GOVERNMENT OF WESTERN AUSTRALIA

Curriculum Council

Tertiary Entrance Examination, 2006

Question/Answer Booklet

PHYSICS

Please place your student identification label in this box

Student Number: In figures

In words ______________________________

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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
Physics: Formulae and Constants Sheet (inside front cover of this Question/Answer Booklet)

To be provided by the candidate
Standard items: Pens, pencils, eraser or correction fluid, ruler, highlighter

Special items: MATHOMAT and/or Mathaid, drawing compass, protractor, set square and calculators satisfying the conditions set by the Curriculum Council for this subject.

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: 744

Structure of this paper

Section	No. of questions	No. of questions to be attempted	No. of marks out of 200	Proportion of examination total
A Short Answers	15	All	60	30%
B Problem Solving	7	All	100	50%
C Comprehension and Interpretation	2	All	40	20%

Instructions to candidates

1. The rules for the conduct of Tertiary Entrance Examinations are detailed in the booklet *TEE Handbook*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in the spaces provided in this Question/Answer Booklet.

3. You may remove the enclosed *Physics: Formulae and Constants Sheet* from the booklet and use as required. This sheet is not to be handed in at the end of the examination.

4. Your answers to questions involving calculations should be evaluated and given in decimal form. It is suggested that you quote all answers to three significant figures, with the exception of questions for which estimates are required. Despite an incorrect final result, you may obtain marks for method and working, provided these are clearly and legibly set out.

5. Questions containing the specific instruction "**show working**" should be answered with a complete, logical, clear sequence of reasoning showing how your final answer was arrived at. For these questions, correct answers which do not show working will not be awarded full marks.

6. Questions containing the instruction "**estimate**" may give insufficient numerical data for their solution. You should provide appropriate figures to enable an approximate solution to be obtained.

7. When descriptive answers are required, you should display your understanding of the context of a question. An answer which does not display an understanding of Physics principles will not attract marks.

SECTION A: Short Answers **(60 Marks)**

Attempt **ALL** 15 questions in this section. Each question is worth 4 marks. Answers are to be written in the space provided.

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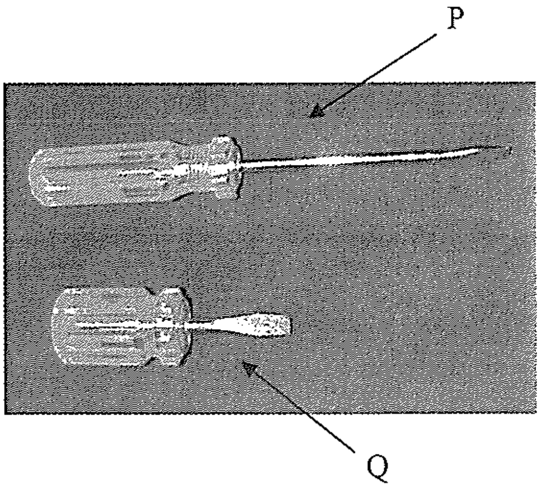
1. From a **context** you have studied, give an example of either BEATS or DIFFRACTION, and describe the conditions under which it occurs.

2. Wind can produce a deep 'moaning' sound in a chimney. **Estimate** the lowest frequency of the sound produced if a chimney is about 3 m in length. Assume that the chimney is open at both ends.

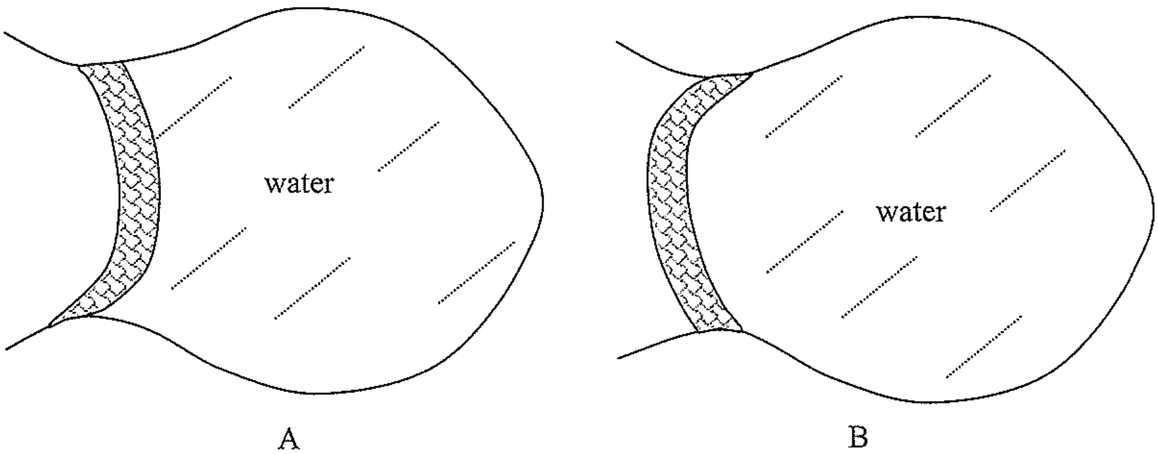
3. Consider the following picture of two screwdrivers, labelled P and Q. Which is the better one to use to loosen a screw that is particularly tight?



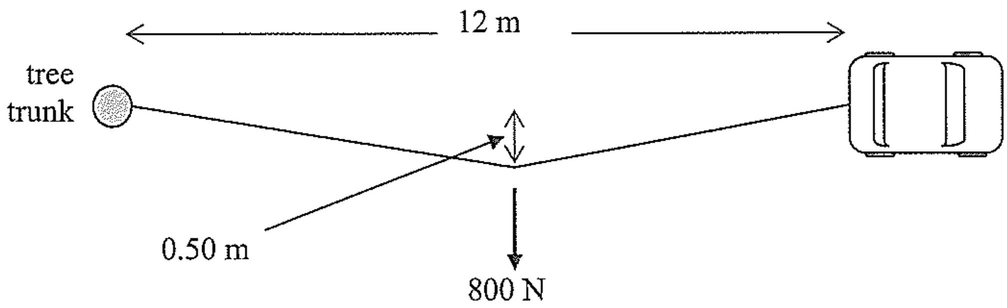
Answer ____________________

Explain your answer.

