TERTIARY ENTRANCE EXAMINATION, 1994

QUESTION/ANSWER BOOKLET

PHYSICS

Please place your student identification label in this box

SEA STUDENT NUMBER – In figures

In words _____

_____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

TO BE PROVIDED BY THE SUPERVISOR

This Question/Answer Booklet comprising 36 pages
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: Drawing instruments, templates and calculators satisfying the conditions set by the Secondary Education Authority.

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.

SEE NEXT PAGE

INSTRUCTIONS TO CANDIDATES

This examination consists of **THREE (3)** sections.

SECTION A : Short Answers. This section contains 15 questions and is worth 30% (60 marks out of 200) of the marks for the examination. Answer **ALL** questions in this section.

SECTION B : Problem Solving. This section contains 8 questions and is worth 50% (100 marks out of 200) of the marks for the examination. You are required to answer:

ALL of Questions 1, 2, 3, 4 and 5
EITHER Question 6a **OR** 6b
EITHER Question 7a **OR** 7b
EITHER Question 8a **OR** 8b.

SECTION C : Comprehension and Interpretation. This section contains 2 questions and is worth 20% (40 marks out of 200) of the marks for the examination. Answer **BOTH** questions in this section.

Write your answers in the spaces provided beneath each question. The value of each question (out of 200) is shown following each question.

The enclosed *Physics: Formulae and Constants Sheet* may be removed from the booklet and used as required.

Note that (where appropriate) answers should be given numerically and that they should be evaluated and not left in fractional or radical form. Choose an appropriate number of significant figures but usually no more than three.

Calculators satisfying the conditions set by the Secondary Education Authority may be used to evaluate numerical answers.

Despite an incorrect final result, credit may be obtained for method and working, provided these are clearly and legibly set out.

Questions containing the instruction "**ESTIMATE**" generally provide insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained.

SEE NEXT PAGE

SECTION A : Short Answers

Marks Allotted: 60 marks out of 200 total (30%)

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

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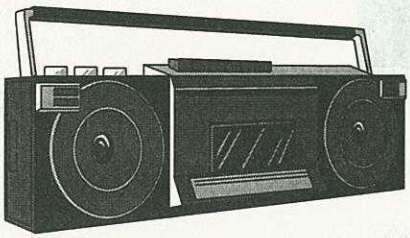
1. An air particle (A) is at the position shown below, between a loudspeaker and a listener.



A

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(a) Clearly state the meaning of the following terms:

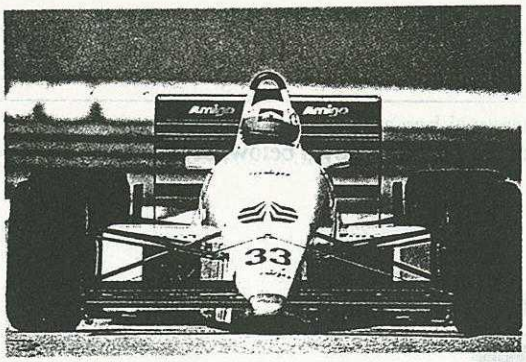
displacement :

amplitude :

(b) Describe the motion of the particle A in response to the sound wave. In your description, use the terms **displacement** and **amplitude.**

2. Explain why electrical power is transmitted at very high voltages.

3. Fast racing cars are built along the lines illustrated in the diagram.



What two features of this racing car design make it particularly stable?

(1) _____

(2) _____

4. A power station generator produces a maximum current of 21.9 kA at a voltage of 16 kV. This current is carried by a power line which runs perpendicular to the Earth's magnetic field which has a value of 2.0×10^{-5} T. Find the magnitude of the force per metre acting on this power line.

SEE NEXT PAGE

5. You can make a soft drink bottle "sound" by blowing over the top of it. **ESTIMATE** the frequency of the lowest possible note that you could get from a 1 L soft drink bottle in this way. Indicate any assumptions that you make and show clearly how you obtained your estimate.

6. **Regenerative braking** is a concept applied to electric cars as they slow down. In this process the mechanical energy of motion is converted back to electrical energy during periods of deceleration.

(a) If an electric car of mass 1540 kg is travelling at 60 km h^{-1}, assuming no energy losses, calculate the energy that could be recovered as it is brought to rest.

(b) If the car operates on 120 V, what is the minimum time for deceleration if the current must not exceed 200 A?

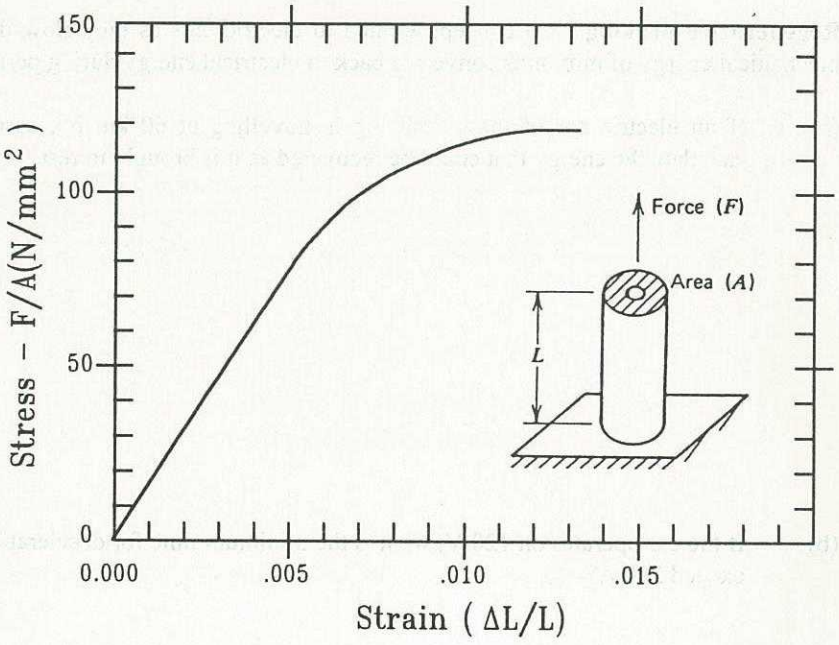
SEE NEXT PAGE

7. Newton's Law of Universal Gravitation can be written as:

$$F = \frac{G m_1 m_2}{r^2}$$

Re-arrange this equation to obtain G, and hence show that the units of G are N $m^2 kg^{-2}$.

8. The graph of stress versus strain for bone is given below.



(a) What is the stress when the bone just breaks?

(b) Using the linear portion of the graph, determine Young's modulus for bone.

SEE NEXT PAGE

9. The letters of the word PERTH, as shown, are to be carved from stone and mounted separately in the ground. The five letters are each going to be 1 m high, 0.75 m wide and 0.5 m deep (thick).

