OCR RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/02

Health Physics

Monday **26 JANUARY 2004** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator
Ruler (cm/mm)

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.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first five questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	7	
3	17	
4	18	
5	16	
6	20	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

Data

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

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,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
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 The eardrum is linked to the oval window at the entrance to the inner ear by three bones called the ossicles. These act as a lever system so that the force F_o on the oval window is greater than the force F_e on the eardrum. Fig. 1.1 shows a schematic diagram of the ossicles.

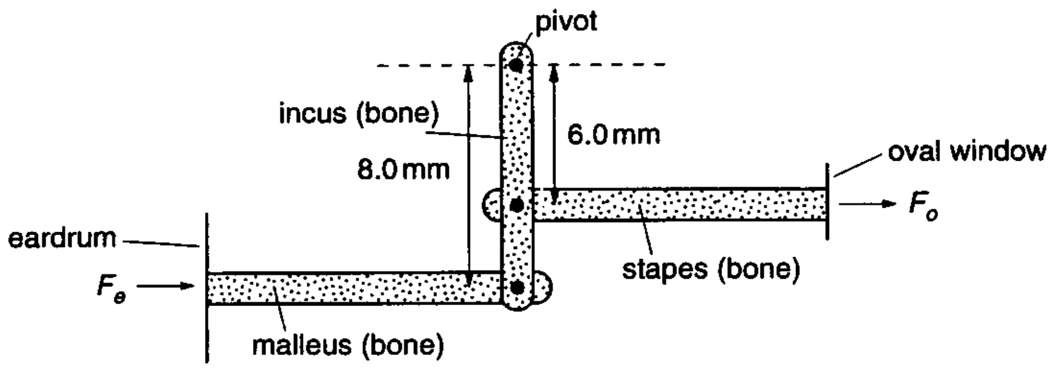

Fig. 1.1

(a) **(i)** Calculate the moment of the force F_e about the pivot for $F_e = 2.6 \times 10^{-4}$ N and an incus length of 8.0×10^{-3} m.

moment = ... Nm [1]

(ii) Hence show that if the stapes makes contact with the incus at a distance of 6.0 mm from the pivot, the force at the oval window is about 3.5×10^{-4} N.

[2]

(b) The area of the eardrum is 65 mm^2. The area of the oval window is 3.2 mm^2. Calculate

(i) the pressure on the ear drum

pressure = ... $N\,m^{-2}$ [3]

For Examiner's Use

(ii) the pressure on the oval window

pressure = ... $N\,m^{-2}$ [1]

(iii) the ratio, $\frac{\text{pressure on the oval window}}{\text{pressure on the ear drum}}$.

ratio = ... [1]

(c) **(i)** State the intensity of sound waves arriving at the ear at which discomfort is experienced.

intensity = ... $W\,m^{-2}$ [1]

(ii) State the value for the threshold intensity I_0.

threshold intensity = ... $W\,m^{-2}$ [1]

(iii) For a given individual, pain is experienced at an intensity of sound waves arriving at the ear of 31.6 $W\,m^{-2}$. Calculate for this individual the intensity level at which pain is experienced.

intensity level = ... dB [2]

[Total: 12]

For Examiner Use

2 Explain, with reference to labelled diagrams, the importance of correct body posture when lifting heavy or bulky objects. You should comment on the forces involved in the back muscles.

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....[7]

[Total: 7]

For Examiner's Use

3 Fig. 3.1 shows a cross-section through an ultrasound transducer.

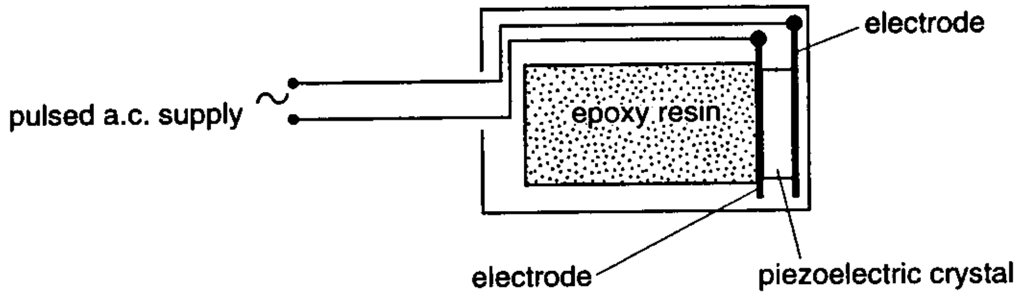

Fig. 3.1

The piezoelectric crystal is backed by a slab of epoxy resin and the power supply to the electrodes either side of the crystal is pulsed. The same crystal is used both to generate and detect ultrasound pulses.

