2024/8268
Web version of 2023/66794

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

ATAR course examination, 2023

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: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course 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.

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	12	12	50	59	30
Section Two Problem-solving	6	6	90	93	50
Section Three Comprehension	2	2	40	41	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 2023: Part II Examinations*. 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 numerical answers, show your working or reasoning clearly. Unless otherwise instructed, 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.

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.

Section One: Short response **30% (59 Marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Unless otherwise instructed, 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 **(5 marks)**

A DC motor is attached to a 6.00 V supply, as shown in the diagram on the right. The square coil has a side length of 8.60 cm and contains 50 turns. The total resistance of the circuit is 3.00 Ω and it sits in a 3.70×10^{-3} T magnetic field.

(a) Which way will the coil rotate when observed from X? Circle your answer. (1 mark)

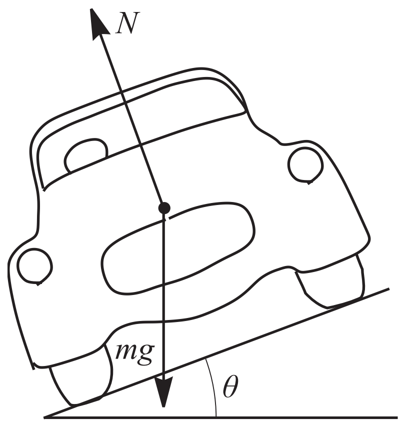
A. Clockwise

B. Anticlockwise.

(b) Calculate the magnitude of the initial torque on the coil in the position shown in the diagram. (4 marks)

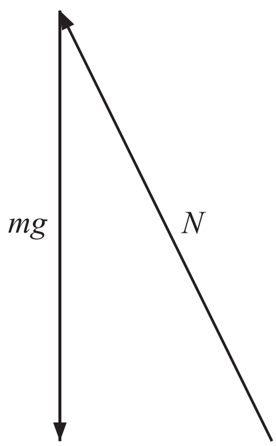
Answer ______________________ N m

Question 2 **(4 marks)**



The free body diagram above shows a car going clockwise around a corner on a banked track without relying on friction.

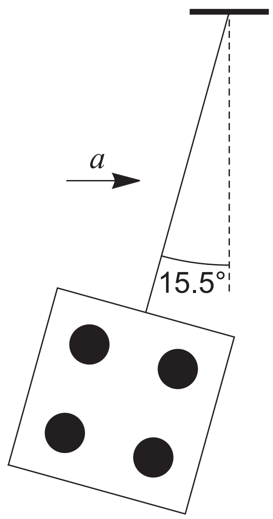
(a) Complete the vector diagram, showing how these two forces result in a centripetal force. Indicate where the angle θ is on your diagram. (2 marks)



(b) With reference to your diagram in part (a), describe why increasing the angle of the track allows the cars to go around the same radius curve at a greater speed. (2 marks)

Question 3 **(4 marks)**

A 370 g single fluffy die on a string is hanging from a baby carriage travelling on a Melbourne tram. The tram accelerates away from the tram stop. At the point of acceleration, the angle between the string and the vertical is 15.5°. Calculate the magnitude of the acceleration of the tram.



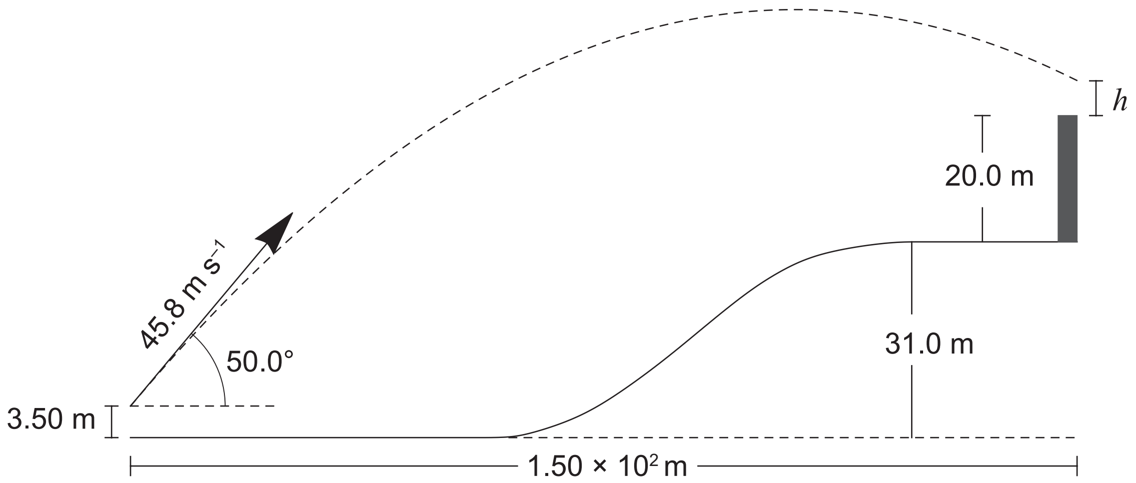
Answer: ______________________ m s^{-2}

Question 4 **(4 marks)**

Calculate the wavelength of a photon with an energy of 1.81 keV.

Answer: ______________________ m

Question 5 **(6 marks)**



A catapult is 1.50×10^2 m away from a 20.0 m high castle wall on top of a 31.0 m hill. It launches a metal ball at 50.0° to the horizontal 3.50 m above the ground at 45.8 m s^{-1}. Calculate how far above the castle wall the ball passes (h).

Answer: ______________ m

Question 6 **(6 marks)**

The photoelectric effect equation is

$$\frac{1}{2}mv_{max}^2 = hf - W$$

The maximum kinetic energy of a liberated electron is equal to the difference between the energy of the incoming photon and the work function of the metal target.

