OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A 2825/02

Health Physics

Monday **28 JUNE 2004** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 90.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first eight questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	7	
2	7	
3	11	
4	10	
5	7	
6	9	
7	14	
8	5	
9	20	
TOTAL	90	

This question paper consists of 16 printed pages.

Registered Charity Number: 1066969
[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \frac{1}{\sin C}$

capacitors in series, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \frac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg\left(\frac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 The human body contains about 200 bones. Movement of some of these bones is brought about by the action of muscles, ligaments and tendons. Each play a vital role during movement.

(a) Explain the function of

(i) a ligament

.....

.....[1]

(ii) a tendon.

.....

.....[1]

(b) Fig. 1.1 shows a head supported by the spinal column. The centre of mass of the head is on a vertical line 0.050 m from a vertical line through the top of the spinal column. The neck muscle acts along a line 0.020 m from the spinal column.

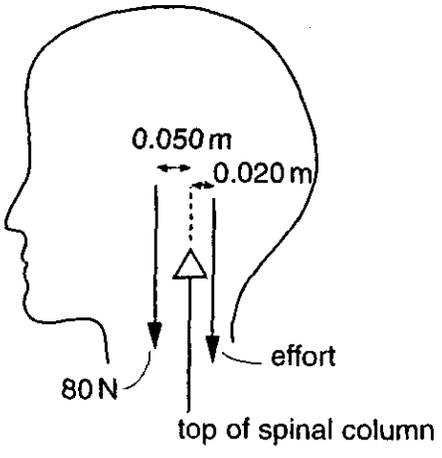

Fig. 1.1

The weight of the head is 80 N. Calculate

(i) the effort applied by the neck muscle to maintain the head in the position shown in Fig. 1.1

effort = ... N [3]

(ii) the mechanical advantage of this lever system.

mechanical advantage = ... [2]

[Total: 7]

2 Fig. 2.1 shows a graph of the variation of the minimum detectable intensity of sound with frequency for a person with normal hearing.

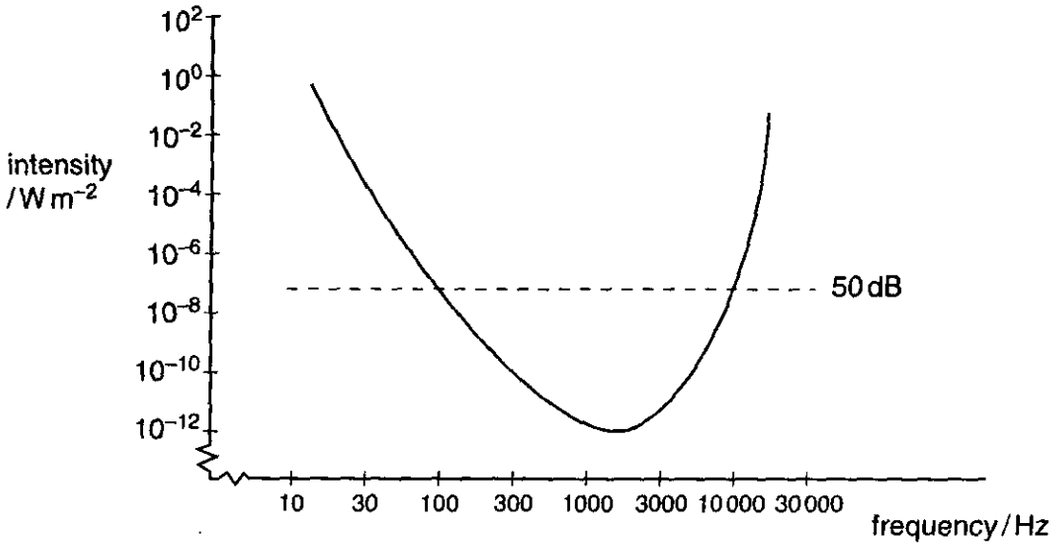

Fig. 2.1

A person with normal hearing listens to sound from a loudspeaker driven by a signal generator. This is set at a constant output intensity level of 50 dB measured at the ear. The frequency of the sound is then varied gradually from 10 Hz through to 30 kHz, as shown by the dotted line in Fig. 2.1.

