THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Health Physics

2825/02

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Thursday 28 January 2010
Afternoon

Duration: 1 hour 30 minutes

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Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

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 seven questions concern Health Physics. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

Examiner's Use Only:			
1			
2			
3			
4			
5			
6			
7			
8			
Total			

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, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

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

Answer **all** the questions.

1 The reflections of ultrasound pulses from interfaces within the body may be displayed as an A-scan on an oscilloscope. Fig. 1.1 illustrates an A-scan display of the intensity of the reflected pulses against time for the interfaces **A**, **B**, **C** and **D** of Fig. 1.2.

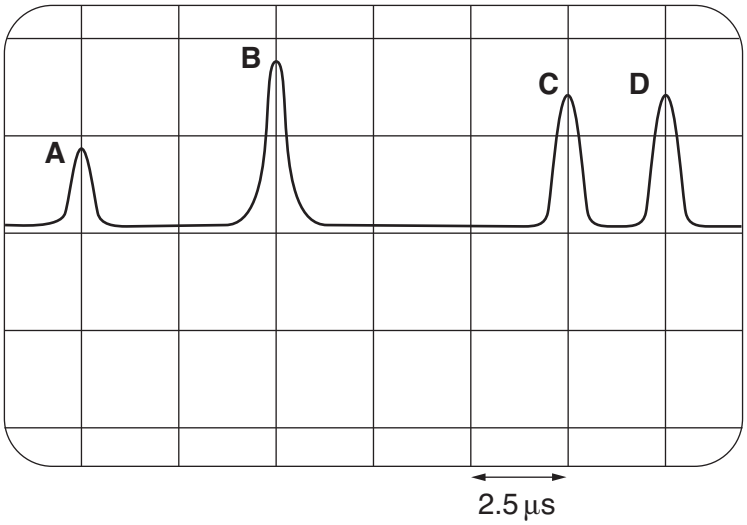

Fig. 1.1

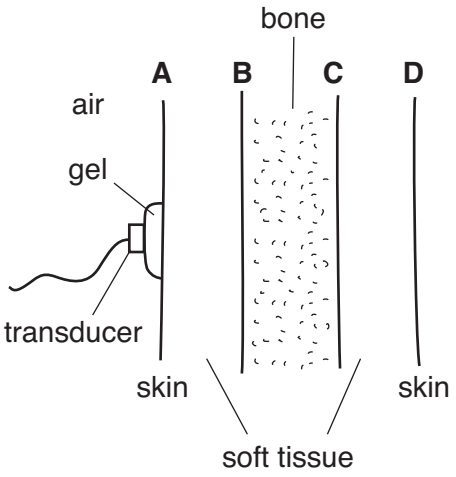

Fig. 1.2

Data:
speed of ultrasound in bone = 4000 m s^{-1}
speed of ultrasound in soft tissue = 1500 m s^{-1}
oscilloscope time-base setting = 2.5 μs per division

(a) Calculate

(i) the time interval between the observed reflections from the front edge **B** and the rear edge **C** of the bone

time interval = ... μs **[2]**

(ii) the thickness of the bone

thickness = ... cm **[3]**

(iii) the distance of the front edge **B** of the bone from the skin **A**.

distance = ... cm **[2]**

(b) State and explain how the trace in Fig. 1.1 might change if an acoustic coupling medium such as gel is **not** used between the transducer and the skin.

.....

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..... **[2]**

[Total: 9]

2 **(a)** Suggest values for the distance of the near point and far point from the eye for a person with normal vision.

near point = ...cm

far point = ...cm

[2]

(b) A patient has a near point of 32 cm and a far point of 96 cm. For the following calculations, assume that all of the refraction takes place at the front surface of the cornea and that the cornea-retina distance is equivalent to 1.7 cm in air.

(i) Suggest the eye defects from which the patient suffers.

.....

..... **[2]**

(ii) Calculate the power of the eye of the patient when an object is viewed at the near point of 32 cm.

power = ...D **[3]**

(iii) Calculate the power of the corrective lens needed for the patient to view an object at a distance of 25 cm.

power = ...D **[3]**

(iv) Calculate the power of the corrective lens needed for the patient to view an object at infinity.

power = ...D **[3]**

(v) State the type of spectacles that will enable the patient to view clearly objects at 25 cm and then at infinity.

