RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A **2825/02**

Health Physics

Friday **1 FEBRUARY 2002** Afternoon 1 hour 30 minutes

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

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	9	
2	7	
3	5	
4	14	
5	8	
6	16	
7	11	
8	20	
TOTAL	90	

This question paper consists of 20 printed pages.

(NH/CG) S13332/2

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

[Turn over

Answer **all** the questions.

1 **(a)** Fig. 1.1 illustrates the posture adopted by a person who is just supporting a 200 N weight.

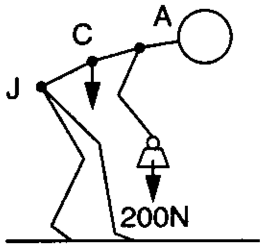

Fig. 1.1

Describe what happens to the fibres of the back muscles as the person lifts the 200 N weight from the ground.

....

....[2]

(b) Fig. 1.2 illustrates the lines of action of the forces acting on the spine as the person adopts the posture of Fig. 1.1. The back muscles act together to produce a resultant force E. The line of action of E passes through the centre of gravity C of the body at an angle of 10° to the spine. The 200 N weight acts through a point A on the spine. The distances of the centre of gravity C and the point A from the lumbosacral joint J are 0.50 m and 0.75 m respectively.

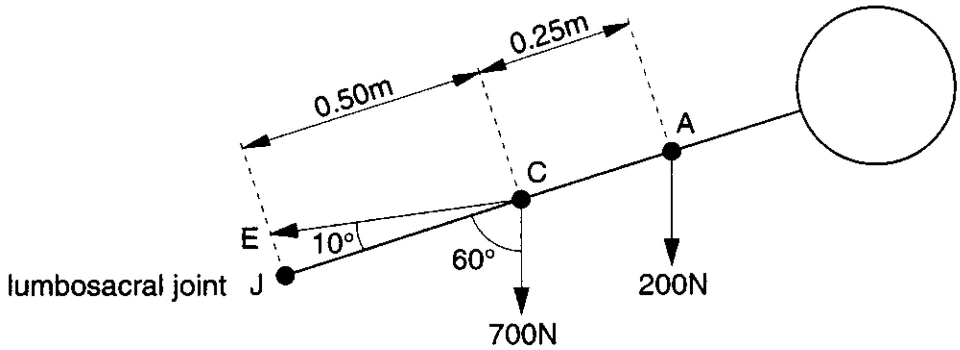

Fig. 1.2

For Examiner's Use

The spine of this person is inclined at an angle of 60° to the vertical. The person has a weight of 700 N.

Calculate the magnitude of the effort E needed by the back muscles in order to maintain the posture in Fig. 1.1.

effort = ... N [4]

(c) Fig. 1.3 illustrates a second posture adopted by the same person in order to support the same weight.

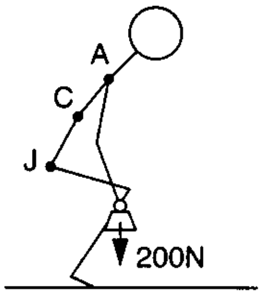

Fig. 1.3

Explain why the posture shown in Fig. 1.3 is the better way to lift the 200 N weight.

....

....

....

....[3]

[Total : 9]

[Turn over

For Examiner's Use

2 Fig. 2.1 illustrates the path of two rays of light from an object O to a convex lens and from the convex lens to an image I. The convex lens has a focal length of 4.0 cm.

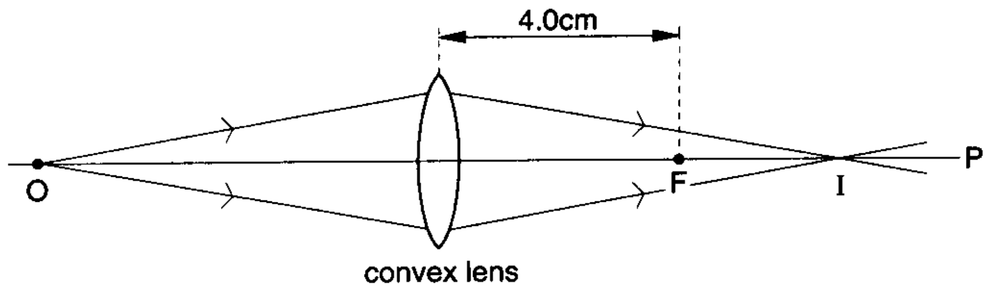

Fig. 2.1

(a) State the common term for

(i) the point F, ...

