Curriculum Council

Tertiary Entrance Examination, 2003

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

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: 593

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	8	8*	100	50%
C Comprehension and Interpretation	2 passages	All	40	20%

* Note that in Section B there is internal choice in one question. For this question only one alternative should be answered. Markers will be instructed to mark only the first attempt among the alternatives (unless clearly cancelled).

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. Jill has a rope tied to a tree on which she swings out over a lake (diagram 1).

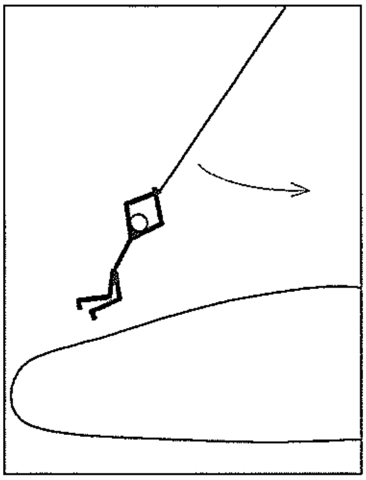


Diagram 1

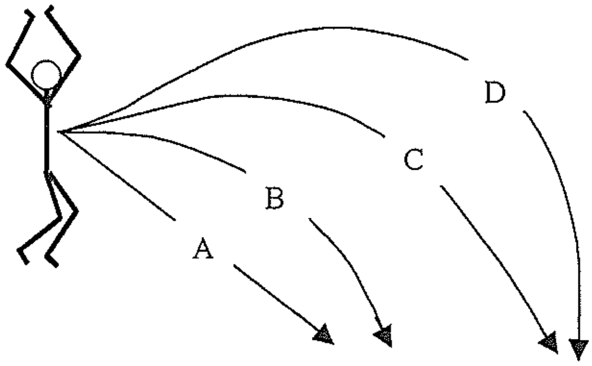


Diagram 2

(a) If she lets go of the rope at the instant it is vertical what will be her subsequent trajectory? Choose A, B, C, or D from diagram 2.

ANSWER __________

(b) What force(s) act on Jill the instant after she lets go of the rope? Choose one or more forces from 1, 2, 3, 4 and 5 (diagram 3).

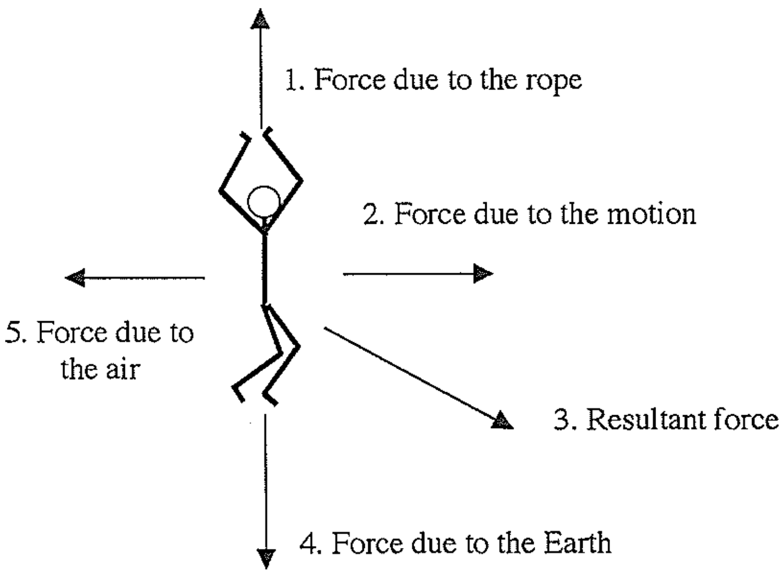


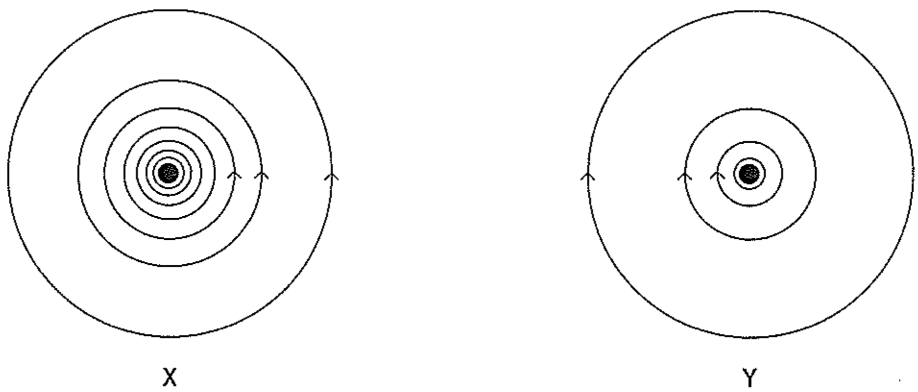
Diagram 3

ANSWER ________

2. An aeroplane is on approach into Perth airport at an altitude of 1000 m and speed of 85.0 m s^{-1}. The tips of the wings of the plane are 30.0 m apart. The flux density of the Earth's magnetic field in Perth is 5.80 x 10^{-6} T and the angle of dip is 66.0°.

Using the vertical component of the Earth's magnetic field calculate the E.M.F. generated in the aeroplane's wings.

3. The magnetic flux associated with two current-carrying conductors, X and Y, is shown in the diagrams.



Which one of the following statements regarding the currents in the two conductors is consistent with the information given?