4. The diagrams below are aerial views of two dams. Dam walls curved like the one in diagram A are much less likely to collapse than the one shown in diagram B. Explain why. Use either or both diagrams to assist your explanation.



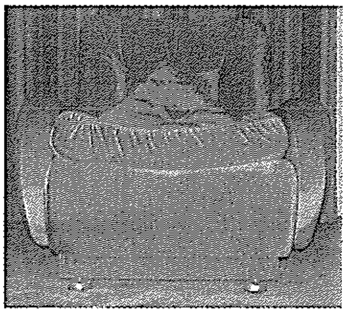
5. Bill and Jane get their car stuck in sand. They tie a non-stretch rope to the car and pull together with a force of 800N, but they are unable to move the car. Bill then notices a tree 12 metres behind the car. He ties the other end of the rope tightly around the tree trunk and then they pull the middle of the rope sideways a distance of 0.50 m with a force of 800 N. What force does the rope now exert on the car?

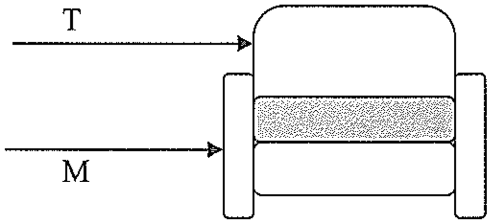


6. Mount Everest is 8.85 km high. The acceleration due to gravity on the top of Mount Everest is:
A. About the same as at sea level.
B. About 10% less than at sea level.
C. Much less than at sea level. Answer ____________________

Explain how you arrived at your answer.

7. If you try to move an armchair sideways by pushing near the top of it (force T), it will tumble over, but if you push nearer the middle of one side (force M) it will slide along. Explain.





8. Some cameras have a shutter that can remain open for an extended period of time. If you use such a camera to take a photograph of the sky at night, the apparent movement of the stars across the sky caused by the Earth's rotation results in a 'star trail' on the film (see photograph below). **Estimate** how long the shutter of the camera was left open in order to record the star trails shown in the photograph. Show your working.

9. Power supplies used in schools contain a transformer to supply electricity at voltages lower than 240 V.

(a) Why is the input current to the transformer different from the output current?

(b) Assuming that the transformer is 90% efficient, calculate the size of the input current to the transformer when it is used to light a 50 W, 12 V lamp.

10. A 1.25 tonne car is driven on two bridges at a speed of 72 km/h. Bridge A is straight and level. Bridge B is part of a circular curve with a radius of 80 m (see diagrams below).

For each bridge, find the vertical force on the bridge due to the weight of the car.

A 

B 

11. Is the light emitted during fluorescence **longer** or **shorter** in wavelength than the light absorbed? Explain, using an energy level diagram.

12. The nylon string of a tennis racquet is under a tension of 250N. If the string has a diameter of 2.00 mm, by how much is it stretched from its un-tensioned length of 30.0 cm? Young's modulus for nylon = 5.04×10^9 Pa.

13. Diagram A shows the magnetic field around a bar magnet. The same bar magnet is shown in Diagram B, with a piece of un-magnetised soft iron placed to the right of it. Draw the magnetic field around the magnet and piece of iron.

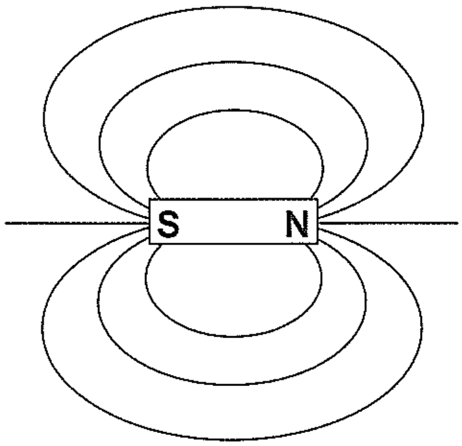
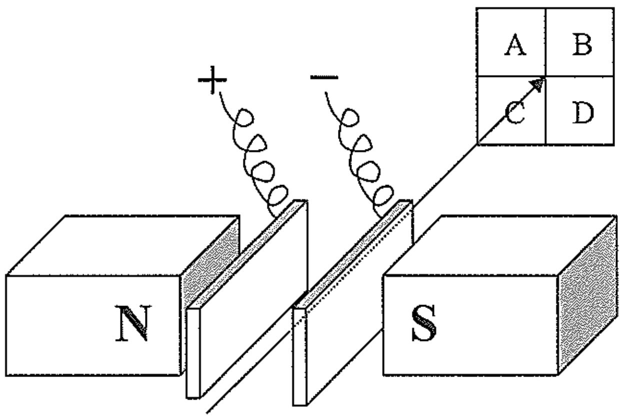


Diagram A

Diagram B

14. A beam of electrons is directed towards the centre of a screen with four quadrants A, B, C and D. When electric and magnetic fields are arranged as shown below, the electron beam is deflected.



Which quadrant of the screen is the beam most likely to strike? Answer ____________

Explain your answer.

