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RECOGNISING ACHIEVEMENT

ADVANCED GCE **2825/05**

PHYSICS A

Telecommunications

TUESDAY 17 JUNE 2008 Afternoon

Time: 1 hour 30 minutes

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

CUP/T42966

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.
- 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 five questions concern Telecommunications. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**13**	
2	**18**	
3	**12**	
4	**10**	
5	**17**	
6	**20**	
TOTAL	**90**	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

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

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Answer **all** the questions.

1 Fig. 1.1 shows a radio signal being broadcast from a transmitter.

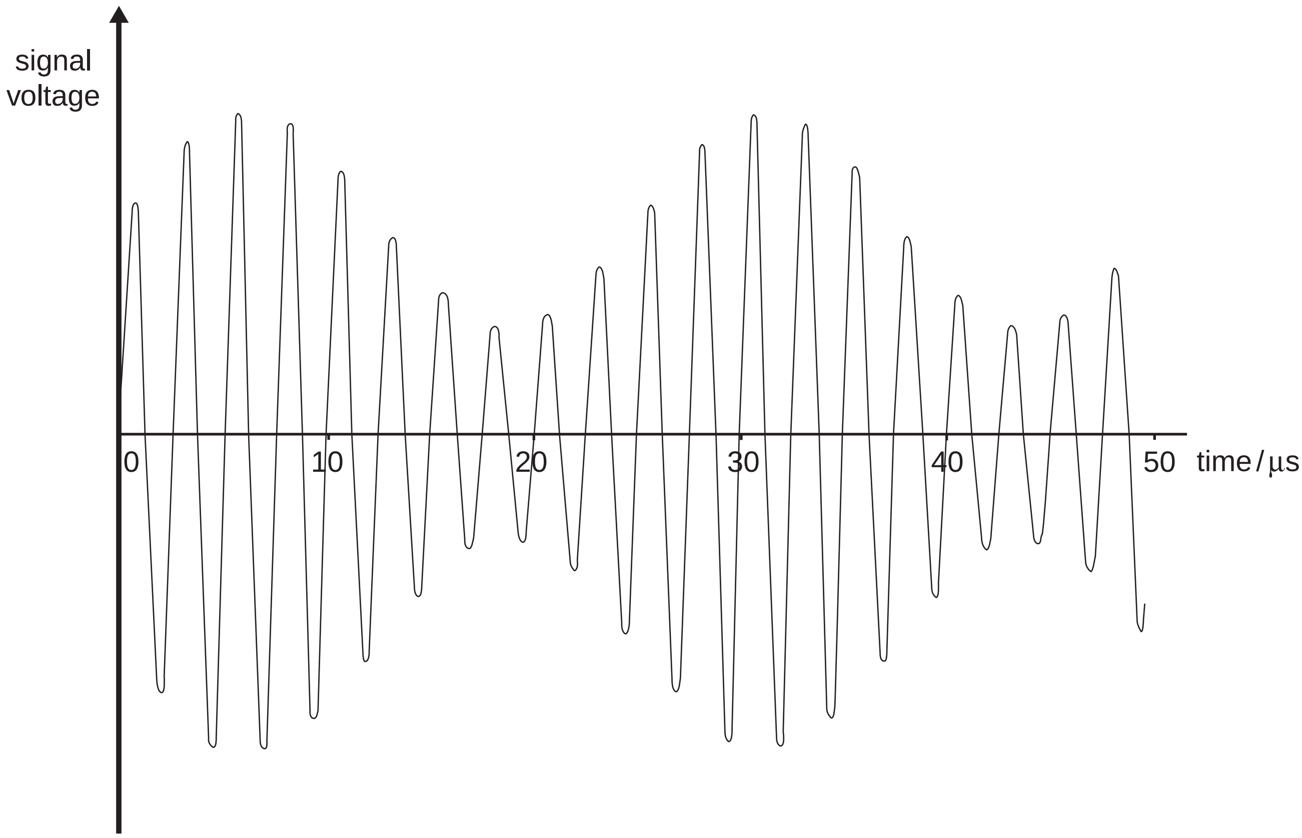

Fig. 1.1

(a) For the signal in Fig. 1.1,

(i) state the type of modulation being used

.... [1]

(ii) calculate the transmission frequency of the radio station

transmission frequency = ... kHz [2]

(iii) calculate the frequency of the modulating signal

modulating frequency = ... kHz [2]

(iv) state the waveband on which this radio signal is being transmitted.