..... **[1]**

[Total: 14]

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

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..... **[9]**

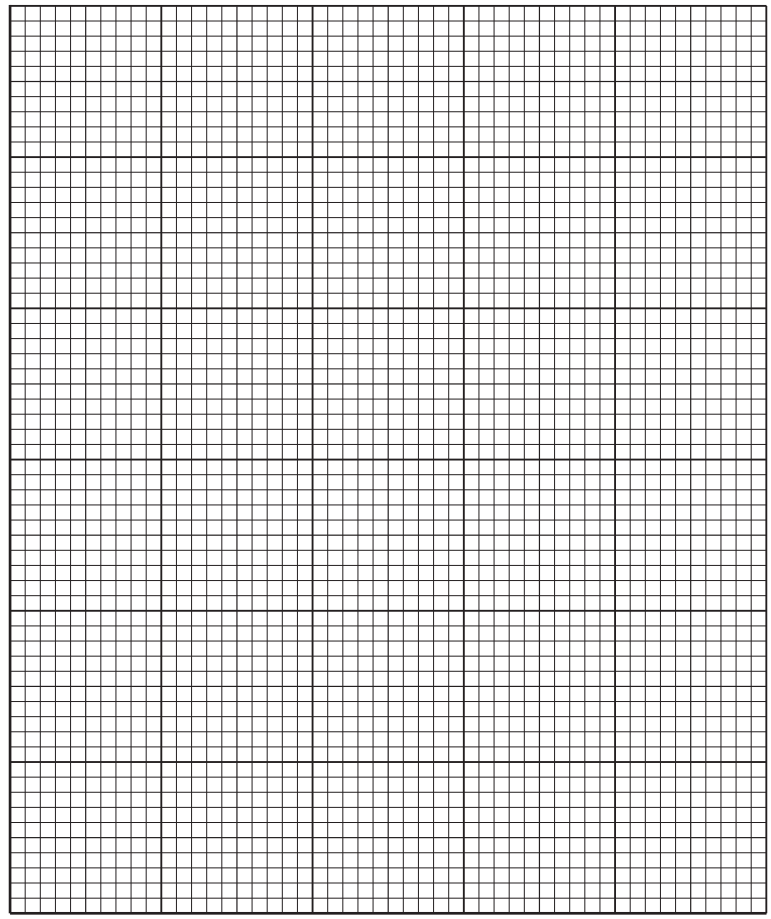
[Total: 9]

4 Fig. 4.1 shows data for the transmitted intensity I of a parallel beam of X-rays after penetration through a material of thickness x.

I / MW m^{-2}	x / mm
0.91	0.4
0.69	0.8
0.52	1.2
0.40	1.6
0.30	2.0
0.23	2.4
0.17	2.8

Fig. 4.1

(a) On Fig. 4.2 plot a graph of I against x.



[4]

Fig. 4.2

(b) Find the thickness that reduces the intensity of the incident beam by one half.

thickness = ... mm **[1]**

(c) Use your answer to **(b)** to calculate the linear attenuation coefficient μ.
Give a suitable unit for your answer.

μ = ... unit ..... **[4]**

[Total: 9]

5 **(a)** A loudspeaker produces 3.0 W of sound power. The area of the diaphragm of the loudspeaker is 16 cm^2.
Calculate the intensity of sound at the diaphragm.

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

(b) Equal changes in intensity are not perceived by the ear as equal changes in loudness.

(i) Calculate the change in intensity level for a sound as its intensity increases from $1.00 \times 10^{-7}\,W\,m^{-2}$ to $2.00 \times 10^{-7}\,W\,m^{-2}$.
Work to 3 significant figures.

change in intensity level = ... dB **[3]**

(ii) Calculate the change in intensity level for the sound as the intensity increases from $2.00 \times 10^{-7}\,W\,m^{-2}$ to $3.00 \times 10^{-7}\,W\,m^{-2}$.

change in intensity level = ... dB **[1]**

(iii) Comment on the intensity changes and the corresponding increases in loudness.

.....

.....

..... **[2]**

(c) The intensity level during a quiet section of a piece of music is 33.0 dB. The intensity level rises during a loud section of the music to 78.0 dB.

Calculate the ratio $\dfrac{\text{intensity at 78.0 dB}}{\text{intensity at 33.0 dB}}$.

ratio = ... **[4]**

[Total: 12]

6 **(a)** When radiation penetrates air, ionisation occurs. The amount of positive charge produced in 1.0 kg of air is called the exposure. For radiation from a particular X-ray source of photon energy 200 keV, the factor *f* relating the exposure in air to the absorbed dose in bone is $38\,J\,C^{-1}$ and in muscle is $37\,J\,C^{-1}$.

The X-ray source produces a charge of $24\,\mu C\,kg^{-1}$ per hour. The energy required to create 1 ion-pair in air is 34 eV.

Calculate

(i) the number of ion-pairs created in 1 kg of air in 1 hour

number = ... **[1]**

(ii) the absorbed dose in 1 hour in air, giving the SI unit for your answer

absorbed dose = ... unit ..... **[3]**

(iii) the absorbed dose in 1 hour in bone.

absorbed dose = ... unit ..... **[2]**

(b) At X-ray photon energies of 30 keV the factor *f* for bone is about 150 J C^{-1} while the factor *f* for muscle remains at about 37 J C^{-1}.

Explain why this 30 keV radiation would be preferred to the 200 keV radiation of **(a)** for the treatment of certain malignant tumours.

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..... **[3]**

(c) Calculate the quality factor if the dose equivalent per hour for this X-ray source is 1.71 mSv for bone.

quality factor = ... **[2]**

[Total: 11]

7 Explain what is meant by the *frequency response* to sound waves of a person with normal hearing and describe and explain how this response varies with age.

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..... **[6]**

[Total: 6]

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8 A householder wants to reduce the amount of mains energy used in his home, in order to combat global warming. He plans to install a device which is powered by a renewable energy source. He considers three options:

A an array of photoelectric cells mounted on his house roof

B a solar panel mounted on the house roof for heating water by solar radiation

C an aerogenerator attached by a short pole to the house chimney.

Option A: Photoelectric cells

Photoelectric cells consist of two layers of different semiconductor materials in contact with each other. When a cell is exposed to solar radiation an e.m.f. is created. See Fig. 8.1. The cells are arranged in an array as shown in Fig. 8.2.

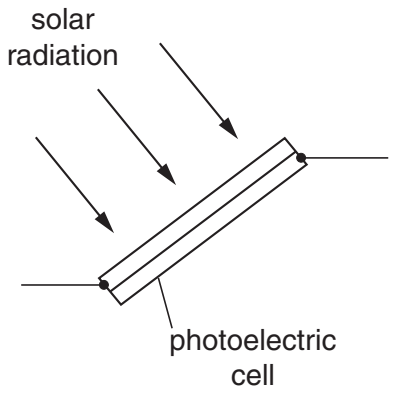

Fig. 8.1

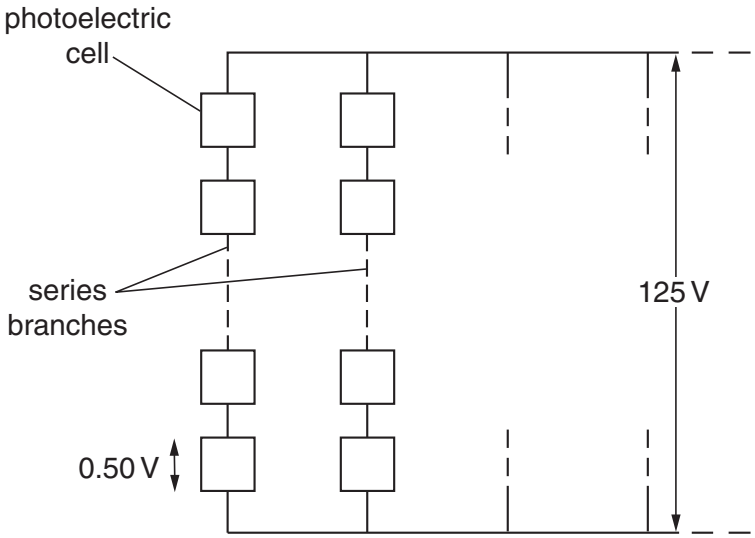

Fig. 8.2

intensity of solar radiation falling on the house	=	800 W m^{-2}
voltage output of each cell for this intensity	=	0.50 V
efficiency of each photoelectric cell	=	10 %
surface area of each photoelectric cell	=	5.0 cm^2
required output from photoelectric cell array	=	125 V

(a) (i) Calculate the total area of photoelectric cells needed to generate 1000 W of electrical power.

area = ... m^2 **[2]**

(ii) Show that the number of photoelectric cells needed is 25 000.

[1]

(iii) The photoelectric cells are arranged as in Fig. 8.2.

1 State the number of cells in **one** series branch. .....

2 State the number of branches in parallel. .....

[2]

(iv) Calculate the current through each photoelectric cell.

current = ... A **[2]**

Option B: Solar Panel

Solar radiation passes through a layer of glass and is absorbed by tubes of water. Cool water flows into the tubes and is heated. Hot water flows out and is led to an insulated storage tank.

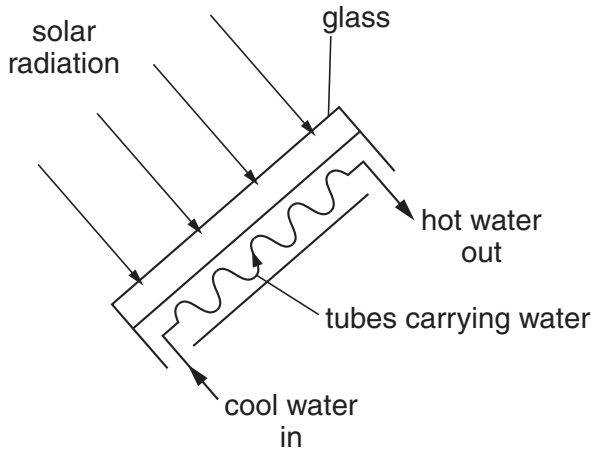

Fig. 8.3

intensity of solar radiation falling on the house	=	800 W m^{-2}
efficiency of solar panel	=	70 %
incoming water temperature	=	20 °C
outgoing water temperature	=	75 °C
specific heat capacity of water	=	4200 J kg^{-1} K^{-1}

(b) (i) Calculate the area of the solar panel needed for the water to gain 1000 J of heat energy per second.

area = ... m^2 **[2]**

(ii) Calculate the rate in kg s^{-1} at which water must flow through the tubes in order to emerge at 75 °C.

rate = ... kg s^{-1} **[3]**

Option C: Aerogenerator

This consists of a fan that rotates in the wind, and an electrical generator.

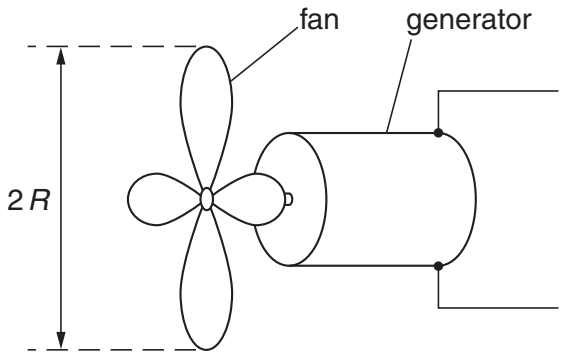

Fig. 8.4

efficiency of aerogenerator = 40 %
wind speed = 5.0 m s^{-1}
density of air = 1.3 kg m^{-3}

(c) The air flowing through the fan in 1 second is a body of air having a cylindrical shape, of diameter 2*R* and length *v* where *v* is the speed of the air. See Fig 8.5.

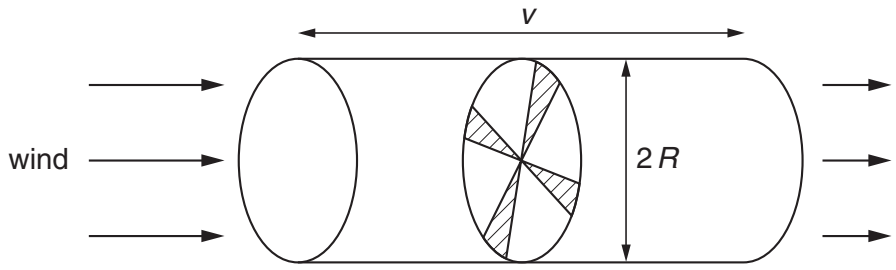

Fig. 8.5

The aerogenerator supplies 1000 J of electrical energy from this air in 1.0 second. This is 40 % of the initial kinetic energy of the air.

(i) Show that the initial kinetic energy of the cylinder of air is 2500 J.

[1]

(ii) Calculate the mass of this cylinder of air.

mass = ... kg **[2]**

(iii) Calculate the radius R of the aerogenerator fan.

R = ... m **[2]**

(d) The householder needs to make a choice.
Comment on the appropriateness or otherwise of **one** of these energy-generating processes for the house.

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..... **[3]**

[Total: 20]

END OF QUESTION PAPER