(a) Describe the generation and detection of ultrasound by a piezoelectric crystal. Explain why the epoxy resin is needed and give reasons for pulsing the ultrasound.

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....[8]

[Turn over

For Examiner's Use

(b) Fig. 3.2 shows a cross-section through a part of a body. Ultrasound is pulsed through the centre of the section so that it passes first through an organ and then through a bone. Fig. 3.3 is an oscilloscope trace of the reflected ultrasound signal received from the gel-skin boundary and then from the front and back edges of first the organ and then the bone.

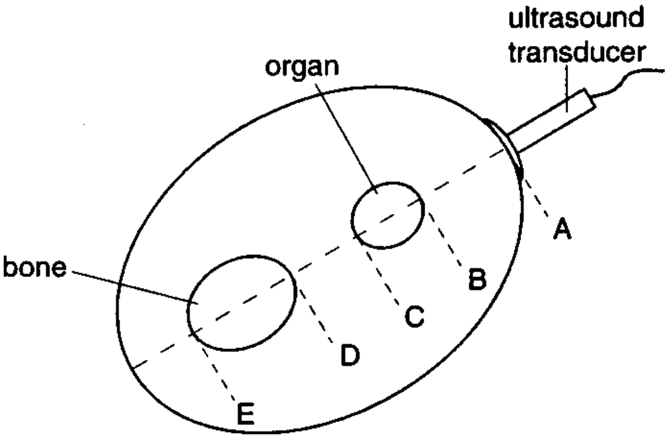

Fig. 3.2

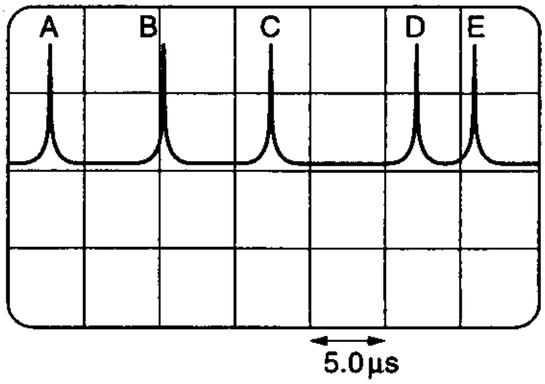

Fig. 3.3

Data:

speed of ultrasound in organ	$1.6 \times 10^3\ \text{m s}^{-1}$
speed of ultrasound in bone	$4.1 \times 10^3\ \text{m s}^{-1}$
speed of ultrasound in soft-tissue	$1.1 \times 10^3\ \text{m s}^{-1}$
time-base setting	$5.0\ \mu\text{s cm}^{-1}$

(i) Deduce from Fig. 3.3 the time interval during which the ultrasound travels in the organ.

time interval = ... s [1]

(ii) Calculate the distance travelled by ultrasound through the organ.

distance = ... m [1]

For Examiner's Use

(iii) Calculate the thickness of the organ.

thickness = ... m [2]

(iv) Calculate the thickness of the bone.

thickness = ... m [3]

(c) Explain **one** example where ultrasound is used rather than X-rays for medical imaging.

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....[2]

[Total: 17]

4 Fig. 4.1 shows a cross-section through an eye.

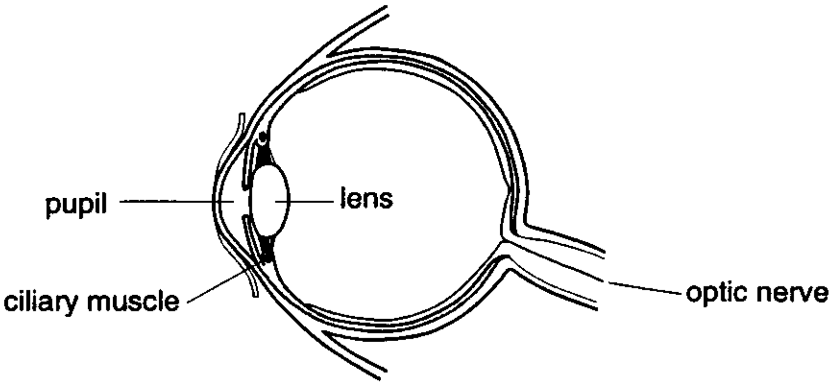

Fig. 4.1

(a) On Fig. 4.1, label clearly

(i) the vitreous humour

(ii) the cornea.

[2]

(b) Explain the function of

(i) the ciliary muscles

....

....[2]

(ii) the optic nerve.

....

....[1]

(c) Describe the symptoms experienced by a person who is short-sighted. You should include a reference to both the near point and far point of this person in your response.

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....[3]

(d) One of the eyes of a long-sighted person has a near point of 62 cm and a retina-cornea distance of 1.9 cm. Assume that the refracting system of this eye is equivalent to a single thin lens situated at the front surface of the cornea.

Calculate

(i) the focal length of the refracting system of this eye when focusing on an object at the near point of 62 cm

focal length = ... *m* [3]

(ii) the power of the refracting system of the eye when focusing on the object at the near point

power = ... D [2]

(iii) the maximum change in power during accommodation for this eye

change in power = ... D [2]

(iv) the power of the corrective lens that will enable this person to view an object clearly at a distance of 25 cm.

power = ... D [3]

[Total: 18]

For Examiner's Use

5 **(a)** The biological effects of exposure to ionising radiation may be described as either *stochastic* or *non-stochastic*.
Explain the difference between a *stochastic* and a *non-stochastic* effect giving an example of each.

stochastic ....

....

....

non-stochastic ....

....

....[4]

(b) The absorbed dose due to X-rays and γ-rays may be monitored by measuring *exposure*.
Define *exposure*.

....

....[2]

(c) (i) Calculate a value for the absorbed dose due to an exposure of $0.22\,\mathrm{C\,kg^{-1}}$ in a period of one hour. You should give an appropriate unit for your answer.
The energy required to produce one ion-pair in air is 34 eV.

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

(ii) State **two** factors, other than exposure, that determine the value of the absorbed dose for a person.

....

....

....

....[2]

For Examiner's Use

(d) Calculate, using your answer to **(c)(i)**, the dose equivalent if half of the energy absorbed was due to radiation with a quality factor of 2 while the remainder was due to radiation with a quality factor of 3. You should give an appropriate unit for your answer.

dose equivalent = ... unit .... [4]

[Total: 16]

6 Scintillation counters have been widely used to detect particles in high energy physics experiments. A scintillation counter consists of a sheet of plastic scintillator material coupled to a photomultiplier tube, as shown in Fig. 6.1.

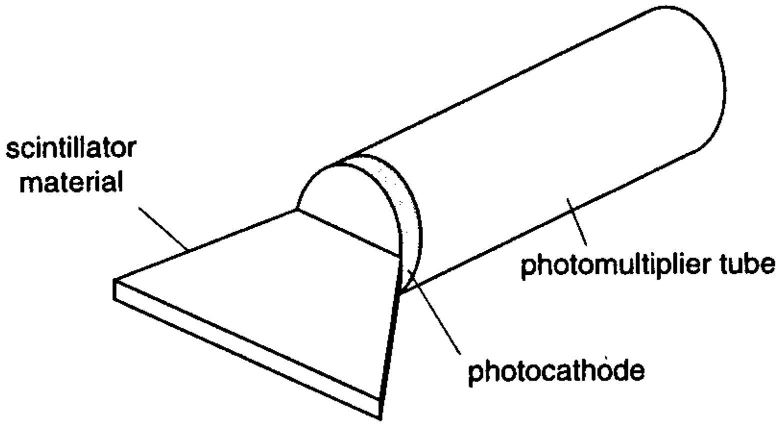


Fig. 6.1

The scintillator material produces a tiny flash of light when struck by a high energy particle. This light undergoes total internal reflection within the scintillator material until it reaches the photocathode of the photomultiplier tube. Fig. 6.2 shows this and also the internal structure of the photomultiplier tube.