.... [1]

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(b) State and explain why a normal domestic radio capable of receiving the signal in **(a)** would not be able to play the information being carried.

....

....

....

.... [2]

(c) **(i)** On the axes of Fig. 1.2, draw the frequency spectrum of the signal of Fig. 1.1.

Include numerical values on the frequency axis. [3]

Fig. 1.2

(ii) State what is meant by the bandwidth of a signal.

.... [1]

(iii) Using the frequency spectrum you have drawn in Fig. 1.2, calculate the bandwidth of the radio signal.

bandwidth = ... kHz [1]

[Total: 13]

2 A student wishes to control the motor in a toy car using torches. The student designs the circuit shown in Fig. 2.1 to be fitted on the car roof.

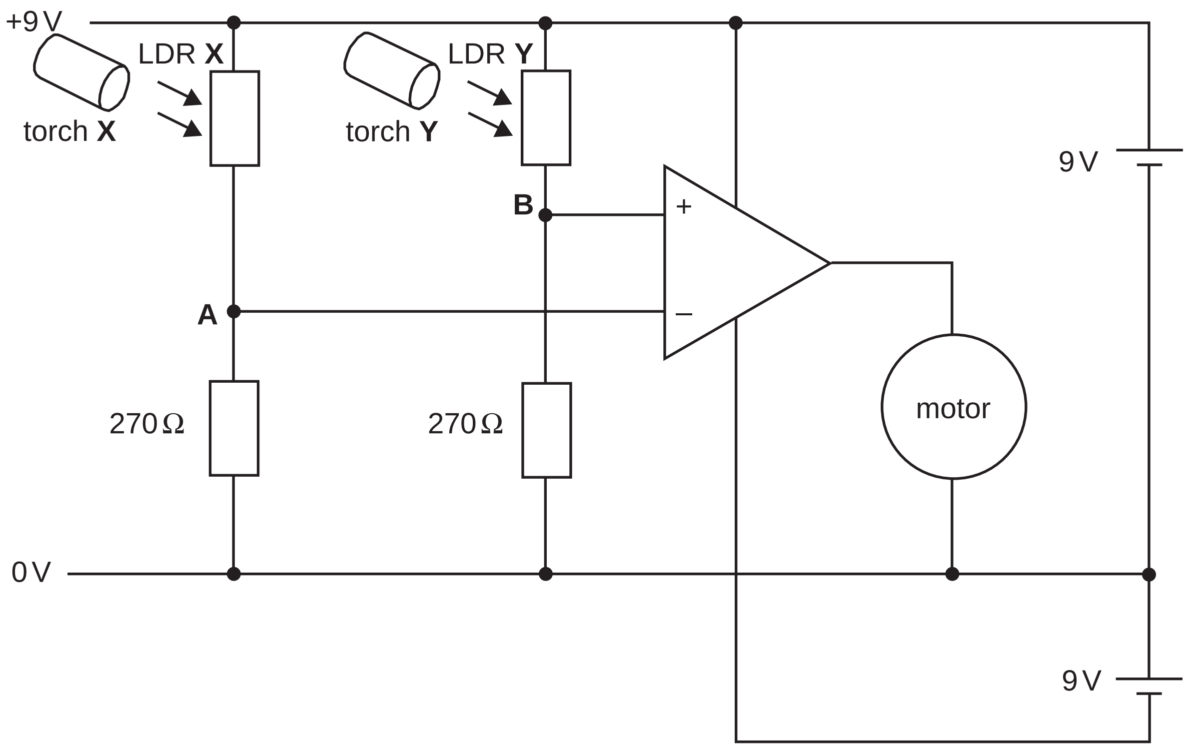

Fig. 2.1

Torch **X** and torch **Y** are identical. The student intends to hold one in each hand and will only point a torch at its corresponding LDR. The student can then switch a torch on or off as appropriate.

(a) The circuit contains two components labelled LDR **X** and LDR **Y**.

(i) State what the letters LDR stand for.

.... [1]

(ii) State the change in a LDR when its torch is switched on.

.... [1]

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(b) **(i)** When torch **X** is shone at LDR **X**, its resistance is 230 Ω.

1 Calculate the current in LDR **X**.

current = ... A [2]

2 Calculate the voltage at **A**.

voltage at **A** = ... V [1]

(ii) The student then assumed that when both torches are switched on, the resistance of each LDR is the same. Write down a value for the voltage at **B** when both torches are switched on.

voltage at **B** = ... V [1]

(iii) Explain how the motor should respond when both torches are switched on.