The current in X is flowing in the:

A. opposite direction to, and is less than the current in Y.

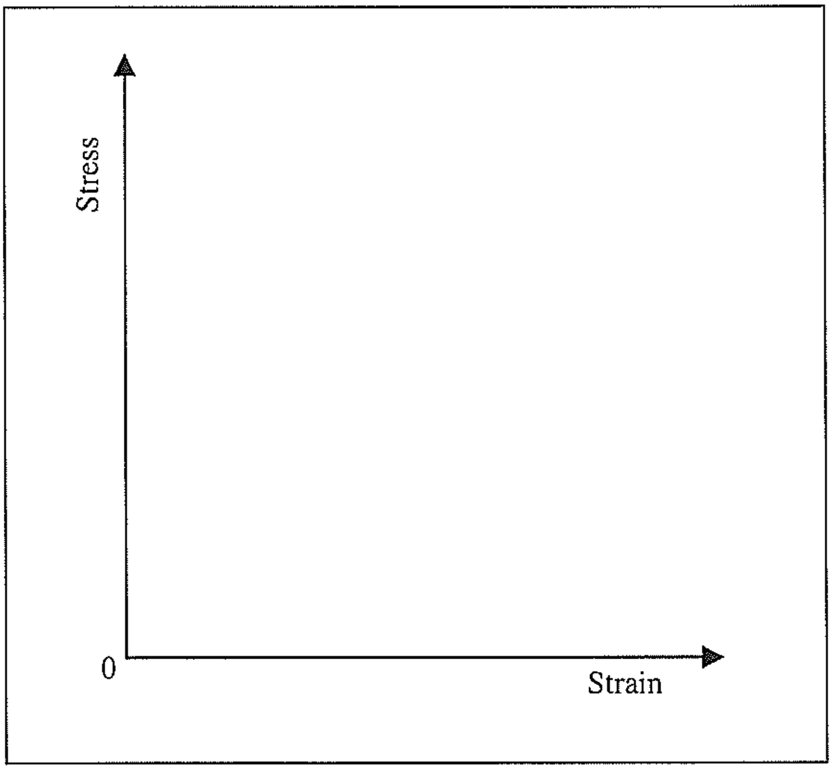
B. same direction as, and is less than the current in Y.

C. opposite direction to, and is greater than the current in Y.

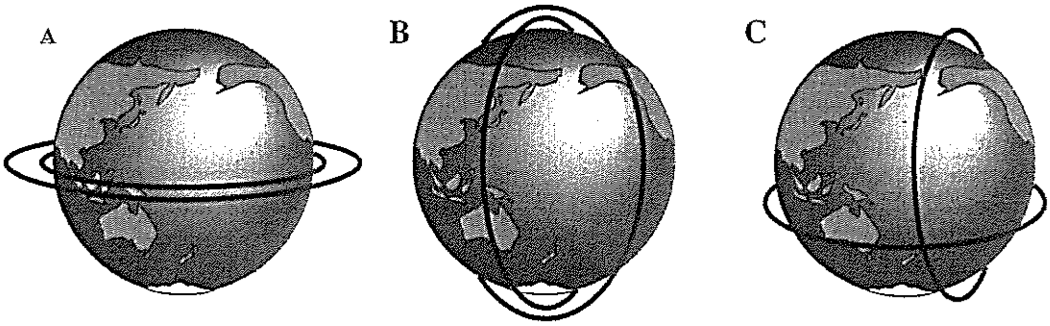
D. same direction as, and is greater than the current in Y.

ANSWER_______

4. Describe the difference between **ductile** and **brittle** materials. Draw a stress-strain graph to illustrate the differences.



5. Satellites orbiting freely around the Earth are sometimes placed in equatorial orbits (diagram A) and sometimes in polar orbits (diagram B). Explain why the orbits in diagram C are physically impossible for satellites.



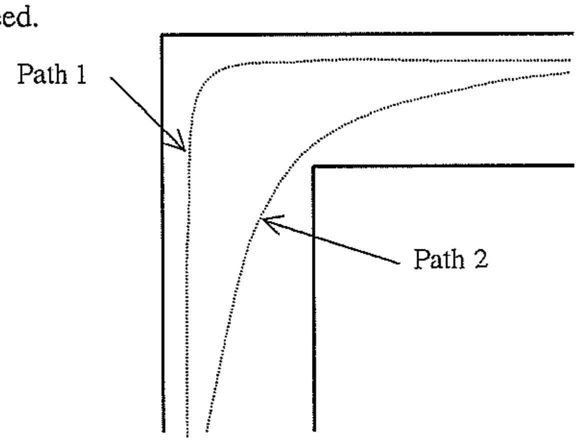
Equatorial orbits different radii

Polar orbits of different orientations and radii

6. In a school experiment to measure the speed of sound a student walks across an oval towards a large flat wall while clapping her hands at a constant rate of 4 claps per second. She hears the direct sound of her clapping as well as the echo off the wall in front of her. She notes that at one point the direct sound and echo seem to be in time with each other. As she moves away from this point they get more and more out of time, but then return to be in time again. She then measures the distance between these two positions and finds that it is 43 m.

What value would she calculate for the speed of sound using these data?

7. Triathlon cyclists riding through the streets prefer path 2 to path 1 when turning around a corner at high speed.



Which of the following statements is the LEAST reasonable physical explanation for the cyclists' preference?

A. For the same frictional force, a cyclist on Path 2 can maintain a higher speed than a cyclist on Path 1.

B. Path 1 has a smaller radius than path 2, resulting in a smaller centripetal force on the cyclist on Path 1.

C. The cyclist on Path 1 has to decelerate and then accelerate much more than the cyclist on path 2, thus requiring more power.