Give one letter which:

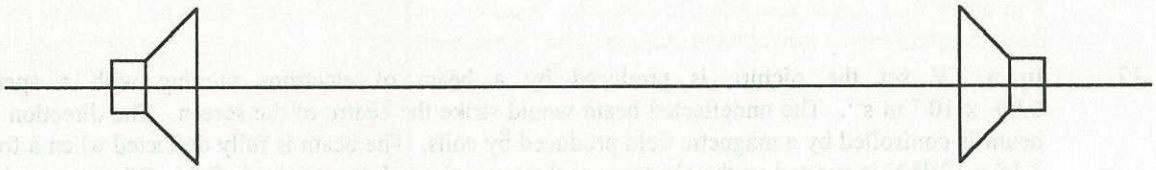
(a) will be stable when stood upright. _____

(b) will stand up, but is least stable. _____

(c) will not stand upright without additional support. _____

(d) has its centre of gravity outside of the stone. _____

10. Two loudspeakers, positioned as shown below, are connected to the same source and are emitting a single note. A person walking from one loudspeaker to the other hears the sound loud at some positions and quieter at others.



(a) Explain why this is so.

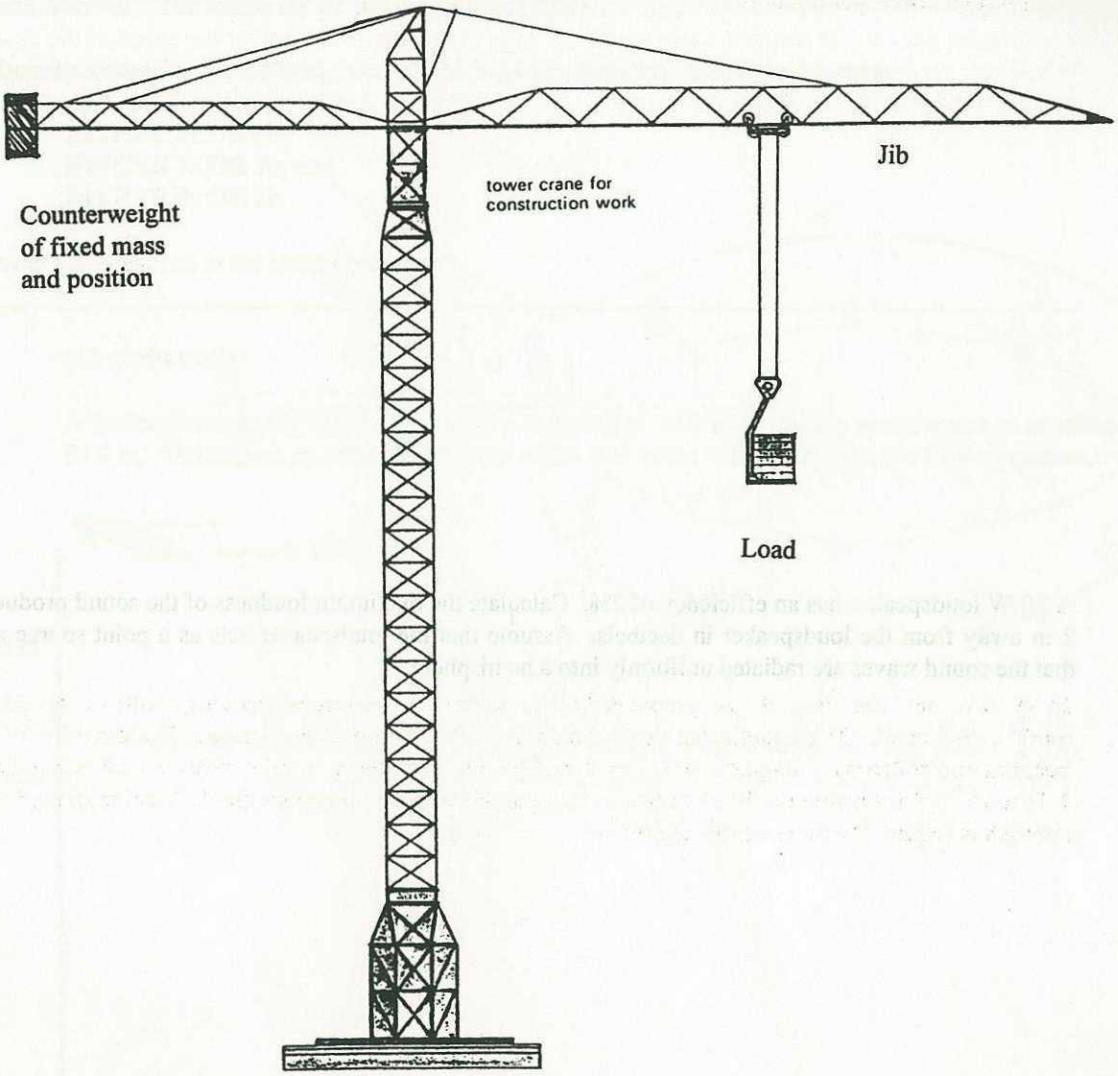
(b) What is the smallest distance between a loud and a quiet spot if the frequency is 250 Hz?

11. An AC generator produces 10.0 V when the coil is rotated at 500 rpm. Assuming that the magnetic field does not change, find the emf when the rate of rotation of the coil is increased to 1200 rpm. (rpm = revolutions per minute)

12. In a TV set the picture is produced by a beam of electrons moving with a speed of 6.00×10^{7} m s^{-1}. The undeflected beam would strike the centre of the screen. The direction of the beam is controlled by a magnetic field produced by coils. The beam is fully deflected when a force of 1.15×10^{-14} N is exerted on the electrons as they pass through the magnetic field. What magnetic field strength is required to produce this deflection?

