OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A

2825/05

Telecommunications

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	15	
2	12	
3	13	
4	8	
5	6	
6	16	
7	20	
TOTAL	90	

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

(NH/CG) S13335/3

[Turn over

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 **(a)** Fig. 1.1 shows a part of the signal produced by a microphone positioned in front of a loudspeaker. The loudspeaker is emitting a pure tone (i.e. a pure sine wave).

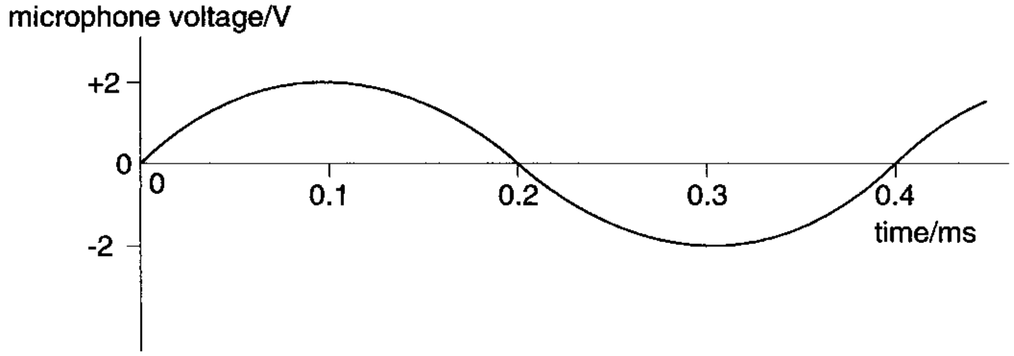

Fig. 1.1

(i) State and explain whether the signal shown in Fig. 1.1 is an analogue signal or a digital signal.

....

....[2]

(ii) Calculate the frequency of the signal of Fig. 1.1.

frequency = ... kHz [2]

(iii) On the axes of Fig. 1.2, plot the frequency spectrum of the signal of Fig. 1.1, marking important points on the frequency axis. [1]

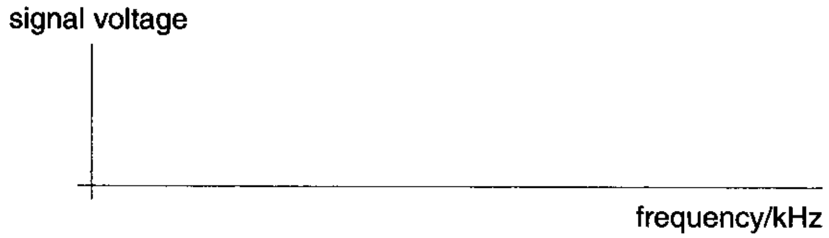

Fig. 1.2

(iv) State the bandwidth of the signal of Fig. 1.1.

bandwidth = ... kHz [1]

For Examiner's Use

(b) Fig. 1.3 shows an unmodulated carrier waveform.

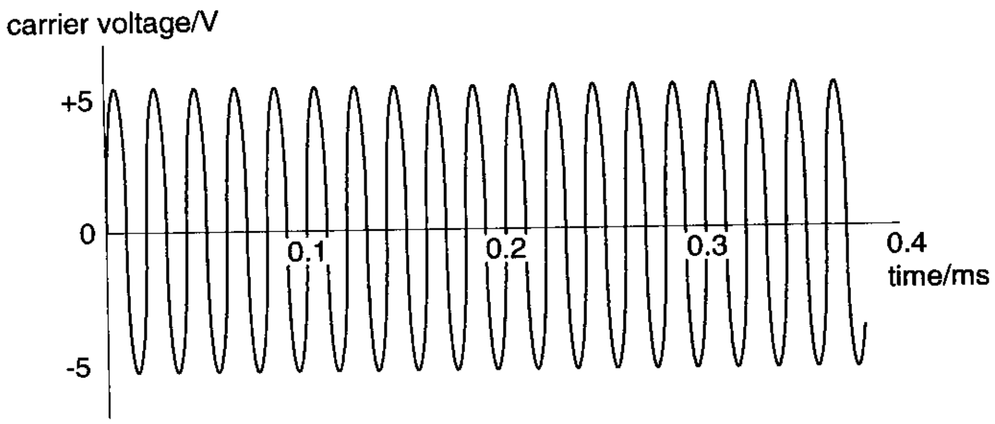

Fig. 1.3

Calculate the frequency of the carrier.

carrier frequency = ... kHz [1]

(c) The carrier of Fig. 1.3 is now amplitude modulated by the signal of Fig. 1.1.

