Curriculum Council
Government of Western Australia

WACE
Western Australian Certificate of Education

Tertiary Entrance Examination, 2007

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, Constants and Data 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.

Structure of this paper

Section	Number of questions	Number of questions to be attempted	Marks available
A Short Answers	15	All	60
B Problem Solving	7	All	100
C Comprehension and Interpretation	2	All	40

Instructions to candidates

1. The rules for the conduct of Western Australian external examination are detailed in the *TEE/WACE 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, Constants and Data 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 you arrived at your final answer. 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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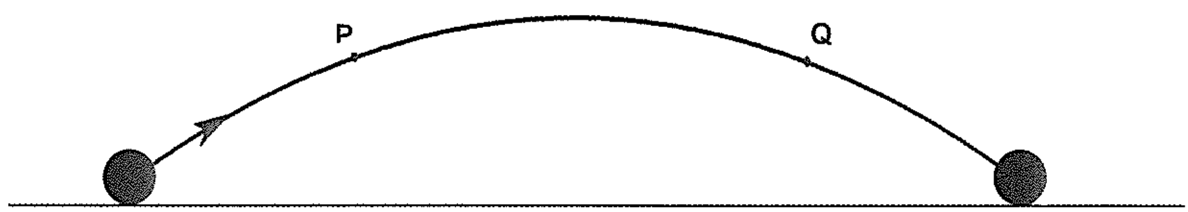
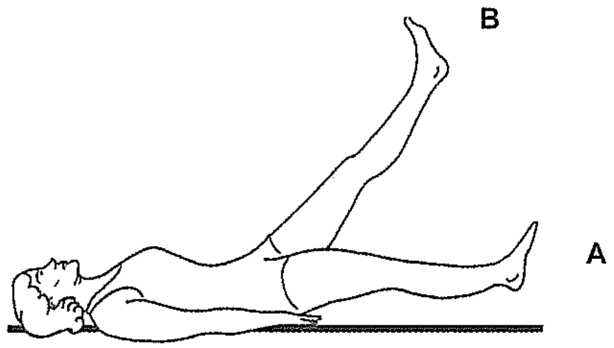
1. The diagram shows the trajectory of a golf ball (ignoring air resistance). The golf ball moves from left to right, as shown in the diagram.



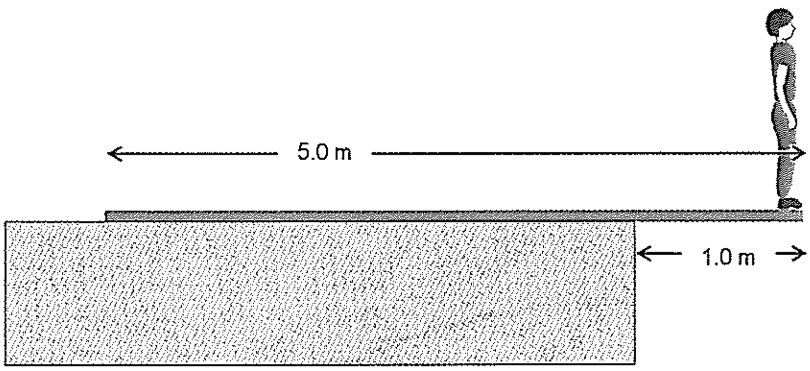
(a) With dotted arrows (like this - - - - - ->), show the direction of the resultant **velocity** of the ball at positions P and Q.

(b) With solid arrows (like this ———→), show the direction of the resultant **acceleration** of the ball at positions P and Q.

2. An exercise for strengthening muscles is illustrated below. Explain why it is much harder to hold your leg still in position A than it is to hold it still in position B. Use the diagram to assist your explanation.

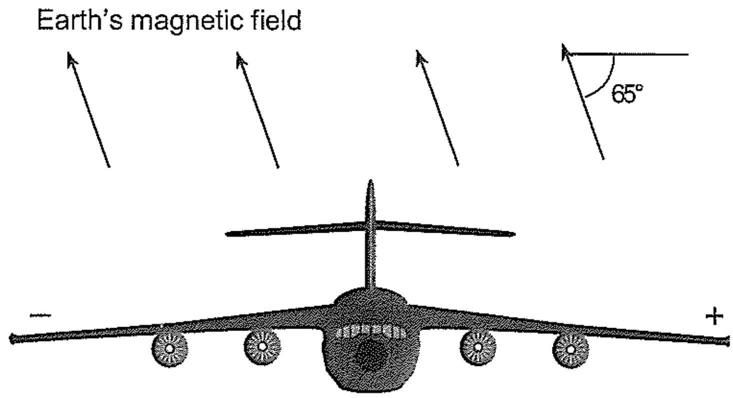


3. A boy stands on the end of a rigid uniform plank lying on a brick wall. Estimate the minimum mass of the plank. Justify your answer.



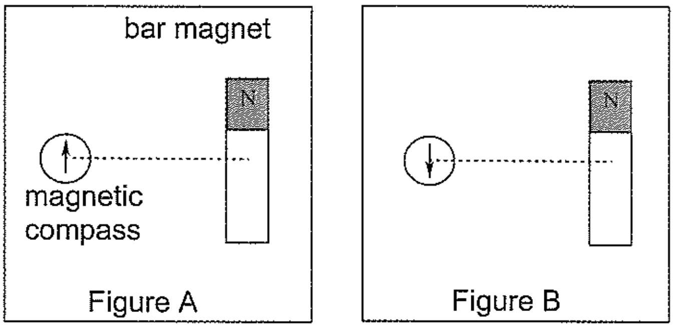
4. The Global Positioning System enables users with GPS sets to determine their position on the surface of the Earth with great accuracy. The satellites that form the Global Positioning System orbit the Earth at an average altitude of about 2.0×10^4 km, every 12 hours. What is the speed of a typical GPS satellite?

5. An aeroplane is flying across Australia. The Earth's magnetic field, which acts at 65° to the horizontal and has a strength of 2.70×10^{-5} T, induces an emf between the wingtips of the aeroplane as shown below.



The aeroplane has a wingspan (distance from wingtip to wingtip) of 59.5 m and has a speed of 270 m s^{-1}. Calculate the emf induced.

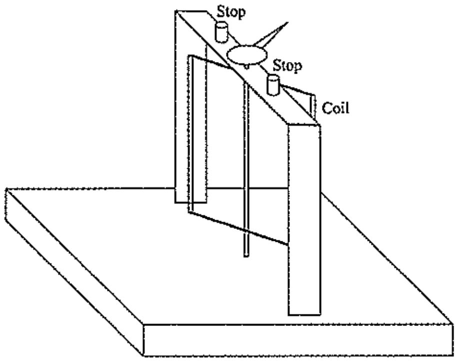
6. Figures A and B below show two different configurations of a magnetic compass and a bar magnet lying together on a flat table.