(ii) the line OFP .... [2]

(b) Calculate

(i) the power of the lens,

power = ... D [2]

(ii) the distance from the lens to the image for an object positioned 6.0 cm from the lens.

distance = ... cm [3]

[Total : 7]

3 In order to demonstrate the idea of the *depth of field* of an optical system, a student uses a small light bulb as an object, a convex lens and a screen as shown in Fig. 3.1.

(a) Explain what is meant by *depth of field*.

....

....[1]

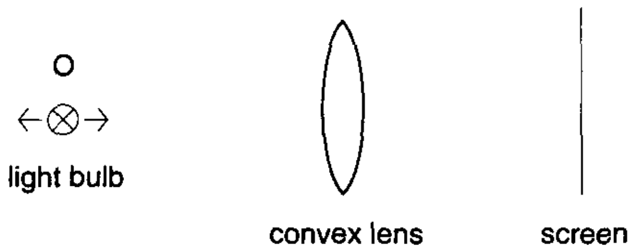

Fig. 3.1

When the bulb is positioned at O, a sharp image of the filament of the source is formed on the screen.

(b) Describe the effect on the image formed at the screen, of moving the bulb to and fro as shown by the arrows in Fig. 3.1.

....

....

....

....

....[2]

(c) Suggest how this movement of the object might be used to explain depth of field.

....

....

....[2]

[Total : 5]

For Examiner's Use

4 **(a)** On the graph of Fig. 4.1, sketch the variation with frequency of the minimum intensity of sound detectable by a person with normal hearing. [4]

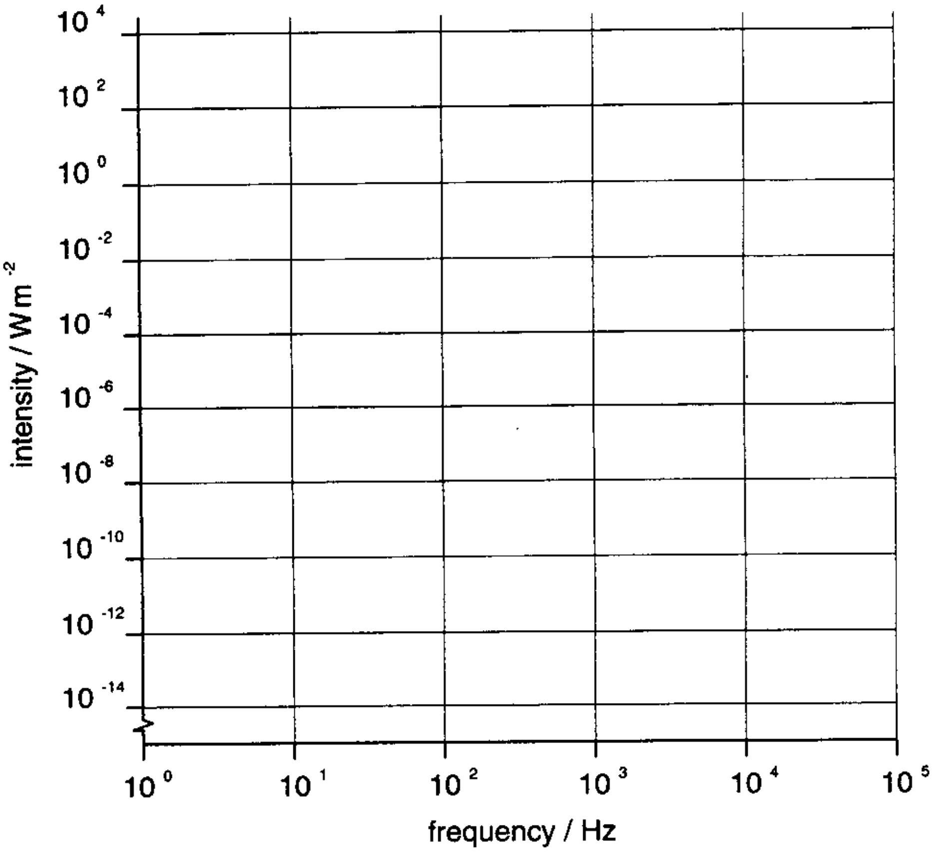

Fig. 4.1

(b) Suggest a reason for the shape of your graph at frequencies around 2 kHz.