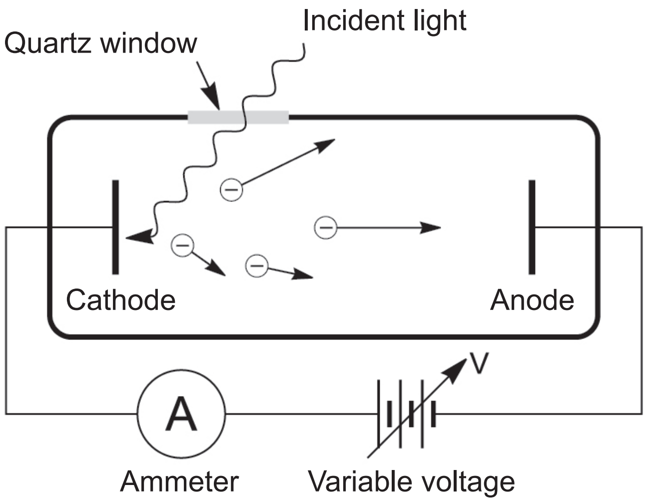


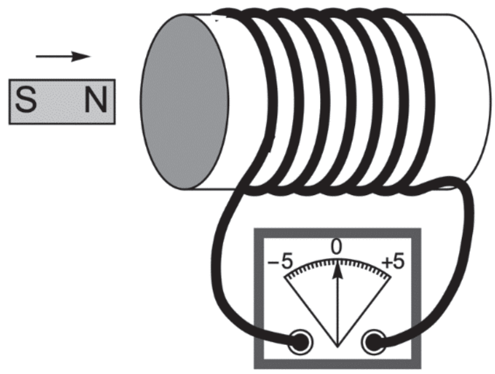
Figure 1: Photoelectrons are released from a metal target in a vacuum tube

(a) Describe how, and under what circumstances, electrons are liberated from the target by incoming photons. (2 marks)

(b) Discuss how the maximum kinetic energy of the liberated electrons is experimentally determined. (4 marks)

Question 7 **(7 marks)**

The north pole of a bar magnet is moved at a constant speed of 0.370 m s^{-1} towards a coil of wire. The coil has seven turns and a cross sectional area of 0.0240 m^2. The ends of the wire are connected to a galvanometer (which measures very small currents).



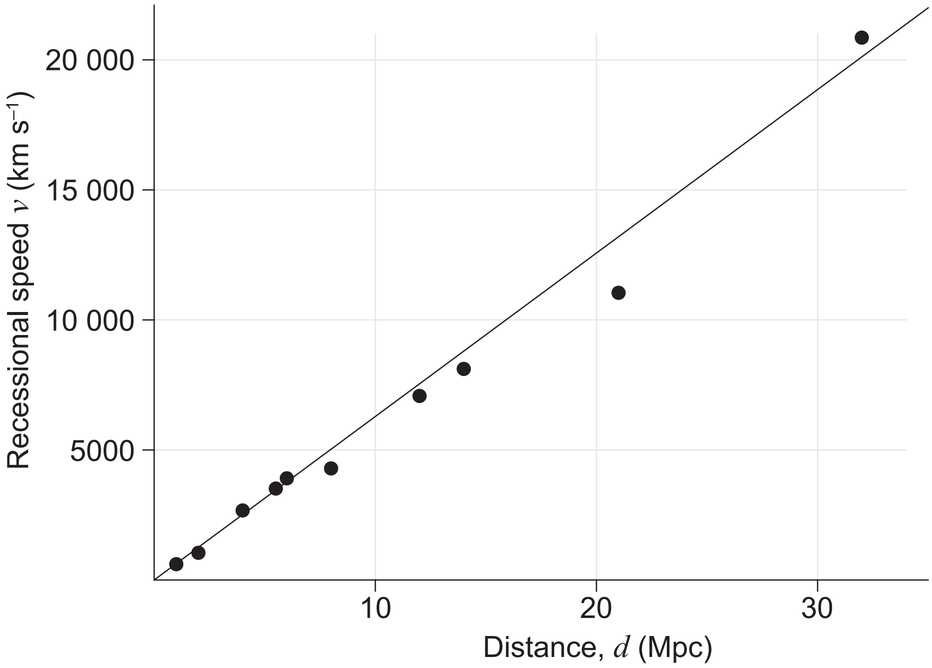
(a) State Lenz's law. (2 marks)

(b) With reference to Lenz's law, explain why the needle in the galvanometer moves to the left, i.e. the current in the galvanometer flows right to left. (3 marks)

(c) Explain why the emf induced in the coil is not constant, even though the speed of the magnet remains constant. (2 marks)

Question 8 **(6 marks)**

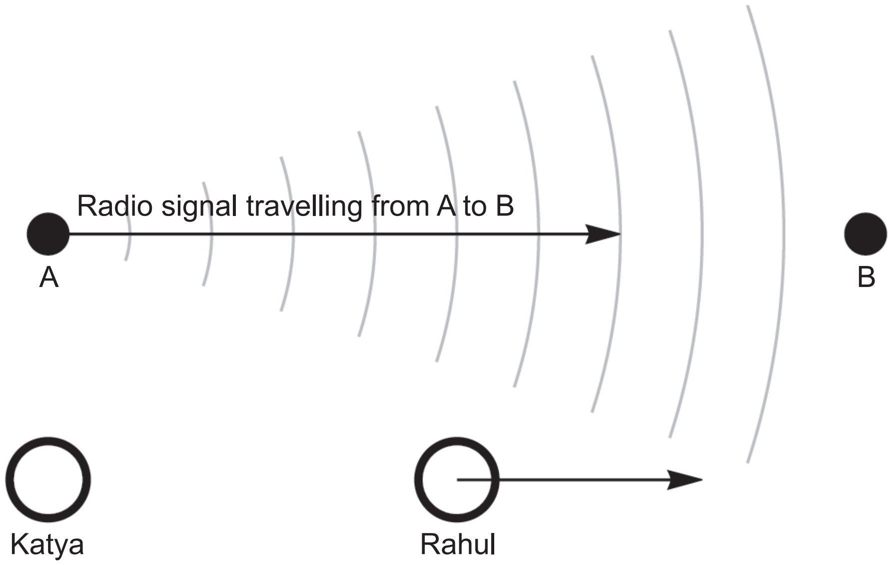
Edwin Hubble found that the further a galaxy is away from an observer, the faster it is receding. Below is a graph of data showing this relationship.



Using the graph above, estimate the distance in kilometres to a galaxy that is receding at 4.5% of the speed of light.