SEE NEXT PAGE

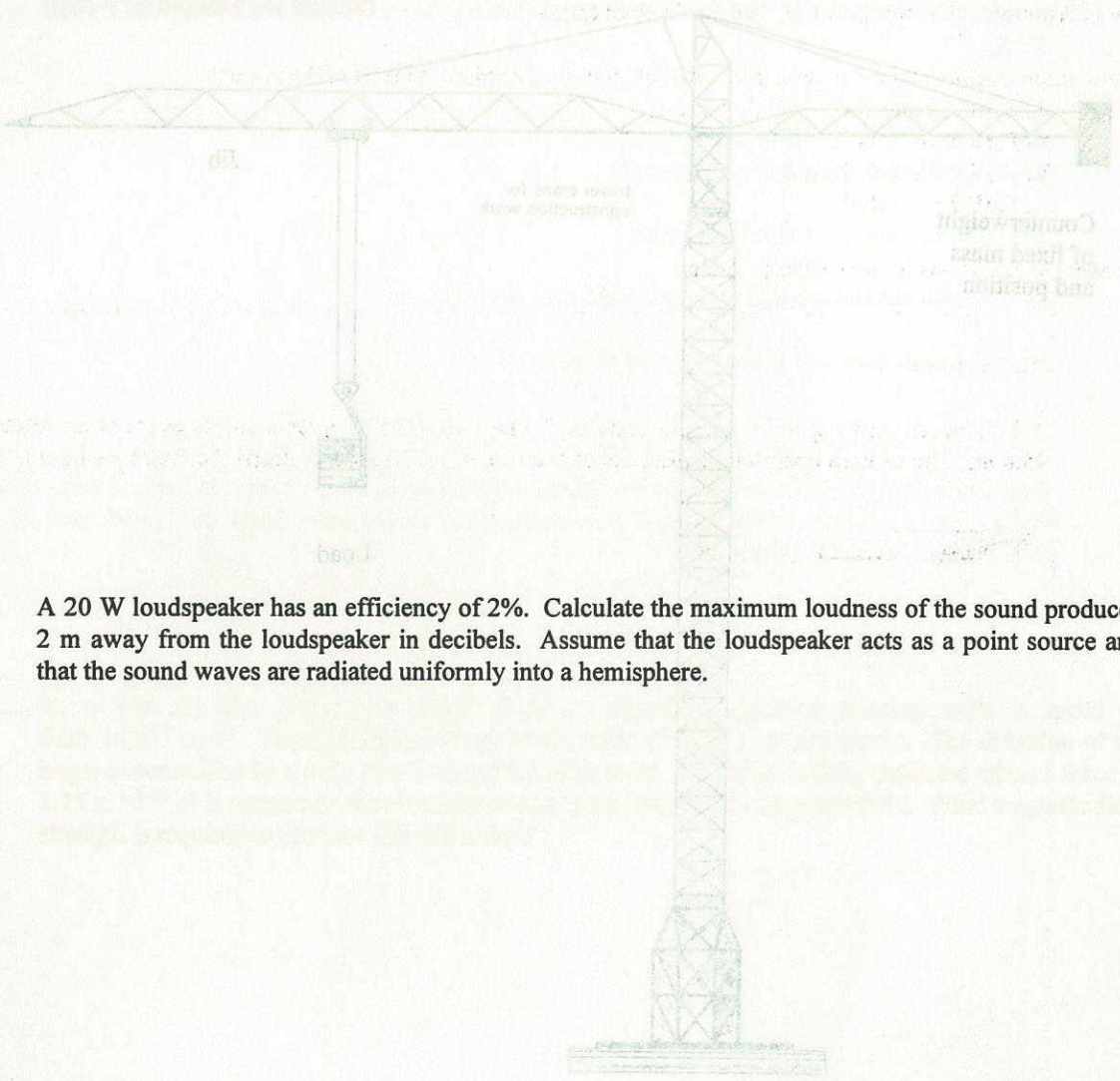
13. A large tower crane similar to those often seen on construction sites is shown in the diagram.



Such cranes do not have a single load limit but have a table indicating the maximum allowed load for each metre of distance along the jib.

If you calculate the product of load and distance in each case, what would you expect your results to indicate? Explain your answer briefly.

14. **ESTIMATE** the energy of an X-ray photon. Clearly show your reasoning in obtaining your estimate.



15. A 20 W loudspeaker has an efficiency of 2%. Calculate the maximum loudness of the sound produced 2 m away from the loudspeaker in decibels. Assume that the loudspeaker acts as a point source and that the sound waves are radiated uniformly into a hemisphere.

END OF SECTION A

SEE NEXT PAGE

SECTION B : Problem Solving

Marks Allotted: 100 marks out of 200 marks total (50%)

This section contains 8 questions, three of which contain a choice. You should answer:

ALL of the questions 1, 2, 3, 4 and 5,
EITHER 6a **OR** 6b,
EITHER 7a **OR** 7b, and
EITHER 8a **OR** 8b.

Answer the questions in the spaces provided.

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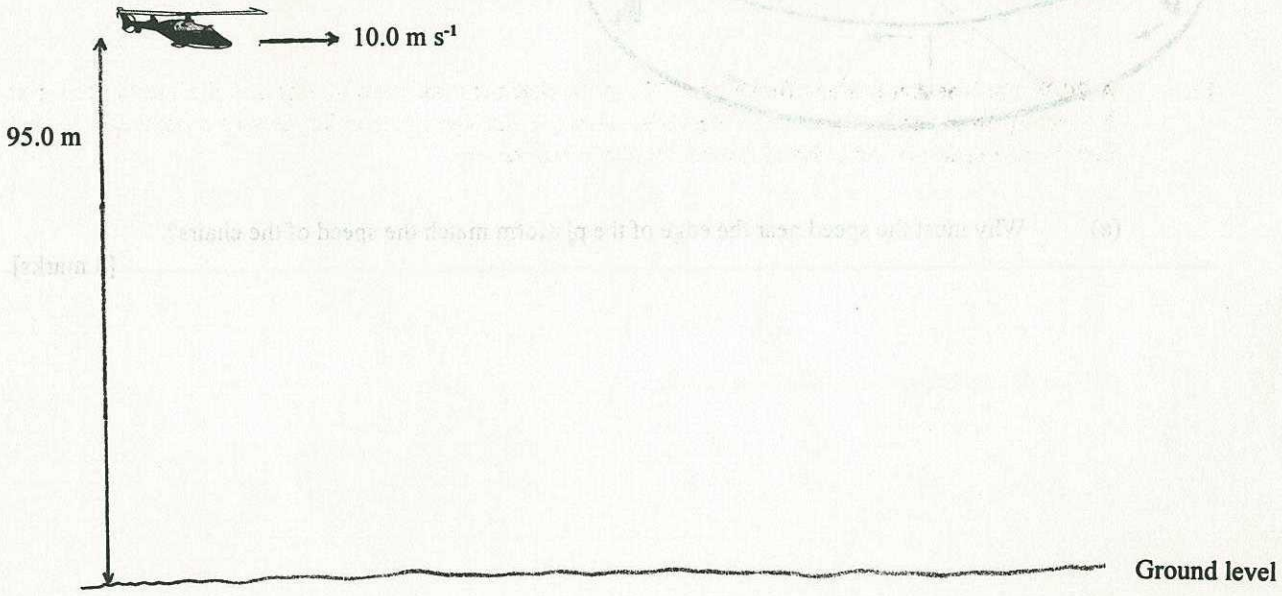
1. (10 marks total)

A helicopter carrying a TV camera crew is flying at 10.0 m s^{-1} over a sports event at an altitude of 95.0 m. The camera operator, leaning out of the side of the helicopter drops the 8.00 kg camera.