....

....

....

....[2]

(c) The intensity of a sound is measured by an observer at a distance of 1.0 m from a loudspeaker and is recorded as 1.0×10^{2} W m^{-2}. Assume that the intensity of the sound varies as $1/r^2$, where r is the distance of the loudspeaker from the observer.

(i) State the value of the threshold intensity I_0.

I_0 = ... W m^{-2} [1]

For Examiner's Use

(ii) Show that the intensity of the sound at a distance of 4.0 m from the loudspeaker is 6.3 W m^{-2}.

[2]

(iii) Calculate the intensity level of sound at a distance of 4.0 m from the loudspeaker. Give an appropriate unit for your answer.

intensity level = ... [3]

(iv) Explain whether it is acceptable to stand at a distance of 4.0 m from the loudspeaker.

....

....[2]

[Total : 14]

5 The reflections of ultrasound pulses from interfaces within the body may be displayed as an A-scan on an oscilloscope. Fig. 5.1 illustrates an A-scan display of the intensity of the reflected pulses against time for the interfaces A, B, C and D of Fig. 5.2.

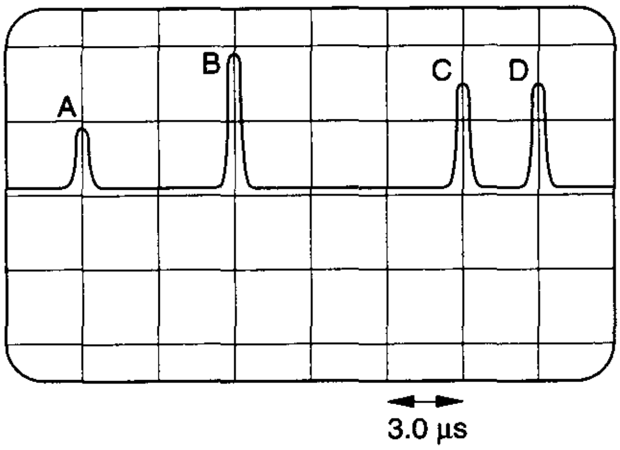

Fig. 5.1

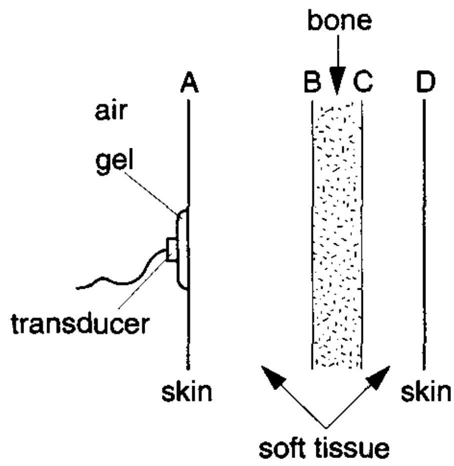

Fig. 5.2

The speed of ultrasound in bone and soft tissue is $4000\,\text{m}\,\text{s}^{-1}$ and $1500\,\text{m}\,\text{s}^{-1}$ respectively. The time-base on the oscilloscope is set at 3.0 μs per division.

(a) **(i)** Calculate the time interval between reflections received from the front edge B and the rear edge C of the bone.

time interval = ... μs [2]

For Examiner's Use

(ii) Calculate the thickness of the bone.

thickness = ... cm [2]

(iii) Calculate the depth of the front edge B of the bone below the skin A.

depth = ... cm [2]

(b) Explain how the trace in Fig. 5.1 might change if an acoustic coupling medium such as gel is **not** used between the transducer and the skin.

....