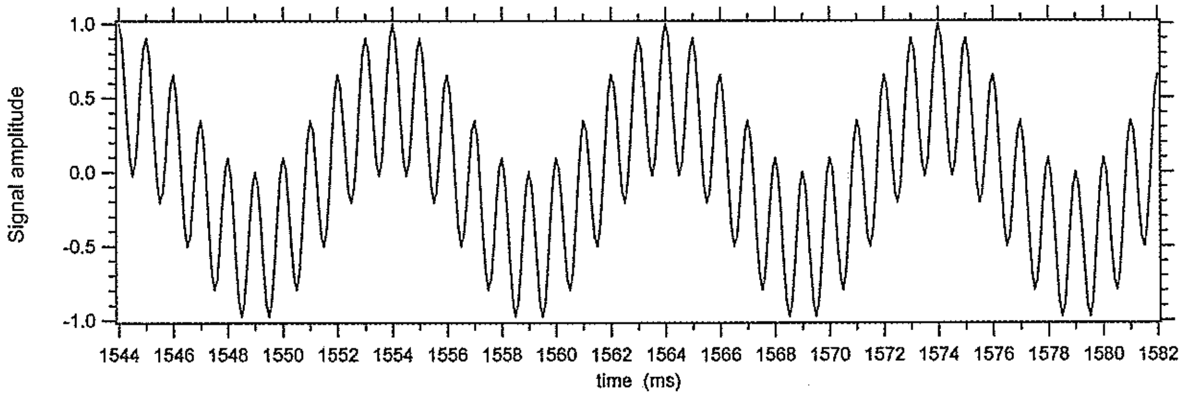
(a) Ignoring any effects due to the Earth's magnetic field, which of the two figures (A or B) correctly shows the direction of the compass needle?

(b) Explain carefully the reasons for your choice.

7. At the equator, the Earth's magnetic field is horizontal and has a magnetic field strength of 1.2×10^{-5} T. A square coil of wire with a side length of 30.0 cm is mounted vertically (as shown below) and rotated through 180°. What magnetic flux is cut?



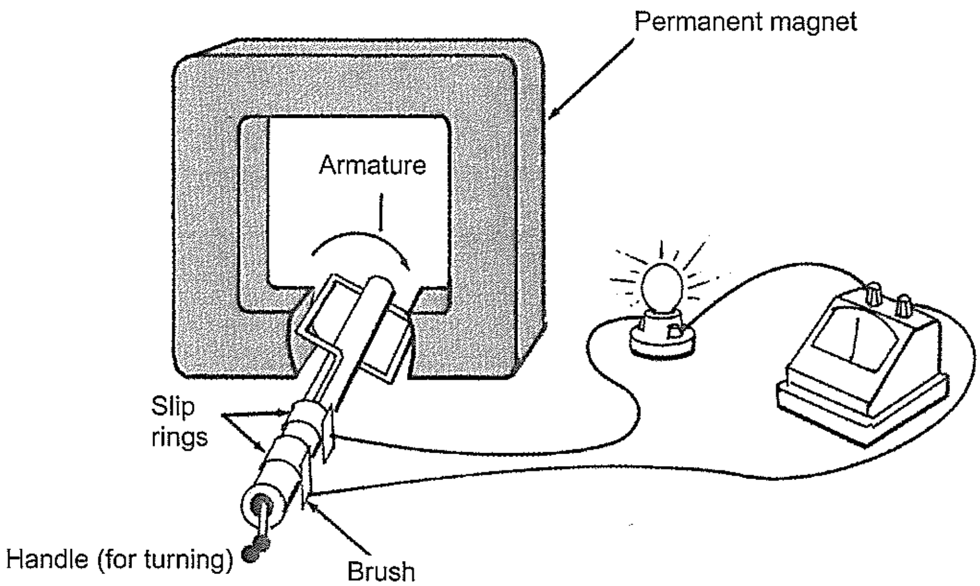
8. The following oscilloscope trace shows the superposition of two waves. The horizontal axis is in milliseconds.



Calculate the frequency of each wave.

9. Light is said to exhibit a dual nature, behaving as both a wave and a particle. From a context you have studied, describe two phenomena, one of which demonstrates light showing wave-like behaviour, and one that demonstrates light showing particle-like behaviour.

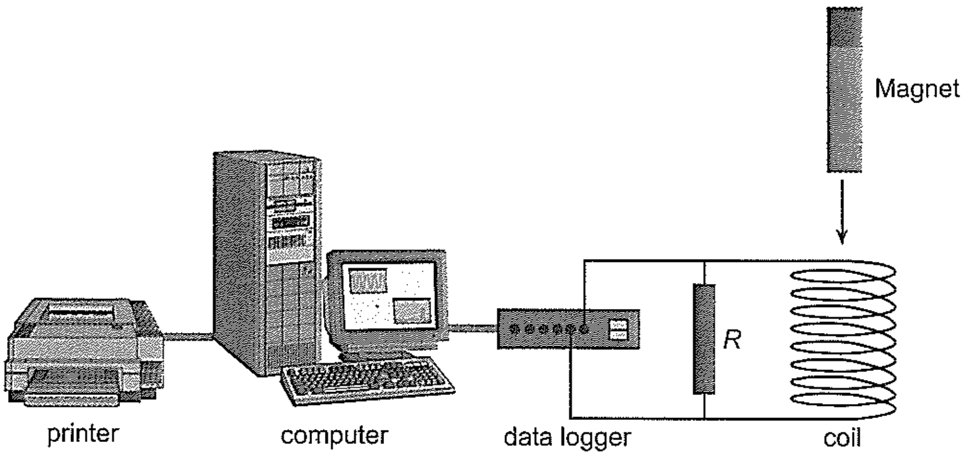
10. The apparatus shown below represents a common classroom demonstration.



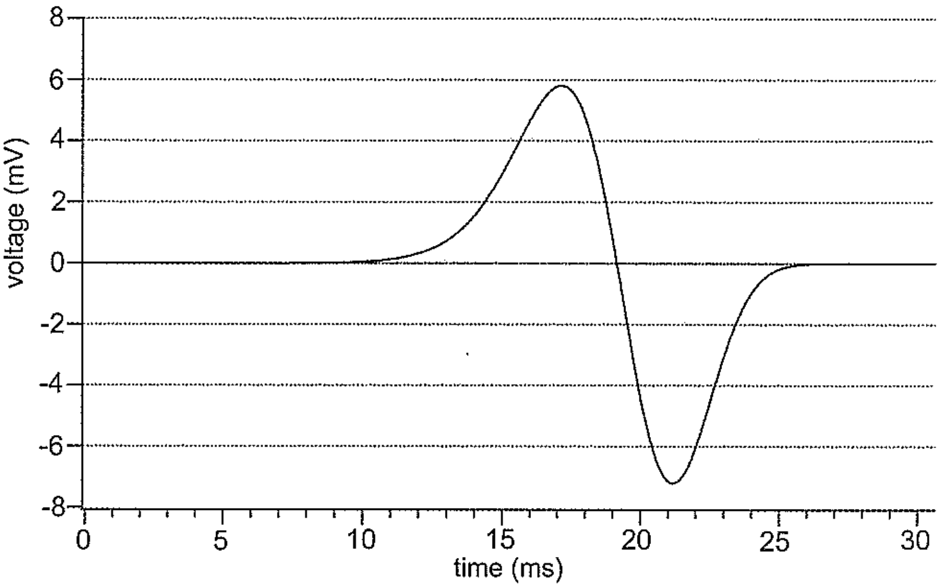
(a) What particular device is being demonstrated?

