional to their distance from any observer in the Universe. The red shift of a galaxy is a measure of its recession velocity. The plot below shows Hubble's 1929 data.



The gradient of the fitted line is 464 km s^{-1} Mpc^{-1} and is now known as the Hubble constant, H_0. A parsec is an astronomical unit of distance and a megaparsec, Mpc, is equivalent to 3.086×10^{19} km. Since both kilometres and megaparsecs are units of distance, the simplified units of H_0 are s^{-1}.

The assumption that the relationship between recession velocity and distance is linear, implies that the value of H_0 is constant throughout the Universe. If this is not true then the position that we collect our data from is unique, the only point in the Universe where the red shift is measured to be the same in all directions – i.e. the central point of the Universe.

The age of the Universe should be equivalent to $\frac{1}{H_0}$. In 1929 the age of the Universe was measured using other methods and determined to be over 10 gigayears. The discrepancy between the age of the Universe determined from Hubble's constant and the previously measured value led to scepticism over the cosmological models based on Hubble's data and motivated the development of the 'Steady State' model of the Universe.

(a) Use the gradient of Hubble's graph to calculate a value of H_0 in yr^{-1}. (3 marks)

(b) Use the plot of Hubble's data to explain why there would be scepticism about his proposed relationship between the velocities of the galaxies and the distance from the observation point. (2 marks)

Question 20 (continued)

Later work found that Hubble had confused two different kinds of Cepheid variable stars that are used for calibrating distances, and also that what Hubble thought were bright stars in distant galaxies were actually large nebulae where large stars were beginning to form.

Improvements in data collection and astronomical observation techniques have led to revisions of the value of Hubble's constant. The table below contains more recent data for Cepheid variable stars.

Distance (Mpc)	Recession velocity (km s^{-1})
28.60	2120
81.00	5150
129.0	7880
171.0	10 900
235.0	14 800
381.0	20 900
476.0	28 800

(c) Use the data from the table to plot a straight line graph on the grid provided. (4 marks)

(d) Using the graph, calculate the value for Hubble's constant in yr^{-1} provided by this set of data. (3 marks)

(e) Use the value of Hubble's constant, derived from the data above, to calculate the age of the Universe in years. (2 marks)

(f) Indicate on your graph the extent of the data collected by Hubble in 1929. Refer to this to explain why Hubble's value for the age of the Universe was so different from current estimates. (3 marks)

See next page

If you wish to have a second attempt at this item, the graph is repeated at the end of the Question/Answer Booklet. Indicate clearly on this page if you have used the second graph and cancel the working on the graph on this page.

Question 20

(g) An alternative to the Big Bang model is called the Steady State model, which states that our Universe looks the same from every spot in it and at every time. A Steady State Universe has no beginning or end. The Steady State model states that although the Universe is expanding it does not change its look over time because new matter must be formed to keep the density equal over time. The implication of the Steady State model for Hubble's data is that the Earth is in a unique position in the Universe; i.e. the only point from which the expansion would look the same in all directions, allowing a linear relationship between recession velocity of a galaxy and its distance from the observer. If we were located anywhere else in the Universe, the data would produce a quadratic relationship between the recession velocities of galaxies and their distances away from the observer.

The table below shows four key points about the Steady State model. Use this table to compare the Big Bang model of the Universe with the Steady State model. (4 marks)

Steady State model	Big Bang model
The Universe is expanding.	
The Universe has no beginning or end.	
The Earth is in a unique position in the Universe.	
The Universe does not change its look over time.	

End of questions

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ACKNOWLEDGEMENTS

Section One

Question 2 Data source: University of Washington. (2012). *Values of wavelength in Cepheid variable spectra data*. Retrieved January 14, 2012, from www.astro.washington.edu/courses/labs/clearinghouse/labs/HubbleLaw/galaxies.html.

Question 10 Image of a motorcyclist by courtesy of the examining panel.

Question 11 Image of a plunger by courtesy of the examining panel.

Section Two

Question 14 Data source: NASA. (2012). *Kepler Mission*. Retrieved January 10, 2012, from http://kepler.nasa.gov/Mission/discoveries/.

Question 17 Image of a brick-saw by courtesy of the examining panel.

Question 18 Data and diagram from: Curriculum Council. (2006). *Physics Tertiary Entrance Examination, 2006.* Osborne Park: Curriculum Council, pp. 24, 26.

Section Three

Question 20 Graph from: Hubble, E. (1929). A relation between distance and radial velocity among extra-galactic nebulae. *Proceedings of the National Academy of Sciences,* 15(3), pp. 168–173. Retrieved January 10, 2012, from http://apod.nasa.gov/diamond_jubilee/d_1996/hub_1929.html.

Data source: Wright, E.L. (2009). *Ned Wright's cosmology tutorial*. Retrieved January 10, 2012, from www.astro.ucla.edu/~wright/cosmo_01.htm.

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