....[2]

[Total : 8]

For Examiner's Use

6 Fig. 6.1 illustrates the essential features of a basic X-ray tube.

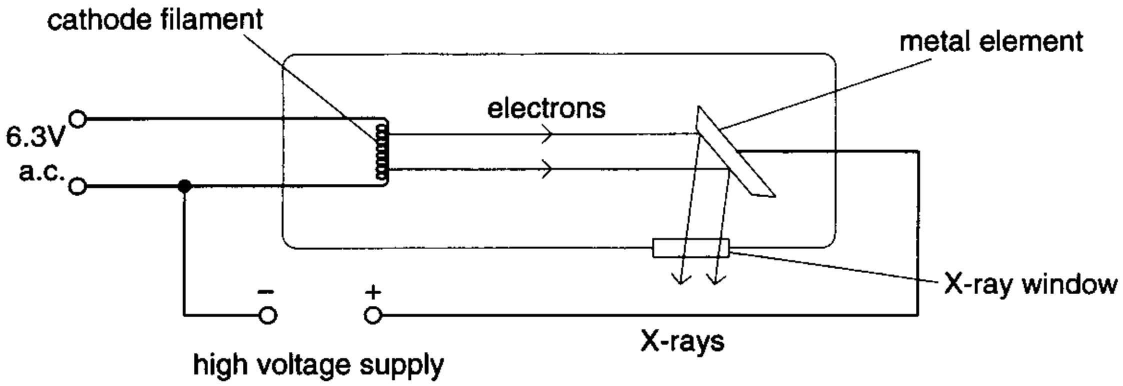

Fig. 6.1

(a) **(i)** Describe, with reference to the energy conversions within the X-ray tube, the production of X-rays.

....

....

....

....

....

....[3]

(ii) Explain why it is necessary for the X-ray tube to be evacuated.

....

....[2]

For Examiner's Use

(b) Fig. 6.2 shows relative intensities of X-rays of different wavelengths emitted from a 100 kV X-ray tube.

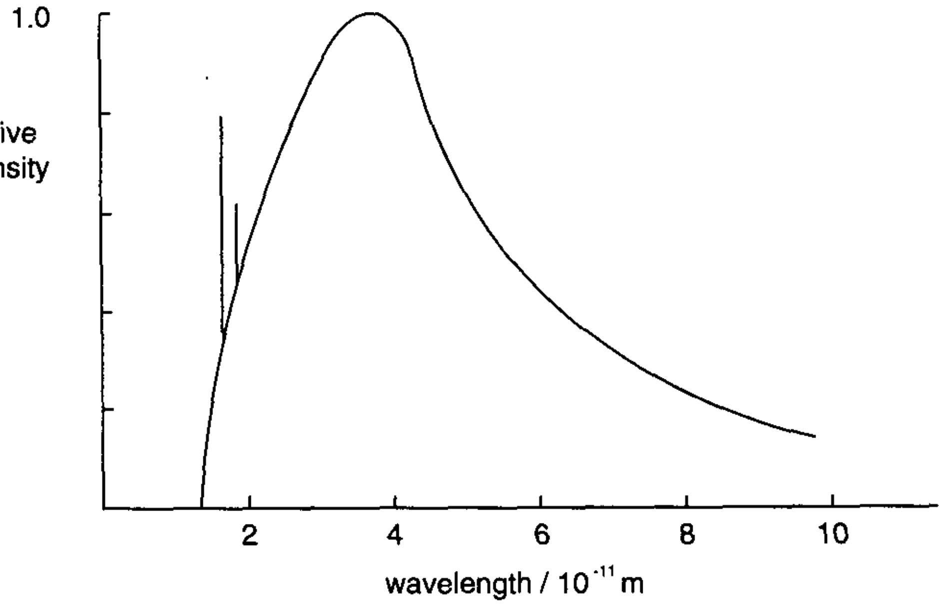

Fig. 6.2

(i) Explain why X-rays of a range of wavelengths are produced.

....

....

....

....[2]

(ii) Suggest how **two** features of the X-ray spectrum might change if the tube voltage is increased.

....

....

....