(b) Justify your answer to (a) in terms of two features of the apparatus.

11. A classroom demonstration is shown below. A coil is connected to a resistor *R*. The emf generated in the coil is recorded by a data logger connected across the ends of the resistor.



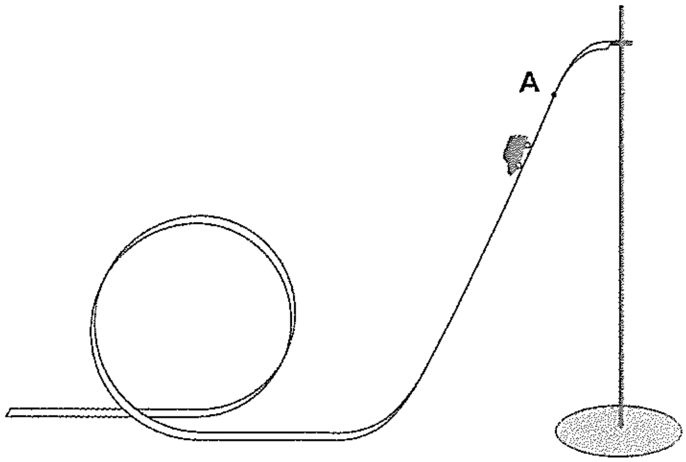
These data are processed to produce a graph that shows emf versus time when a bar magnet is dropped so that it falls freely through the coil.



(a) Explain why the generated emf reverses.

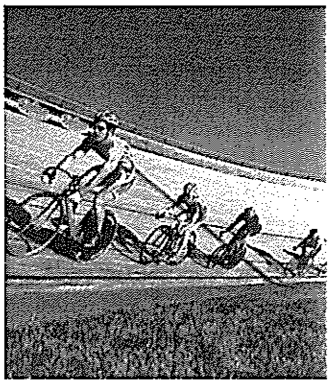
(b) Explain why the magnitude of second peak (–7.2 mV) is greater than the magnitude of the first peak (+5.8 mV).

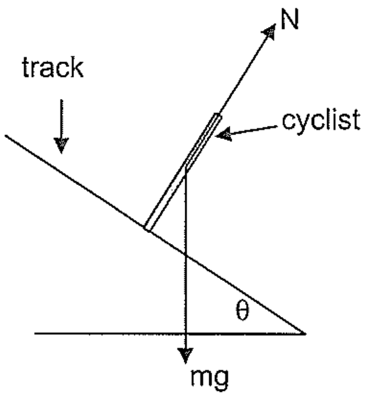
12. The diagram below shows a toy car doing a 'loop the loop'. The car **just remains in contact** with the track at the top of the circle. The loop has a radius of 0.4 m.
If the car starts from rest at point A, what is the height of A above the ground?
You should ignore any effects due to friction. Hint: Apply the principle of conservation of energy.



13. A low-pressure sodium lamp emits light of wavelength 590 nm and has a power rating of 130 W. If the lamp is 85% efficient, how many 590 nm photons are emitted every second?

14. A velodrome is an oval-shaped cycle track, parts of which are steeply banked. The riders in the picture are travelling at 15.5 m s^{-1}, the radius of curvature of the banked track is 35 m and there is no tendency for the bikes to slide up or down the slope. Calculate the angle of bank, θ.





15. An electric saw motor running at a normal speed draws a relatively small current. However, if the saw jams, preventing the motor shaft from turning, the current increases dramatically and the motor can overheat. Explain why the current increases so much.

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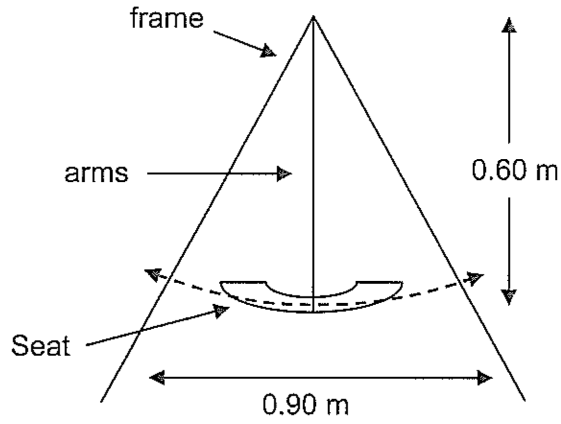
SECTION B: Problem Solving (100 Marks)

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

1. (13 marks)

The picture below shows an electronic baby-swing consisting of a metal and plastic (PVC) frame and a seat suspended from the frame by two arms made from PVC plastic. The baby is placed in the seat of the swing and an electric motor moves the swing to and fro. The line diagram is a side view showing dimensions.



Side view

(a) The seat and its arms have a mass of 3.0 kg. If a baby of mass 3.6 kg is placed in the seat, what is the tension in each arm of the swing when the swing is **at rest**?

(3 marks)

(b) The swing moves through a distance of 0.90 m in 1.6 s. What is the centripetal acceleration of the swing at its lowest point, as shown in the diagram?

(3 marks)

(c) What is the tension in each arm of the swing when it is in motion and at its lowest point?
(3 marks)

(d) The manufacturers recommend that the maximum mass of a child to be placed in the swing be 10 kg. If a 15 kg child is placed in the swing, and the swing is set in motion, is it likely that the arms of the swing will break, due to tension? Justify your answer.

Useful information:

diameter of swing arm = 1.50 cm
breaking stress = 55 x10^6 Pa

(4 marks)

2. (17 marks)

An underground electric power cable contains three identical metal conductors separated by insulating layers. The resistance of 10.0 m of a single conductor is measured to be $1.74 \times 10^{-5}\ \Omega$. The cable delivers 240 V AC power to households through two of the conductors.

(a) What is the purpose of the third conductor?

(2 marks)

(b) If the total power drawn is 346 kW, how much current flows through the cable?

(3 marks)

(c) The total length of the cable is 543 m. How much power is lost as heat in the cable?