(i) On the axes of Fig. 1.4, sketch the resulting waveform. [4]

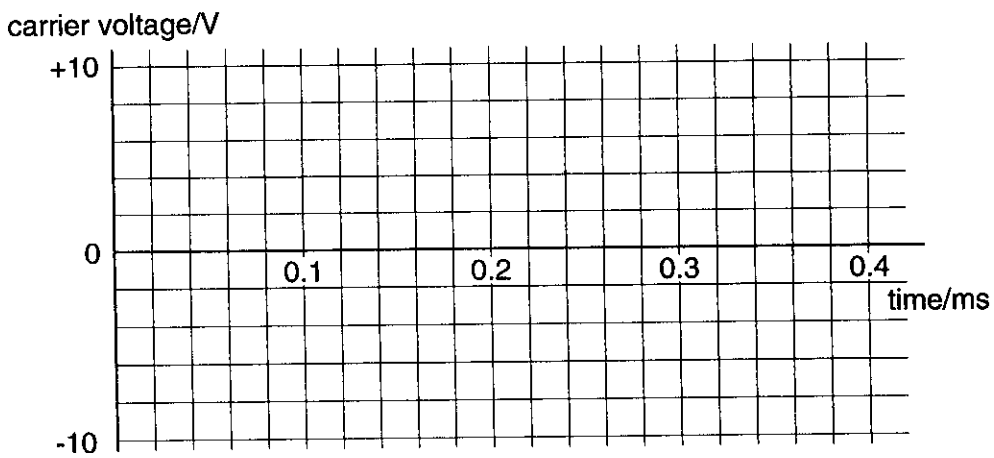

Fig. 1.4

[Turn over

(ii) On the axes of Fig. 1.5, draw the frequency spectrum of the modulated carrier waveform of Fig. 1.4. Label important points on the frequency axis. [3]

Fig. 1.5

(iii) Calculate the bandwidth of the AM signal of Fig. 1.4.

AM bandwidth = ... kHz [1]

[Total : 15]

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Turn to page 8 for Question 2.