(a) On the diagram above, **SKETCH** the trajectory of the TV camera as it falls to the ground. [2 marks]

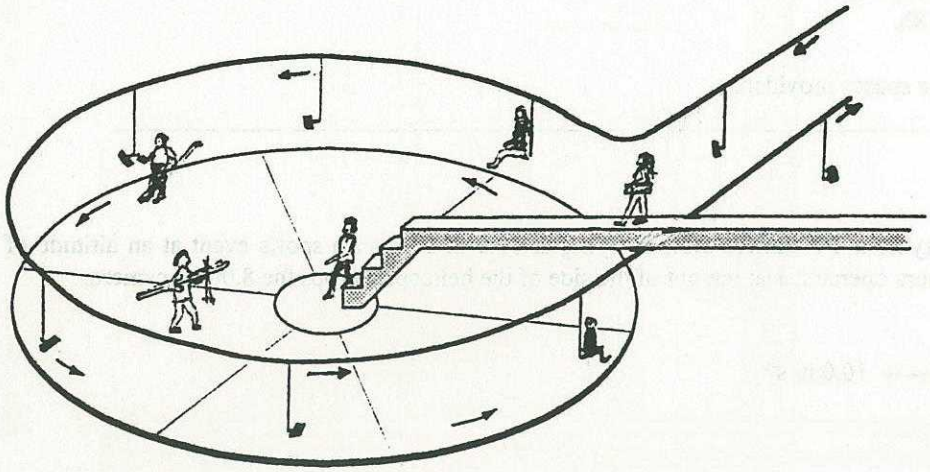
(b) Draw on the diagram, a vector to show the displacement of the TV camera when it hits the ground. [2 marks]

(c) With an X (cross), show on the diagram the position of the helicopter at the instant the TV camera hits the ground. [2 marks]

(d) Because of the shape of the camera, air resistance reduces its vertical acceleration to 9.4 ms^{-2}. How long will it take for the camera to reach the ground? [4 marks]

2. (10 marks total)

Chairlifts at some ski resorts have chairs which do not stop to let passengers on and off. Instead, there is a rotating platform in which the speed near the edge of the platform matches the speed of the chairs. People get on and off the platform via a small bridge and stairs to a small stationary platform in the middle of the rotating platform.



(a) Why must the speed near the edge of the platform match the speed of the chairs?

[3 marks]

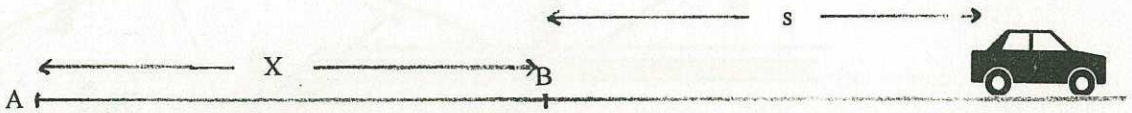
(b) Why did the engineer design the system so that people enter and leave the rotating platform in the central area?

[3 marks]

(c) Susan, whose mass is 56.5 kg, is standing near the edge of the 10 m diameter platform where the speed is about 1.5 m s^{-1}. What minimum force of friction must be acting between her shoes and the platform surface to prevent her sliding off the platform? [4 marks]

3. (12 marks total)

A group of physics students decide to measure the torque produced by the motor in an electric car. One student drives the car from rest at point A while the others position themselves 40 m apart along the track. The first of these students is located at B, a distance X from A. All students start their stopwatches as the car moves off from A and each person stops their watch as the car passes them. The acceleration of the car is assumed constant, and equal to F/m. The torque applied to the wheels is $\tau = r F$. The radius of the car wheels is 0.28 m and the mass of the car is 733 kg.



It is known that the relationship between s (the car's displacement from B) and t (the time elapsed) is given by the following equation

$$s = X + \left\{\frac{\tau}{2rm}\right\} t^2$$

The students obtained the following results:

s =	0	40	80	120	160	200	m
t =	8.0	11.5	14.0	16.0	18.0	19.0	s

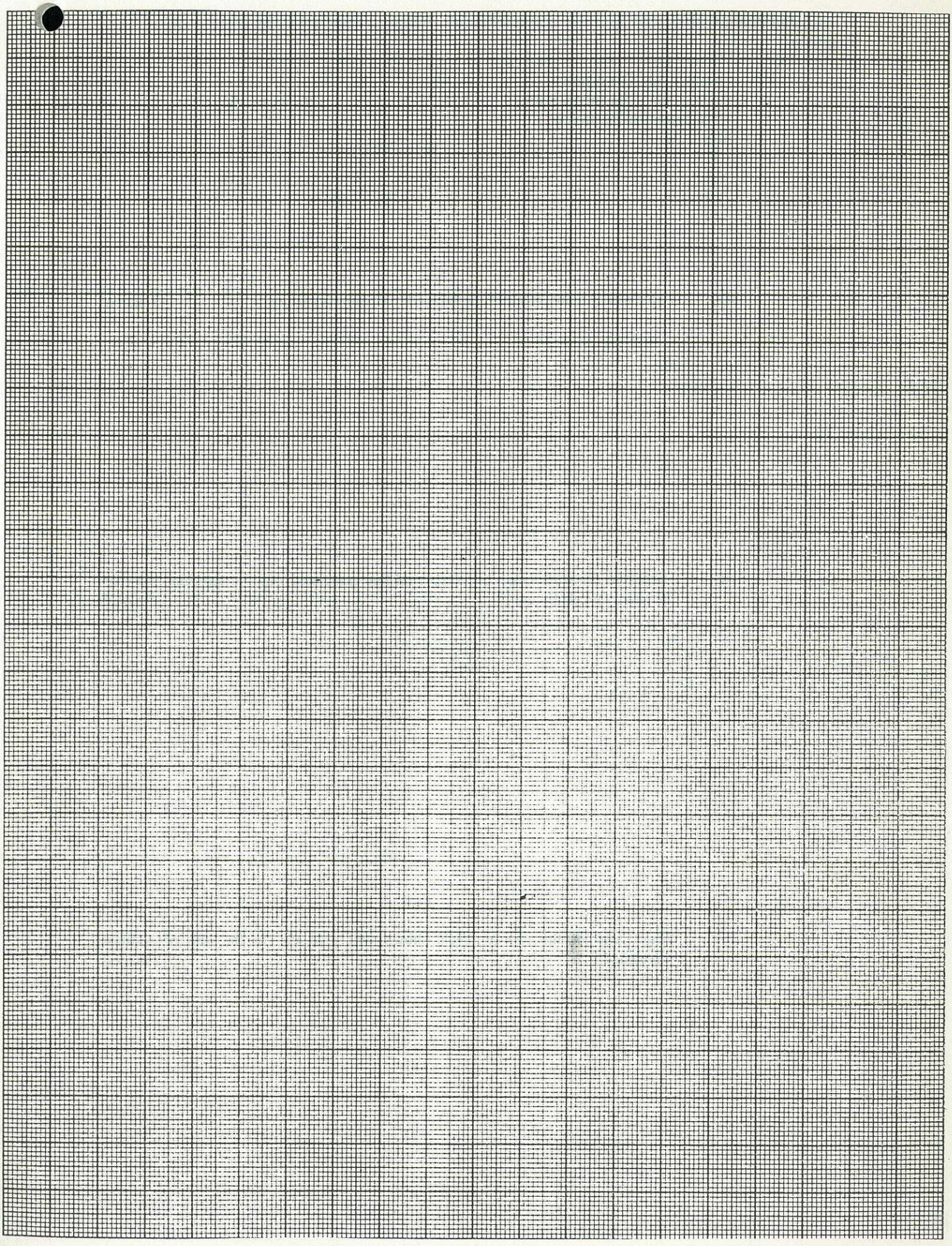
(a) Use this data to draw a **straight line** graph on the graph paper on the next page. [6 marks]