....

.... [2]

(c) If torch **X** is switched off while torch **Y** remains on, explain how the circuit should behave and the motor respond.

....

....

.... [3]

(d) State how the motor should respond to

(i) both torches being switched off

.... [1]

(ii) torch **X** on and torch **Y** off.

.... [1]

Question 2 continues over the page.

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[Turn over

(e) The student finds that, once the circuit is built, the toy car is very difficult to control.

(i) Suggest why in practice the behaviour of the motor predicted in **(b)(iii)** when both torches are turned on is **not** observed.

....

....

....

.... [3]

(ii) The teacher explains that using the op-amp as a comparator was a bad idea and that the student should have designed his circuit around an op-amp with negative feedback.

Explain why adding negative feedback could improve the performance of this circuit.

....

....

.... [2]

[Total: 18]

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3 A teacher wishes to demonstrate and measure the attenuation per kilometre in a pair of copper wires. Fig. 3.1 shows a communication system set up between the physics laboratory and the gym.

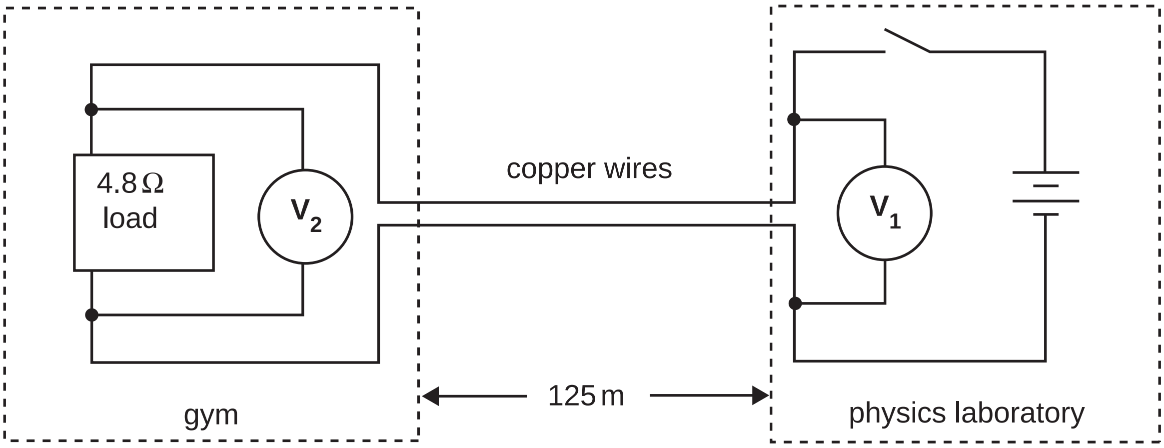

Fig. 3.1

The class in the physics laboratory makes the following observations:

- each copper wire is 125 m long
- the load resistance in the gym is 4.8 Ω
- the copper wire has a cross-sectional area of 0.40 mm^2
- copper has a resistivity of $1.8 \times 10^{-8}\,\Omega\,m$
- when the switch is closed the reading on voltmeter $\mathbf{V_1}$ is 24 V

The teacher then challenges the class to calculate the reading on the voltmeter $\mathbf{V_2}$ before they all move over to the gym in order to measure it.

(a) **(i)** Show that the total resistance of the copper wires is about 11 Ω.

[3]

(ii) Hence show that the voltmeter $\mathbf{V_2}$ should read about 7 V.

[2]

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(b) **(i)** Calculate the power input to the copper wires at the laboratory end.

power input = ... W [2]

(ii) Calculate the power delivered to the load at the gym end.

power output = ... W [2]

(iii) Hence calculate the attenuation in dB km^{-1} along the communication system.

attenuation = ... dB km^{-1} [3]

[Total: 12]

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4 Fig. 4.1 shows the block diagram of an amplitude-modulated radio receiver.

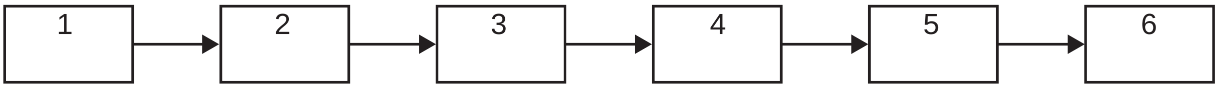

Fig. 4.1

State the name and explain the function of each block in the diagram.