(a) Use Fig. 2.1 to explain what will be heard by the person.

.....

.....

.....[3]

[Turn over

For Examiner's Use

(b) Suggest and explain **two** factors that might affect threshold intensity levels.

factor 1 .....

.....

factor 2 .....

.....[4]

[Total: 7]

3 A student wishes to determine the power of one of the convex lenses in his spectacles. He decides to base his experiment on the lens formula

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}.$$

(a) State the meaning of the letters *u* and *v*.

u .....

v .....

[1]

(b) For one arrangement of laboratory apparatus, the student measures and records *u* as 75 cm and *v* as 150 cm.

Calculate, using the student's measurements,

(i) the focal length of the lens

focal length = ... m [2]

(ii) the power of the lens.

power = ... D [2]

For Examiner's Use

(c) The student then wishes to estimate the power of his eye without the aid of the corrective lens.
He finds that his near point is situated at a distance of 50 cm from his eye and estimates the distance of the cornea from the retina for his eye as 1.9 cm. For the calculations in **(c)** and **(d)**, assume that all of the refraction in the eye occurs at the front surface of the cornea.

Use the data to calculate the power of the unaided eye of the student when focusing on an object at the near point.

power = ... D [2]

(d) The student puts on his spectacles and notices that the near point is much closer to his eye.

(i) Calculate the combined power of his eye and corrective lens when viewing an object at the new near point.

power = ... D [1]

(ii) Calculate the distance of the near point from the eye when the student is wearing his spectacles.

distance = ... m [2]

(iii) State, giving a reason, whether the lens is appropriate for correcting the vision of this student.

.....

.....[1]

[Total: 11]

[Turn over

For Examiner's Use

4 **(a)** Briefly describe the processes in which X-rays are used

- in a simple X-ray system to image a broken bone in a leg
- to image the brain using a CT scanner.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....[5]

(b) The system used for imaging a broken leg would not be suitable for imaging the brain. With reference to the properties of X-rays, explain why a CT scanner produces a much more useful image of the brain than a conventional X-ray image.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....[5]

[Total: 10]

For Examiner's Use

5 **(a)** The intensity I of a parallel monoenergetic X-ray beam after passing through a thickness x of a medium is given by the equation

$$I = I_0 e^{-\mu x}$$

where I_0 is the incident X-ray intensity and μ is a constant.

(i) State the name of the constant μ.

.....

(ii) Give **two** factors that determine the value of μ.

factor 1 .....

factor 2 .....

[3]

(b) A parallel monoenergetic X-ray beam passes through 2.5 cm of a material. Calculate the value of μ if the emergent X-ray beam has an intensity of 0.42 of its initial value. Give a unit for your answer.

μ = ... unit ..... [4]

[Total: 7]

6 **(a)** Ionising radiation has both a *direct* and *indirect effect* on living matter. Explain, giving an example of each, the terms

(i) *direct effect*

.....

.....[2]

(ii) *indirect effect.*

.....

.....[2]

[Turn over

For Examiner's Use

(b) (i) Explain why, during the treatment of malignancies by ionising radiation, cancerous cells are killed at a greater rate than healthy cells.

.....

.....

.....[2]

(ii) Suggest and explain a method that might be employed during the treatment of a malignancy to reduce the damage to the surrounding healthy cells.

.....

.....

.....[3]

[Total: 9]

7 A mother is singing to her baby. The intensity level at the ear of the baby, who is situated at a distance of 4.0 m from the mother, is 62 dB.

(a) Show that the intensity of sound at the ear of the baby is $1.60 \times 10^{-6}\,W\,m^{-2}$.

[2]

(b) The data in Fig. 7.1 below show the intensity of sound at the baby's ear due to the mother singing at various distances from the baby.

intensity / $W\,m^{-2}$	1.60×10^{-6}	4.00×10^{-6}	6.30×10^{-6}	8.60×10^{-6}	1.85×10^{-5}
distance / m	4.0	2.5	2.0	1.7	1.2
$\frac{1}{d^2}$ / m^{-2}					

Fig. 7.1

It is suggested that the intensity I, varies with distance from the mother d, according to the following equation

$$I = \frac{k}{d^2}$$

where k is a constant.