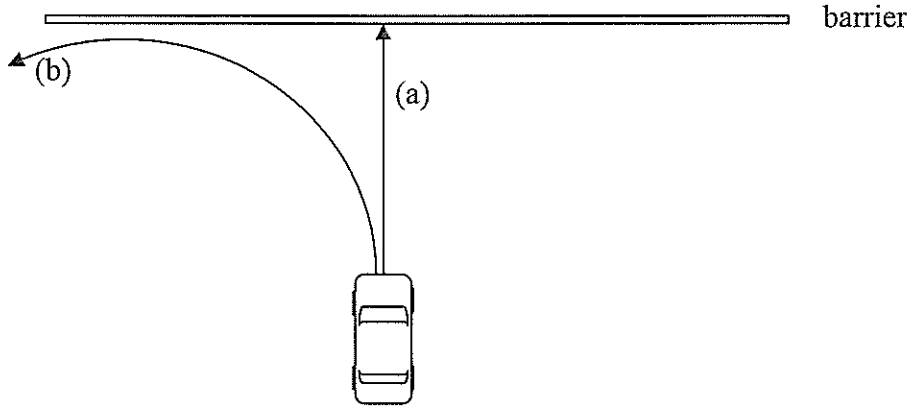
15. A stunt car driver drives at high speed directly at the middle of a long barrier. When he is a certain distance away, he can either:

(a) without changing direction, apply the brakes and stop before hitting the barrier, OR

(b) without braking, avoid hitting the barrier by turning away in a circular path.

Which of the two options is more likely to enable him to avoid hitting the barrier?

Clearly explain your answer in words or justify it by showing your working.



Answer ________________

Explanation

SECTION B: Problem Solving **(100 Marks)**

Attempt **ALL** 7 questions in this section.

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1. [11 marks]

Inventor's 'mosquito' makes noisy teens buzz off.

An inventor claims to have found the perfect solution to rowdy teenagers: noise!

Howard Stapleton says his device, the 'mosquito', emits an uncomfortable, high-pitched ultrasonic sound that can be heard by children and teenagers, but almost no one over the age of 30 can hear it. The 'mosquito' has successfully driven noisy teenagers away from shops in several towns.

From ABC Online: Thursday, December 1, 2005

(a) What does the phrase 'high-pitched, ultrasonic sound' mean? [2 marks]

(b) Most adults cannot hear sounds above 18 kHz. What is the shortest wavelength sound that most adults are able to hear? [3 marks]

(c) Assume that **two** 'mosquitoes' are attached to the ceiling of a shop, each emitting sound at 5.00 W with a frequency of around 18 kHz. What will be the sound intensity level (in dB) at a point 3.00 m from both of them?

[6 marks]

2. [13 marks]

Blood consists mostly of red blood cells suspended in a liquid called plasma. Red blood cells are separated from plasma using a blood centrifuge. A schematic diagram of a blood centrifuge is shown in Figure 1.

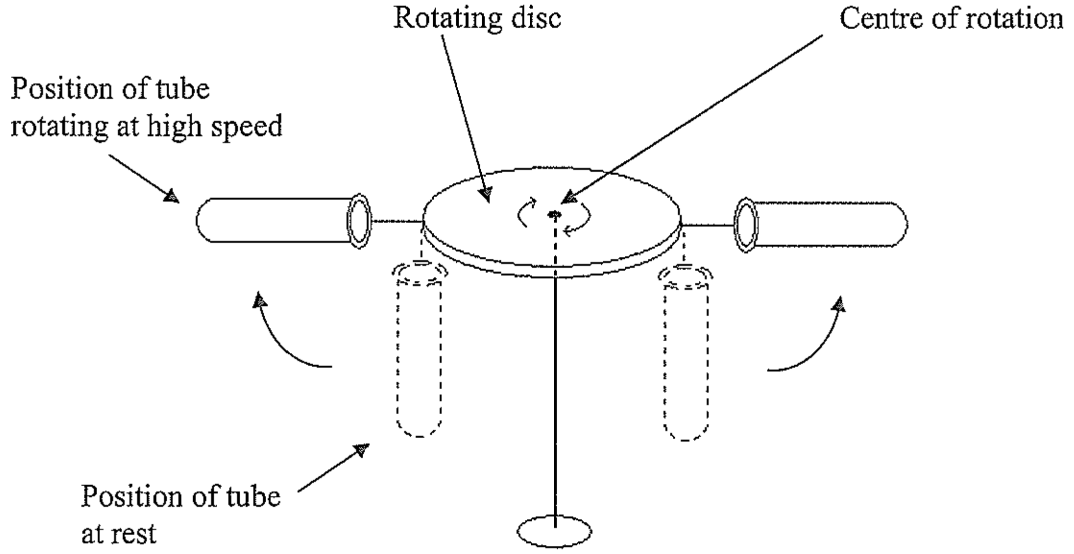


Figure 1

Test tubes of blood are initially suspended vertically from a horizontal disc. As the disc rotates the test tubes are flung outwards and upwards. As the disc rotates faster, the test tubes will swing upwards until they are horizontal. In this position, the red blood cells move into the ends of the test tubes, as shown in Figure 2. After this process, the plasma can be poured off, leaving the red blood cells behind.