The answer for the first block has been completed for you.

1 aerial converts electromagnetic waves into small currents

2 ....

....

....

3 ....

....

....

4 ....

....

....

5 ....

....

....

6 ....

....

.... [10]

[Total: 10]

5 **(a)** For any telecommunications company operating a communication channel, multiplexing is essential to their business.

(i) Explain briefly what is meant by *multiplexing* and why it is important.

....

....

.... [2]

(ii) Frequency-division multiplexing is used in the radio network. Explain the differences between *frequency-division* multiplexing and *time-division* multiplexing.

....

....

....

....

....

.... [4]

(b) An optic fibre cable is made to carry the digitised samples of two different analogue signals **A** and **B**. Each analogue signal is sampled at a frequency of 500 Hz and each sample is composed of 4 bits. Each bit lasts for 2.5 μs. The two digitised signals are then sent alternately along the optic fibre using time-division multiplexing.

Fig. 5.1 shows a snapshot of 23 samples from the signals in a continuous section of the fibre (shown in two lengths for reasons of scale).

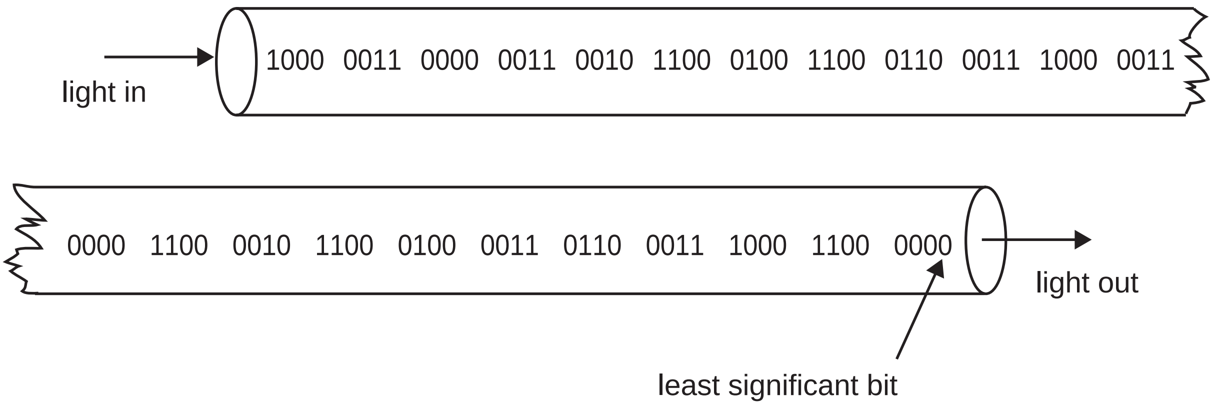

Fig. 5.1

(i) State the maximum frequency of analogue signal which can be digitised. Explain your reasoning.

maximum frequency = ... Hz

.... [2]

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(ii) Calculate the maximum number of separate analogue signals, each sampled and digitised in the same way, which can be made to pass along the optic fibre together.

maximum number = ... [2]

(iii) On the axes of Fig. 5.2, draw two labelled sketch graphs to show the variation with time of the two recovered analogue signals. You should convert each 4-bit sample to an equivalent decimal value. Assume the first sample to emerge is signal **A**. [5]