For Examiner's Use

(i) In order to verify this suggestion, complete Fig. 7.1 and use the data to plot on Fig. 7.2, a graph of I against $\frac{1}{d^2}$. [5]

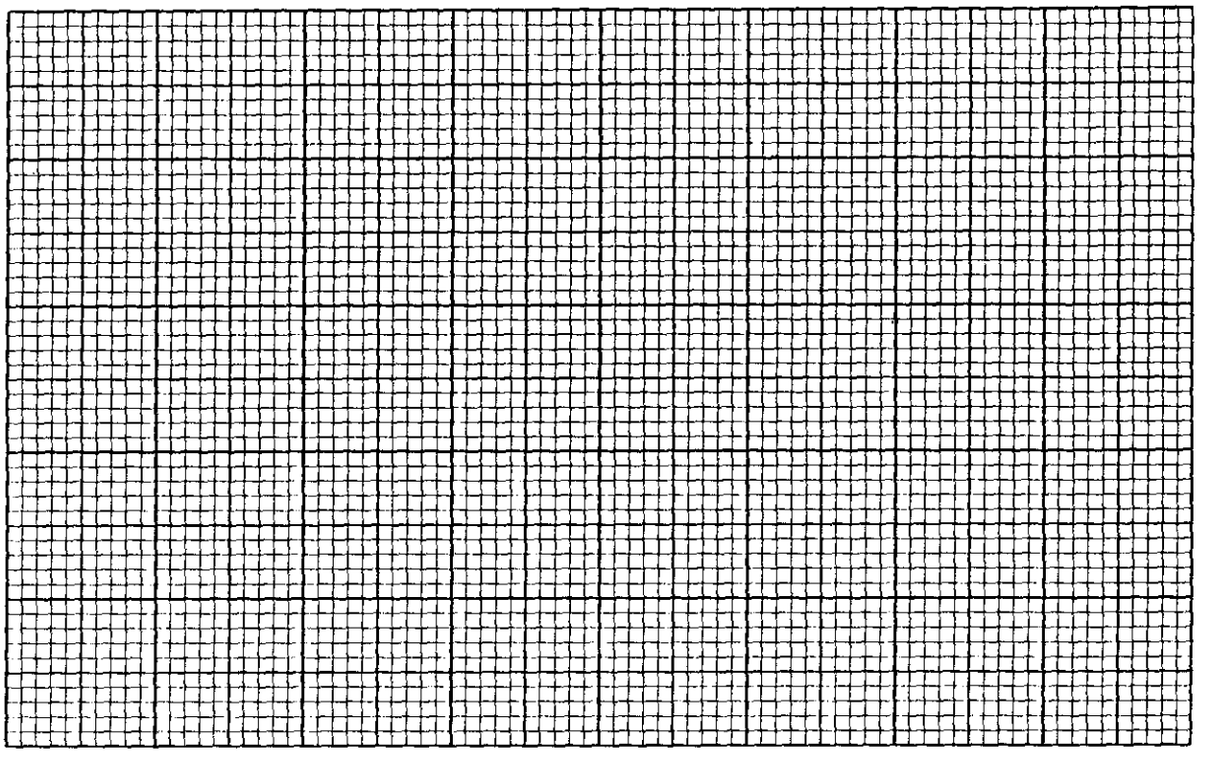

Fig. 7.2

(ii) Explain whether your graph supports the suggestion that the intensity is inversely proportional to the square of the distance from the source.

.....

.....[2]

(c) The mother sings with a steady output power while moving towards her baby, stopping at a distance of 0.60 m from the baby. Explain whether her baby will experience any physical discomfort due to the singing.

.....

.....[4]

For Examiner's Use

(d) As the mother moves towards the baby, the increase in intensity causes an increase in the loudness perceived by the baby. Suggest why the loudness is not proportional to the intensity.

.....

.....[1]

[Total: 14]

8 Describe the cellular effects of a laser when used as a scalpel and the subsequent macroscopic effects on human tissue. Explain the advantages of the use of a laser as a scalpel compared with conventional surgery.

.....

.....

.....

.....

.....

.....

.....

.....[5]

[Total: 5]

For Examiner's Use

9 A student is concerned to keep fit and equally concerned to minimise the use of electricity from the national grid. The student decides to combine the two issues and designs the system shown in Fig. 9.1. The chain on the exercise bicycle turns a d.c. generator which passes a current through a heating coil immersed in a hot water tank. The idea is that the student exercises for a certain length of time and instead of simply "wasting" energy in pedalling, the energy is used to heat the water necessary for a shower when finished.

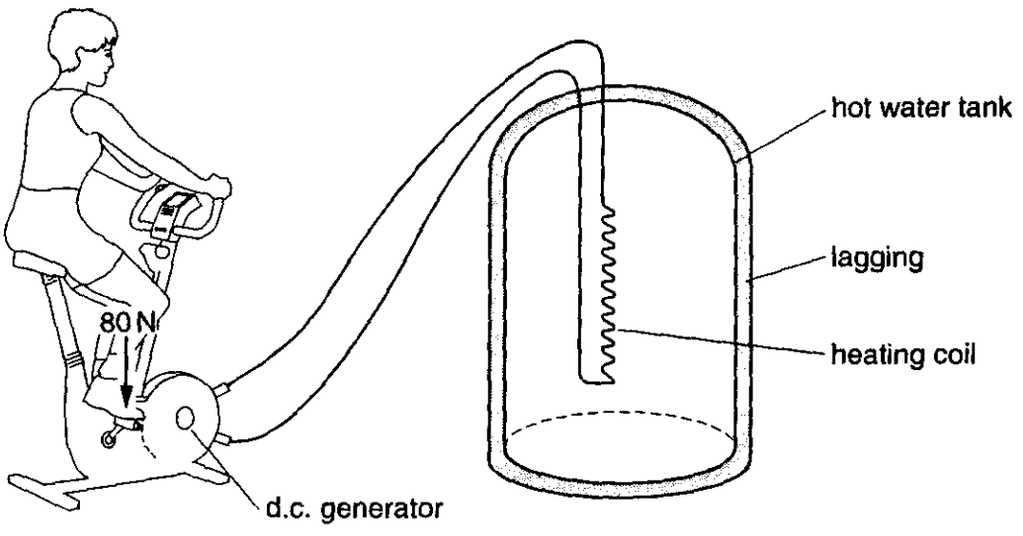

Fig. 9.1

The specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(a) The water enters the hot water tank at a temperature of 8 °C and is required to be heated to 38 ° C for an acceptable shower. The shower lasts for 5 minutes during which time the water flows at a rate of 0.15 kg s^{-1}. Calculate

(i) the mass of water used during the shower

mass of water = ... kg [2]

(ii) the energy required to heat the water for the shower.

energy = ... J [2]

[Turn over

For Examiner's Use

(b) When pedalling on the exercise bicycle, each foot spends half the cycle doing work and the other half relaxing. While doing work, an average tangential force of 80 N is applied to each pedal. The pedal is positioned at a radius of 20 cm from the axle and the student maintains 1.3 revolutions per second.

(i) Show that the work done by the student during one revolution of the pedals is about 100 J.

[2]

(ii) Calculate the power produced by the student while pedalling.

power = ... W [1]

(iii) Calculate the total number of revolutions of the pedals required before the energy expended by the student equals that required to heat the water.

number of revolutions = ... [1]

(iv) Calculate the time for which the student must pedal in order to deliver the heat energy required.

time = ... hour [2]

For Examiner's Use

(c) The d.c. generator being driven by the exercise bicycle has an internal resistance of 1.2 Ω and produces an e.m.f. of 24 V while delivering a current of 5A.

(i) Show that the resistance of the heater element in the hot water tank is 3.6 Ω.

[3]

(ii) Calculate the length of heater wire required if the element is made from resistance wire of resistivity $1.5 \times 10^{-7}\,\Omega\,m$ and cross-sectional area 0.32 mm^2.

length ..... m [3]

(d) In practice, the student would have to pedal for an even longer time than your answer to **(b)(iv)**. By considering energy losses, give reasons for this. Include some calculations in your answer.

.....

.....

.....

.....

.....[4]

[Total: 20]

END OF QUESTION PAPER