Answer: ______________________ km

Question 9 **(3 marks)**



A radio signal is emitted from Spaceship 'A' and arrives at Spaceship 'B'. A and B are stationary with respect to Katya. In her frame of reference, A and B are a distance d_1 apart, and the signal takes time t_1 to travel.

Rahul is moving parallel to the radio waves between A and B with constant velocity near the speed of light with respect to Katya and the two spaceships. In his frame of reference, A and B are a distance d_2 apart, and the signal takes time t_2 to travel.

Derive an expression for d_2 in terms of d_1, t_1 and t_2. Show your reasoning and state any assumptions. (Hint: It is not necessary to use length contraction or time dilation.)

Answer: d_2 = ____________________

Question 10 **(4 marks)**

Estimate the de Broglie wavelength for a standard men's basketball travelling at 10.0 m s^{-1}.

Answer: ______________________ m

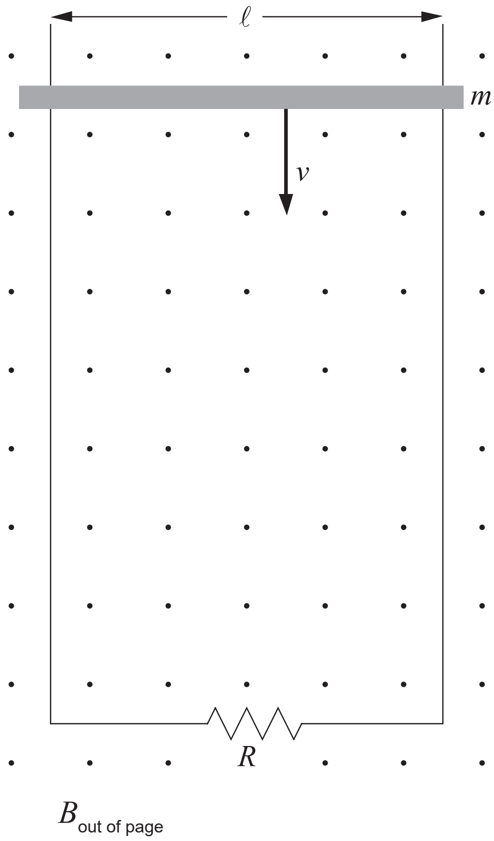
Question 11 **(4 marks)**

The table below lists four subatomic particles. Identify the category to which they belong in the second column and state whether or not they are bound by the strong nuclear force in the third column.

Particle	**Category (meson, baryon or lepton)**	**Bound by strong nuclear force (yes or no)**
Proton		
Pion		
Neutrino		
Muon		

Question 12 **(6 marks)**

A metal bar of mass m is falling through a uniform horizontal magnetic field of strength B. The effective length of the bar in the field is ℓ. The bar, which maintains contact with the frictionless wire, completes an external circuit with a resistance of R. Derive an expression for the velocity of the bar in terms of m, g, R, B and ℓ given the velocity is constant.



Answer: v = ______________________

End of Section One

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

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

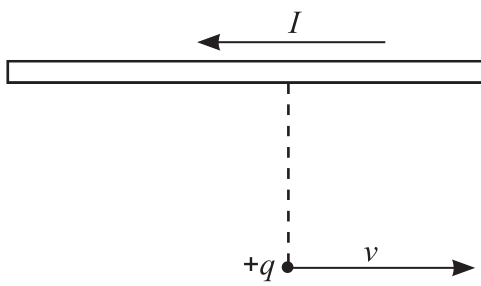
When calculating numerical answers, show your working or reasoning clearly. Unless otherwise instructed, give final answers to **three** significant figures and include appropriate units where applicable.

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 13 **(17 marks)**



A positive charge of 4.80×10^{-19} C is 35.0 cm below an extremely long straight wire carrying a current of 2.51 A to the left. The positive charge is moving parallel to the wire with a velocity of 1.57×10^{4} m s^{-1} to the right, at the instant shown in the diagram above.

(a) Calculate the strength of the magnetic field 35.0 cm from the wire. (3 marks)

Answer: ______________________ T

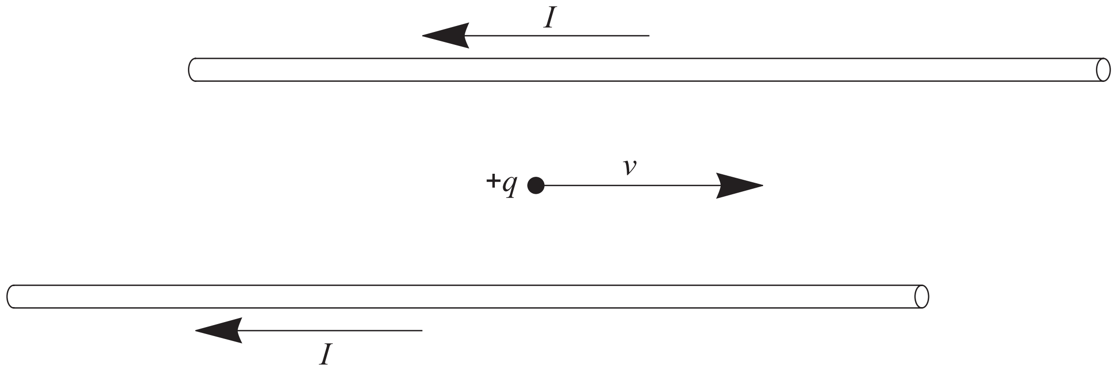
(b) Calculate the force experienced by the particle as it moves through this magnetic field. Include the direction of the force in your answer. If you could not obtain an answer to part (a), use 2.51×10^{-6} T. (3 marks)

Answer: ______________ N Direction: ______________

(c) With reference to **two** relevant equations on the data sheet, discuss why the path the particle takes is not circular. (5 marks)

Question 13 (continued)

(d) The particle is now moving midway between two wires with equal currents flowing in the same direction. In this position, the particle experiences no net force.



