OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A 2825/02

Health Physics

Thursday **26 JUNE 2003** Morning 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 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 six questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	8	
2	21	
3	11	
4	6	
5	15	
6	9	
7	20	
TOTAL	90	

This question paper consists of 16 printed pages.

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

[Turn over

For Examiner's Use

Answer **all** the questions.

1 Fig. 1.1 shows the variation with frequency of the threshold of hearing for a normal person.

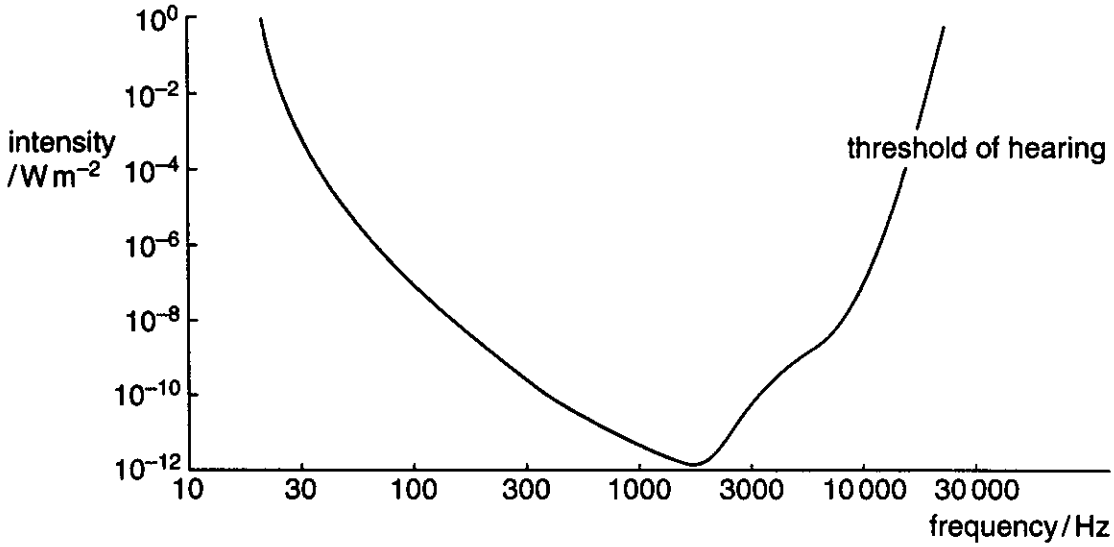

Fig. 1.1

(a) (i) Explain what is meant by *threshold of hearing*.

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.....[1]

(ii) Describe with reference to Fig. 1.1, what is meant by the *frequency response* of the ear.

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.....[2]

(iii) Suggest a reason why the graph dips to a minimum value.

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.....[1]

For Examiner's Use

(b) A person with normal hearing is exposed to a sound of frequency 200 Hz and intensity level at the ear of 23 dB.

(i) Calculate the intensity of this sound at the ear.

intensity = ... Wm^{-2} [3]

(ii) State and explain whether this sound would be detected by this person.

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.....[1]

[Total: 8]

[Turn over

For Examiner's Use

2 A patient is to have radiotherapy on a tumour.
In order to reduce exposure to low energy X-rays, the X-ray beam is passed through an aluminium filter. A thickness of 2.8 mm of aluminium reduces the intensity of this X-ray beam to one half (1/2) of its original value.

(a) (i) Calculate the thickness of aluminium that will reduce the intensity of the incident radiation to one eighth (1/8) of the original intensity.

thickness = ... mm [1]

(ii) Show that the linear attenuation coefficient μ for aluminium is about 250 m^{-1}.

[3]

(b) The energy of each X-ray photon that emerges in the beam is unchanged yet the power of the X-ray beam is reduced by the aluminium. Suggest why.

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.....[2]

(c) A short pulse of X-rays is used for the therapy.
Data for this therapy is as follows.

photon energy = 80 keV
energy required at the site of the tumour = 0.020 J
power of the beam = 200 W
mass of tumour = 0.065 kg

Calculate

(i) the energy of a single photon, in joules

energy = ... J [2]

For Examiner's Use

(ii) the number of X-ray photons required to deliver 0.020 J

number = ... [2]

(iii) the time interval needed for the delivery of 0.020 J

time interval = ... s [2]

(iv) the absorbed dose. Give a suitable unit for your answer.

absorbed dose = ... unit ..... [4]

(d) Describe and explain the direct and indirect microscopic effects of the interaction of X-rays with living tissue.