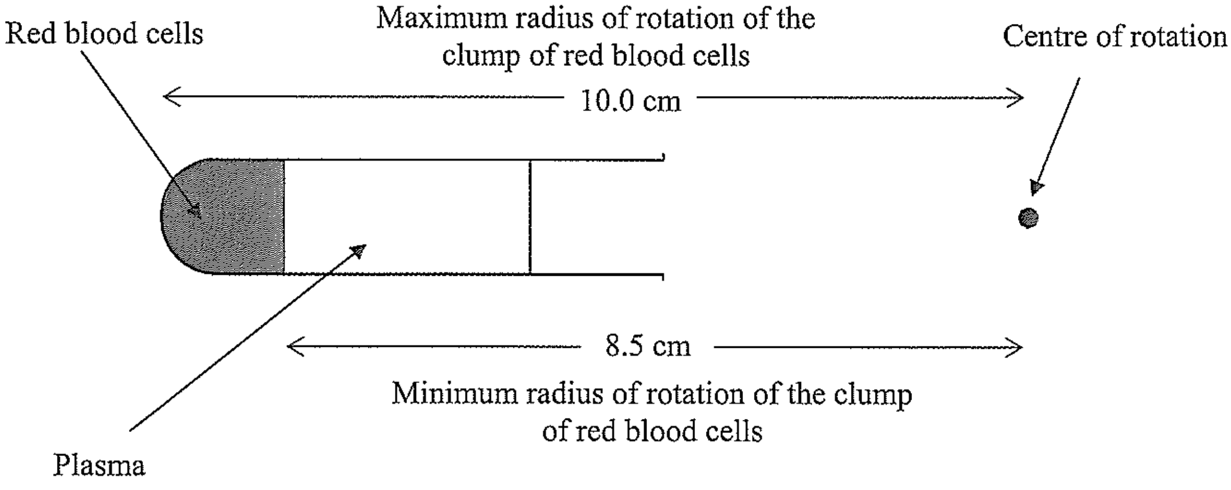


Figure 2

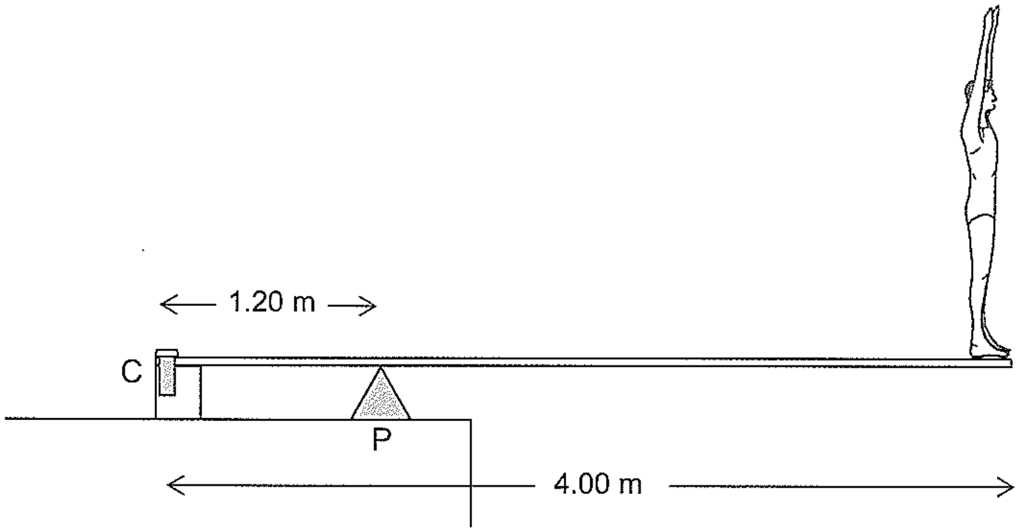
(a) If the centrifuge in Figure 1 contains red blood cells (as shown in Figure 2) and is rotating at 4500 revolutions per minute, what is the maximum speed of the red blood cells in the test tubes? [4 marks]

(b) What is the maximum centripetal acceleration of the red blood cells in the test tubes? [3 marks]

(c) A red blood cell has a mass of approximately 89 ng. Given that red blood cells break if subjected to a force greater than 8.0 mN, what is the maximum rotational frequency of this centrifuge if no cells are to be damaged? [6 marks]

3. [16 marks]

A springboard diver with a mass of 62.5 kg is standing on the end of a diving board as shown below. The springboard has a mass of 120 kg. A clamp at C holds the end of the board in place.

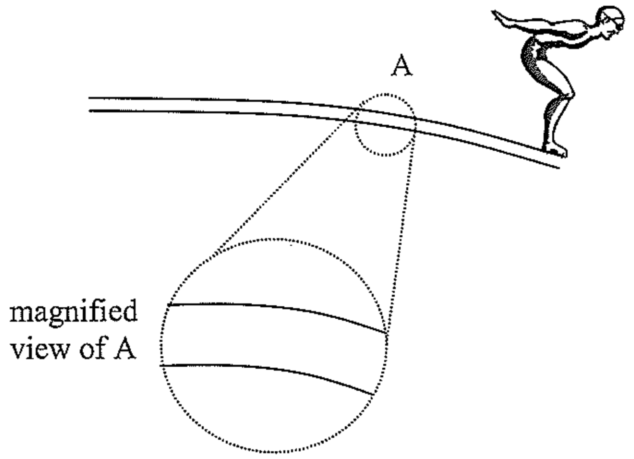


Assume for parts (a) and (b) only that the springboard is uniform and rigid (i.e. does not bend).

(a) On the diagram, use arrows to show the direction of the forces on the board due to the pivot point (P) and the clamp (C). [2 marks]

(b) Calculate the forces acting on the clamp (C) and the pivot point (P) when the diver is standing on the end of the board. [6 marks]

(c) Diving boards are not rigid, but bend down when the diver bounces on them, as shown in the diagram below. [8 marks]



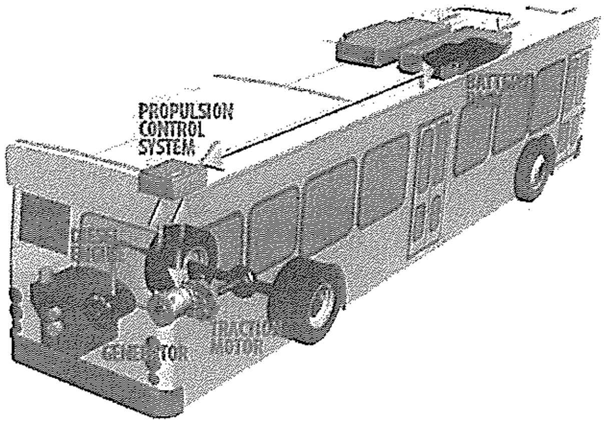
(i) On the magnified view of A, carefully label where the material of the bent board is under compression and where the material of the bent board is under tension.

(ii) Explain why a diving board bends a lot when the diver bounces on the end but hardly bends at all when the diver is standing still.

(iii) In view of your answers to earlier parts of this question, if you had to choose an appropriate material for making a diving board, what two properties of the material would you consider, and why?

4. [17 marks]

Below is a schematic diagram of an electric/combustion hybrid bus which uses both a conventional diesel engine and an electric motor to turn the wheels.