(4 marks)

(d) Describe the structure, including the turns ratio, of a transformer that could be used to change the voltage from 66 kV to 240 V. Draw a diagram if it will help your description.

(5 marks)

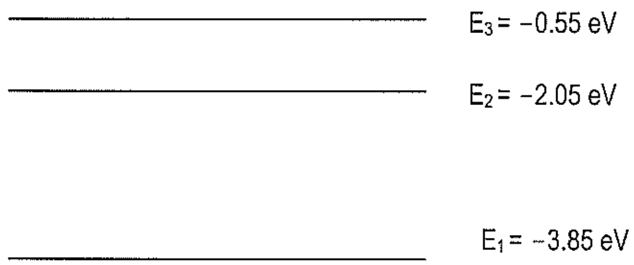
(e) Electric power is transported over large distances at high voltages (e.g. 66 kV) rather than at 240 V. Explain why.

(3 marks)

3. (15 marks)

The colour of many corals is due to fluorescent proteins. Stony coral contains the protein P-620, and when exposed to ultraviolet light, it glows with a particularly bright colour. People with aquariums that contain living coral use lamps that emit UV light to ensure that the coral is always coloured.

A partial energy level diagram for P-620 is shown below:



(a) Calculate the wavelength of the ultraviolet light needed to cause this effect.

(4 marks)

(b) Calculate the wavelength of the **emission line** with the shorter wavelength and hence determine the colour of stony coral under UV light.

(5 marks)

colour	*wavelength* (nm)
red	700
orange	620
yellow	560
green	515
blue	470
indigo	440
violet	410

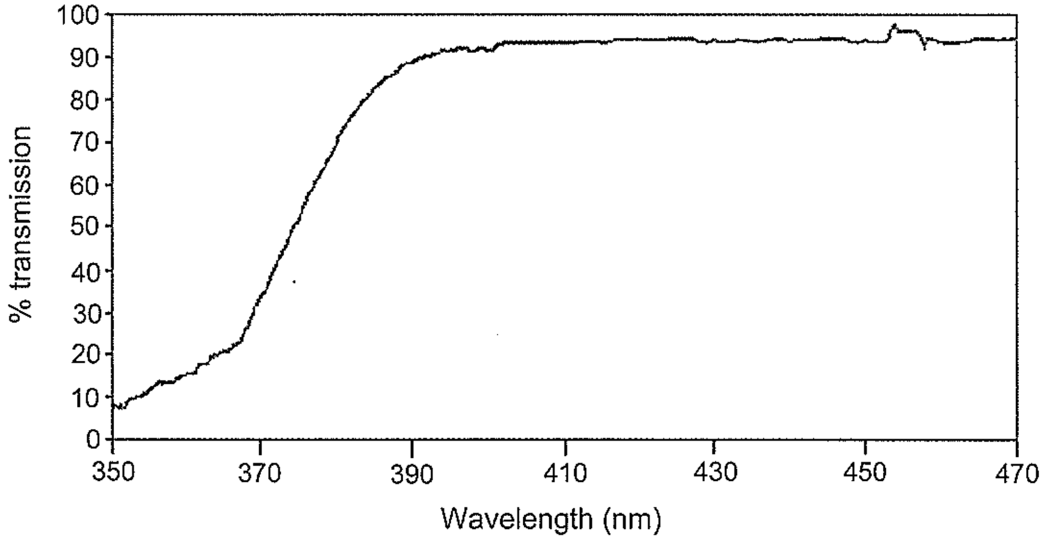
(c) Many of the UV lamps sold to aquarium owners have acrylic-coated safety covers, designed to shield people from the more dangerous forms of UV radiation.

(6 marks)

(i) Why is UV radiation considered harmful to humans?

(ii) The following graph shows the transmission properties of an acrylic-coated safety cover. At least 50% transmission is needed for enough UV light to illuminate coral in an aquarium.

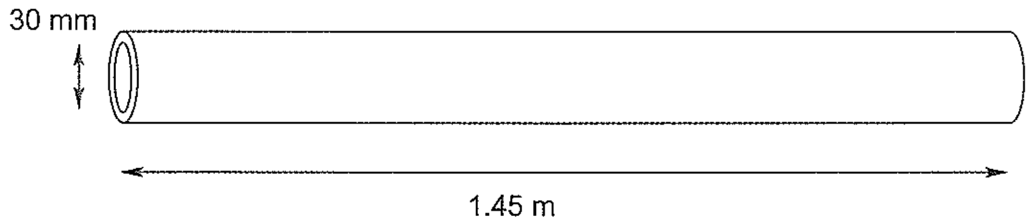
Transmission of UV-A Radiation by an Acrylic 'Safety Coating'



Determine the percentage transmission of the particular UV light that can cause stony coral to fluoresce, and hence explain whether or not this material would be a suitable cover for an aquarium lamp if the owner wanted stony coral to fluoresce.

4. (14 marks)

A didgeridoo is a wooden musical instrument shaped like a hollow straight tube. The sound is produced when the player blows into one end through a mouthpiece moulded with beeswax. To investigate the sound of such an instrument, some students are given a uniform hollow plastic tube with length 1.45 m and internal diameter 30.0 mm.



(a) Assume that the tube is a vibrating air column **open at both ends** and filled with dry air at 25°C. What is the expected fundamental frequency?

(3 marks)

(b) One of the students realises that when it is played, the didgeridoo will be filled with air from the lungs of the player, which would be at 37°C with water vapour and carbon dioxide present. The speed of sound in a gas depends on the temperature T (in degrees Celsius) and the molar mass *M* (in kg) according to the formula:

(5 marks)

$$\text{speed} = 3.41 \times \sqrt{\frac{(273 + T)}{M}} \qquad \text{(SI units)}$$

Expired air from the lungs has a molar mass of approximately 0.0296 kg.

Calculate the speed of sound in the tube and hence the fundamental frequency in this case.

(c) The students recorded the sound from the tube when played by an experienced didgeridoo player. They found the fundamental frequency was 88 Hz, which was well below what they had expected. One of the students thought that the mouth, throat and lungs of the player might have increased the effective resonant length, thus causing the lower frequency.