[Turn over

2 Fig. 2.1 shows the variation with time of part of a signal which is to be transmitted using pulse code modulation.

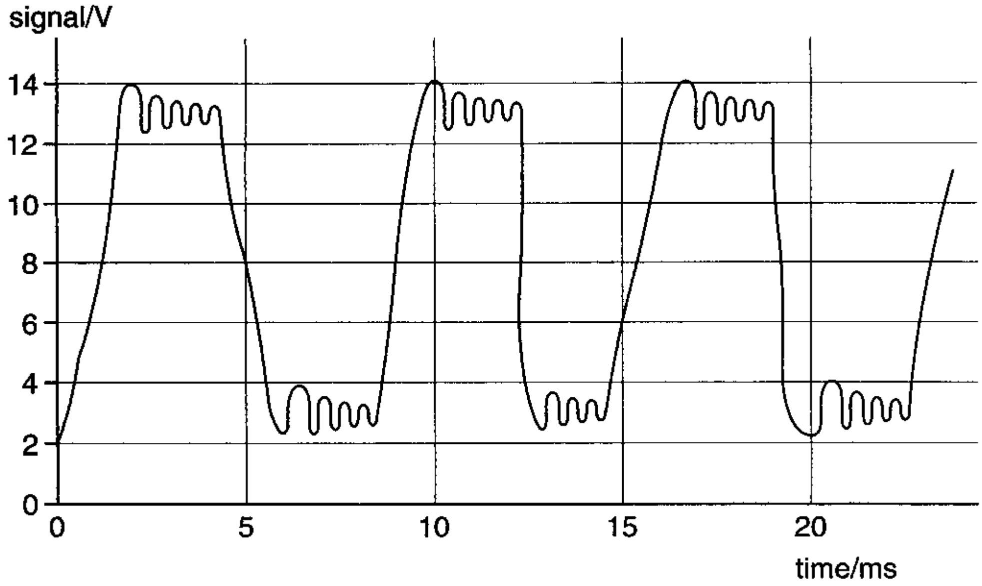

Fig. 2.1

The signal is sampled at $t = 0$ and at 5 ms intervals thereafter. Each sample becomes a 4-bit code in binary with quantisation steps of 1 V.

(a) State the full name of the electronic circuit used to turn each sample into a 4-bit code.

....[1]

(b) During the time shown in Fig. 2.1, there will be five samples taken. In the boxes below, write down the codes resulting from each sample. The code for the first sample has been added to the first box to guide you.

0010				

[2]

(c) The above five samples are transmitted as a digital signal along a cable, one bit after another. Calculate the longest time for which a bit could last to allow this system to operate.

time = ... ms [1]

For Examiner's Use

(d) At the receiving end of the cable, each code is made to produce the equivalent sample voltage. Each recovered sample is then reformed into a signal. On the axes of Fig. 2.2, plot the recovered signal at the receiving end of the cable. [2]

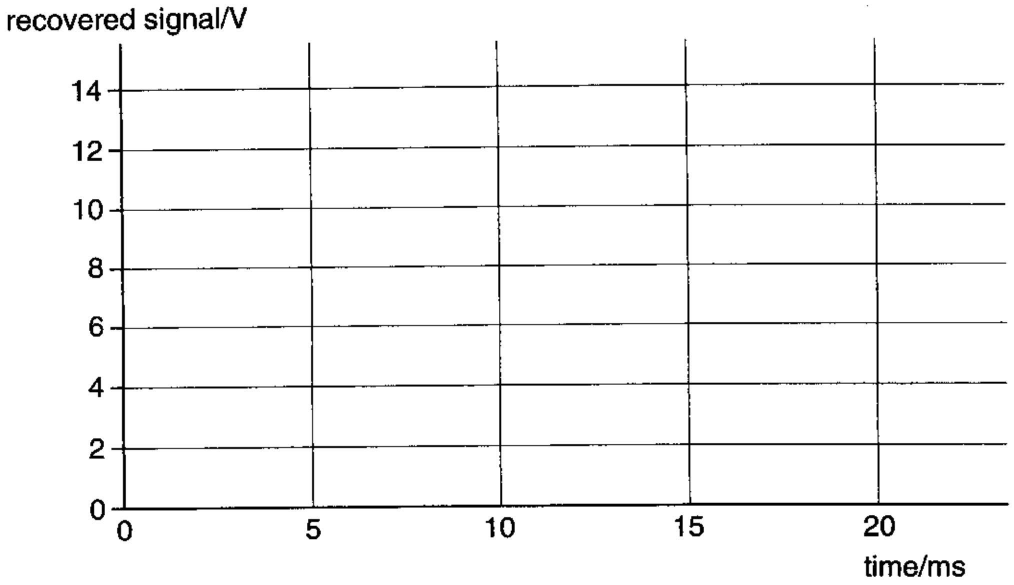

Fig. 2.2

(e) Explain why this signal differs from the original signal of Fig. 2.1.

....

....

....[2]

(f) Suggest **two** changes which could be made to the digitising process to allow the recovered signal to be much more like that of the original. Numerical values are expected in your answer with some explanation.

....

....

....

....