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.....[5]

[Total: 21]

[Turn over

3 For a normal eye, the power P, required to focus the eye on an object at a distance x, is given by the relationship

$$P = \frac{a}{x} + b$$

where a and b are constants.
Fig. 3.1 contains data of the power P of the eye when focusing on an object at a distance x.

x/m	x^{-1}/m^{-1}	P/D
8.0	0.125	52.6
4.0		52.7
2.0		52.8
1.0		53.6
0.50		54.6
0.25	4.00	56.6

Fig. 3.1

(a) Complete the table in Fig. 3.1. [2]

For Examiner's Use

(b) On Fig. 3.2, plot values of P (y-axis) against x^{-1} and draw a line of best fit. [3]

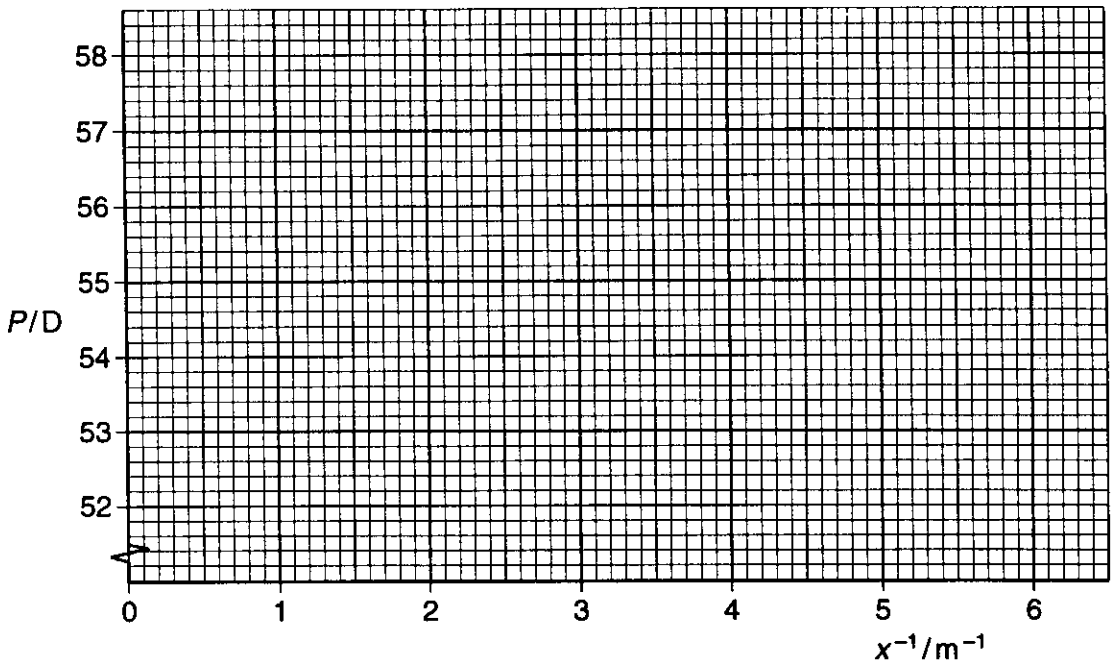

Fig. 3.2

(c) Calculate the gradient of the graph and hence a value for a.

a = ... [2]

(d) Deduce a value for the constant b. Give a suitable unit for your answer.

b = ... unit ..... [2]

(e) State the significance of b and explain why its value is a constant.

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.....[2]

[Total: 11]

[Turn over

For Examiner's Use

4 When a normal eye focuses on an object at infinity and then on an object at the *near point* of 25 cm, *accommodation* is said to occur.

(a) Explain the meaning of the terms

(i) *near point*

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(ii) *accommodation.*

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[2]

(b) A short-sighted eye has a near point of 15 cm.

(i) Calculate the power of a lens which will move the near point to 25 cm.

power = ... D [3]

(ii) State the shape of the lens in **(i)**.

.....[1]

[Total: 6]

For Examiner's Use

5 Fig. 5.1 shows the hip joint at the top of the femur where the leg bone is attached to the pelvis. The leg lifts when the abductor muscle contracts.

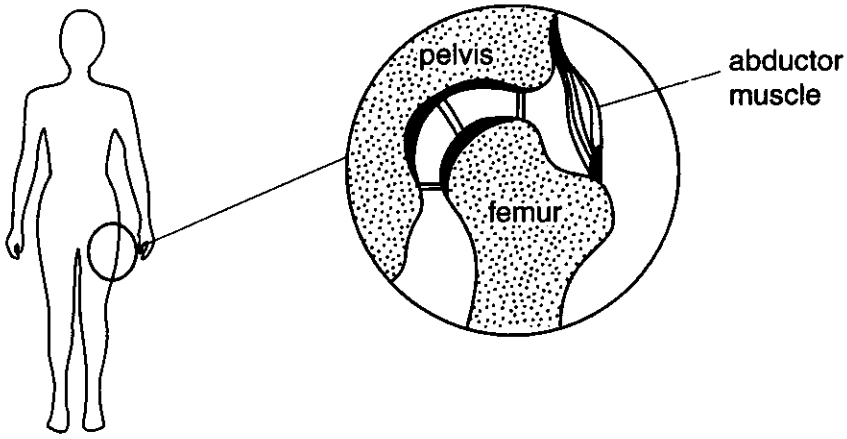

Fig. 5.1

(a) On Fig. 5.1, label

(i) the position of a tendon, T,

(ii) the positions of the ligaments, X.