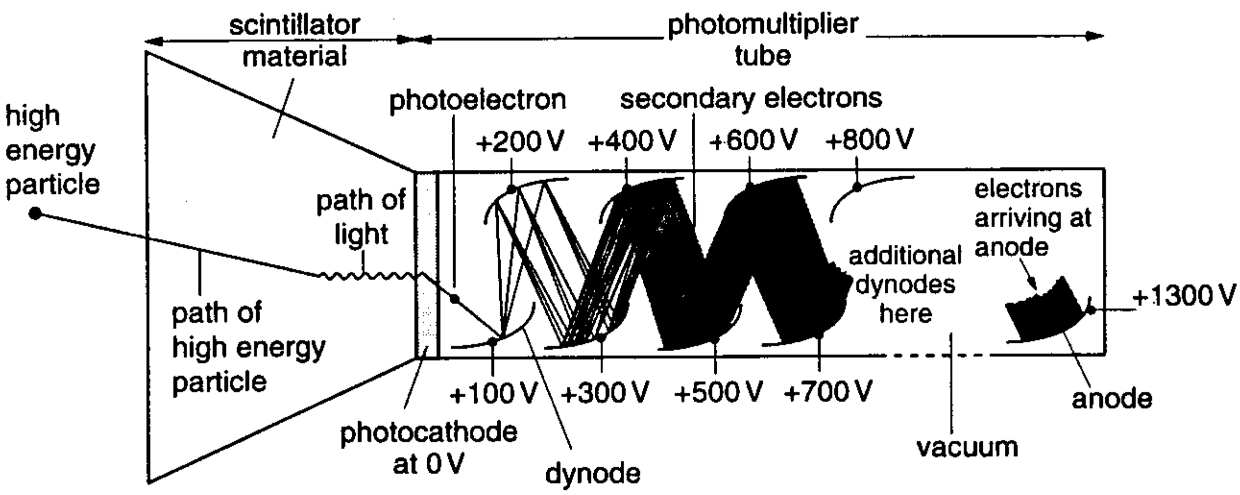


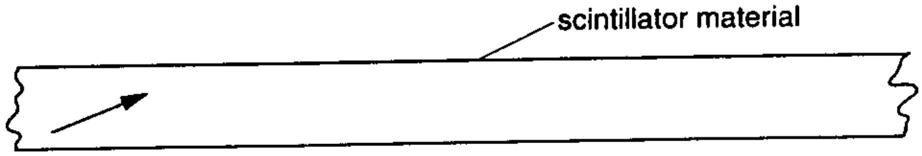
Fig. 6.2

When the flash of light reaches the photocathode, the photoelectric effect causes an electron, called a photoelectron, to be emitted from the photocathode. This electron is attracted by a potential difference between the photocathode and the first curved plate, called a dynode. When the electron hits the first dynode, with 100 eV energy in this case, several *secondary* electrons are emitted. These are accelerated to the next dynode, where the process is repeated. The pulse of charge at the final dynode, called the anode, can be measured by an electronic system.

For Examiner's Use

(a) The diagram below shows a section of the scintillator viewed from the side.

(i) Explain, with the aid of the diagram, how the light may be transmitted along the scintillator by total internal reflection.



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....[3]

(ii) The scintillator material has a refractive index of 1.58. Calculate the critical angle C for this material in air.

critical angle = ...° [2]

(b) In a particular experiment, a single high energy particle loses 1.5 MeV of energy in the scintillator material and in losing this energy produces 1.0×10^4 photons of wavelength 413 nm.

(i) Show that the energy of one photon of wavelength 413 nm is about 3.0 eV.

[2]

(ii) What percentage of the particle's energy loss has been converted into light in the scintillator material?

percentage = ...% [2]

(c) The photocathode is coated with potassium which has a work function ϕ of 2.2 eV.

(i) Calculate the threshold wavelength for potassium.

threshold wavelength = ... nm [2]

(ii) Why would zinc, which has a work function of 4.3 eV, be unsuitable for the photocathode coating?

....

....[1]

(iii) Calculate the maximum speed v_{max} of the photoelectrons emitted from the potassium photocathode.

v_{max} = ... m s^{-1} [3]

(d) **(i)** In the photomultiplier tube, there are 13 dynodes, including the anode, and 3 secondary electrons are emitted at each dynode per incident electron. Calculate the number of electrons received at the anode for one electron leaving the photocathode.

number = ... [2]

(ii) This pulse of electrons lasts 3.0×10^{-9} s. Calculate the average current during this pulse.

average current = ... A [3]

[Total: 20]

END OF QUESTION PAPER

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