....[4]

[Total : 12]

[Turn over

3 Fig. 3.1 shows a circuit designed to operate a small filament bulb under certain light conditions.

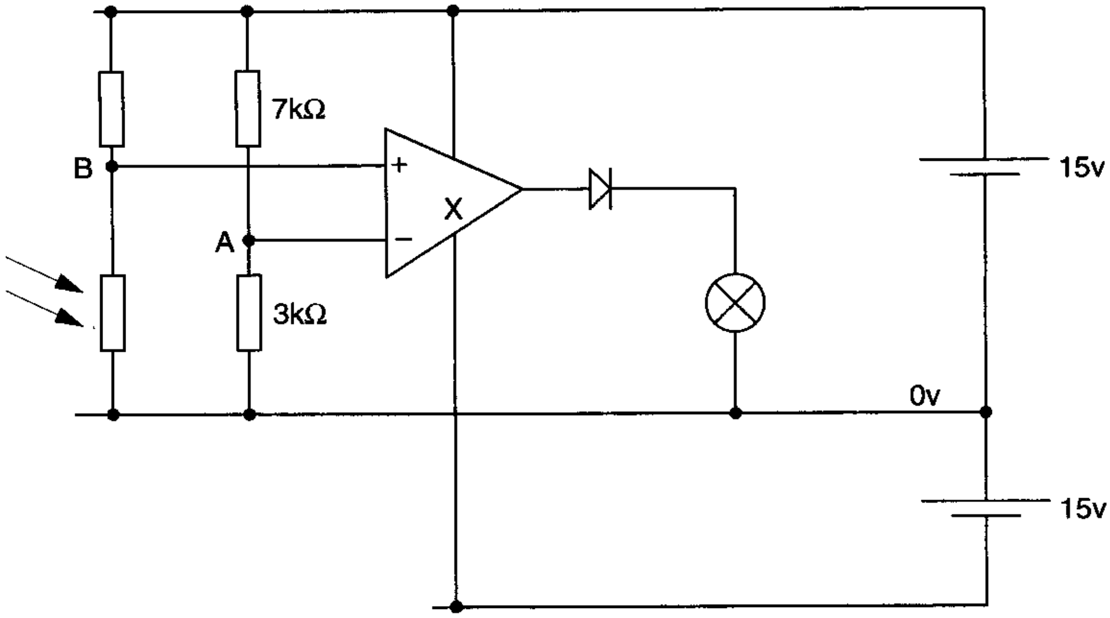

Fig. 3.1

(a) State the full name of the light sensor in Fig. 3.1.

....[1]

(b) State the name of the electronic component labelled X.

....[1]

(c) Calculate the voltage at the point A.

voltage = ... V [2]

(d) **(i)** *Describe how the resistance of the light sensor changes as the light intensity changes from darkness to brightness.*

....

....[1]

(ii) Hence explain the corresponding changes in the output voltage of the component X. *In your explanation, refer to your answer to* **(c)**.

....

....

....

....

....

....[4]

(e) In Fig. 3.1, the output of component X is connected through a diode to the small filament bulb.

(i) Explain why the diode is necessary.

....

....

....[2]

(ii) Explain how the state of the lamp depends on the light intensity reaching the sensor.

....

....

....[2]

[*Total* : 13]

For Examiner's Use

4 The radio wave spectrum is composed of various wavebands. Three of these wave bands are labelled as LF, HF and UHF. For each of these wavebands complete Fig. 4.1 below. [8]

waveband	full name	frequency range	propagation	typical use
LF	Low frequency	30 kHz – 300 kHz	Diffraction over curved Earth	
HF				
UHF				TV broadcasting

Fig. 4.1

[Total : 8]

For Examiner's Use

5 Since the 1980s there has been a move by all telecommunications companies to replace coaxial cable with optic fibre. State and explain **three** reasons for this change.

1. ....

....

....

2. ....

....

....

3. ....

....

....

[6]

[Total : 6]

For Examiner's Use

6 Fig. 6.1 shows a satellite in a geostationary orbit around Earth. In this orbit, the satellite does not appear to move relative to any fixed observer on Earth.

