OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **2825/02**

PHYSICS A

Health Physics

FRIDAY 25 JANUARY 2008 Morning

Time: 1 hour 30 minutes

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

CUP/T36925

Candidate Forename

Candidate Surname

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or 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.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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	9	
2	15	
3	8	
4	8	
5	14	
6	16	
7	20	
TOTAL	90	

This document consists of **16** printed 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,	$n = \dfrac{1}{\sin C}$
capacitors in series,	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \dfrac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 Fig. 1.1 shows a schematic diagram of an arm supporting a weight of 80 N at the hand. A force *b* is provided by the biceps muscle. The 80 N weight is 34 cm from the fulcrum **F** . The weight of the lower arm is 12 N and acts at a point 15 cm from **F**. The angle between the line of action of force *b* and the horizontal lower arm is 60°. The biceps muscle may be considered to be attached at a single point to both the lower and upper arm bones at a distance of 3.0 cm and 20 cm respectively from the fulcrum **F**.

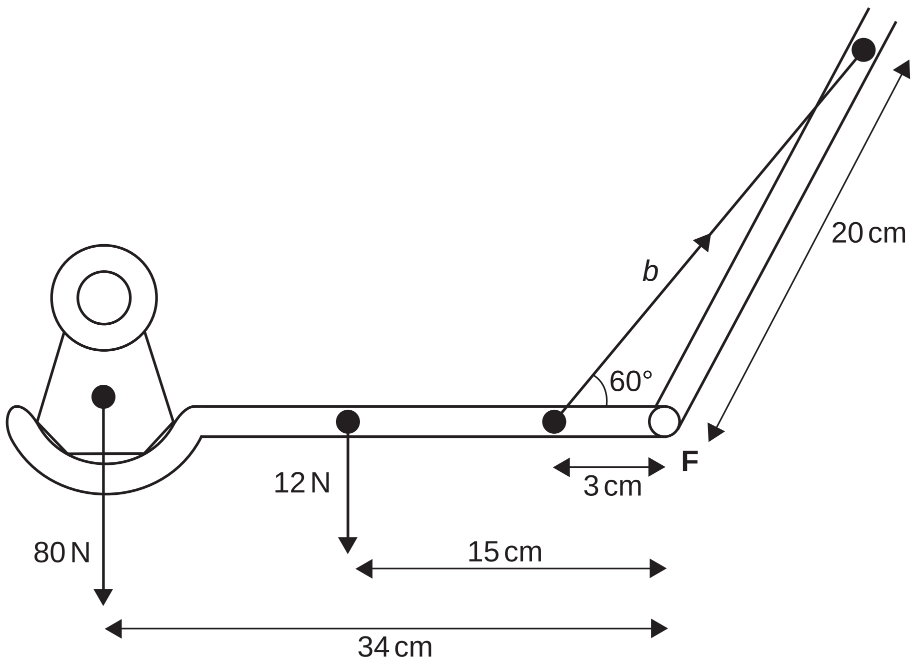

Fig. 1.1

(a) Calculate for the lower arm

(i) the force *b* needed by the biceps muscle to maintain the lower arm in the horizontal position

b = ... N [4]

(ii) the mechanical advantage for lifting the 80 N load.

mechanical advantage = ... [2]

(b) **(i)** Explain how the force *b* will change when the arm is outstretched so that the line of action of *b* makes an angle of 30° with the horizontal lower-arm bone.

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.... [2]

(ii) Hence explain the change, if any, in the mechanical advantage.

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.... [1]

[Total: 9]

2 Fig. 2.1 shows the paths of two rays from an object situated between the far point **F** and the near point **N** of one eye of a patient. Refraction is shown at the cornea and at the lens.

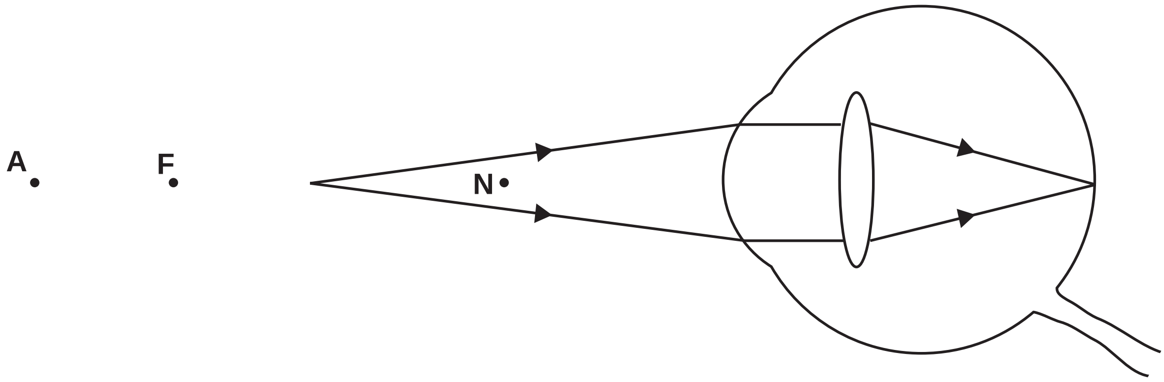

Fig. 2.1

In Fig. 2.1 point **A** is just beyond the far point **F**.