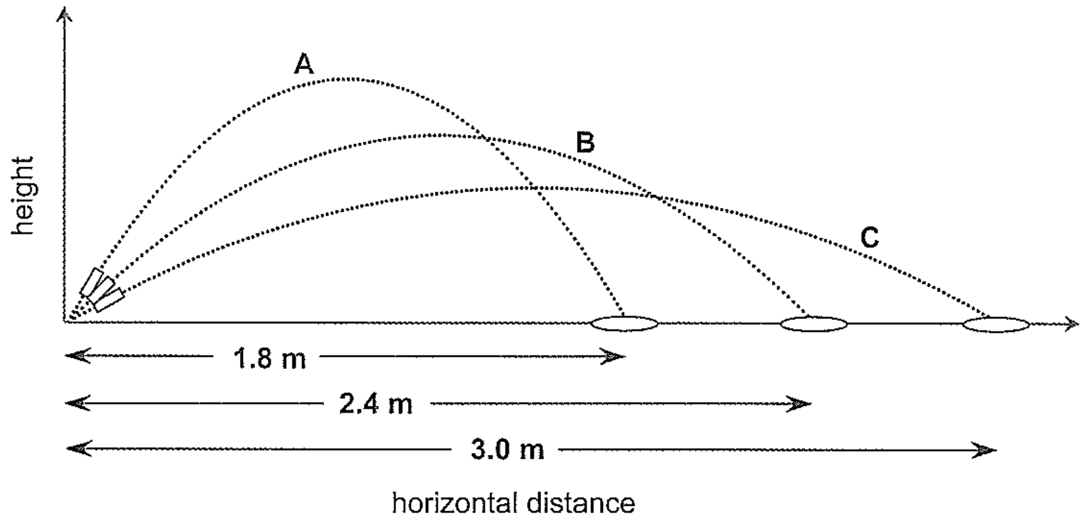
(6 marks)

(i) What extra length would be required to account for the measured frequency?

(ii) Does your answer fit with the thinking of the student who attempted to explain the lower observed fundamental frequency? Explain your answer.

5. (16 marks)

The diagram below shows part of a water fountain. It consists of three nozzles at ground level that fire three short jets of water in parabolic paths (A, B and C) through the air. The jets of water fall into three different holes in the ground. The centres of the holes are at the distances shown.



(a) The nozzle for B is directed at 45.0° above the horizontal. The water jet is in the air for 0.70 s and lands in the middle of the hole. What is its initial velocity?

(4 marks)

[If you could not answer part A, use an initial velocity of 4.89 m s^{-1} for water jet B in the rest of this question.]

(b) What maximum height is reached by the water jet from nozzle B?

(4 marks)

(c) The holes in the ground each have a diameter of 20.0 cm. The diameter of a water jet is 2.0 cm. If wind is blowing horizontally with a constant velocity of 0.28 m s^{-1} in the direction that the water travels, will the water jet following trajectory B still land in the hole? Show sufficient working to justify your answer.

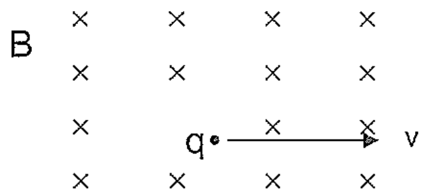
(4 marks)

(d) The nozzle for A is directed at an angle of 60.0° above the horizontal and the nozzle for C is directed an angle of 30.0° above the horizontal. The initial velocity of A is 5.83 m s^{-1} and the initial velocity of C is 4.52 m s^{-1}. If all three water jets leave at the same instant, in what order will they land in their respective holes? Show sufficient working to justify your answer.

(4 marks)

6. (12 marks)

A proton (q) is injected with velocity (v) into a uniform magnetic field (B), which is perpendicular to v, as shown in the diagram below.



(a) The magnetic field strength is 0.200 T and the proton's speed is 1.10 Km s^{-1}. Calculate the magnitude of the force on the proton, and show the direction of this force on the diagram above. You may ignore gravitational and electric fields.

(4 marks)

(b) The magnetic force causes the proton to move along a circular path with radius r given by:

$$r = \frac{m v}{qB}$$

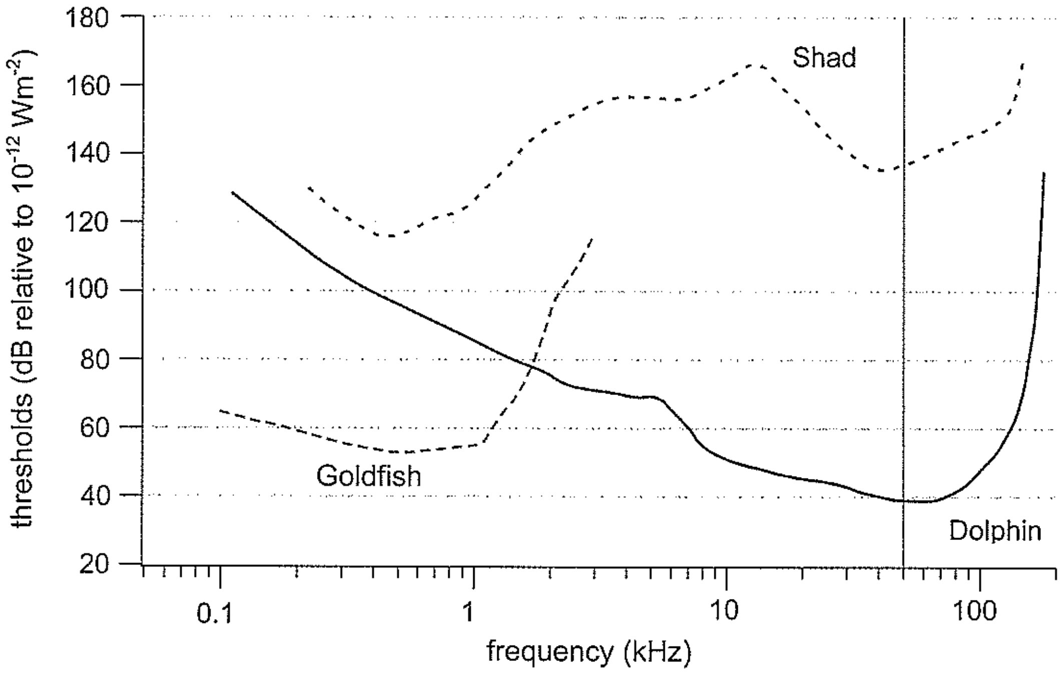
What value of field strength B would produce a circular path of radius 15.0 mm for a proton with constant speed of 10.0 km s^{-1}?

(4 marks)

(c) Show that the period of the circular orbit is independent of the radius of the orbit (i.e. the period is always the same, no matter how large or small the circular orbit).
(4 marks)

7. (13 marks)

The following graph shows the hearing ranges and sensitivities of goldfish, dolphins and a fish called a shad. The hearing threshold, given in dB relative to 10^{-12} Wm^{-2}, is the lowest sound level that can be detected at each frequency. The hearing ranges are given in kHz.



(a) Using information from the graph, give **two** differences between the hearing of goldfish and the hearing of dolphins.

(3 marks)

(b) Dolphins commonly communicate with one another using a frequency of 50 kHz (shown by the vertical line on the graph).