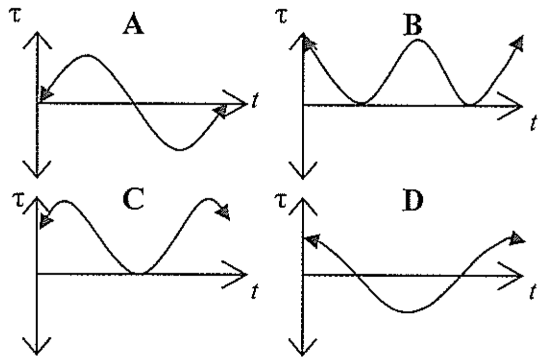
The bus has a bank of 12V lead-acid batteries on its roof to provide electricity to the motors through the propulsion control system. The batteries are recharged using current generated (i) directly by the operation of the combustion engine, and (ii) by regenerative braking which incorporates electric motors in the braking system. In effect, the electric motors become generators, driven by the turning wheels.

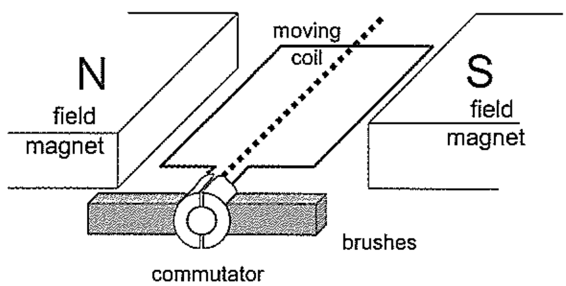
(a) [3 marks]

(i) List all variables that contribute to the torque of an electric motor.

(ii) Drivers must be able to vary the speed of the buses as they drive in traffic. Which of the variables listed above could be quickly altered in order to vary the speed of the electric motors?

(b) Which of the following graphs of torque (τ) versus time (t) would best represent one revolution of the armature coil as it is used to drive the wheels of the bus. [2 marks]





Answer _______________

(c) If the 200 kW electric motor in the bus is 68% efficient at converting electrical energy into kinetic energy of the bus, what is the maximum speed that the bus can achieve after accelerating for 4.0 seconds from a stationary start? The mass of the bus is 4.4 tonnes.

[4 marks]

(d) [3 marks]

(i) Explain how the energy efficiency of the bus is improved by regenerative braking.

(ii) In addition to the regenerative braking system, the buses are also fitted with mechanical brakes. Briefly say why this would be necessary.

(e) If the bus is traveling at 60 kmh^{-1}, **estimate** the maximum EMF that could be supplied to recharge the batteries during regenerative braking. The electric motor/generator has a diameter of about 70 cm and has a 2.0 T magnetic field. Assume that there is no mechanical braking, and that the braking system is not geared.

[5 marks]

5. [12 marks]

Cancerous cells have often experienced a mutation (chemical change) to their genetic material (DNA) and, as a result, these cells multiply at a greater rate than normal cells. Chemical changes to sections of DNA molecules result if photons of electromagnetic radiation ionise atoms within the DNA molecules.

(a) [3 marks]

(i) What properties would electromagnetic radiation require in order to damage a cell within a person's body through ionisation?

(ii) Do X-rays have the required properties to damage cells through ionisation? Explain your answer.

(b) Evidence suggests that the minimum energy required to ionise any section of DNA is about 32 eV. [4 marks]

(i) What wavelength of photons would a person need to be exposed to in order to cause damage to cells by ionisation?

(ii) To what region of the electromagnetic spectrum do photons with this wavelength belong?

(c) When atoms absorb photons with energies less than their ionisation energies, they may be excited to higher energy states. They only absorb photons of specific energies however. [5 marks]

(i) Explain why.

(ii) If a photon has more than the required energy for ionisation, what happens to the excess energy?

(iii) Some people suggest that microwave radiation used to carry mobile telephone signals can cause brain tumours (cancer cells) in phone users. With reference to the electromagnetic spectrum, is it likely that microwave radiation is responsible for damage to cells through ionisation that will cause cancer? Give reasons for your answer.

6. [16 marks]

An electron microscope uses magnetic fields to focus a wide beam of electrons to a point. A beam of electrons with the same speed can be focused to a point by a magnetic field region shaped as shown in Diagram A.

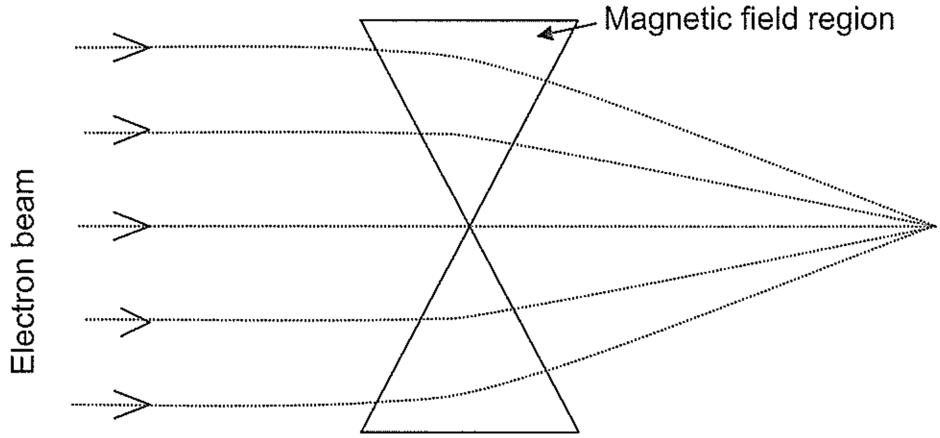


Diagram A

(a) [6 marks]

(i) Use dots and/or crosses to show the direction of the magnetic field in the two triangular regions in Diagram A. Briefly describe the field.

(ii) Explain why the triangular shape of the magnetic field in Diagram A focuses the electron beam to a point. Use a diagram if it will help your explanation.