....[2]

[Turn over

For Examiner's Use

(c) The table of Fig. 6.3 shows data of the intensity I of an X-ray beam after penetration through a thickness x cm of a medium.

I / W m^{-2}	12.0	10.3	8.70	7.40	6.30	5.40	4.60	3.90	3.30
x / cm	0.000	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160

Fig. 6.3

(i) On Fig. 6.4, plot these data. [3]

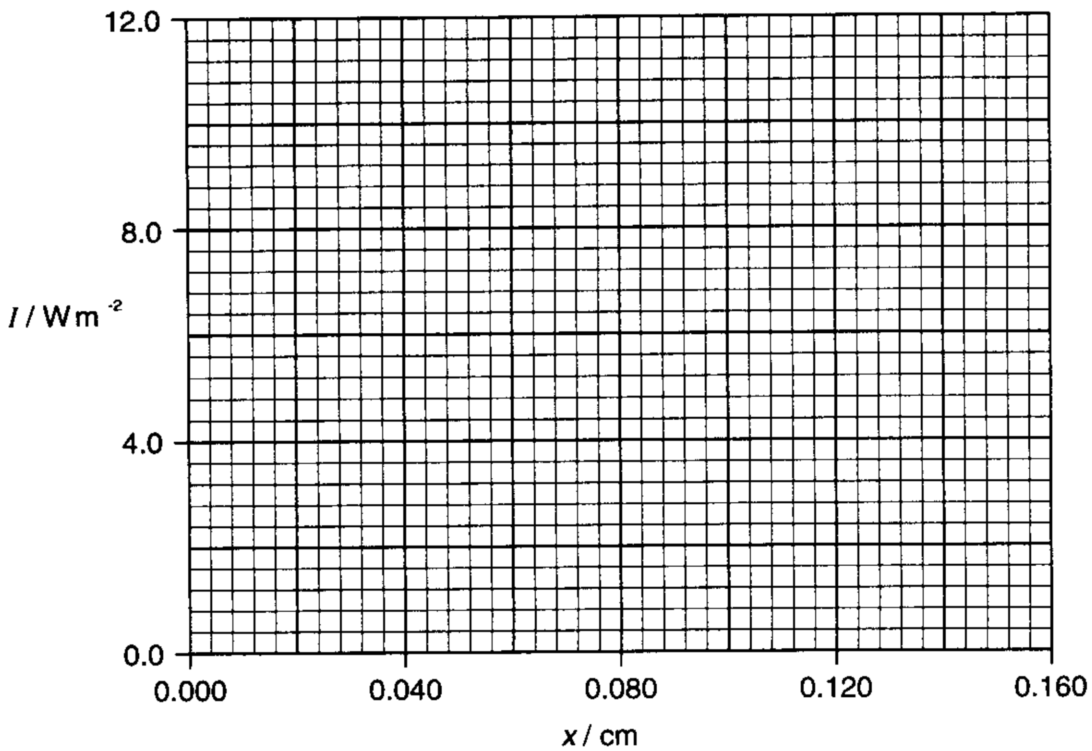

Fig. 6.4

(ii) Use your graph to find the thickness of the medium that causes the X-ray intensity to halve.

thickness = ... cm [1]

For Examiner's Use

(iii) Use your answer to **(ii)** to calculate the total linear absorption coefficient μ, of the medium.

μ = ... cm^{-1} [3]

[Total : 16]

7 **(a)** Ionising radiation has both direct and indirect effects on living tissue. Explain with an example of each, what is meant by

(i) direct effect ....

....

....

(ii) indirect effect ....

....

....
[4]

(b) An ionisation chamber is used to measure exposure to ionising radiation. A source emits two types of radiation. In a time interval of 60 s, the measured exposure is $6.4 \times 10^{-6}\,C\,kg^{-1}$. The energy required for the production of one ion-pair is $5.4 \times 10^{-18}\,J$.