[2]

(b) Explain the function of the ligaments.

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.....[1]

(c) Each hip joint supports a weight of 0.35 of the total body weight of 700 N. Calculate the weight of each leg.

weight = ... N [2]

(d) Explain what a person must do to balance on one leg when the other is lifted off the ground.

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[Turn over

(e) A student constructs a model leg to show how the action of the thigh muscle at the knee lifts the lower leg. Fig. 5.2 shows the structure of the model and the relative positions of the centre of mass of the lower leg, fulcrum P (knee joint) and line of action of the thigh muscle.

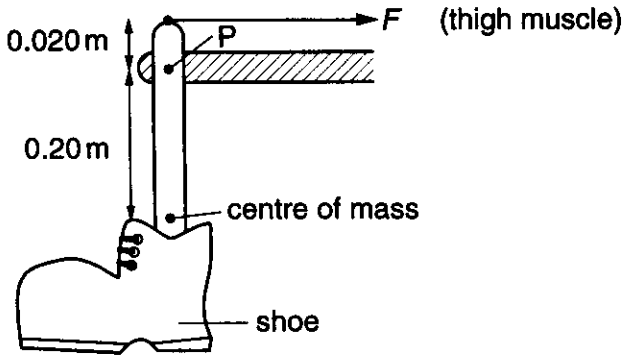

Fig. 5.2

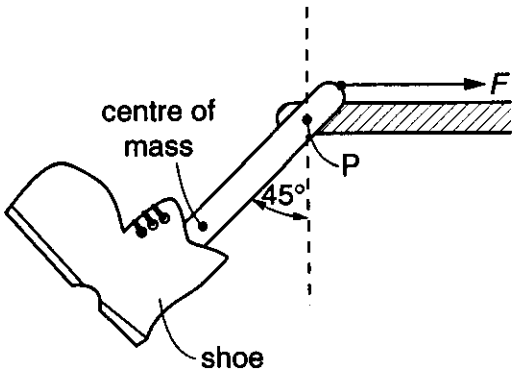

Fig. 5.3

The mass of the lower leg is 4.0 kg with a centre of mass 0.20 m from P. The thigh muscle acts at a point 0.020 m from P. The thigh muscle contracts and the lower leg is maintained at an angle of 45° to the vertical. (See Fig. 5.3).

Calculate for the model shown in Fig. 5.3

(i) the moment of the lower leg about P

moment = ... N m [3]

(ii) the force *F* applied by the thigh muscle

F = ... N [2]

For Examiner's Use

(iii) the mechanical advantage of the system.

mechanical advantage = ...[3]

[Total: 15]

6 A doctor suggests that a patient with a head injury is to have a magnetic resonance image (MRI) scan rather than an X-ray. Explain briefly the principles of physics involved in MRI scanning. State **two** advantages of this type of imaging over X-ray imaging.

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[Total: 9]

[Turn over

For Examiner's Use

7 Electric vehicles offer many advantages over those powered by internal combustion engines. However, they suffer from one overwhelming problem – storing the energy. In spite of massive research into battery technology, the traditional lead-acid car battery is still best for storing energy. It can hold 20 times more energy per kg than its nearest competitor, the nickel-cadmium rechargeable cell.

A typical lead-acid battery has the following properties.
storage capacity = 0.75 kW h
volume = 7.0×10^{-3} m^3
mass = 16 kg
terminal voltage = 12 V

Petrol has the following properties.
energy available = 50 MJ kg^{-1}
density = 700 kg m^{-3}

(a) Suggest **two possible** advantages of electric vehicles over conventional petrol powered vehicles.

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(b) The storage capacity of a battery is often quoted in ampere-hours. This is the number of hours for which a fully charged battery can supply a current of 1 A. Use the data to estimate the capacity in ampere-hours of a typical lead-acid battery.

capacity = ... ampere-hour [3]

(c) A bank of lead-acid batteries of total mass 960 kg is used to power a car.

(i) Calculate the total energy (in MJ) available.

energy = ... MJ [3]

For Examiner's Use

(ii) The drag force on the car at 25 m s^{-1} is 300 N. Estimate how far it could travel at this speed on a level road using the energy stored in these batteries.

distance = ... m [3]

(d) **(i)** Calculate the mass and volume of petrol that provides the same energy as the 960 kg of lead-acid batteries.

mass of petrol = ... kg

volume of petrol = ... m^3 [4]

(ii) The volume of petrol calculated in **(d)(i)** is very small.

Explain why, in practice, a greater volume of petrol is needed to travel the distance calculated in **(c)(ii)**.

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(e) Discuss the significance of your answers for the future adoption of electric vehicles rather than petrol vehicles.

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.....[3]

[Total: 20]