(b) When electrons with a speed of 2.05×10^6 m s^{-1} enter the magnetic field, they experience a force of 4.59×10^{-14} N. What is the strength of the magnetic field? [4 marks]

(c) The triangular magnetic field region is now replaced by a rectangular field as shown in Diagram B. [3 marks]

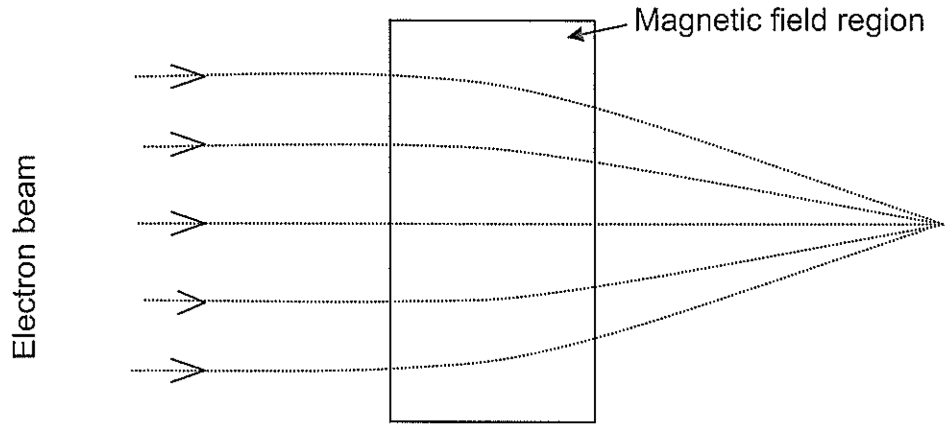


Diagram B

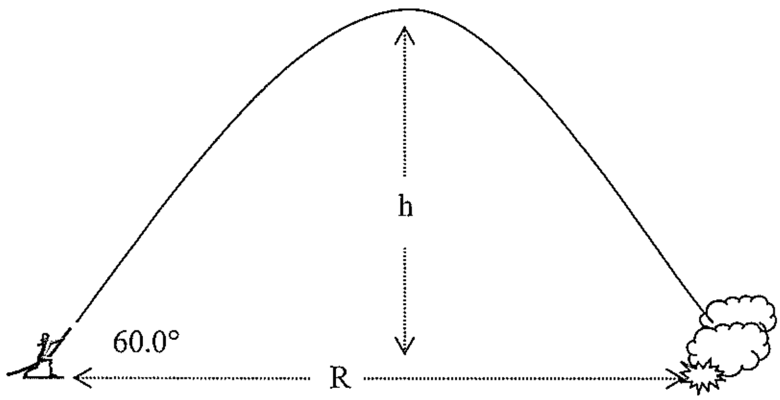
Describe the magnetic field within the rectangle that could focus the electrons. Use the diagram above to illustrate your answer.

(d) From the context you have studied, briefly describe an example where magnetic fields affect, or are used to control, the direction of movement of charged particles. [3 marks]

7. [15 marks]

(a) Calculate the maximum possible height (h) and horizontal range (R) for a stream of water from a fire hose if it is directed at a speed of 40.0 m s^{-1} and at a launch angle of 60° above the horizontal.

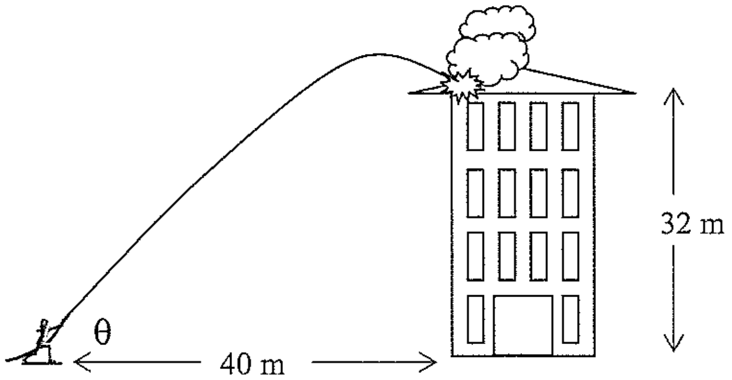
[4 marks]



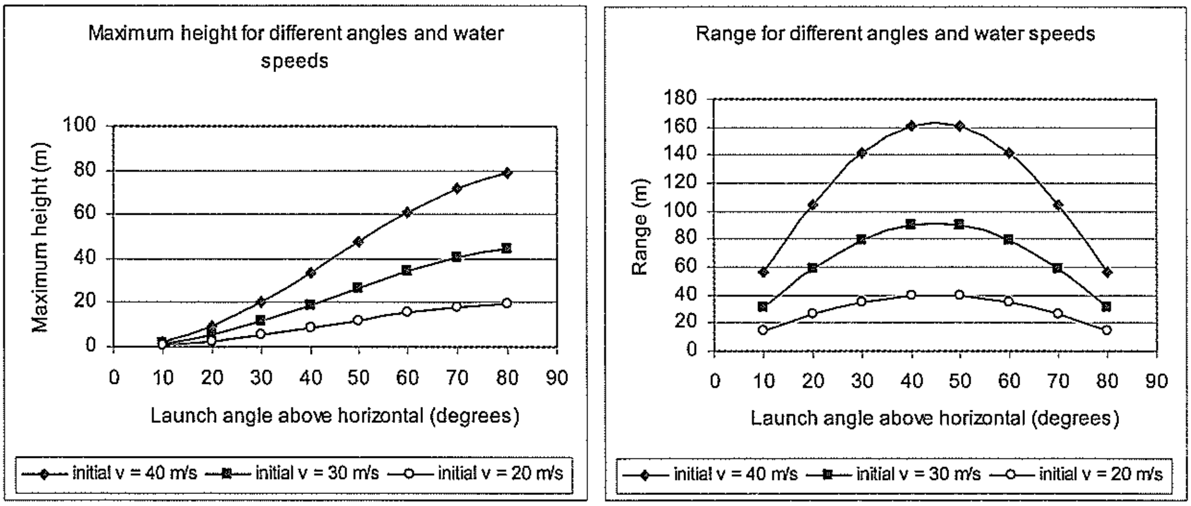
(b) Helicopters are often used to drop water onto small bush fires. A helicopter approaching a bush fire at a speed of 22 m s^{-1} must release the water no closer than 150 m horizontally from the fire and then turn quickly away to avoid flying over the fire. What is the minimum height that this helicopter can fly at this speed to ensure that the water reaches the fire?