(a) **(i)** On Fig. 2.1, draw **two** lines to show the paths of two rays from **A**, through the eye and ending on the retina. [2]

(ii) Describe how an object situated at point **A** will appear to this patient.

....

.... [1]

(b) This patient's eye is short-sighted.

(i) State the corrective lens for this eye.

.... [1]

(ii) Explain, without calculation, how the corrective lens will affect the position of the near point of this eye. Your answer should refer to the power of the corrective lens.

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.... [4]

(c) The patient has a cornea-retina distance of 1.9 cm. For this part of the question, assume that all of the refraction in the eye occurs at the cornea.

Calculate

(i) the power of the eye when focusing on an object at the patient's far point of 60 cm

power = ... D [3]

(ii) the power that this eye should have when focusing at infinity

power = ... D [2]

(iii) the power of the corrective lens required to enable this eye to focus at infinity.

power = ... D [2]

[Total: 15]

3 Explain how the hearing of a person varies across the audible range of frequencies and intensities. Your answer should make reference to

- relevant numerical values of frequency and intensity
- factors that affect hearing.

A sketch graph may help your answer.

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.... [8]

[Total: 8]

4 Fig. 4.1 shows a cathode ray oscilloscope (c.r.o.) trace of an ultrasound pulse which is reflected from the front edge of a bone of thickness 2.5 cm.

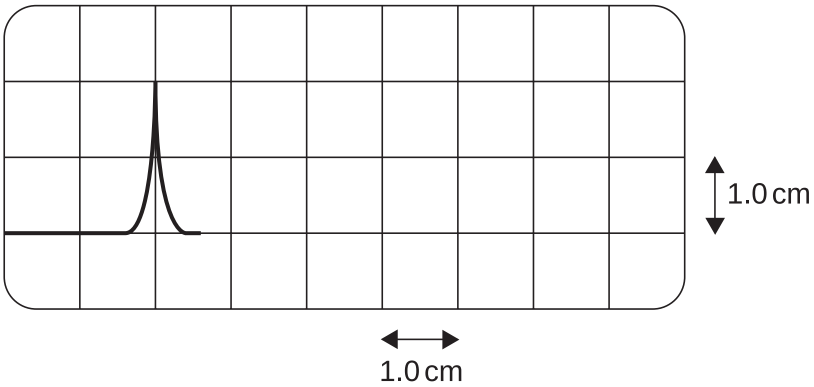

Fig. 4.1

(a) (i) Calculate the time taken for the ultrasound pulse to travel through the bone to the rear edge. The speed of ultrasound in bone is $4.0 \times 10^3\,\text{m s}^{-1}$.

time = ... s [2]

(ii) The time-base on the c.r.o. is set to $2.0\,\mu\text{s cm}^{-1}$.

On Fig. 4.1 draw the position of the peak generated by the reflection of the pulse from the rear edge of the bone. [2]

(b) State **two** common uses for ultrasound imaging. For each give a reason why ultrasound would be used in preference to conventional X-ray imaging.

Use 1 ....

....

....

Use 2 ....

....

.... [4]

[Total: 8]

5 An X-ray tube provides a beam with photon energy 0.050 MeV. The exposure to X-rays from this beam is 3.5×10^{-4} C kg^{-1}. Fig. 5.1 shows the variation with photon energy of the factor f which is given by $f = \dfrac{\text{absorbed dose in a substance}}{\text{exposure in air}}$.