(5 marks)

(i) Calculate the wavelength of a 50 kHz sound wave in sea water

(ii) At this frequency, give the hearing threshold of

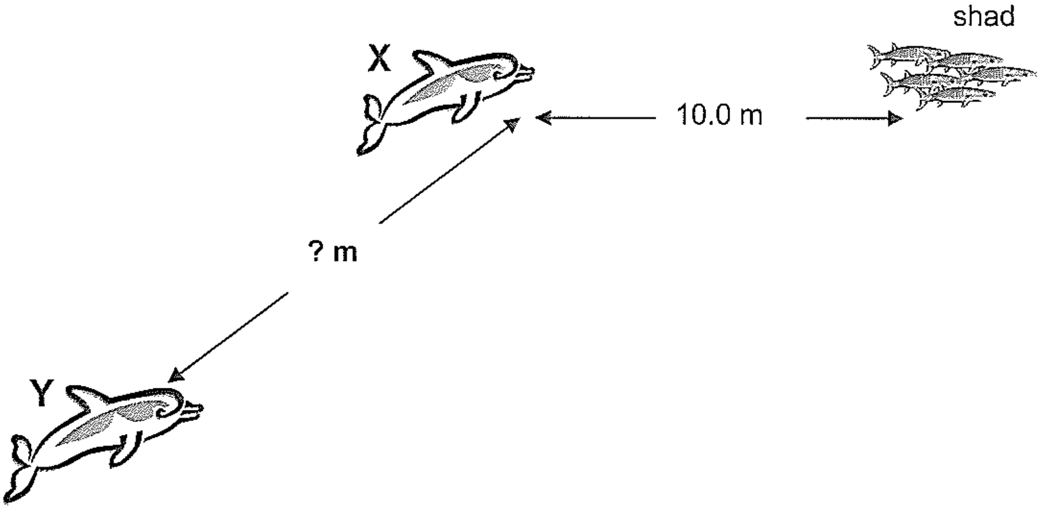
a shad ____________________; a dolphin ____________________

SEE NEXT PAGE

(c) Dolphins eat shad. Dolphin X is 10.0 m from a school of shad and wants to send a 50 kHz sound signal to dolphin Y telling it that dinner (the shad) is nearby, but not so loudly that the shad are able hear it. How far away can dolphin Y be so that it can hear dolphin X but the shad can't?

For this problem, assume that sound intensity drops off as the inverse square of distance, and neglect absorption in water. (Hint: the distance is more than 100 km!)

(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 of them. Candidates are reminded of the need for the clear and concise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

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1. ELASTICITY OF WOOD (20 marks)

A teacher gave a group of students an experiment about the elasticity of wood. The following is the record of the experiment that Ashley wrote in her laboratory report book.

Background

Wood is an elastic material because it stretches a lot without breaking. Trees sway and bend in the wind but break only when they bend too much. When wood is bent, one side is compressed and the other side is stretched. If a wooden column (like a wooden ruler) is held upright and pressed downward, it can suddenly bend out sideways. This is called buckling. The amount of force needed to make it buckle depends on Young's modulus as well as the shape of the piece of wood. I looked up the internet (www.ukuleles.com) and found out Young's modulus for different woods (see my table).

Wood	**Young's modulus (Pa)**
Pine	0.66×10^9
Western Red Cedar	7.58×10^9
Butternut	8.14×10^9
Maple	11.3×10^9
Douglas Fir	13.0×10^9
Hickory	14.9×10^9
Jarrah	17.0×10^9

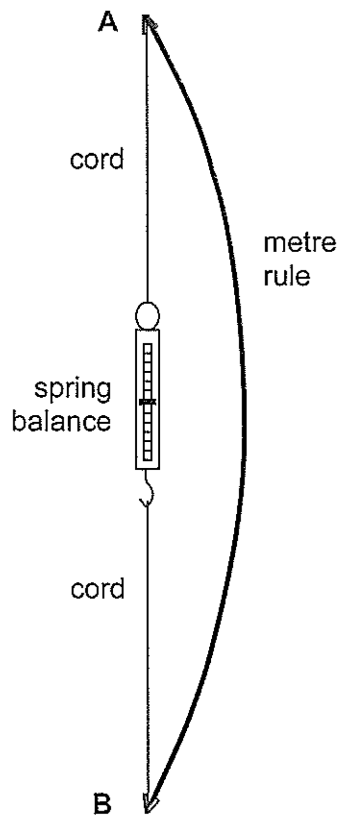
Aim

The aim of the experiment was to measure Young's modulus for the wood in a metre rule and see if we could identify the wood.

Method

We were given seven pieces of metre rules that had been cut into different lengths. We measured the width and thickness of one piece, and then the length of all pieces.

We then placed a flat metal hook on each end of one piece of wood, tied some non-stretch cords to the hooks and to the top of a spring balance. We pulled the cord until the metre rule was only *just* starting to buckle (bend), then tied the cord to the hook of the string balance. We measured the tension in the cord with the spring balance (this is called the *buckling force*). We then did this for all the other pieces of wood.



Results

Dimensions of wood pieces: Width (W) = 2.86 cm
Thickness (T) = 0.40 cm

Length, L (m)	Buckling force, F_b (N)
1.00	15
0.92	18
0.82	23
0.71	30
0.62	40
0.51	59
0.40	95

Conclusion

We found that, as the pieces of wood became shorter, we needed more force to make them buckle.

These questions ask you to analyse Ashley's data and what she has written in her laboratory notebook.

(a) The equation that relates buckling force (F_b) and length (L) of a piece of wood is

$$F_b = \left(\frac{\pi^2 W T^3}{12}\right)\frac{Y}{1} \times \frac{1}{L^2} \quad \text{where} \quad \left(\frac{\pi^2 W T^3}{12}\right) \text{ is a constant for each piece of wood.}$$

Calculate the value of this constant, and write it in the appropriate space in the equation below.

(3 marks)

$$F_b = \left(\qquad\right)\frac{Y}{1} \times \frac{1}{L^2}$$

Young's modulus can therefore be calculated from the gradient of a graph of F_b against $\frac{1}{L^2}$

(b) Make the necessary calculations and draw a graph of F_b (on the vertical axis) against $\frac{1}{L^2}$ (on the horizontal axis). (5 marks)

Length, L (m)	Buckling force, F_b (N)	
1.00	15	
0.92	18	
0.82	23	
0.71	30	
0.62	40	
0.51	59	
0.40	95	

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(c) Determine the gradient of the graph and write it here:

(3 marks)

(d) Determine Young's modulus for the type of wood used to make the metre rule.

(4 marks)

(e) Using your answer to (d) and the table in Ashley's laboratory notebook page, identify the wood from which the metre rule was most likely made. Explain your reasoning. (If you could not answer (d), use the value 2×10^{10} Pa.)

(2 marks)

(f) The first sentence in the "Background" section of Ashley's report is incorrect physics. Explain why the sentence is not correct.