(i) The diagram below shows the view of the wires from the front left. The current is flowing out of the page. Draw the composite magnetic field generated by the two current-carrying wires. Indicate clearly the location of the charge q on your diagram. (4 marks)

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

(ii) Describe why the charge q experiences no net force in this position. (Ignore any gravitational effects.) (2 marks)

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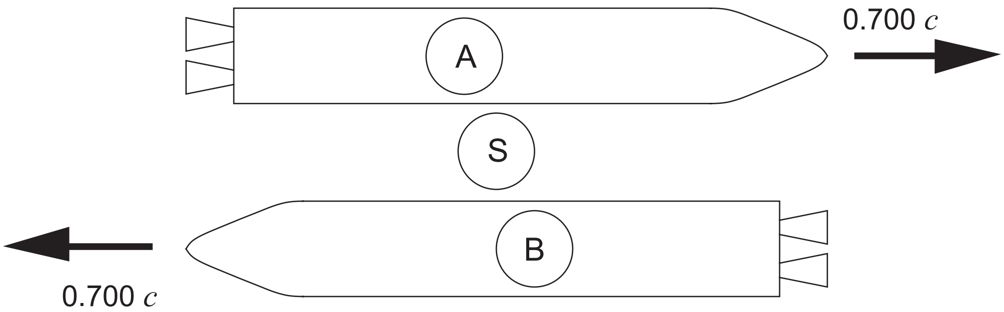
Question 14 **(13 marks)**



Two 5.00×10^2 m long identical spaceships, 'A' and 'B', pass by an observer S while moving in opposite directions. The observer S measures the velocity of spaceship A as 0.700 c and spaceship B as –0.700 c.

(a) (i) Calculate the velocity of A (in m s^{-1}) as measured by B. (4 marks)

Answer: ______________________ m s^{-1}

(ii) Explain why the magnitude of the velocity of B as measured by A would be the same as your answer for part (a)(i), only in the opposite direction. (3 marks)

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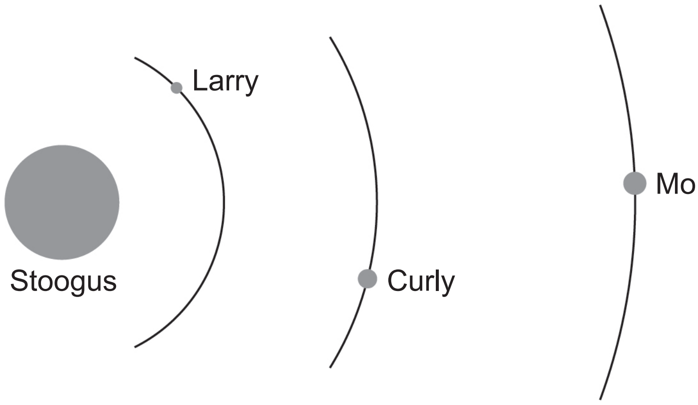
(b) Calculate the duration of one second on A as measured by the observer S. (3 marks)

Answer: ______________ s

(c) Calculate the length of B as measured by A. If you could not obtain an answer to part (a)(i), use 0.870 c. (3 marks)

Answer: ______________ m

Question 15 **(14 marks)**



A recently discovered planet (Stoogus) in a distant solar system has three moons (Larry, Curly and Mo) orbiting at different distances. Stoogus has a mass of 2.37×10^{24} kg and a day on Stoogus lasts 7.50 Earth hours. Assume all three moons have circular orbits as their masses are insignificant compared to that of Stoogus.

(a) Curly is a geosynchronous satellite that orbits above one specific spot on Stoogus' surface. Calculate the radius of Curly's orbit. (5 marks)

Answer: ____________________ m

(b) The gravitational field strength that Mo experiences due to Stoogus is 4.50×10^{-3} m s^{-2}. Calculate the distance between the centre of mass of Mo and the centre of mass of Stoogus. (4 marks)

Answer: ____________________ m

(c) (i) Derive the mathematical relationship between a moon's orbital speed v and its distance r from the planet's centre of mass. (3 marks)

Answer: ______________

(ii) Use this relationship from part (c)(i) to identify which moon of Stoogus has the greatest orbiting speed. Justify your answer. (2 marks)

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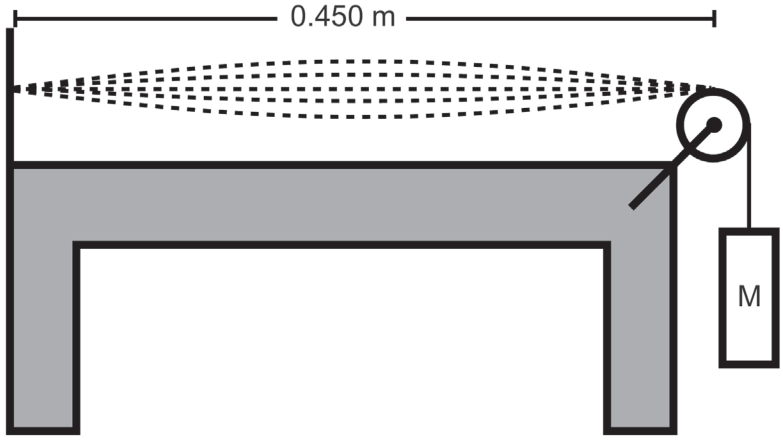
Question 16 **(18 marks)**



A group of students set up the apparatus shown in the diagram above to measure the mass per unit length of a thin and strong steel wire. On each successive trial, they increased the mass of the counterweight M, further stretching the wire. They then plucked the steel wire and measured the frequency of the vibrating wire using a strobe light. The length L of the vibrating portion of the wire, shown in the diagram above, was 0.450 m. Their results are given in the table below.

Mass (kg)	1.50	2.00	2.50	3.00	3.50	4.00
Frequency (Hz)	105	120	135	150	160	170

The students observed the wire vibrating in its fundamental mode, where wavelength $\lambda = 2L$, and substituted this into the wave equation $v = \lambda f$. They also used the following equation for the speed v of a wave along a wire under tension:

$v = \sqrt{\frac{T}{\mu}}$ where T is the tension in the wire (in N) and μ is the mass per unit length (in kg m^{-1}).