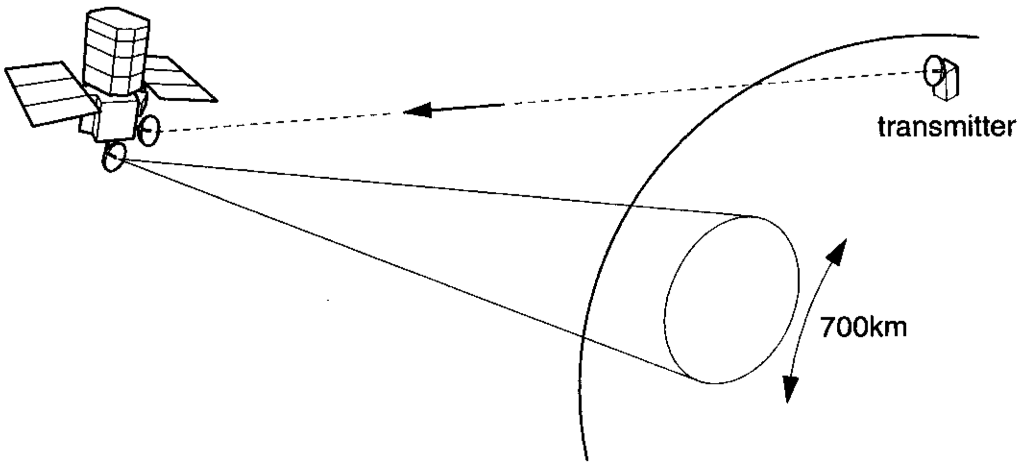

Fig. 6.1

A transmitter, in the south of France, beams a 3.5 kW signal on a carrier frequency of 12 GHz up to the satellite. The satellite picks up the 12 GHz signal and changes the carrier frequency to 10 GHz without altering the modulation or the information being carried. The new amplified downlink carrier signal has an output power of 350 W and is broadcast to Europe over an area called a footprint. The diameter of the footprint is 700 km.

(a) State the **two** conditions which have to be met for a satellite to be in a geostationary orbit.

1. ....

2. ....

[2]

(b) Use Newton's law of gravitation to show that the orbital speed of a geostationary satellite is independent of the mass of the satellite.

[3]

(c) The mass of Earth is 6.0×10^{24} kg. Show that the radius of orbit of a geostationary satellite is approximately 4.2×10^{7} m.

[4]

(d) The satellite carries rechargeable batteries as well as solar cells. Explain why both are necessary.

....

....

....[2]

(e) The solar cells are required to produce 600 W from sunlight of intensity 1.5 kW m^{-2}. If the efficiency of these cells is 5%, calculate the area of solar cell required.

area = ... m^2 [2]

(f) The satellite transmits a power of 350 W into a footprint of diameter 700 km. Calculate the maximum power which can be received on Earth by a dish of diameter 75 cm.

power received = ... W [2]

(g) The carrier frequency transmitted to the satellite is not the same as that broadcast from it. Explain why there is a difference between these two frequencies.

....

....

....[1]

[Total : 16]

7 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 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. 7.1.

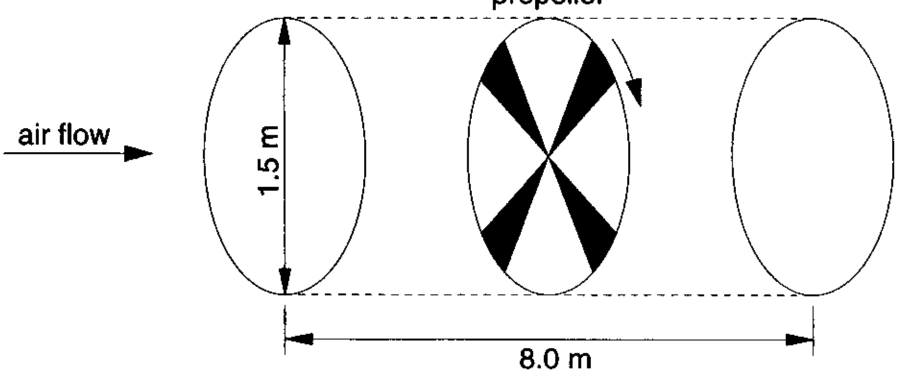

Fig. 7.1

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	$= 7.0 \times 10^6$ J
density of air	$= 1.3$ kg m^{-3}

For Examiner's Use

(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]

For Examiner's Use

(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]

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