(3 marks)

2. TIDES ON JUPITER'S MOON, IO (20 marks)

The planet Jupiter and its moons are like a miniature solar system. The moons orbit Jupiter, bound by gravitational attraction, in the same way that the planets orbit the Sun. The four largest moons were discovered and named by Galileo in 1609. The table below gives the details of the three Galilean moons that are closest to Jupiter: Io, Europa and Ganymede. Each of the three moons lie on the plane of Jupiter's equator and rotates so that the same side always faces the planet.

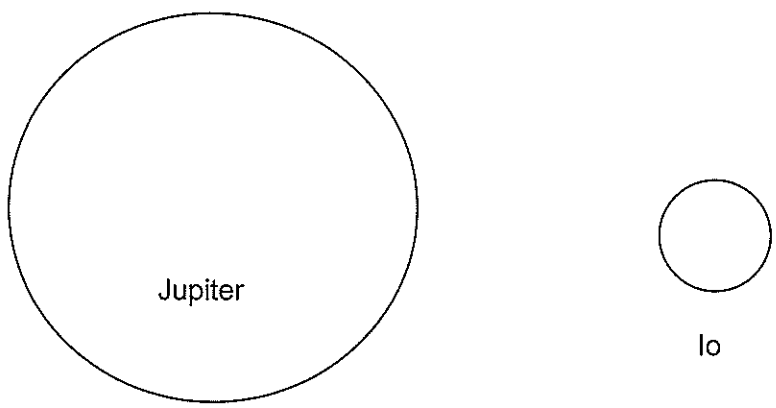
Name	Orbital radius (m)	Orbital period (days)	Radius of moon (m)	Mass of moon (kg)
Io	4.22×10^8	1.769	1.82×10^6	8.94×10^{22}
Europa	6.71×10^8	3.551	1.52×10^6	4.87×10^{22}
Ganymede	10.70×10^8	7.155	2.61×10^6	14.9×10^{22}

Io is best known for its active volcanoes that eject sulfurous fumes that constantly re-form into the yellow brown surface and hide any meteoric craters. What force is responsible for powering the volcanoes on Io? It is too small to have heat left over from its formation, and radioactive decay in its interior could not generate the tremendous energy required to power all of its volcanic activity. The answer is tidal heating. Tidal heating is the heating of the interior of one planetary body caused by varying stresses resulting from the gravitational pull of other planetary bodies.

Jupiter is an enormous planet with a mass of 1.90×10^{27} kg and a radius of 7.14×10^7 m. As a result, Jupiter exerts a tremendous gravitational force. Io, on the other hand, is a tiny moon orbiting very close to the giant planet. Io is therefore affected very strongly by the pull of Jupiter's gravity.

If Io was Jupiter's only moon, it would not be subject to varying internal stresses. The other moons orbiting nearby exert a gravitational pull of their own. Io's volcanic activity is thus caused by the powerful force of Jupiter's gravity, coupled with the gravitational pull of the two moons closet to Io: Europa and Ganymede. Jupiter pulls Io inward toward itself, while the gravity of the outer moons pulls it in other directions. As a result, Io is subjected to tremendous tidal forces that alternately squeeze and stretch its interior. This causes Io's surface to rise and fall by about 100 metres. This perpetual friction generates enormous amounts of heat and pressure within Io, causing molten material and gases to rise through fractures in the crust and erupt onto the surface.

For the following questions, assume that Jupiter's moons follow circular orbits. Use this diagram of Jupiter and Io if you need it.



(a) Calculate the gravitational acceleration on the surface of Io due to its own mass.

(4 marks)

(b) At the surface of Io that is facing toward Jupiter, calculate the gravitational acceleration due to the mass of Jupiter.

(3 marks)

(c) From your answers to (a) and (b), find the **net** gravitational acceleration at the surface of Io facing toward Jupiter.

(2 marks)

If you could not calculate an answer to (c), use the value of 1.10 m s^{-2} for the following questions.

In a similar manner to parts (a) to (c), the net gravitational acceleration on the surface of **Io facing away from Jupiter** can be shown to be **2.51 m s^{-2}**. Thus there is a different gravitational acceleration on opposite sides of the planet.

When further calculations are made to include the gravitational effects of Europa and Ganymede, the difference in the gravitational acceleration at the inner and outer surfaces of Io are found to vary as a function of time, as shown in Figure 1 below. Δg is the amount of extra tidal acceleration due to Europa and Ganymede.

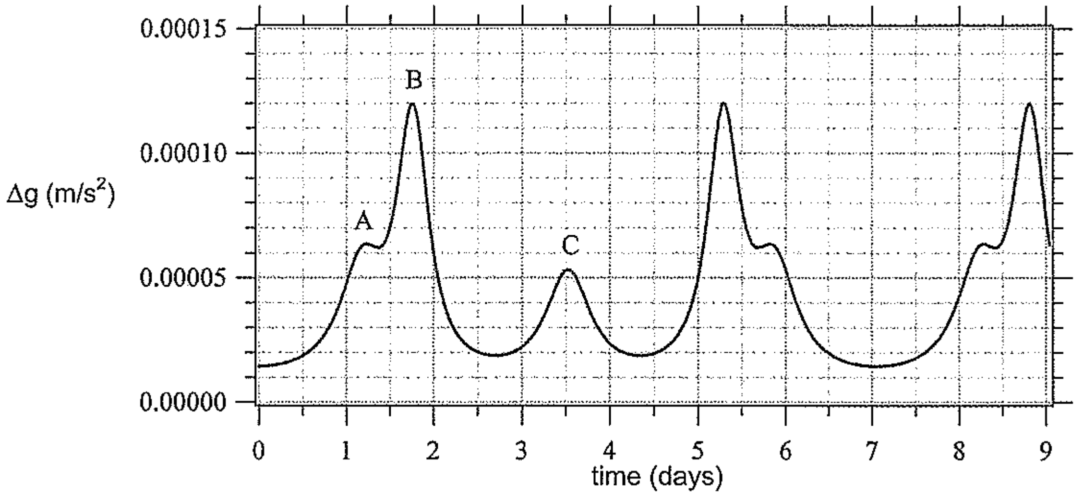


Figure 1: Calculated extra tidal acceleration due to Europa and Ganymede.

(d) The stress on Io due to Jupiter is constant. Why then does the surface of Io rise and fall so dramatically?

(3 marks)

(e) The consequence of the extra tidal stresses on Io can be calculated from $\frac{h}{R_{Io}} = \frac{\Delta g}{g_o}$

where h is the increase in surface height of Io, R_{Io} is Io's mean radius, Δg is the extra tidal stress plotted in Figure 1, and g_o is the mean value for Io's surface gravitational acceleration. Using this formula, the values from the graph (Figure 1) and data in the article, calculate the maximum height h that would be expected to result from the tidal effects of Europa and Ganymede on the surface of Io. Only answers supported by working will be given marks.