D. Path 2 is shorter than Path 1, so at the same speed a cyclist on Path 2 will take less time.

ANSWER_______

8. A particular organ pipe, open at only one end, has a length of 1.5 m. This tube sustains a standing wave at its third harmonic.

(a) What is the distance between one node and the adjacent antinode?

(b) What is the frequency of the sound heard?

9. A guitar string of length L is stretched tight and waves of speed v can travel down its length. Show how you would derive an expression that represents the lowest frequency of the standing waves produced on the string.

10. An underwater microphone is used to monitor the sound signal from submarines A and B. The following measurements were recorded.

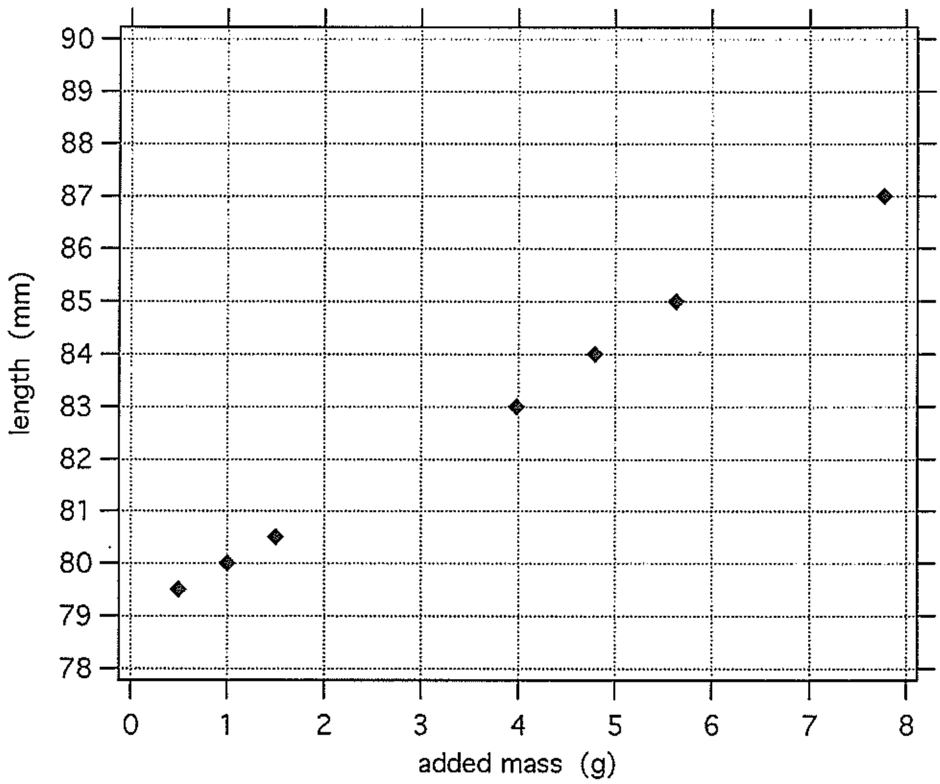
source	*level*
A	22 dB
B	17 dB

Determine $\frac{I_B}{I_A}$ - i.e. the ratio of the intensity of sound from B to the intensity of sound from A.

11. Draw **two** labelled diagrams that clearly illustrate the difference between diffraction and refraction of wave fronts.

12. A gift shop beside a highway contains numerous novelty items suspended on threads from the shop's ceiling. When a large truck rumbles past many items are seen to sway slightly. One item swings wildly and continues for some time after the truck is no longer heard. Explain these observations with reference to the physical principles involved.

13. The following data were collected by measuring the length (in mm) of a piece of spider's thread while varying the mass (in grams) suspended from it. The cross-sectional area of the thread was 4.8×10^{-7} m^2. Sketch a line of best fit to the data and calculate from this Young's modulus for the spider thread.



14. An electron with a speed of 2.0×10^3 m s^{-1} travels through a region with an electric field of 110 V m^{-1} and a magnetic field of 0.5×10^{-4} T.

[*Hint:* Electric field strength is given by $E = \frac{F}{q}$]

(a) What arrangement of the two fields will produce the maximum forces on the electron?

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(b) Which field (electric or magnetic) could produce the largest force on the free electron?

15. Give a brief explanation of the phenomenon of fluorescence. Provide an example from the context you have studied.

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

Attempt **ALL** 8 questions in this section.

Note that Question 8 has alternatives. Follow the directions in this question with care.

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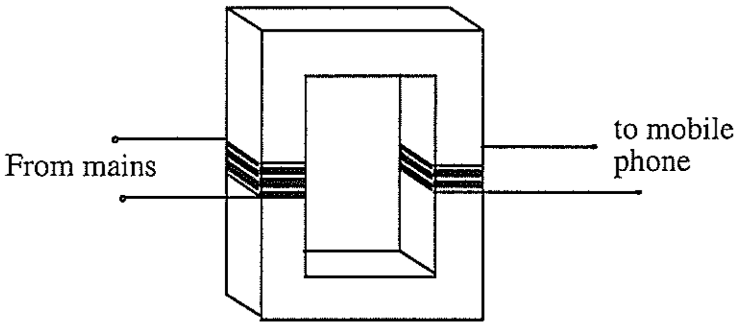
1. [Total 14 marks]

A mobile phone runs on a 3.6 V DC battery or a 3.6 V AC transformer that you are able to plug into the mains power supply (240 V AC). A diagrammatic sketch of the transformer is shown below. The primary coil of the transformer has 2000 turns and the transformer is 75% efficient.



(a) A current of 335 mA is required in the secondary coil to operate the phone. What is the power output of the transformer?

[3 marks]

(b) What power is supplied to the transformer from the mains?

[3 marks]

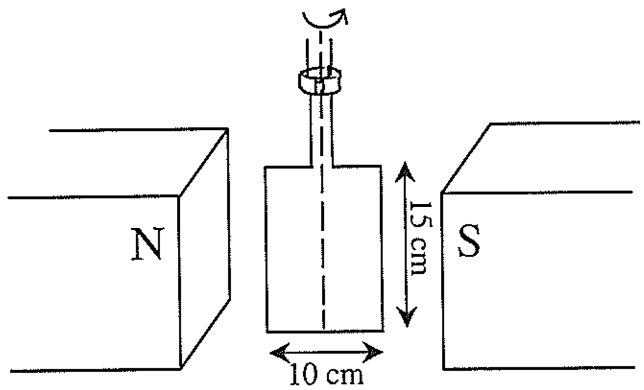
(c) What is the current in the primary coil?

[4 marks]

(d) Give **two** reasons that may account for the reduction in efficiency of the transformer. [4 marks]

2. [Total 11 marks]

In the diagram below we have a simple motor consisting of a single rectangular coil of 40 turns and dimensions 10 x 15 cm, carrying a current of 1.5 A. It is suspended in the centre of a uniform magnetic field of 1.2 T and is fed current through a split-ring commutator.



(a) Calculate the torque when the coil is: [6 marks]

(i) parallel to the magnetic field.

(ii) at right angles to the magnetic field.

Q2 cont.

(iii) at 45° to the magnetic field.

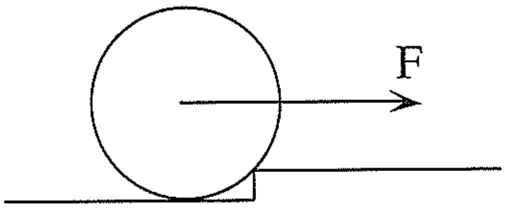
(b) [5 marks]

(i) Explain why the arrangement shown in the diagram would not result in a smooth rotation of the coil.

(ii) Give an example of **one** modification that could be made to make the rotation of the coil smoother AND explain why this would do so.

3. [Total 13 marks]

A gardener is pulling a heavy garden roller up a rough concrete step as shown below in the diagram. The wheel has a mass of 22 kg and a radius of 1.0 m. The step is 0.40 m high.



(a) What initial force is just sufficient to turn the wheel so that it will rise over the step?

[5 marks]

(b) Explain what happens to the size of this horizontal force as the wheel rises.

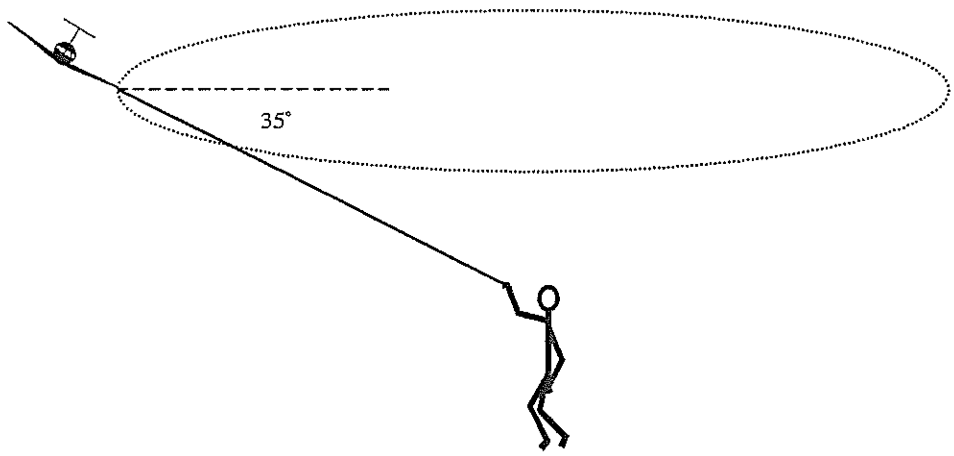
[4 marks]

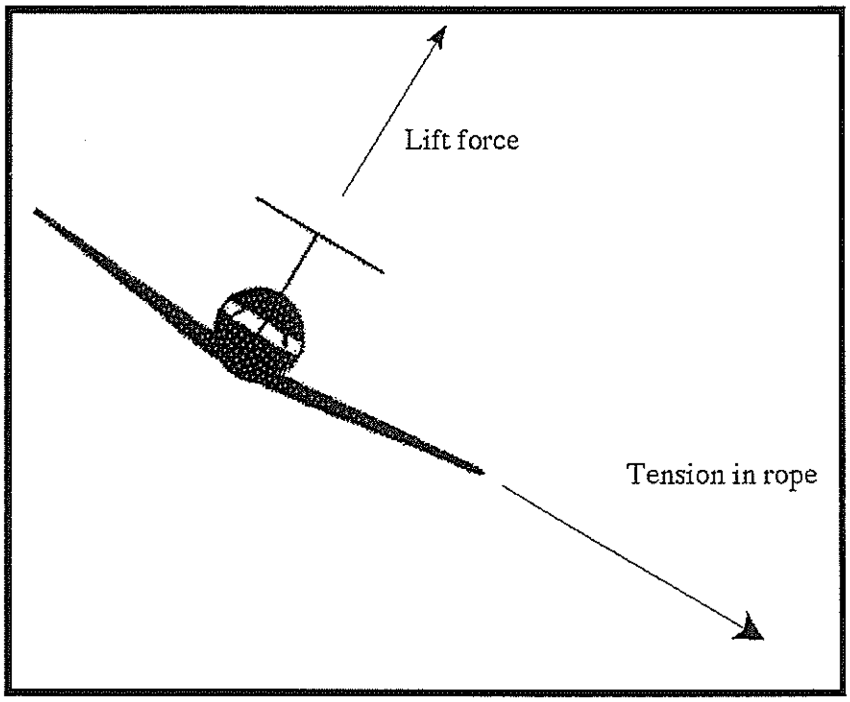
(c) The gardener decides to pull the wheel at an angle of 20° above the horizontal. Is there an advantage to doing this? Explain, using a clearly labelled diagram.

[4 marks]

4. [Total 12 marks]

The diagram below shows a person holding a model aeroplane in horizontal circular motion by a light rope, which is at an angle of 35° to the horizontal.





(a) If the tension in the rope is 22 N and the lift force perpendicular to the wings of the model aeroplane is 34 N, what centripetal force keeps the plane in circular motion?

[4 marks]

(b) What is the mass of the model aeroplane?

[4 marks]

(c) What will be the speed of the model aeroplane if it moves in a circle with a radius of 15 m?

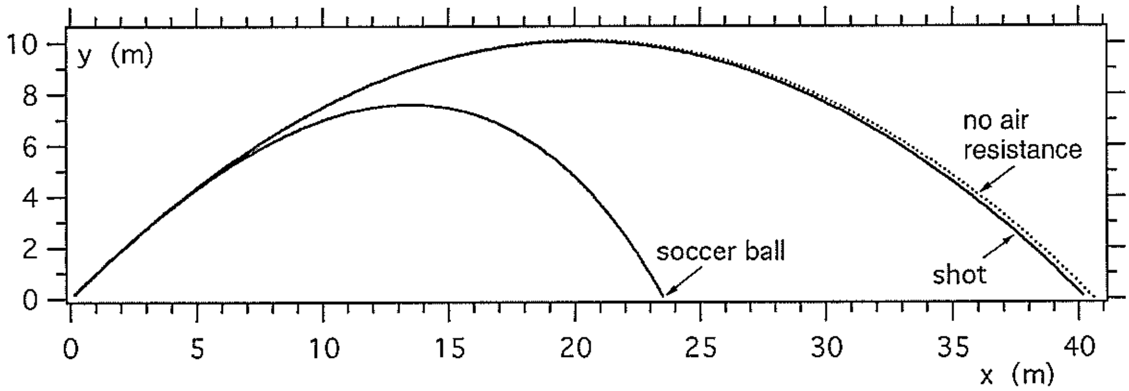
[4 marks]

5. [Total 13 marks]

The masses and diameters of a soccer ball and a shot are shown below. (A shot is a steel ball used in athletic events.)

	Mass (kg)	Diameter (cm)
Soccer ball	0.50	25
Shot	7.0	12

The following diagram shows the trajectories of a soccer ball and a shot projected into the air at the same initial speed and angle (45°). The **dotted line** shows the **calculated** trajectory if air resistance is ignored.



The theoretical range of a projectile is 40.7 m (no air resistance), whereas the actual ranges are 40.6 m for the shot and 23.9 m for the soccer ball. Assume no spin for either object.

(a) When both balls are projected with the same speed, what causes the air resistance on the soccer ball to be greater than the air resistance on the shot?

[4 marks]

(b) Explain why the range of the soccer ball is less than the range of the shot. [Hint: there are **two** physical reasons].

[4 marks]

(c) Calculate the launch speed of either object.

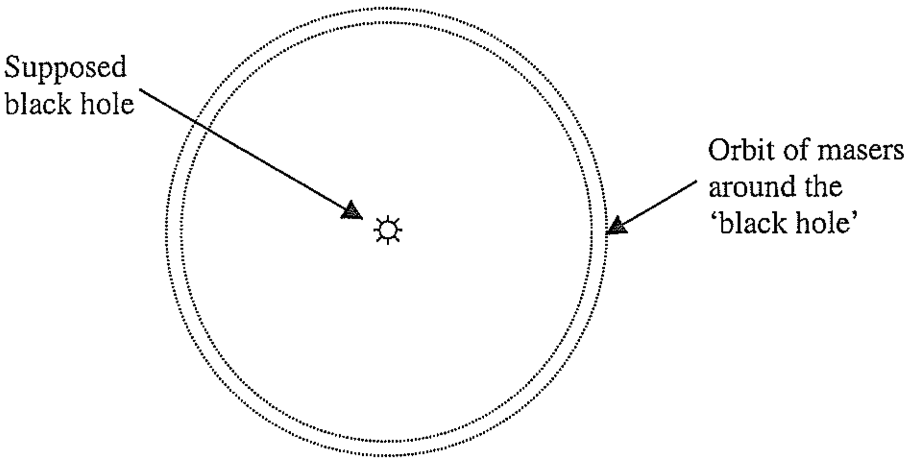
[5 marks]

6. [Total 12 marks]

Black holes are very small, extremely dense stellar objects, with gravitational fields so large that not even light can escape from them. Hence we cannot see them directly with any sort of telescope.

Astronomers using radiotelescopes have observed **masers** in space. These are rotating disks of small molecules that amplify background microwave radiation. The masers appear to be orbiting nothing. Since this is impossible, astronomers believe that there is a black hole at the centre of the orbit.

One such series of masers orbits a predicted black hole at a radius of about 2.5 light-years (2.4×10^{11} km) and with a period of about 6×10^{8} s.



(a) Calculate the mass of the black hole at the centre of the orbit.

[4 marks]

(b) Calculate the centripetal acceleration of the masers (i.e. the gravitational field strength at the distance of 2.4×10^{11} km from the centre of the black hole).

[4 marks]

(c) Since gravitational field strength, g, is inversely proportional to the square of the distance from the centre of an object, calculate g at the edge of the black hole, assuming it has a radius of 1000 m.

[4 marks]

7. [Total 16 marks]

Consider a hypothetical single electron atom for which the electron can only occupy one of three energy levels:

-1.2 eV, -2.8 eV and -5.0 eV

where 0 eV corresponds to a "free" electron (ie: ionised atom).

(a) Sketch an energy level diagram showing the atom's energy levels as well as that of a free electron.

[4 marks]

(b) How much energy (in joules) is required to ionise the atom in its ground state?

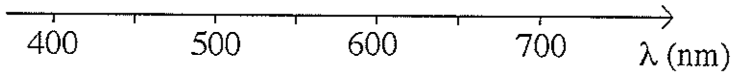
[4 marks]

(c) Calculate the wavelengths of the lines in the absorption spectrum.

[4 marks]

(d) Describe and sketch the **visible** part (400 nm to 700 nm) of the absorption spectrum.

[4 marks]

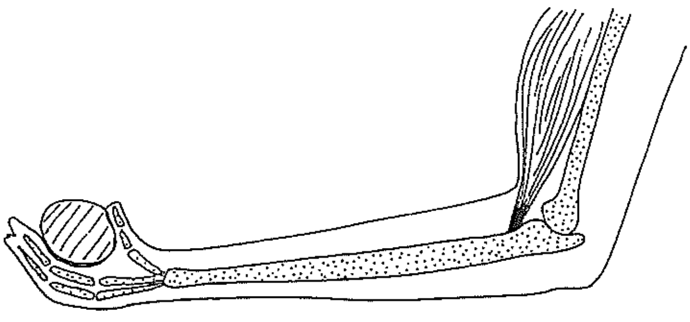


8. [Total 9 marks]

Answer ONLY ONE of the following (8A OR 8B), depending on the context you have studied:

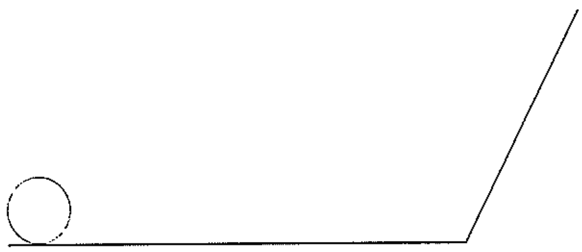
EITHER: *Context - Human and animal frames*

8A. The diagram below shows the position of bones and muscle in a person's arm as they hold a heavy object.



(i) On the schematic diagram of the arm below, draw in all relevant forces acting on the **lower** arm.

[4 marks]

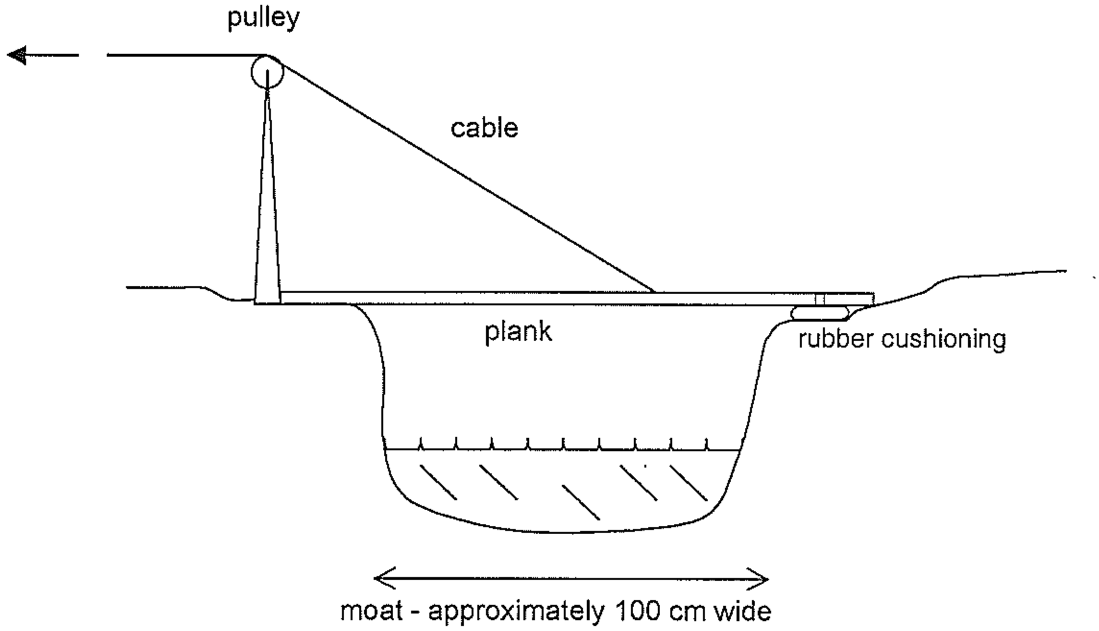


(ii) If the object has a mass of 4.0 kg, estimate the force that must be exerted by the muscle on the bone to hold the lower arm horizontal. Use your own arm as a model and don't forget that it has mass. State any assumptions that you make in working out an answer. As a guide, this page is 21 cm wide.

[5 marks]

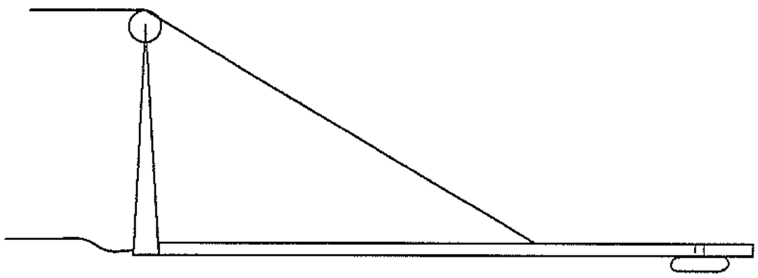
OR: *Context - Bridges and buildings* Don't answer this if you answered 8A.

8B An engineer planning a children's playground designs a drawbridge to cross a 100 cm wide (approximately) moat. The bridge is an 8.0 kg uniform plank with a piece of rubber cushioning, of mass 2.5 kg, at one end. Children are to raise the bridge by pulling on a single cable that runs over a pulley that is about waist high for a 10 year-old. The plank pivots about the base of the pulley support when it is raised or lowered. The cable is to be attached about two-thirds of the distance along the plank from the base of the pulley support.



(i) In the space below, complete the diagram showing all relevant forces acting on the **plank** when the cable is pulled.

[4 marks]



Q8b cont.

(ii) Estimate the force that a child must exert on the cable to start raising the drawbridge. State any assumptions that you make in working out an answer.

[5 marks]

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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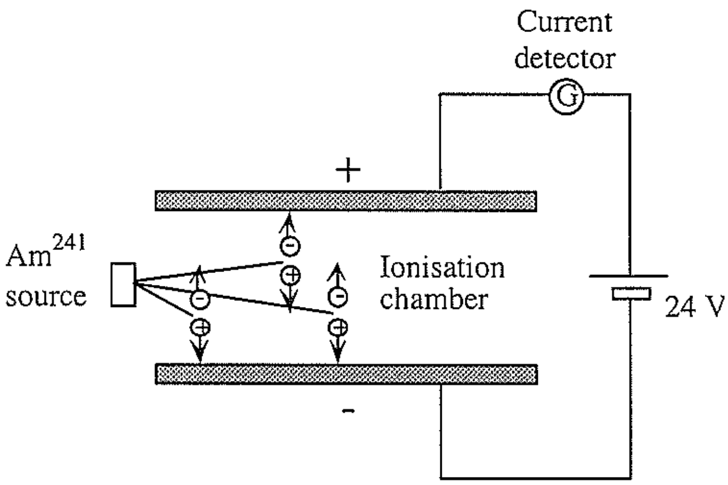
1 IONISATION SMOKE DETECTORS [Total 20 marks]

(Paragraph 1)
The vital ingredient of most household smoke detectors is a very small quantity of americium-241 (Am-241) with a half-life of 432 years. One gram of americium oxide provides enough active material for more than 5000 household smoke detectors.

(Paragraph 2)
Americium-241 emits alpha particles and low energy gamma rays. The alpha particles are absorbed within the detector, while most of the gamma rays escape harmlessly. The americium is present in oxide form in the detector. The alpha particles emitted by the Am-241 collide, in the detector's ionisation chamber, with the oxygen and nitrogen in air to produce charged particles called ions. A low-level electric voltage applied across the chamber is used to collect these ions, causing a steady small electric current to flow between two electrodes. When smoke enters the space between the electrodes, the alpha radiation is absorbed by smoke particles. This causes the rate of ionisation of the air and therefore the electric current to fall, which sets off an alarm.



Schematic diagram of detector operation.

(Paragraph 3)
Product Description from a commercial website:

ZF11 24V Ionisation Smoke Detector
An automatic detector which responds to the presence of hot smoke in the chamber which triggers an ionisation monitoring current.

Specifications

Detector Principle	Ionisation Chamber
Nominal Voltage	24 V DC
Current Consumption (no smoke, no alarm):	30 to 45 μA at 24 V.
Current Consumption (alarm sounding):	52 mA
Alarm Indicator	Red light emitting diode (LED)
Construction:	Polycarbonate V-O rated to UL 94 housing with stainless steel terminals.
Mass	102 grams.
Dimensions (Approx)	100 mm (diameter) x 42 mm
Operating Environment	-20°C to +60°C

[Alert Electrical Wholesalers Limited website]

(a) Outline briefly the physical process by which the radioactive source creates ions in the air in the detector.

[4 marks]

(b) In a reported incident, a smoke detector malfunctioned when a strong bar magnet was placed nearby. Using an appropriate diagram suggest a possible physical explanation for this failure.

[4 marks]

(c) In the absence of smoke in the detector, the ionisation caused by the decay of the americium-241 produces a few 10's of pico-amperes. This is only a small fraction of the quoted specifications under these conditions. Suggest a reason to account for this.

[4 marks]

(d) The smoke detector is powered by a 24 V battery which has been charged to store 0.020 kW-hours of energy. In the absence of any fire, how often should the battery be changed? (i.e. how long will it take for the battery to go flat?)