Using these equations they derived the relationship below.

$$T = (4L^2 \mu) f^2$$

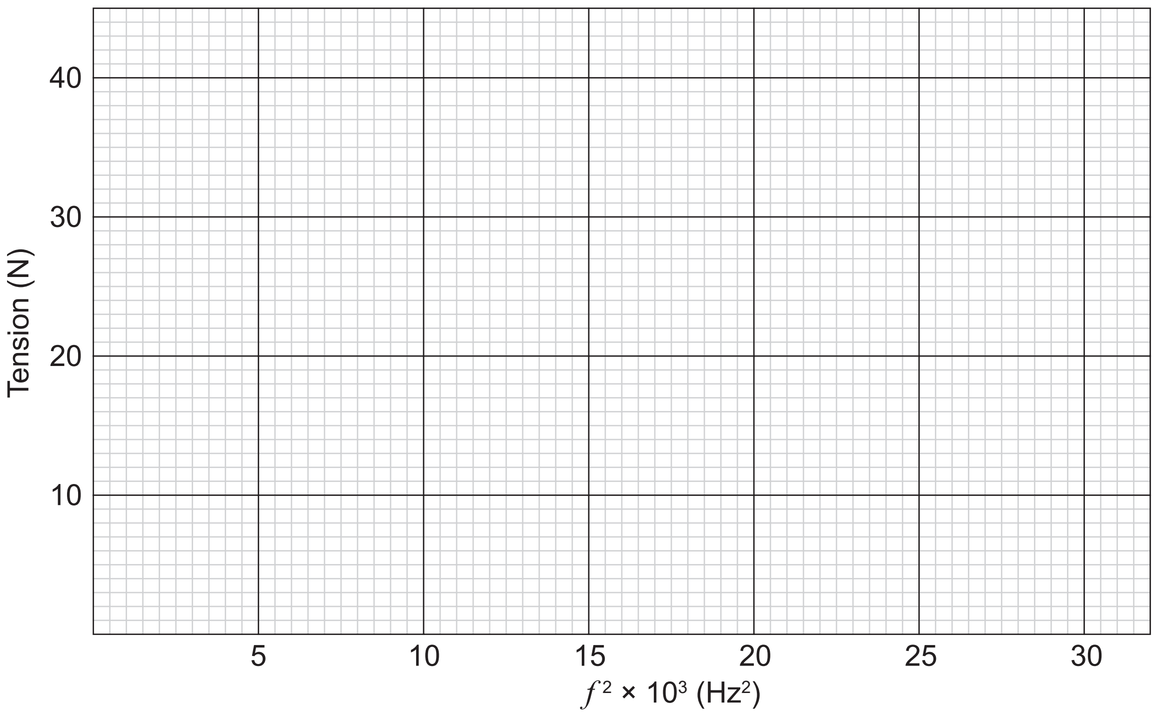
(a) Show how the students derived this relationship. (4 marks)

The students then manipulated their data so as to graph this relationship and produce a straight line.

(b) Make the adjustments to the data and place the results in the table below. Give your answers to **three** significant figures and express f^2 in scientific notation. (4 marks)

Mass (kg)	1.50	2.00	2.50	3.00	3.50	4.00
Tension (N)						
f^2 (Hz^2)						

(c) Graph your data on the grid below. Include a line of best fit. (3 marks)



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

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Question 16 (continued)

(d) Use the gradient of your line of best fit to calculate the mass per unit length in kg m^{-1} of the steel wire. Indicate clearly the two points used and express your answer to the appropriate number of significant figures. (5 marks)

Answer: ____________________ kg m^{-1}

(e) In the summary of their report, the students had to identify any variables that could affect the accuracy of their value. They identified correctly an important assumption they had made, which may have caused their value to be slightly different from the theoretical value. This had nothing to do with human error, inaccurate equipment, atmospheric conditions or calibration of instruments. Describe their assumption. (2 marks)

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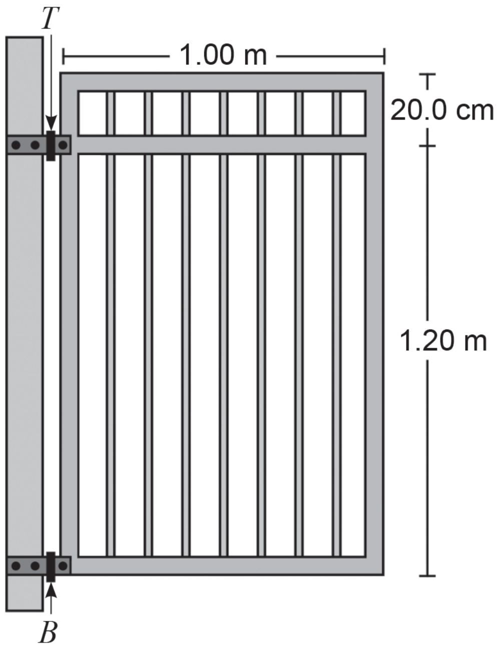
Question 17 **(14 marks)**

A uniform garden gate is attached to its support by two hinges (T and B). The top hinge (T) is fixed 20.0 cm below the top of the gate and the bottom hinge is fixed to the bottom of the gate. The gate has a mass of 25.7 kg. It is 1.00 m wide and 1.40 m tall.



Note: The top hinge takes all of the vertical weight force of the gate. The bottom hinge keeps the gate lined up correctly.

(a) By taking moments around B, calculate the horizontal component of the reaction force of T on the gate. Include a direction in your answer. (5 marks)

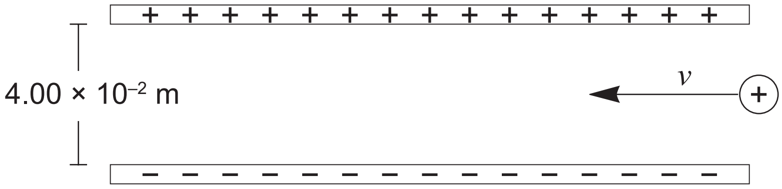
Answer: ____________________ N Direction: ____________________

(b) Calculate the overall reaction force of T on the gate. Include an angle to the horizontal in your answer. If you could not obtain an answer to part (a), use 1.40×10^2 N. (5 marks)

Answer: ____________________ N at ____________________ ° to the horizontal

(c) Discuss how the angle in part (b) would be affected if the top hinge was fixed at the top of the gate. Include a mathematical expression in your answer. (4 marks)

Question 18 **(17 marks)**



In an evacuated chamber, a proton enters an electric field at a speed of 1.79×10^6 m s^{-1} midway between two charged parallel plates and is initially moving parallel to them. The plates are 4.00×10^{-2} m apart and there is a potential difference of 4.80×10^3 V between them.