[5 marks]

(c) When fighting fires in some buildings, there is a limit to how close fire-fighters can get to the fire. For the fire illustrated below, the fire-fighter cannot stand closer than 40 m from the building. The **best** trajectory for the water for this roof fire is when it reaches its maximum height just before it drops down onto the fire (as shown below).



(i) The graphs below show the theoretical maximum height and range for water fired from a hose at different angles above the horizontal and with three different velocities (20, 30 and 40 m s^{-1}). On each graph, circle the point that correspond to the maximum height and range for a launch angle of 60.0° and launch speed of 40.0 m s^{-1} [2 marks]



(ii) For the fire-fighting situation described above, where the fire-fighter wants the water to land on the fire from a few metres above it, **estimate** the **best** combination of launch angle (θ) and water velocity. Ignore air resistance. Give the angle to the nearest 10° and speed to the nearest 10 m s^{-1}. Briefly explain your choice. [4 marks]

Best angle = ________ Best velocity = ______________

Explanation:

SECTION C: Comprehension and Interpretation **(40 Marks)**

BOTH questions should be attempted.

Read the following passages and answer the questions at the end of each. Candidates are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

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1 TERMINAL VELOCITY [20 marks]

When a ball is falling through the air, the upward air resistance is in the opposite direction to the speed of the ball and in proportion to the speed of the ball. At first the ball accelerates, but when the air resistance becomes equal to the gravitational force, the resultant force is zero, and the ball falls at a constant speed, i.e. its terminal velocity.

This is an example of a situation where the forces acting on an object depend on the speed of the object. Another example is given in the activity described below.

A group of students was given a 'sliding wire' apparatus and asked to investigate any aspect they liked. The apparatus consisted of an inclined plane that was a strong magnet. The angle (α) between the inclined plane and the horizontal could be increased or decreased.

A rigid copper rod, when released from the top, slides down two parallel electrical contact rails connected to a galvanometer. The students noticed that as the rod slid down the plane, a current was induced in the circuit. They also noticed that the rod initially accelerated but soon reached a constant velocity. They chose to investigate this 'terminal' velocity.

The copper rod is rectangular with cross-sectional area A = 25.0 mm^2, length ℓ = 20.0 cm and mass m = 44.0 g and has a resistance R = 1.4 x $10^{-4}\Omega$.

Assume that there is zero friction between the rod and the rails.

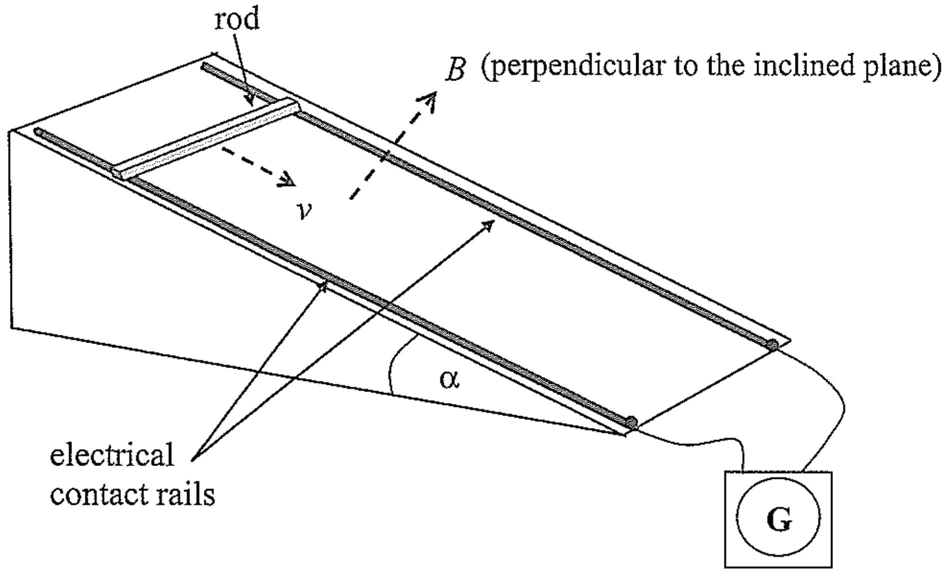

Diagram not drawn to scale

(a) [5 marks]

(i) Describe the forces acting on the rod as it slides down the electrical contact rails and also clearly mark them on the diagram.

(ii) Explain why the rod reaches a constant velocity instead of continuing to accelerate down the inclined plane.

(b) Show that the rod's terminal speed (v_{ts}) can be calculated from the following equation (i.e. derive the equation): [5 marks]

$$v_{ts} = \frac{(mg\sin\alpha)R}{\ell^2 B^2}$$

The students varied the angle of inclination, α and took sufficient measurements to calculate the terminal velocity for a range of angles. Their data are in the table below:

Angle (α)	**Terminal speed** (cm s^{-1})	**Sin α**
20	0.56	
25	0.71	
30	0.83	
35	0.90	
40	1.05	
45	1.19	
50	1.27	
55	1.40	
60	1.44	

(c) [6 marks]

(i) Use the data to produce a graph of terminal velocity against sin α with terminal velocity on the vertical axis. You may use your graphical calculator to draw the graph, or use the graph paper on the opposite page.

If you have used the calculator write the equation of the line of best fit here:

___

(ii) What is the gradient of the line of best fit?

___

(d) Use the gradient you determined to find the strength of the magnetic field B. (If you could not determine a gradient, use the numerical value 1.57) [4 marks]

2 CAVITATION [Total 20 marks]

Bubbles can be injected into liquids, but they can also occur spontaneously from within a liquid as the liquid vaporizes. 'Cavitation' is an example of this and occurs when the fluid pressure P drops below the vapour pressure of the fluid. Cavitation can be achieved through heating, such as when we heat water to boil it, or through an increase in fluid velocity v_f. Fluid pressure can be estimated from Bernoulli's equation:

$$P + \frac{1}{2} \rho v_f^2 = \text{constant}$$

where ρ = density of the fluid.