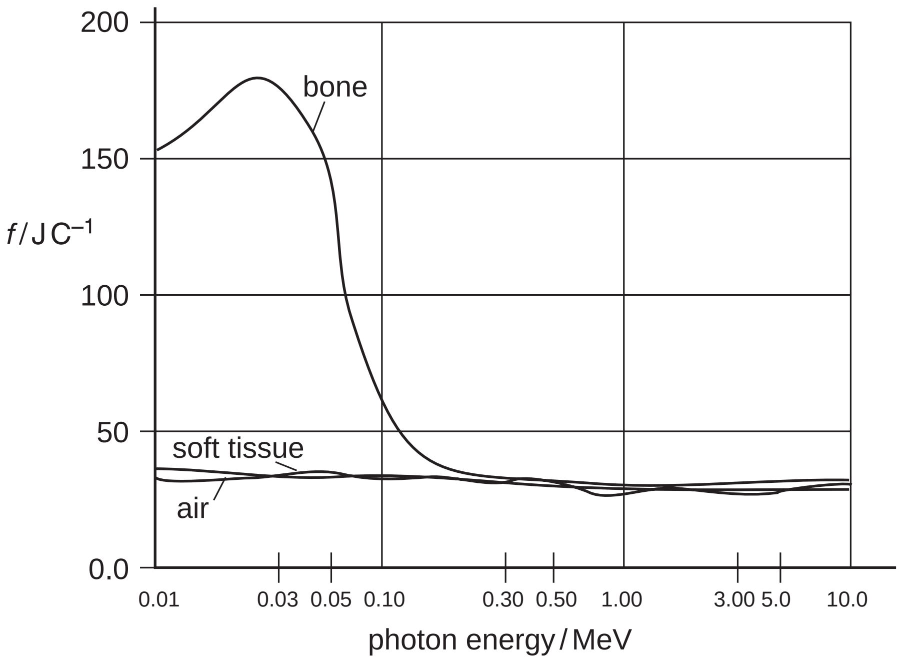

Fig. 5.1

(a) **(i)** Calculate the absorbed dose for a volume of bone which is exposed to these X-rays. Give a unit for your answer.

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

(ii) The X-ray photon energy is increased to 0.20 MeV. The exposure from this beam is unchanged.

Calculate the ratio

$$\frac{\text{absorbed dose for 0.20 MeV X-rays}}{\text{absorbed dose for 0.050 MeV X-rays}}.$$

ratio = ... [1]

(b) In order to treat a bone tumour, a student suggests that it would be preferable to use very high energy X-ray photons rather than low energy X-ray photons as this will deliver more energy to the tumour and so kill more cells. Explain the effect X-rays have on both cancerous and healthy tissue and state with reasons, whether or not you agree with the suggestion.

You should use information from part **(a)** in your answer.

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.... [9]

[Total: 14]

6 An argon-ion laser produces light of two wavelengths 488 nm (blue) and 515 nm (green). Light from this type of laser is used to treat red birthmarks on skin or to perform eye surgery on detached retinas.

(a) (i) Calculate the intensity of the laser beam for a beam diameter of 0.25 mm when the output power from the laser is 5.0 W.

Give a unit for your answer.

intensity = ... unit .... [4]

(ii) The laser is to be used for surgery on a detached retina. The intensity of the beam at the retina is higher than that calculated in **(i)**. Suggest why.

....

.... [1]

(b) The laser light is passed through a **green** filter.

(i) Calculate the energy of a single photon of laser light which emerges from the green filter.

energy = ... J [3]

(ii) The output power for each wavelength emitted by the laser is the same. Calculate the rate at which photons emerge from the green filter. State an assumption made in your answer.

rate = ... s^{-1}

assumption: ....

.... [4]

(c) Birthmarks can be treated by absorption of laser light.

A helium-neon laser emits red light. Suggest why an argon-ion laser is more suitable for treating red birthmarks than a helium-neon laser.

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.... [1]

(d) Explain **three** advantages of laser surgery compared with conventional surgery.

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.... [3]

[Total: 16]

7 The normal temperature of a healthy human body is 37 °C. When an adult person at this temperature is at rest, energy from food is required to maintain normal internal body activity (the basal metabolic rate). On average this energy is supplied to the body at the rate of 75 W. When involved in physical activity, extra energy from food is used. 20% of this extra energy is needed to do mechanical work; the remaining 80% heats the body and has to be dissipated. The energy available from 1 g of food in the form of carbohydrate is about 1.7×10^4 J.

(a) A meal provides a person with 250 g of carbohydrate.

(i) Estimate the period of rest in hours which is provided for by this intake of food.

period of rest = ... hour [2]

(ii) Suggest why the temperature of the person's body remains steady during this period.

....

....

....[2]

(b) A mountaineer of mass 70 kg climbs a mountain to a vertical height of 800 m above the starting point in 1.5 hours. Calculate

(i) the gain in potential energy of the mountaineer

potential energy gain = ... J [2]

(ii) the mass of carbohydrate used to provide this gain in potential energy

mass = ... g [1]

(iii) the minimum total mass of carbohydrate used by the mountaineer.

mass = ... g [3]

(c) A marathon runner, of mass 65 kg, competes on a day when the temperature of the environment is 40 °C. The rate of heating of the runner's body is 900 W.

(i) Calculate the rate of temperature rise of the runner's body. Assume that the body has a specific heat capacity of 4200 J kg^{-1} K^{-1}.

rate of temperature rise = ... K s^{-1} [2]

(ii) Explain why the runner's body cannot lose heat to the surrounding air by the processes of conduction, convection and radiation.

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....[2]

(iii) The runner maintains normal body temperature by using heat from the body to evaporate water (sweat) from the surface of the skin. The heat required to vaporise 1 kg of water is 2.4×10^6 J. Calculate the mass of water evaporated from the skin in 2.5 hours of running.

mass = ... kg [2]

(iv) To minimise harm to the body **during the race**, state and explain **two** precautions the runner should take.

1. ....

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2. ....

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....[4]

[Total: 20]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE