OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A

2825/02

Health Physics

Thursday **27 JUNE 2002** 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.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	11	
2	14	
3	10	
4	12	
5	10	
6	5	
7	8	
8	20	
TOTAL	**90**	

This question paper consists of 15 printed pages and 1 blank page.

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,
$$s = ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

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,
$$p = \tfrac{1}{3}\frac{Nm}{V}<c^2>$$

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

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 **(a)** Figs. 1.1–1.3 illustrate three positions of a leg and foot as a person walks.

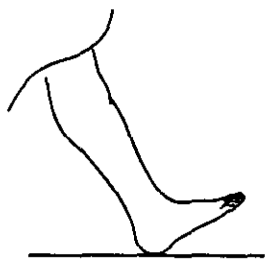

Fig. 1.1

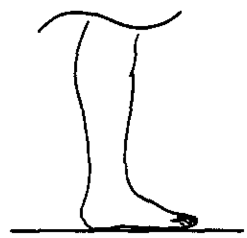

Fig. 1.2

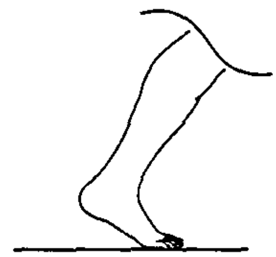

Fig. 1.3

(i) On Figs. 1.1, 1.2 and 1.3, draw an arrow to show the direction of the resultant force exerted by the floor on the foot. [3]

(ii) Describe the effect of friction on the motion of the foot in Figs. 1.1–1.3.

Fig. 1.1 ....

....

Fig. 1.2 ....

Fig. 1.3 ....

....

[3]

(b) In order to stand on tip-toe and maintain the stance, a person leans forward as shown in Fig. 1.4.

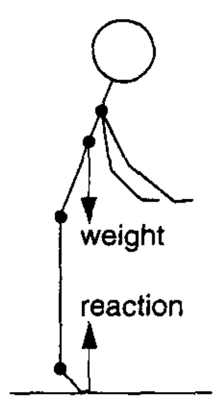

Fig. 1.4

Fig. 1.5 shows a free body force diagram of one of the feet for this person during the stance. The tension *T* in the calf muscles lifts the heel while the force *P* pushes the leg bones onto the foot. The foot has a weight of 40 N. The floor exerts an upward force of 300 N on the foot. Assume that all four forces are acting along lines that are parallel with the vertical.

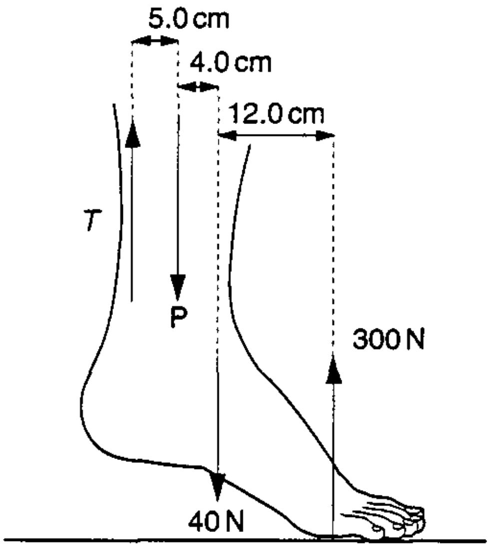

Fig. 1.5

The perpendicular forces between the lines of action of the forces *T* and *P*, *P* and the 40 N weight, and the 40 N weight and the 300 N reaction of the floor are 5.0 cm, 4.0 cm and 12 cm respectively.

Calculate

(i) the tension *T* in the calf muscle

T = ... N [3]

(ii) the push *P* of the leg bones on the foot.

P = ... N [2]

[Total : 11]

2 A person has a near point of 35 cm and a far point of 80 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.

(a) (i) 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]

(ii) Suggest the eye defect or defects from which this person suffers.

....

....[2]

(b) (i) Calculate the power of the eye of this person when an object is viewed at the near point of 35 cm.

power = ... D [3]

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

power = ... D [3]

For Examiner's Use

(iii) Calculate the power of the corrective lens needed for this person to view an object at infinity.

power = ... D [3]

(iv) Describe the type of spectacles that will enable this person to view clearly objects at 25 cm and then at infinity.

....

....[1]

[Total : 14]

3 **(a)** When a sound wave enters the ear, its energy causes a mechanical oscillation in the middle ear and then a pressure wave in the fluid of the inner ear.

(i) Explain, with the aid of a labelled sketch, how the design of the middle ear increases the pressure at the oval window.

....

....

....

....[4]

(ii) Suggest the need for this increase in pressure at the oval window.

....

....[2]

(b) The response of the ear to intensity is not linear. Fig. 3.1 shows different intensities and corresponding intensity levels for sounds of frequency 2.0 kHz.

I/Wm^{-2}	1.0×10^{-12}	4.0×10^{-12}	8.0×10^{-12}
IL/dB	0.0	6.02	

Fig. 3.1

(i) Complete Fig. 3.1. Show your working below.