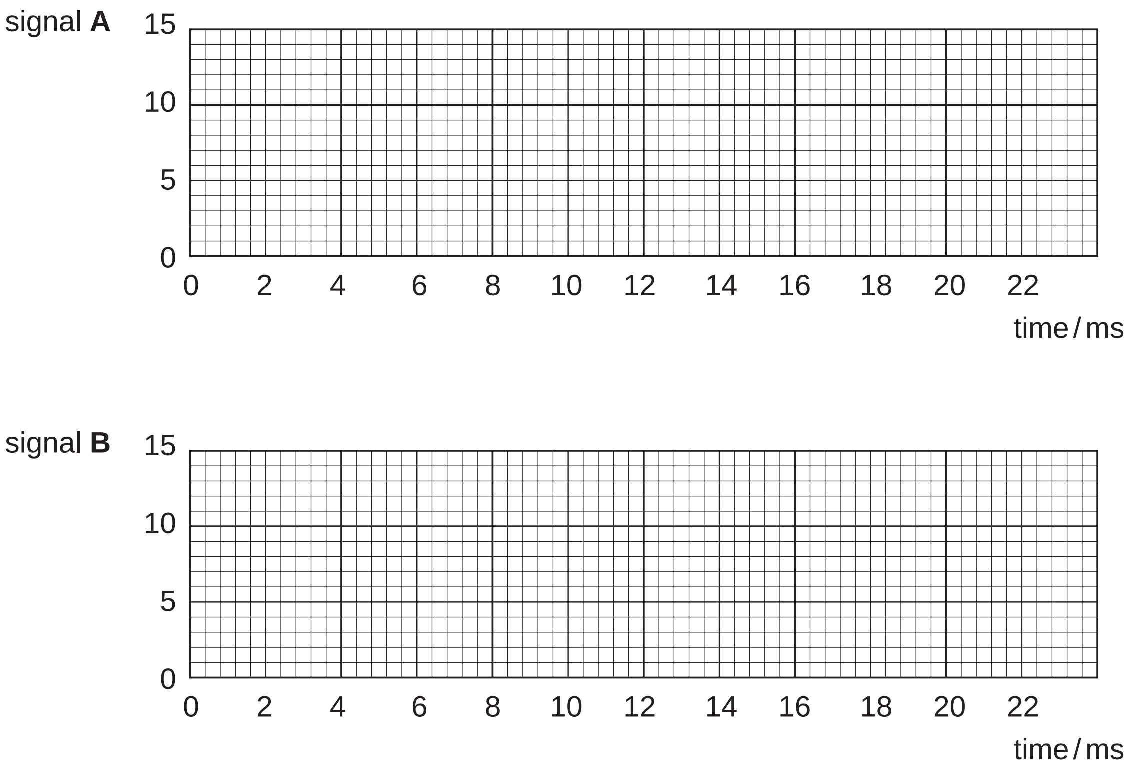

Fig. 5.2

(iv) Calculate the frequency of signal **B**.

frequency of signal **B** = ... Hz [2]

[Total: 17]

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6 A photo-voltaic cell is an electrical component which can generate a current proportional to the intensity of light incident on its light-sensitive surface. One type of solar panel uses a number of photo-voltaic cells in series to provide a sufficient voltage to power a practical device.

(a) The measured intensity of the solar radiation received on the upper atmosphere of the Earth is 1400 W m^{-2}. The mean radius of the Earth's orbit round the Sun is 1.5×10^{11} m.

(i) Show that

1 the surface area of a sphere of radius 1.5×10^{11} m is about 3×10^{23} m^2

[1]

2 the Sun emits radiation with a total power of about 4×10^{26} W into the surrounding space.

[1]

(ii) Calculate the rate of conversion of mass to energy in the Sun.

rate of conversion = ... kg s^{-1} [2]

(b) Explain why, when the Sun is directly overhead at the equator

(i) the maximum intensity received on the surface of the Earth is less than 1000 W m^{-2}

....

.... [1]

(ii) the maximum intensity decreases with distance North and South of the equator.

....

.... [1]

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(c) An ornamental water fountain is driven by a pump powered by the electrical output of a solar panel. The following data is relevant to the operation of the system, which is arranged to give maximum solar power input.

area of light-sensitive surface of panel:	$0.080\,m^2$
solar intensity at the location of the panel:	$750\,W\,m^{-2}$
voltage output of panel:	17 V
current delivered to the pump:	270 mA
delivery rate of the fountain:	$0.50\,m^3$ per hour
efficiency of pump:	35%
density of water:	$1000\,kg\,m^{-3}$

Calculate

(i) the solar power input to the panel

power input = ... W [1]

(ii) the electric power generated by the panel

power generated = ... W [1]

(iii) the efficiency of the panel in converting solar power to electrical power

efficiency = ... [2]

(iv) the height of the fountain of water.

maximum height = ... m [5]

This question continues on page 16

(d) A solar panel of greater area than the one in **(c)** supplies 80 W of electrical power to a heating coil immersed in water.

(i) Calculate the time required to heat 0.50 kg of water from 25 °C to 100 °C, assuming no loss of heat to the surroundings. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

time = ... s [3]

(ii) Suggest **two** reasons why this type of solar panel is unlikely to replace conventional mains-powered electric kettles as a means of boiling water, even when the solar power is a maximum.

1. ....

....

....

2. ....

....

.... [2]

[Total: 20]

END OF QUESTION PAPER

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