Noise production

A bubble produced as a result of cavitation oscillates about its average radius R_0, due to the compressibility of gas, and this causes a series of compressions and rarefactions in the water. If the bubble is formed from a single pressure pulse instead of a continuous movement, the bubble's resonance frequency f_0 survives longer than other frequencies and produces an audible underwater sound like rain. For large enough bubbles, the resonance frequency depends on the normal pressure P_0 and the average bubble radius R_0, and is given by:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3\gamma P_0}{\rho R_0^2}}$$

where ρ = density of the fluid,
$\gamma = 1.4$ for air bubbles in water.

Boat propellers

If boat propellers rotate too fast, bubbles are formed as a result of cavitation. At a normal pressure of 100 kPa and at room temperature, a water velocity of 14 ms^{-1} is sufficient to result in cavitation. As the bubbles collapse, they produce small shockwaves in the water, which can result in serious damage to the surface of the propeller blades.

Snapping shrimp

Snapping shrimp (prawns) use cavitation to stun and even kill prey. The most distinctive feature of these shrimp is a giant claw which when closed rapidly, makes a loud popping sound. It was believed that sound originated from the claw halves hitting each other, but high-speed video imaging with sound detection revealed that a thin water jet is projected when the claw closes. The jet is fast enough for a cavitation bubble to develop. When the bubble collapses, sound is emitted in the form of a shock wave – with a fatal effect on the prey. Figure 1 shows the size of the bubble as it forms and collapses and Figure 2 shows the corresponding sound emission from the bubble, represented as pressure changes in the water.

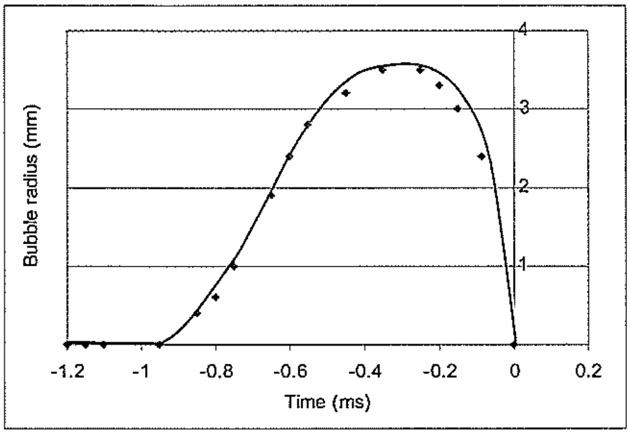

Figure 1. Graph of bubble radius as the bubble forms and collapses over time.

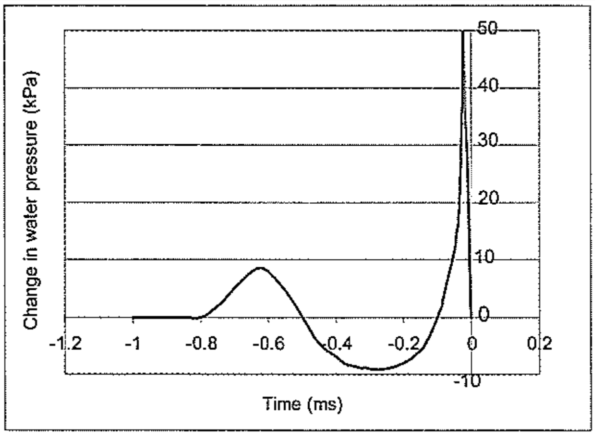

Figure 2. The corresponding sound emission from the bubble, shown as pressure changes in the water over time.

Noise

(a) [7 marks]

(i) Use a diagram to show how cavitation bubbles produce sound.

(ii) Estimate the resonant frequency for spherical water bubbles with a radius of 3 mm. Assume a normal pressure of 100 kPa. Assume that the density of water is 1000 kg m^{-3}.

Boat propellers

(b) [6 marks]

(i) When boat propellers turn, the velocity of water relative to the blades can be assumed to be the same as the speed of the blades. For boat propellers rotating at 300 revolutions per minute, at what distance along the blades from the centre of rotation might you expect cavitation bubbles to start forming?

(ii) What part of boat propeller blades are most likely to suffer damage if cavitation occurs? Explain.

Snapping shrimp

(c) [7 marks]

(i) What is the approximate size of the bubble created by the shrimp's claw?

(ii) How long does it take for a bubble generated by a shrimp to collapse?

(iii) Explain how the snapping shrimp is able to stun or kill its prey through the production of a bubble.

END OF PAPER

Check that you have written your Student Number on the front cover of this booklet.

ACKNOWLEDGEMENTS

SECTION A

Question 8: Anglo–Australian Observatory. (n.d.). [Photograph]. Retrieved June, 2006, from Institute of Astronomy website: http://www.ast.cam.ac.uk/AAO/images/captions/.

SECTION B

Question 3: Reuters. (2005, December 12). *Welsh inventor's 'mosquito' makes noisy teens buzz off.* Retrieved June, 2006, from ABC website: http://www.abc.net.au/news/newsitems/200512/s1520679.htm.

Question 4: Diagram from: Brooklyn College of the City University of New York. (n.d.). *The technology of diesel hybrid-electric buses*. Retrieved June, 2006, from http://acc6.its.brooklyn.cuny.edu/~scintech/hybrid/Technology.html.

Question 6: Adapted from: Sofoulis, N. et al. (Eds). (1994). *Year 12 Physics problems in context*. Perth: Science Teachers' Association of Western Australia.

SECTION C

Question 2: Adapted from: Lohse, D. (2003, February). Bubble puzzles. *Physics Today*, 38–42. Retrieved June, 2006, from http://www.physicstoday.org/pt/vol-56/iss-2/p36.html.

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