[2]

(ii) The intensity of a sound of frequency 2.0 kHz is increased suddenly from 1.0×10^{-12} Wm^{-2} to 4.0×10^{-12} Wm^{-2} and then from 4.0×10^{-12} Wm^{-2} to 8.0×10^{-12} Wm^{-2}.

Explain, with reference to Fig. 3.1, which of the two changes in intensity would cause the perception that loudness has increased by a greater amount.

....

....

....[2]

[Total : 10]

4 **(a)** Describe the properties exhibited by a piezoelectric crystal that make it desirable for use in an ultrasound transducer.

....

....

....

....

....[4]

(b) Ultrasound is reflected at the boundaries between media of differing acoustic impedance.

State the **two** factors upon which acoustic impedance depends.

1. ....

2. ....

[2]

For Examiner's Use

(c) The fraction *f*, of ultrasound reflected at a boundary is given by the equation

$$f = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

where Z_1 and Z_2 are the specific acoustic impedances of the media on either side of the boundary. Fig. 4.1 lists the values of the specific acoustic impedance *Z* for five different media.

medium	Z/kg m^{-2} s^{-1}
air	4.29×10^2
soft-tissue (skin)	1.63×10^6
muscle	1.70×10^6
bone	7.78×10^6
gel	1.42×10^6

Fig. 4.1

(i) Calculate the value of *f* for ultrasound reflected at

1. an air-skin boundary

f = ... [2]

2. a gel-skin boundary.

f = ... [2]

(ii) Hence explain the need for a coupling medium (gel) for effective ultrasound transmission.

....

....

....[2]

[Total : 12]

[Turn over

For Examiner's Use

5 Magnetic resonance imaging (MRI) relies on the *precession* of nuclei of atoms that have an odd number of protons and/or neutrons when placed in a strong magnetic field.

(a) Explain the term *precession*.

....

....[2]

(b) State the atom most commonly used in MRI and describe the properties that make it suitable for this purpose.

....

....

....[3]

(c) When electromagnetic radiation is applied to a patient undergoing MRI, the frequency of the radiation is the *Larmor frequency*.

Explain the term *Larmor frequency* and state the part of the electromagnetic spectrum in which it is to be found.

....

....[2]

(d) A short pulse of electromagnetic radiation is initially applied to the patient. The atoms take a short time to return to their equilibrium state. This time, known as the *relaxation time*, is measured.

State how the relaxation time allows the differentiation of tissue types.

....

....[1]

(e) Give **two** reasons for the choice of MRI in preference to an X-ray for the purpose of imaging the brain.

1. ....

....

2. ....

....[2]

[Total : 10]

For Examiner's Use

6 The biological effects of exposure to radiation may be classified as being either stochastic or non-stochastic.

(a) Give an example of a non-stochastic effect.

....[1]

(b) Explain how the effect described in **(a)** differs from a stochastic effect.

....

....

....

....

....[4]

[Total : 5]

7 **(a)** Define the *gray*.

....

....[1]

(b) A person of mass 70 kg receives an absorbed dose of 4.2×10^{-7} Gy from an X-ray source.

(i) Estimate the energy absorbed for this person. Assume that the whole body absorbs the energy uniformly.

energy = ... J [2]

(ii) Estimate the exposure for this person. Give an appropriate unit for your answer. Assume that the energy required to produce 1 ion-pair in body tissue is the same as that in air and has the value 5.44×10^{-18} J.

exposure = ... [4]

(iii) Discuss the assumption made in **(b)(i)**.

....

....[1]

[Total : 8]

For Examiner's Use

8 The following passage is based on a scientific article.

Power stations are normally most efficient when running under full load. The variation in demand over a day means that there must be capacity to meet peak demand, but much of this will be out of use for most of the day. This is wasteful of capital equipment when it is standing idle and of the fuel needed to run the station up to full demand and down at times of minimum demand.

The demand shown for January in Fig. 8.1 below is met for most of the day by power stations which are called *base load* stations. It has been suggested that during periods of peak demand, hydroelectric stations may be used to top-up the supply. The water for the hydroelectric stations is pumped into reservoirs at times when the *base load* stations' output is greater than demand. This is called a 'pumped storage' system.