(4 marks)

(f) The orbital positions of Io, Europa and Ganymede that correspond with the labelled points A, B and C from Figure 1 are shown in Figure 2. This shows the orbital planes such that as time increases, all satellites orbit about Jupiter in an anti-clockwise direction.

(4 marks)

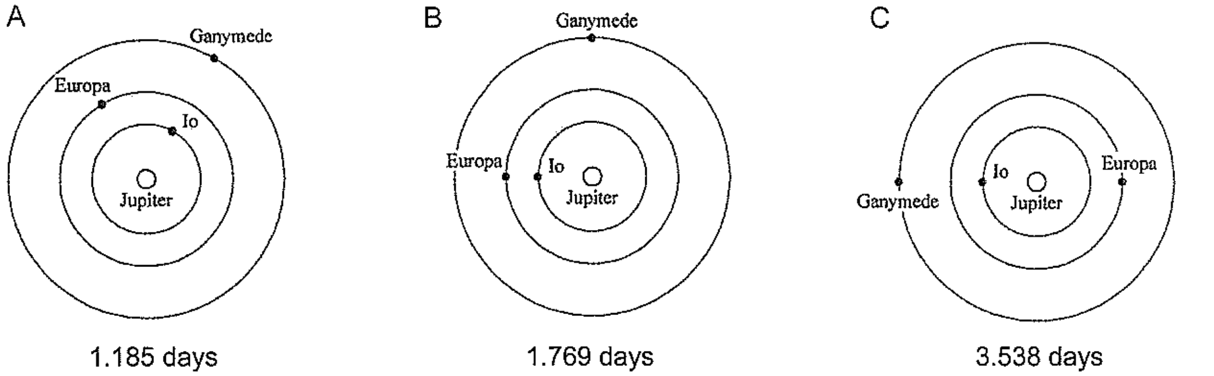
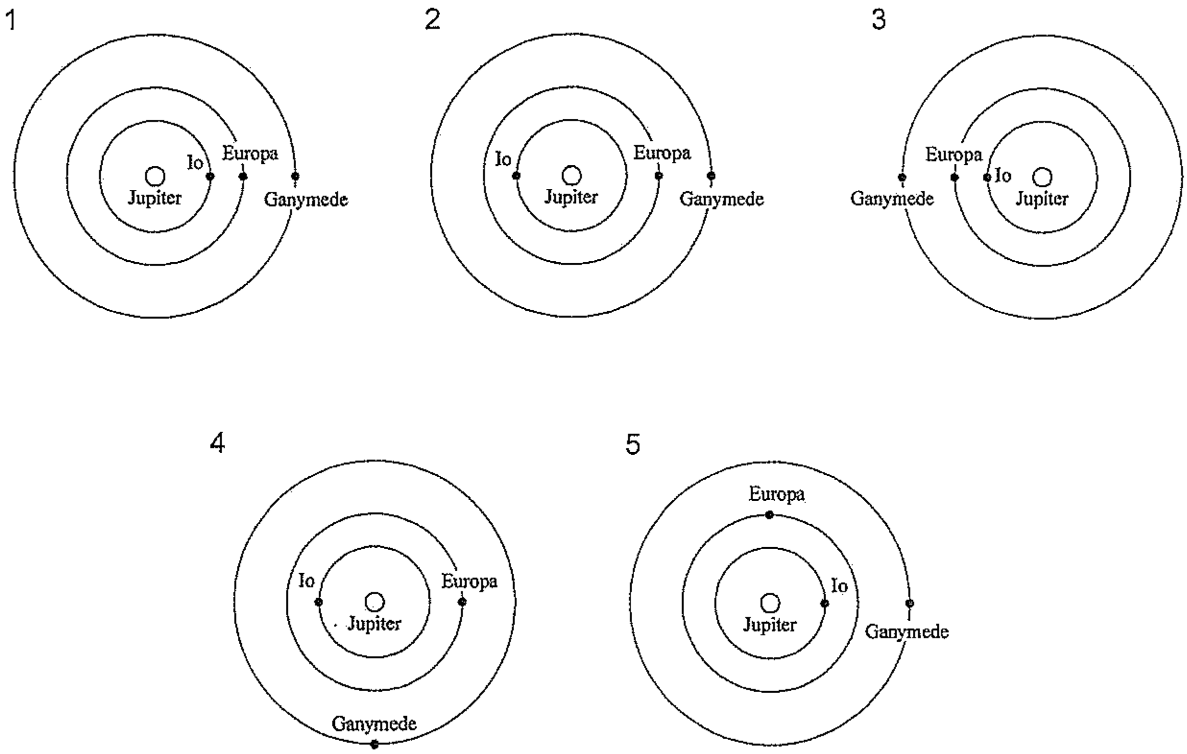


Figure 2: Orbital configurations at positions A, B and C in Figure 1.

Which one of the five orbital configurations below best represents the positions of the three satellites Io, Europa and Ganymede at time t = 0 days, and is consistent with Figure 2 and the other information provided in this question?



Answer: ____________________________________

END OF PAPER

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

ACKNOWLEDGEMENTS

SECTION A

Question 5: Diagram from IOP: Institute of Physics (2007). *TAP 414–8: Emf in an airliner.* Retrieved August, 2007 from: http://www.iop.org/activity/education/Teaching_Resources/Teaching%20Advanced%20Physics/Fields/Electromagnetism/file_4623.doc

Question 8: Diagram from: from IOP: Institute of Physics (2007). *TAP 414–7:Rates of change.* Retrieved August, 2007 from: http://www.iop.org/activity/education/Teaching_Resources/Teaching%20Advanced%20Physics/Fields/Electromagnetism/file_4622.doc

Question 10: Diagram from Zitzewitz, P. & Murphy, J. (1990). *Physics principles and problems.* Columbus, Ohio: Merrill Publishing. p. 450.

Question 14: Image from National Sports Centre (2007). *Velodrome Photo Gallery.* Retrieved August, 2007 from http://www.nscsports.com/facilities/velo/gallery.htm

SECTION B

Question 1: Image from Walmart (2007). *Fisher–Price Power Plus Swing, Circus Plaid.* Retrieved from http://www.walmart.com/catalog/product.do?product_id=4241538

Question 3: Graph from Advanced Aquarist's Online Magazine (2007). *Coral Colouration, Part 4.* Retrieved August, 2007, from http://www.advancedaquarist.com/2007/2/aafeature#h15

Question 7: Data from Whitlow, W.L. (1993). *The sonar of dolphins.* New York: Springer-Verlag.

SECTION C

Question 1: Developed from Casey, J. (1993). The elasticity of wood. *The Physics Teacher*, 31, pp. 286-287.

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