(a) (i) Calculate the downward force exerted on the proton by the electric field. (3 marks)

Answer: ________________ N

(ii) Choose which mathematical relationship (A, B, C or D) describes the path taken by the proton when it enters the field. Circle your answer. (1 mark)

A. $y \propto x$ B. $y \propto \frac{1}{x}$ C. $y \propto \sqrt{x}$ D. $y \propto x^2$

(b) Given that the proton does not exit the field before hitting the bottom plate, how far from the right hand end of the bottom plate does the proton land? Ignore any effects due to gravity. (7 marks)

Answer: ________________ m

(c) Calculate the velocity of the proton just before it strikes the bottom plate. Include an angle in your answer. (6 marks)

Answer: ____________________ m s^{-1} at ____________________ ° to the horizontal

End of Section Two

Section Three: Comprehension **20% (41 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. Unless otherwise instructed, give final answers to **three** significant figures and include appropriate units where applicable.

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Suggested working time: 40 minutes.

Question 19 **(21 marks)**

The Big European Bubble Chamber (BEBC)

Figure 1: The BEBC

Fundamental particles are extremely small and usually fast moving. This makes them hard to detect. If they are passed through a medium which records the path of their movement, new particles can be identified by their behaviour. The products of collisions between known particles can also be observed.

One such medium is superheated hydrogen. A superheated liquid is one which is held just above its natural boiling point. These liquids are unstable and 'boil' when the slightest disturbance is experienced. Charged particles moving at high speeds will cause the formation of tiny bubbles in the hydrogen and therefore leave a trace of the particles' trajectory. An example of this is shown in Figure 2 on page 31.

Figure 2: The collision of a gamma ray and a hydrogen atom's electron in a bubble chamber

A gamma ray enters from the left and collides with the electron of a hydrogen atom. It is neutral so there is no trace. Its path is shown as a dotted line. The gamma ray loses some energy which creates an electron and its antiparticle, a positron. The electron from the hydrogen atom recoils to the bottom right. Because the chamber is in a strong magnetic field, the charged particles spiral in different directions and with different momenta.

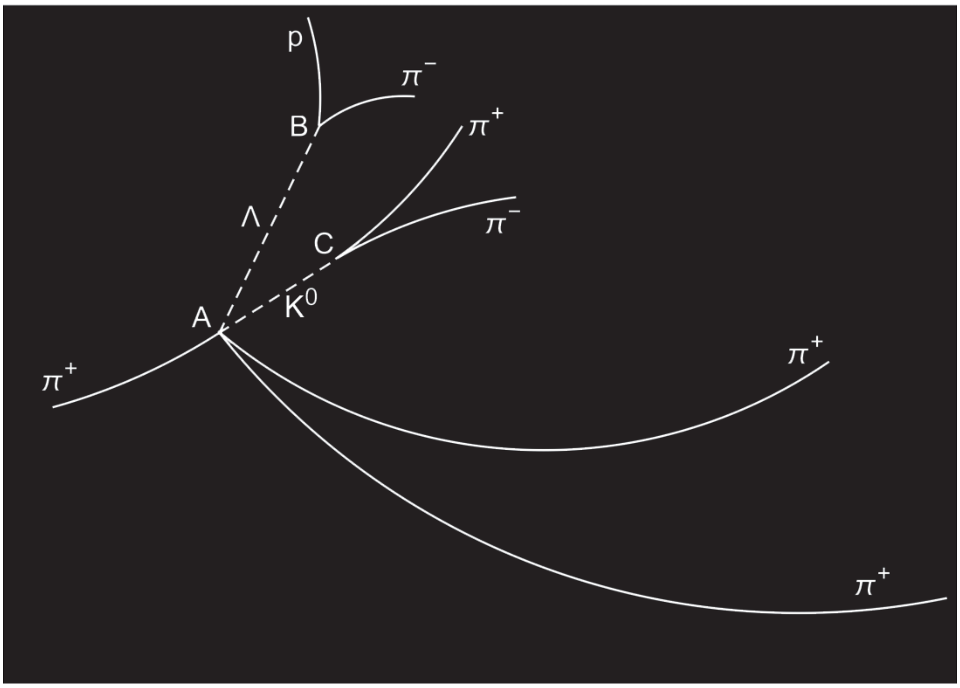

Figure 3: The collision between a positive pion and a proton in a bubble chamber

In Figure 3, a positive meson called a pion (π^+) enters from the left and strikes a proton at A. The pion and the proton become two new pions, a kaon (K^0) and a lambda particle (Λ). Both the kaon and lambda particles are neutral so they travel in straight lines and do not leave a trail. The lambda particle decays into a proton and a negative pion at B. The kaon decays into a positive and a negative pion at C.

Question 19 (continued)

In summary, a proton and one pion have been converted into a proton and five pions. There are three varieties of pion: +, –, and 0. The antiparticle of the positive pion is the negative pion and the π^0 is its own antiparticle.

(a) Discuss how the diagram in Figure 2 on page 31, shows that the two charged particles produced in the collision have different momenta. (4 marks)

(b) Explain how one proton and one pion can be converted into one proton and five pions. (3 marks)

(c) Why do the lambda and kaon particles leave no tracks in the bubble chamber? (2 marks)

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(d) Is charge conserved in the overall reaction? Justify your answer with a calculation of the total charge before and after the collision. (4 marks)

(e) List a possible quark composition of the π^+ and π^- particles. (3 marks)

Particle	Quark composition
π^+	
π^-	

(f) The approximate mass of the incoming π^+ is 2.48×10^{-28} kg. If the radius of the circular path the pion is taking is 2.30 mm and it has a forward velocity of 3.70×10^5 m s^{-1}, estimate the strength of the magnetic field in the bubble chamber. (5 marks)

Answer: ______________________ T

Question 20 **(20 marks)**

Polarisation of light

Figure 1: Pair of polarised sunglasses

When you buy a pair of polarised sunglasses, the main purpose they serve is to reduce the intensity of light hitting your eyes. How they achieve this is described below.

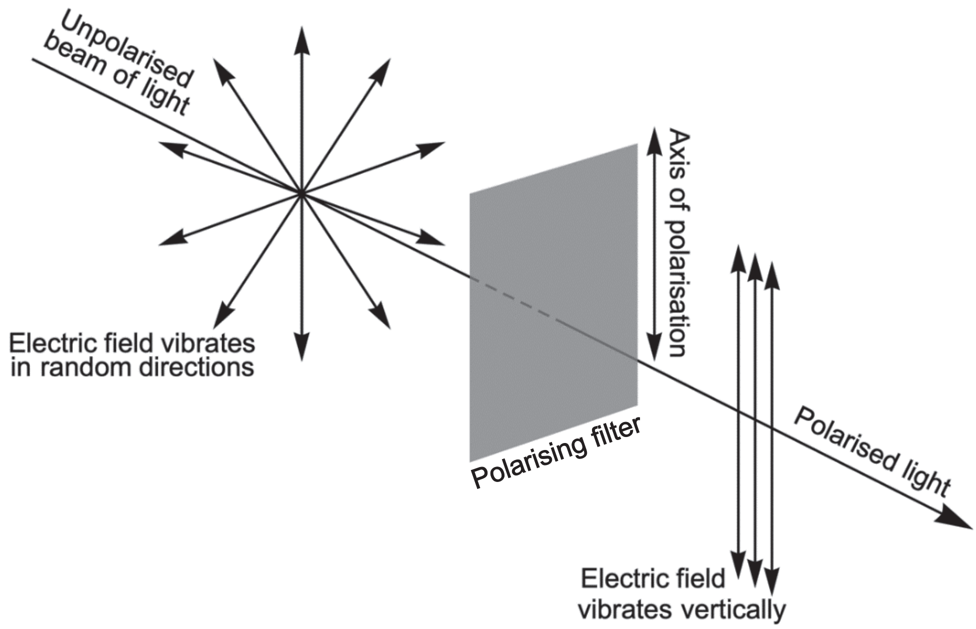

Figure 2: Randomly polarised light passing through a polarising filter

Light waves are a combination of oscillating magnetic and electric fields. As the magnetic field changes, it induces a changing electric field, which in turn induces a magnetic field and so on. A beam of light consists of transverse waves oscillating in all directions around the line of propagation. A polarised filter can be thought of as a series of slits that only allows those waves to pass through with their electric fields oscillating in the same direction as the axis in the filter.

But the filters do not have actual slits in them. The material consists of long chain polymers. Electrons in these chains are free to move along the chains but not between them. A light wave's electric field does work on these electrons and causes them to absorb the wave's energy. Therefore, light waves which are polarised parallel to the chains get absorbed and those travelling perpendicular pass through undisturbed. Those travelling at an angle to the chains are partially absorbed. The axis of the filter is perpendicular to the chains.

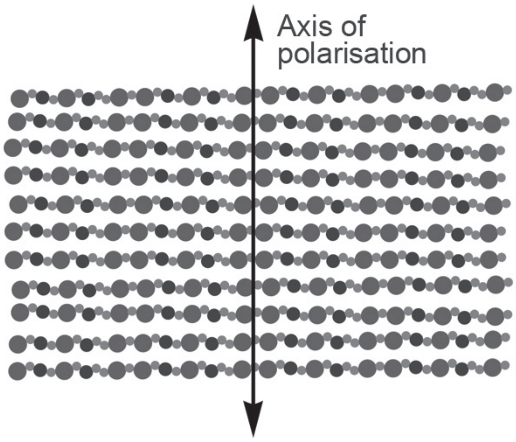

Figure 3: Axis of polarisation is perpendicular to the aligned long chain polymer molecules

Figure 4 illustrates this point. Only the component of the electric field parallel to the axis of a polarising filter is allowed to pass. In the diagram, angle θ represents the angle between the direction of polarisation of incident light and the axis of a polarising filter. After passing through the filter, the amplitude of the electric field has been reduced by a factor of $\cos\theta$.

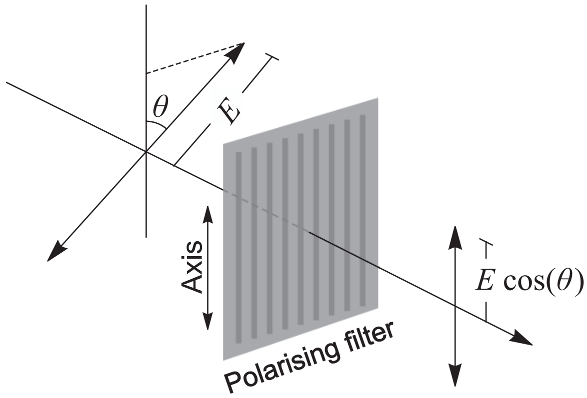

Figure 4: Polarising filter with angle θ shown

Since intensity of a wave is proportional to its amplitude squared, the intensity I of the transmitted wave is related to the initial intensity I_0 of the incident light by the following relationship, known as Malus' Law:

$$I = I_0 \cos^2\theta.$$

A single polarising filter reduces the wave's intensity by exactly 50.0%. Intensity is measured in watts per square metre (W m^{-2}).

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Question 20 (continued)

(a) With reference to Figure 3 on page 35, discuss how unpolarised light can become polarised. (4 marks)

(b) Define the axis of a polarising filter and describe its function. (2 marks)

(c) According to Malus' Law, at what angle to the direction of polarisation of the incident light should the axis of a polarising filter be oriented in order to

(i) allow the light to pass without reduction in intensity? (1 mark)

Answer: ____________ °

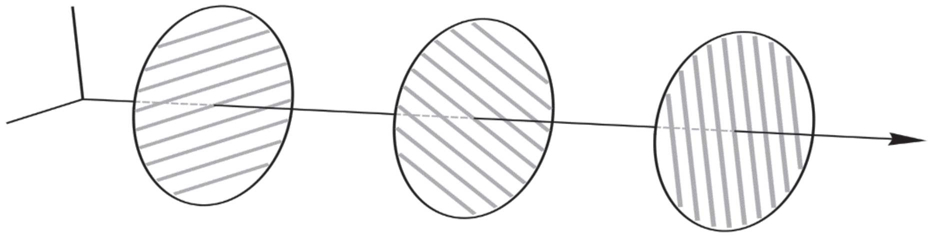
(ii) completely block the passage of the light? (1 mark)

Answer: ____________ °

(d) Use Malus' Law to calculate the angle between the direction of polarisation of the incident light and the axis of a polarising filter if the incoming light has its intensity reduced by 75.0%. (4 marks)

Answer: ____________________°

(e)



A group of students placed two polarising filters at right angles and saw no light being transmitted. They placed a third filter between the first two at 45.0° to each one and noticed light was transmitted.

(i) Explain how inserting the third filter allowed light to hit the screen when no light was hitting it before. (3 marks)

(ii) What percentage of the original light's intensity is hitting the screen with the third filter in place? (2 marks)

Answer: ____________________ %

Question 20 (continued)

(f) A photon's energy is given by $E = hf$. When light passes through a polarising filter, the total energy transmitted is reduced but the frequency of each photon remains the same. Using the particle model of light, account for the reduction in transmitted energy. (3 marks)

End of questions

Supplementary page

Question number: ________________

Supplementary page

Question number: ______________

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Supplementary page

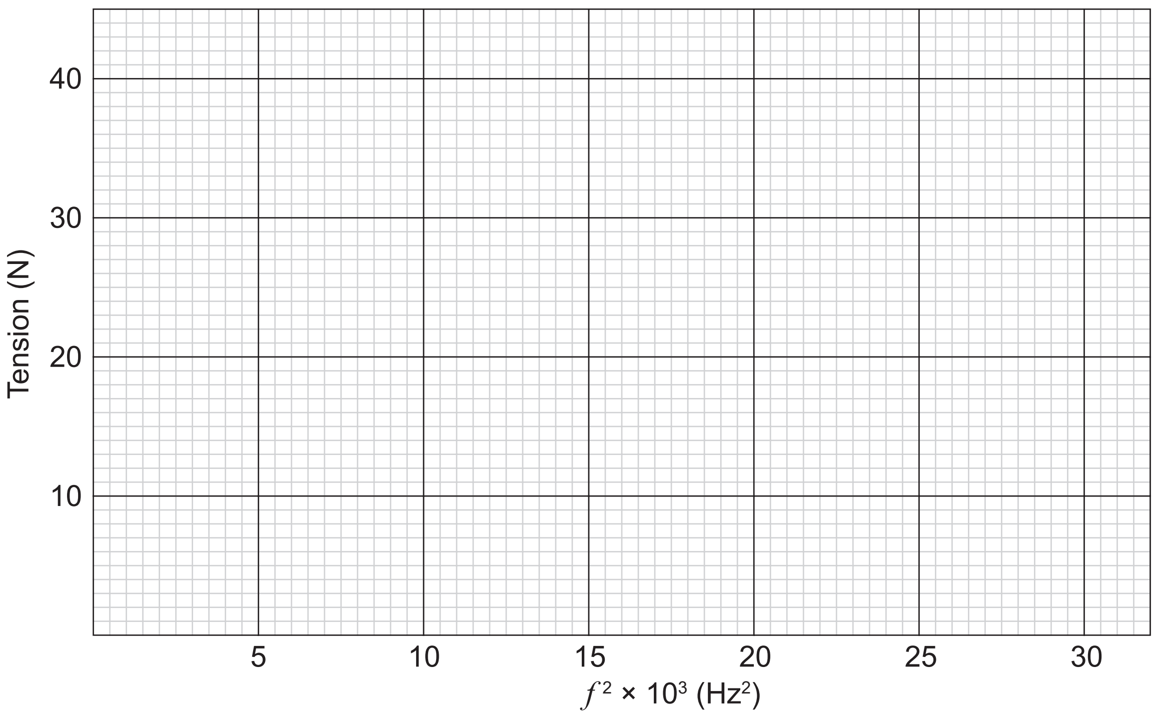
Question number: __________

Supplementary page

Question number: ____________

Spare diagram for Question 13(d)(i)

Spare grid for Question 16(c)



ACKNOWLEDGEMENTS

Question 1	Figure 2 adapted from: Excel@Physics. (n.d.). [Diagram of DC motor]. Retrieved April, 2023, from http://www.excelatphysics.com/magnetism-and-electromagnetism-question.html
Question 19	Figure 1: Zenz, S. (2005). *Big European Bubble Chamber* [Photograph]. Retrieved April, 2023, from https://commons.wikimedia.org/wiki/File:Big_European_Bubble_Chamber.jpg Used under a Creative Commons Attribution-ShareAlike 3.0 Unported licence. Figure 2: Walo, R. (2018). *Trails of an Electron and Positron in a Bubble Chamber* [Diagram]. Retrieved April, 2023, from http://model31.pl/en/electron-and-positron-similarities-and-differences/
Question 20	Figure 1: Dhumal, N. (2015). *Red Lens Sunglasses on Sand Near sea at Sunset Selective Focus Photography* [Photograph]. Retrieved April, 2023, from https://www.pexels.com/photo/red-lens-sunglasses-on-sand-near-sea-at-sunset-selective-focus-photography-46710/ Paragraphs 4 and 5 adapted from: Urone, P. P., & Hinrichs, R. (2012). 27.8 Polarization. In *College Physics.* Retrieved April, 2023, from https://openstax.org/books/college-physics/pages/27-8-polarization Used under a Creative Commons Attribution 4.0 licence. Figure 4 adapted from Urone, P. P., & Hinrichs, R. (2012). *Figure 27.42 A polarizing filter* […] *its axis* [Diagram]. Retrieved April, 2023, from https://openstax.org/books/college-physics/pages/27-8-polarization Used under a Creative Commons Attribution 4.0 licence.

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