[4 marks]

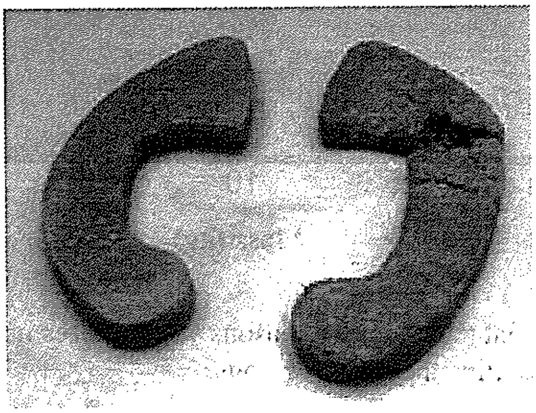
(e) When the presence of smoke sets off the alarm a sound is produced. At one metre from the detector the sound pressure level is 80 dB above the threshold of human hearing. People only a short distance away have been found to sleep through the sound of a fire alarm. Estimate the sound level at a distance of 15 m from this smoke detector alarm.

[4 marks]

2 LONG JUMPING IN THE ANCIENT OLYMPICS [Total 20 marks]

(Paragraph 1)
Long jump has been featured in the Olympics since 708 BC, but as vase paintings in the top photograph show, there is an interesting difference between the way ancient athletes performed their jumps and the way modern ones do. Ancient Olympians took off holding *halteres,* or jumping weights (see photograph 2). The weights, made of stone or lead, improved a jumper's performance.

Photograph 1



Photograph 2

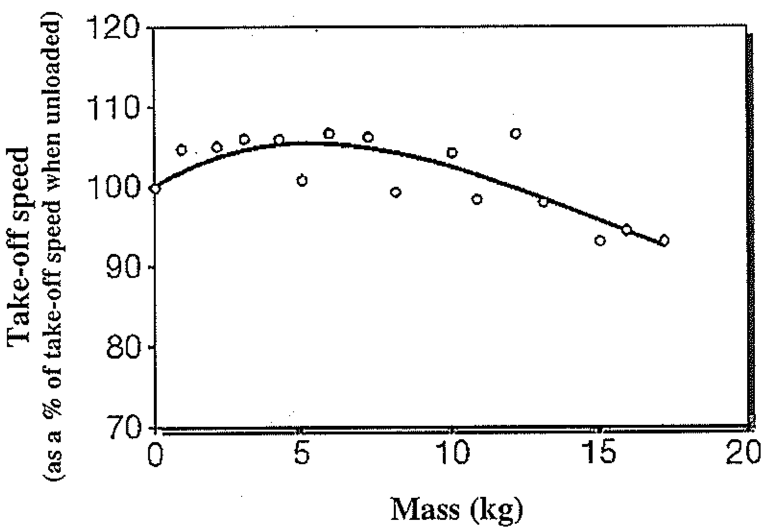
(Paragraph 2)
One key to understanding the improvement is the relationship between the jumpers' feet and their centre of mass. Before take-off, they hold the halteres extended backward. At take-off, the jumper swings the halteres forward and up. The centre of mass of the weighted jumper is therefore further forward and higher than it would be without the halteres. As the jumper prepares to land, the halteres are swung down and backward so that, on landing, the feet of the weighted jumper are further forward of the centre of mass than they are for modern unweighted athletes.

(Paragraph 3)
Because the initial position and velocity of the centre of mass of an object determines its subsequent trajectory, halteres should improve the jump distance, provided that their extra weight does not excessively reduce the take-off speed. Two physicists, Alberto Mignetti and Luca Ardigó, at Manchester Metropolitan University in England, have analysed this effect using both human subjects and computer simulations.

Q2 cont.

(Paragraph 4)
They found that for an unchanged take-off speed, an athlete carrying two 3-kg halteres and swinging them first forward and then back could improve their jump distance by 6%. They also found that takeoff speed actually *increased* by 5-7% when jumpers were loaded with halteres within a specific weight range (see graph). The greater take-off speed led to increases in distance beyond those generated by using the halteres to shift the feet relative to the centre of mass. Minetti's explanation is that moderately loaded muscles can exert greater force than unloaded muscles, thus generating increased power.

Graph of take-off speed vs mass of haltere



(a) The article suggests that there are two reasons why halteres improved the performance of the athletes. Briefly outline these **two** reasons.

[4 marks]

(b) Sketch one or two **labelled** diagrams to illustrate how an athlete carrying halteres can use them to change the position of his/her centre of mass. Use simple stick figures if you wish.

[4 marks]

(c) What does the graph suggest was the likely mass of the halteres used by ancient athletes? Explain your answer.

[4 marks]

(d) Suppose that a 76 kg athlete carries two 12 kg halteres. For a running take-off, the athlete is effectively on one leg with 90% of his mass above that leg.

(i) Determine the percentage increase in stress on the leg bone compared with a take-off without halteres.

[4 marks]

(ii) During the jump, the athlete swings the halteres in a vertical semicircle of radius 75 cm and with a speed of 6.2 m s^{-1}. What force must he exert on each haltere at the lowest point of its swing so that he doesn't drop them?

[4 marks]

END OF PAPER

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

ACKNOWLEDGEMENTS

SECTION A

Question 5: Parham, R. (1998). *Applications for senior secondary physics.* Adelaide: South Australian Science Teachers' Association, p. 18.

SECTION C

Question 1: Adapted from: *Product catalogue*. (n.d.). Retrieved 2003 from http://www.alertelectrical.com/product.asp?typeID=31&subID=0&prodID=456

Question 2: Minetti, A. E., & Ardigo, L.P. (2002). Biomechanics: Halteres used in ancient Olympic long jump. *Nature*, *420*, 141–142.

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