(i) Calculate the absorbed dose for this exposure. Give an appropriate unit for your answer.

absorbed dose = ... [3]

(ii) Fig. 7.1 shows the quality factors for a range of ionising radiations.

type of radiation	quality factor
X-rays, γ-rays, β-particles	2
slow neutrons	5
fast neutrons, protons	10
α-particles	20

Fig. 7.1

Calculate the dose equivalent when half of the exposure in **(b)(i)** is due to γ-rays and half to α-particles.

dose equivalent = ... Sv [4]

[Total : 11]

8 A couple who find modern life too stressful decide to move to a Scottish island which has no mains electricity supply.

There are two ways in which they could provide a power supply. One method is to lay a long-distance supply cable from another island which has mains electricity. The other method is to equip themselves with an aerogenerator and rechargeable batteries.

One disadvantage of using a long-distance supply cable is that the potential difference available at the user's end of the cable is less than the p.d. at the supply end of the cable. Because of this and the cost of laying a sufficiently thick cable, they decide to use an aerogenerator and batteries.

Rechargeable 12 V batteries are available and these will provide a reservoir of energy which can be increased by adding extra batteries. However, a battery will deliver only 80% of the energy stored in it.

The island is usually windy so they plan to keep the batteries charged by means of the aerogenerator. This consists of a rotating propeller of diameter 1.5 m, which drives a generator. The overall efficiency of the aerogenerator is 40%. It works by converting into electrical energy some of the kinetic energy of the air passing through the propeller. The average wind speed on the island is $8.0\,\mathrm{m\,s^{-1}}$. This means that all the air inside a cylinder 8.0 m long, of diameter 1.5 m, passes through the propeller in 1 second. This is illustrated in Fig. 8.1.

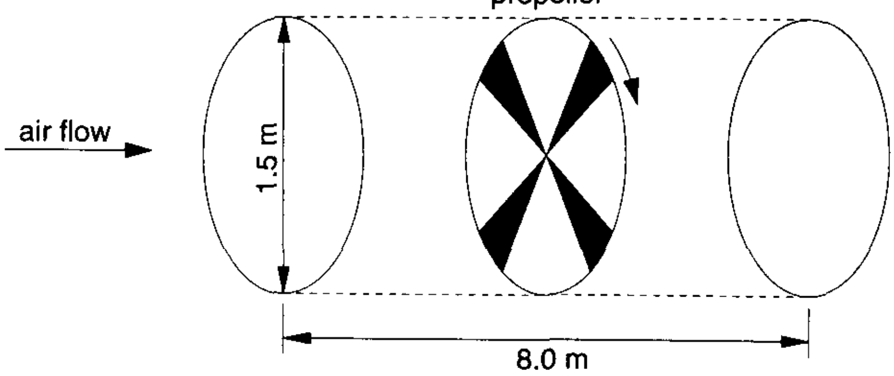

Fig. 8.1

Although the island is normally windy, there are periods of calm. Meteorological information suggests that the longest such period would be 40 hours. The couple estimate that their average power requirement during these periods would be 160 W.

Additional information:

amount of energy stored by one rechargeable battery $= 7.0 \times 10^6\,\mathrm{J}$

density of air $= 1.3\,\mathrm{kg\,m^{-3}}$

(a) Explain why the p.d. available to the user of a long mains cable would be less than the p.d. at the supply end of the cable.

....

....

....

....[3]

(b) Suggest why it is not possible for the aerogenerator to achieve an efficiency of 100%.

....

....

....

....

....

....[2]

(c) **(i)** Show that the mass of air contained in a cylinder of diameter 1.5 m and length 8.0 m is approximately 18 kg.

[2]

(ii) Calculate the kinetic energy of 18 kg of air travelling at 8.0 m s^{-1}.

energy = ... J [2]

(iii) Hence calculate the average power output of the aerogenerator.

power = ... W [1]

(d) Calculate the average time taken by the aerogenerator to recharge one battery fully.

time = ... s [2]

(e) **(i)** State what form of energy is stored by a battery.

....[1]

(ii) Give **one** reason why the energy delivered by a battery is less than the energy input.

....

....

....[1]

(f) **(i)** Calculate the greatest amount of energy which needs to be delivered by the batteries during a 40 hour period of calm weather.

energy = ... J [2]

(ii) Calculate the total energy which the set of batteries must be capable of storing.

energy = ... J [2]

(iii) Calculate the minimum number of rechargeable batteries that will be needed.

[2]

[Total : 20]