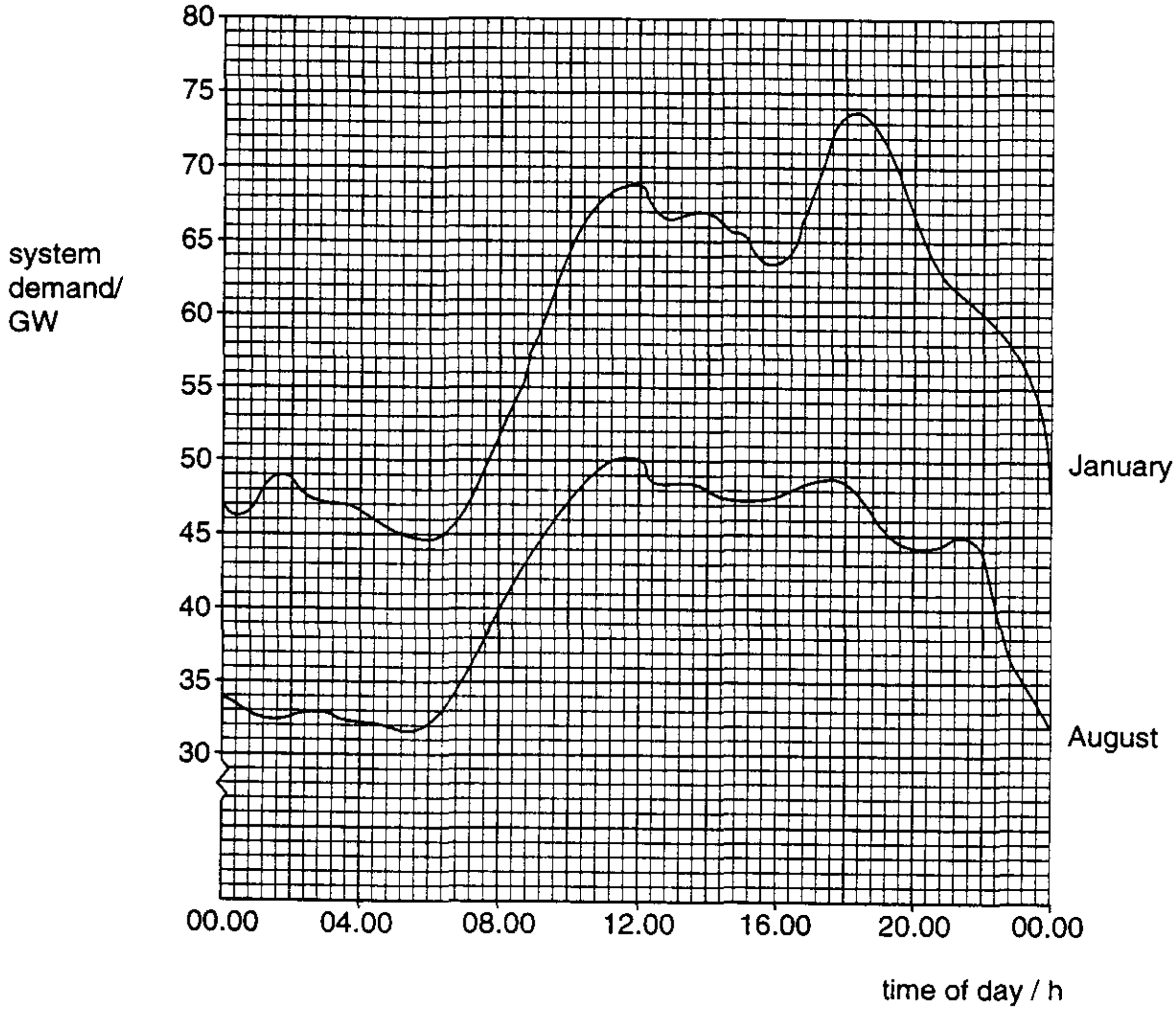

Fig. 8.1

Fig. 8.1 shows the average variation in electricity demand from the electricity companies in the UK with time of day for January and August.

For Examiner's Use

Answer the following questions about this passage.

(a) State **four** major features of the graphs of Fig. 8.1 for January and August and suggest reasons for these features.

1. ....

....

2. ....

....

3. ....

....

4. ....

....
[4]

(b) Suggest **two** reasons why a *base load* coal-fired power station cannot simply be switched on or off when the demand suddenly changes.

....

....

....[2]

(c) **(i)** Use Fig. 8.1 to estimate the *base load* power for January, that would allow the system to meet the demand for 18 hours out of a 24 hour period.
Show this as a horizontal line labelled BL on Fig. 8.1.

(ii) Estimate the maximum power output of the hydroelectric power stations needed to meet the extra demand.

power = ... GW
[2]

For Examiner's Use

(d) Water in one of the hydroelectric power stations falls through a vertical distance of 100 m.

(i) Show that the minimum volume of water required per second to flow through the turbines to produce an output of 1.0 GW from the generator is about $1 \times 10^3\,m^3$. (The density of water = $1000\,kg\,m^{-3}$.)

[4]

(ii) Calculate the length of one side of a square reservoir of depth 35 m which would just supply water at a rate of $1.0 \times 10^3\,m^3\,s^{-1}$ for a continuous period of 4 hours.

length = ... m [4]

(iii) Comment on the feasibility of a number of such power stations to meet the extra requirements during periods of peak demand.

....

....[2]

(iv) Give **two** reasons why the actual volume of water required per second to produce an output of 1.0 GW is greater than that calculated in **(d)(i)**.

....

....

....[2]

[Total : 20]