(b) From the **graph**, find :

(i) the torque supplied by the motor [4 marks]

(ii) the distance X between A and B. [2 marks]

SEE NEXT PAGE



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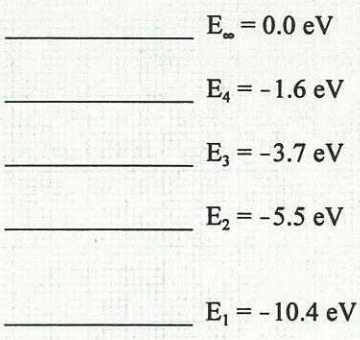
4. (14 marks total)

(a) Mercury vapour lamps produce a bright light. The diagram shows some of the energy levels of the outermost electron in a mercury atom.



(i) Explain why a line spectrum is obtained from mercury lamps. [3 marks]

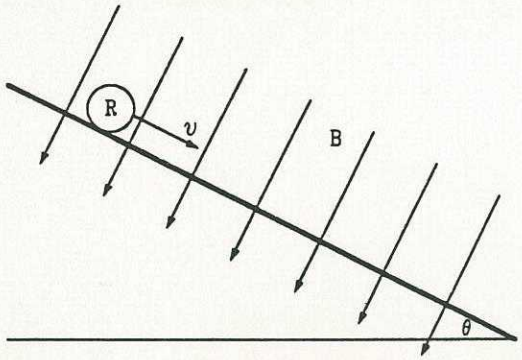
(ii) Determine the wavelength of the spectral line associated with the transition between the energy levels E_3 and E_2. [3 marks]

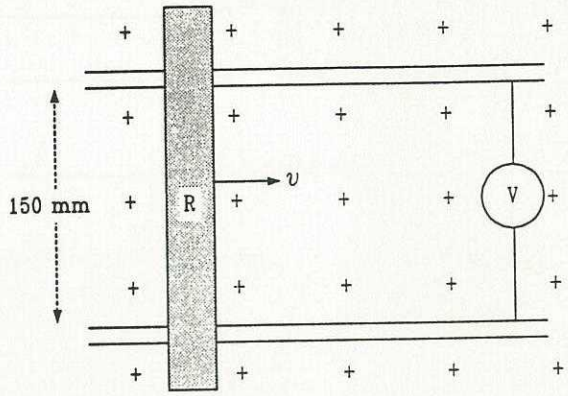
(iii) Which two of the energy levels shown will give rise to the line of shortest wavelength? [2 marks]

(b) Use an example from the context you have studied to explain the principle of **fluorescence.** [6 marks]

5. (12 marks total)

(a) A conducting rod, R, rolls down a pair of parallel rails 150 mm apart as shown in the diagram.





As the rod passes through the perpendicular magnetic field, a voltage is generated.

(i) **SKETCH** the magnitude of the voltage measured across the rails as a function of time. [3 marks]

(ii) At a particular instant, the rod is moving down the rails at a speed of 15 m s^{-1}. If the magnetic field is 0.4 tesla, find the voltage generated across the rails. [4 marks]

(b) "As long as electricity is produced by the combustion of coal and oil, the use of electric cars instead of petrol and the use of electric heaters instead of coal and wood fires, is not going to solve the problems of the emission of CO_2 and other pollutants." Do you agree?

Briefly justify your answer. [5 marks]

Question 6a (page 20) relates to the context *Playgrounds, Funfairs and Physics*
Question 6b (page 22) relates to the context *Sport and Physics*
You must answer only **ONE** of these questions, each worth 14 marks

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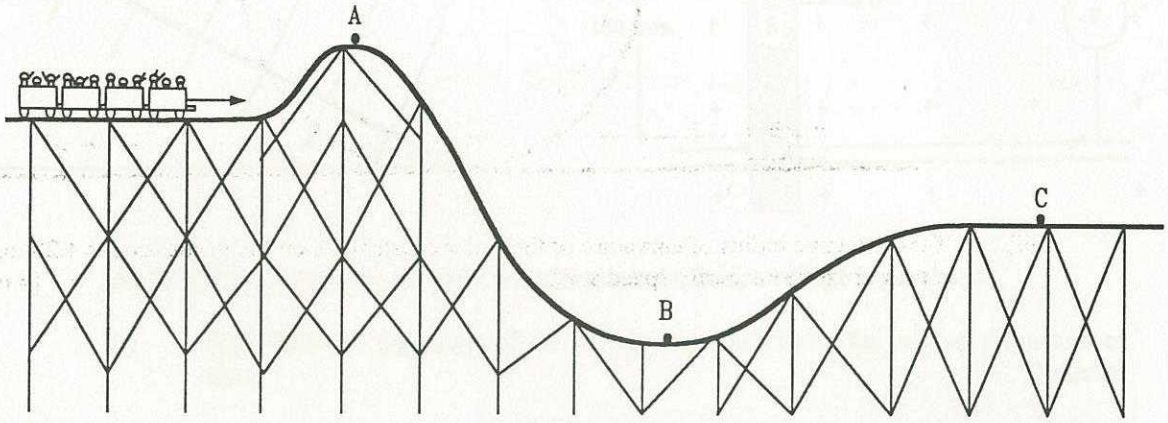
EITHER

6a. While you are in a seat in a stationary roller coaster, the upward force (R) exerted on you by the seat is equal to mg.



(i) If you are in a "free wheeling" roller coaster on the track shown in the diagram above, will the magnitude of the reaction force you experience in positions A, B and C be equal to, less than, or greater than mg ? [3 marks]

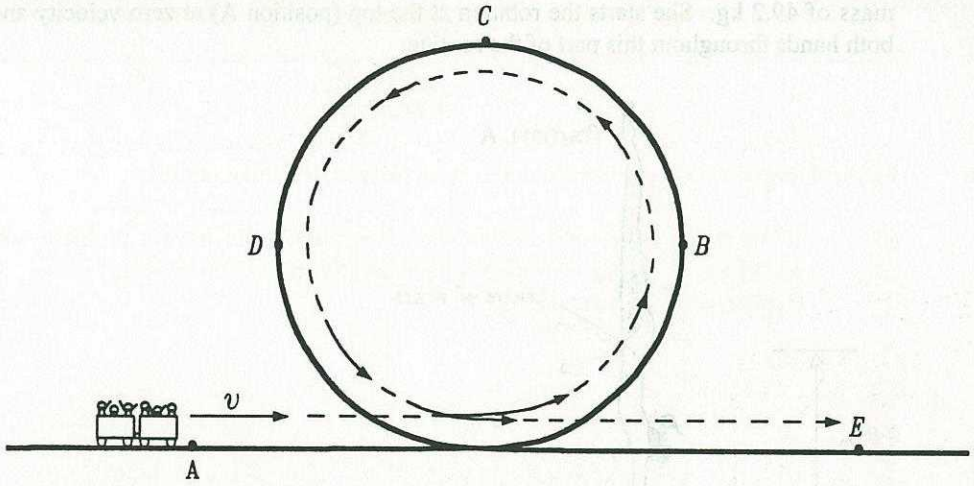
A. _____

B. _____

C. _____

(ii) Seat belts or restraints are normally provided to keep riders in their seats. At which position (A, B or C) are riders most likely to need the seat belts?
Explain why. [3 marks]

Some roller coaster rides carry people on an "inside loop". A design feature of an inside loop is that the speed at the top of the loop must be greater than a certain minimum so that the people will not tend to fall out of their seats while upside down.

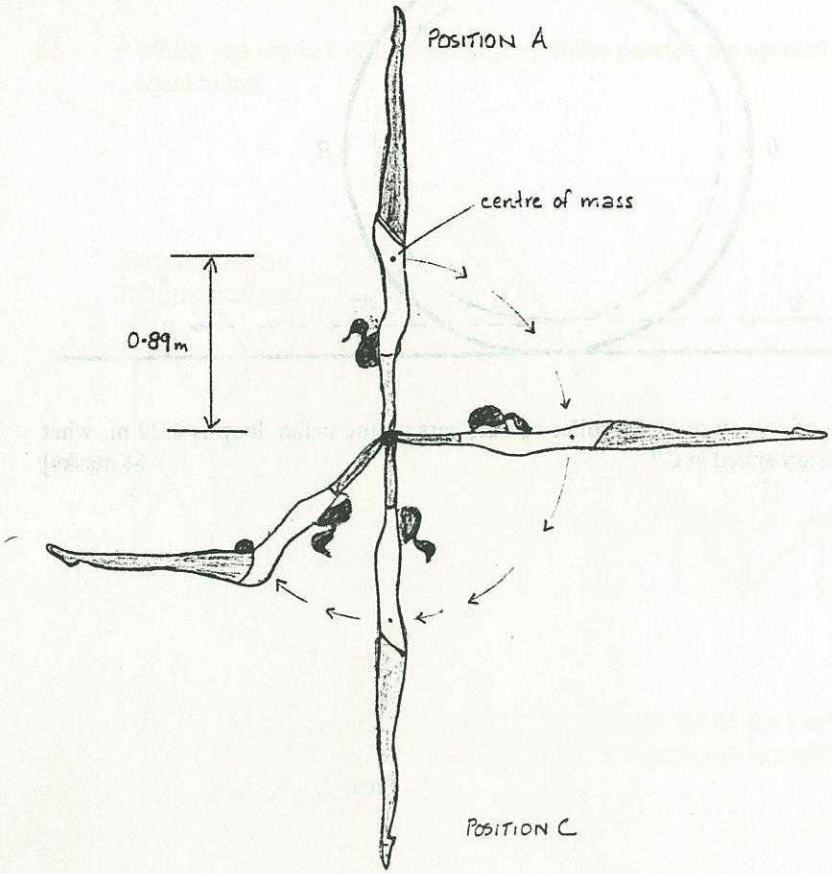


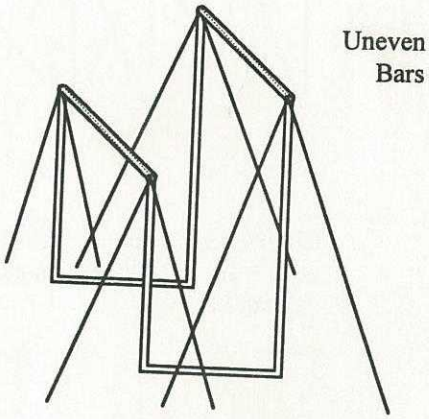
(iii) If the effective radius of curvature of the roller coaster cars on the inside loop is 4.20 m, what is the minimum necessary speed at C? [4 marks]

(iv) To be on the safe side, the engineers make sure that the roller coaster passes position C at 9.0 m s^{-1}. What must be its minimum speed on entering the loop (at position A) so that it will not be slower than 9.0 m s^{-1} at C ? [4 marks]

OR

6b. The diagram below shows a small segment of a gymnastic routine on uneven bars. The gymnast has a mass of 49.2 kg. She starts the rotation at the top (position A) at zero velocity and holds the bar with both hands throughout this part of the routine.





(i) At position A, the magnitude of the force on the gymnast's arms is just mg. Will the magnitude of the force on her arms at B and C be equal to or less than mg? [2 marks]

B. _____

C. _____

(ii) What is the origin of the forces at B and C? [4 marks]

(iii) Assuming negligible air resistance, what will be the speed of the gymnast's centre of mass at position C? [4 marks]

(iv) What is the tension in each of her arms at position C ? [4 marks]

Question 7a (page 24) relates to the context *Speaking and Hearing*
Question 7b (page 26) relates to the context *Musical Instruments and Reproduction*
You must answer only **ONE** of these questions, each worth 14 marks
Note that some parts of Question 7a and Question 7b are the same; **this is not a mistake.**

EITHER

7a. Medical technologists use ultrasound to form images of human organs.

(i) When using ultrasound in this way, it is possible to have a problem with refraction of the sound waves. What condition is necessary for refraction to occur?
Explain your answer. [3 marks]

(ii) Show in a diagram how refraction could affect the image obtained. [3 marks]

(iii) Medical technologists use sound with high frequencies of around 3 MHz for ultrasound. Given that the speed of sound in body tissue is around 1540 m s^{-1}, suggest why lower frequencies are rarely used. [4 marks]

(iv) Humans can quite accurately determine the direction from which a sound is coming. Explain how we do this. Why can we locate high frequency sounds more accurately than low frequency sounds? [4 marks]

OR

7b. Medical technologists use ultrasound to form images of human organs.

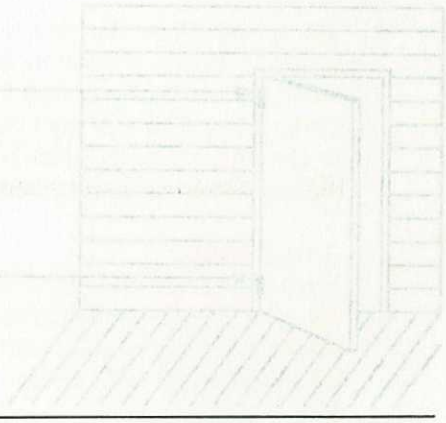
(i) When using ultrasound in this way, it is possible to have a problem with refraction of the sound waves. What condition is necessary for refraction to occur?
Explain your answer. [3 marks]

(ii) Show in a diagram how refraction could affect the image obtained. [3 marks]

(iii) Medical technologists use sound with high frequencies of around 3 MHz for ultrasound. Given that the speed of sound in body tissue is around 1540 m s^{-1}, suggest why lower frequencies are rarely used. [4 marks]

(iv) Explain why it is important that the pair of loudspeakers in a stereo system be connected in phase. How does the effect of incorrect phasing change as the frequency is increased?

[4 marks]



Question 8a (page 28) relates to the context *Bridges and Buildings*
Question 8b (page 29) relates to the context *Human and Animal Frames*
You must answer only **ONE** of these questions, each worth 12 marks

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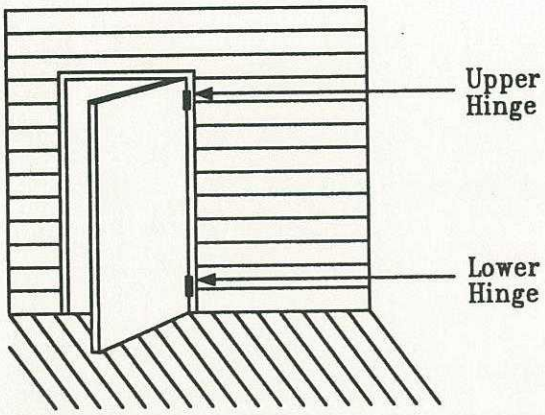
EITHER

8a. Some external house doors are made of solid wood and hung on two hinges, as shown in the diagram below.

(i) With the aid of diagrams show the direction of the force exerted by the upper hinge on the door. Justify your answer. *(Assume that the lower hinge acts as a pivot.)*

[6 marks]



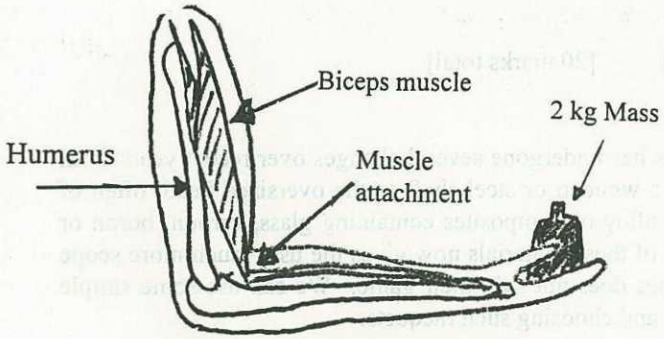
(ii) **ESTIMATE** the total force exerted on the upper hinge. Indicate clearly any assumptions that you make and show clearly how you obtained your estimate.

[8 marks]

OR

8b. In the gymnasium, one of the exercises used to strengthen the biceps muscle is raising and lowering a 2 kg mass with a bent arm as illustrated.

(i) With the aid of diagrams show the direction of the force exerted on the humerus (the bone of the upper arm) at the elbow joint in this situation. [6 marks]



(ii) **ESTIMATE** the tension in the biceps muscle with the arm in the position shown. Show clearly any assumptions that you make and show clearly how you obtained your estimate. [8 marks]

END OF SECTION B

SECTION C : Comprehension and Interpretation

Marks Allotted: 40 marks out of 200 marks total (20%)

BOTH questions should be attempted.

Read both passages carefully and answer all of the questions at the end of each passage. Candidates are reminded of the need for correct English and clear and concise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included where appropriate.

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1. THE PHYSICS OF THE SQUASH RACQUET [20 marks total]

(Paragraph 1)
The design and construction of squash racquets has undergone several changes over recent years from the round-headed wooden racquet with either a wooden or steel shaft to the oversized head, often of non-circular shape and made from aluminium alloy or composites containing glass, carbon, boron or kevlar fibre. The differing dynamic responses of these materials now gives the user much more scope in choosing a racquet which suits, or sometimes does not suit, their game. We can use some simple physics to help define the criteria for designing and choosing such racquets.

(Paragraph 2)
Most readers will be familiar with the concept of the centre of percussion or "sweet spot" on a bat or racquet. You can easily find the centre of percussion of your racquet by holding it between thumb and forefinger at the position where you would normally grip it and measure the period of oscillation. Using this period in the formula for a simple pendulum

$$T = 2\pi \sqrt{\frac{l}{g}}$$

and solving for ℓ gives the distance from the position being held to the centre of percussion. For my racquet I obtained 49 cm, which put the sweet spot right in the middle of the head area.

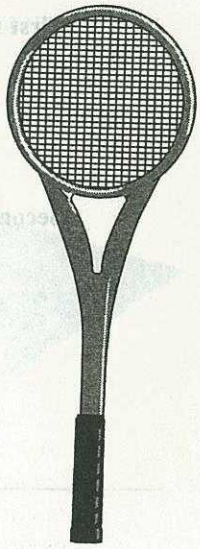
(Paragraph 3)
The significance of this point is that if we consider (for ease of discussion) a ball striking a stationary racquet at the centre of percussion, then the combination of the translation of the centre of mass backwards and rotation of the racquet about the centre of mass produces one point on the racquet which doesn't move - the point where you are holding it. Hence there is no reaction on the user's arm.

(Paragraph 4)
However, this consideration makes it clear that the centre of percussion and the hand position are conjugate points - so if you don't hit the ball in the sweet spot then the point of zero reaction will be somewhat different from where you are holding it. Then it jars! For the racquet designer this produces a problem because a significant number of players hold the racquet where the grip joins the shaft. Why do they do this? The answer is that the racquet is not a rigid body but can flex roughly about the midpoint of the shaft. Since it is not tied at the ends like a guitar string then the nodes of the fundamental mode of vibration are moved in from the ends with one being at the top of the handle. Thus, gripping the racquet at this point reduces the effect on the user's arm of the oscillation of the racquet.

(Paragraph 5)
This gives two possible causes for sore arms from racquet sports - one due to impact (jarring) and the other to oscillation, which will be worst if the oscillation happens to strike a sympathetic resonance in part of your arm structure. The vibrational frequencies of squash racquets can vary from about 100-200 Hz so a racquet which may suit you may be painful for a friend with a different build. The designer can make the amplitude smaller by making the frame stiffer, but this increases the impact shock. The compromise design will also include good damping so that the oscillations die away quickly. Typically the injection moulded composites have the best damping and aluminium the worst while the compression moulded composites have the highest frequencies.

SEE NEXT PAGE

(a) Paragraph 2 describes how to determine the position of the centre of percussion of a racquet. On following the instructions you find that the time for ten oscillations of your racquet is 12.3 s. Where is the centre of percussion of your racquet? [5 marks]



(b) If you do not hit the ball at the centre of percussion, you "jar" your arm. Describe why. [6 marks]

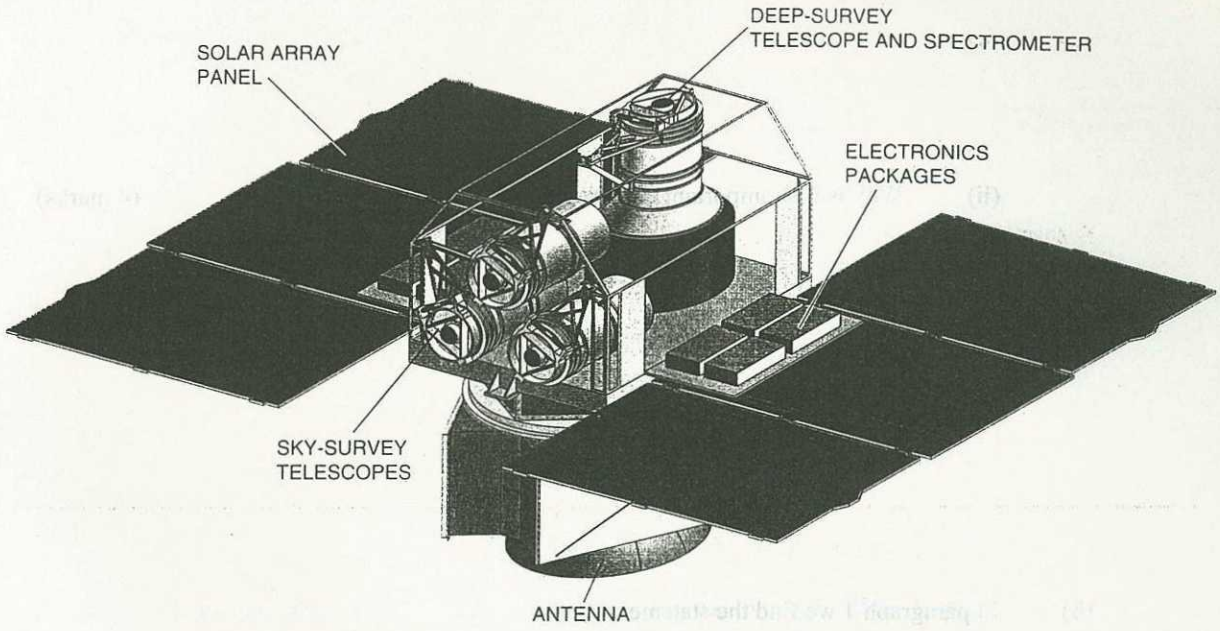
(c) The article states that "... sore arms ... due to ... oscillation (of the racquet), which will be worst if the oscillation happens to strike a sympathetic resonance in part of your arm structure". What is sympathetic resonance and why will soreness be worst as described? [5 marks]

(d) The vibrational frequencies of squash racquets vary from about 100 to 200 Hz. State two factors which might determine the vibrational frequency of a racquet. [4 marks]

First factor :

Second factor :

2. EXTREME ULTRAVIOLET ASTRONOMY [20 marks total]



(Paragraph 1)
On June 7, 1992, the National Aeronautics and Space Administration's *Extreme Ultraviolet Explorer (EUVE)* satellite was placed into an orbit 550 kilometres above the earth. Soaring over the atmosphere, which prevents extreme ultraviolet radiation from reaching earthbound telescopes, *EUVE* has detected a wide variety of astronomical objects. Among them are white dwarfs, coronally active stars and planetary objects in our solar system, all radiating in this high-frequency band. *EUVE* has even seen 10 sources of extreme ultraviolet (EUV) radiation beyond the Milky Way galaxy. This observation was all the more satisfying because of the long-standing prediction that interstellar gas would absorb all EUV radiation coming from even nearby stars, let alone that from extragalactic objects.

(Paragraph 2)
During the 1960s and early 1970s, astronomers believed that extreme ultraviolet radiation – having wavelengths between roughly 10 and 100 nanometres – would be completely absorbed by the interstellar medium. Thus, such light, if emanating from any star other than the sun, could not reach the earth's vicinity. This calculation was based on an estimate of the average density of gas in interstellar space: one hydrogen atom per cubic centimetre, with lesser amounts of helium and other elements. If this material were uniformly distributed throughout the galaxy, EUV astronomy would indeed be impossible.

(Paragraph 3)
G. B. Field, a leading expert on the interstellar medium, proposed that interstellar matter might be distributed quite unevenly. Its density in many directions might be only one tenth of the average. In that case, extreme ultra-violet radiation would penetrate – in those directions – 10 times farther than was normally assumed. Therefore, a volume of space 1,000 times greater than was commonly believed to exist would be observable by EUV light.

(Paragraph 4)
There are four telescopes on *EUVE* (see diagram). Three of these, the "sky survey" telescopes, point in the same direction and explore the EUV sky in four wavelength bands. The direction in which the survey telescopes look out is perpendicular to the axis of rotation of the *EUVE* satellite. As the satellite spins, the telescopes scan a strip of the sky; the strip shifts daily as the earth travels in its orbit around the sun. The entire sky is mapped in six months. The fourth, "deep survey" telescope is aligned parallel to the axis of rotation of *EUVE*. The prolonged exposure allows more sensitivity than does the main survey and reveals fainter sources.

SEE NEXT PAGE

(a) In paragraphs 2 and 3 there is a discussion concerning the **density of interstellar gas.**

(i) What does this refer to? (2 marks)

(ii) Why is it an important consideration in this discussion? (4 marks)

(b) In paragraph 1 we find the statement:

"Soaring over the atmosphere, which prevents extreme ultraviolet radiation from reaching earthbound telescopes..."

Describe one way in which EUV is absorbed by the components of the atmosphere. [3 marks]

(c) Sketch a portion of the electromagnetic spectrum which includes EUV and visible light. Indicate clearly appropriate wavelengths and the average energies of photons of EUV and visible light. (Note: these will need to be calculated.) [6 marks]

(d) How long does it take for the EUV Explorer to make one orbit of the Earth? [5 marks]

END OF QUESTIONS

END OF PAPER