OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/05

Telecommunications

Monday **28 JUNE 2004** Afternoon 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 provided 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.
- 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 Telecommunications. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	9	
2	9	
3	16	
4	17	
5	11	
6	8	
7	20	
TOTAL	90	

This question paper consists of 16 printed pages.

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

For Examiner's Use

Answer **all** the questions.

1 A radio amateur is an individual with a licence to transmit on one of the short-wave bands to other radio amateurs around the world. Fig. 1.1 represents a cross-section of the Earth with a radio amateur transmitting from an aerial in Newcastle, **N**, to a friend in Sydney, **S**.

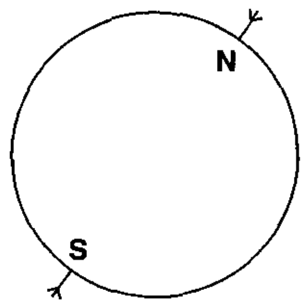

Fig. 1.1

(a) Draw on Fig.1.1 the path taken by the waves in travelling from **N** to **S**. Label any important features of your answer. [2]

(b) Explain why the waves follow this path.

....

....[2]

(c) State the range of carrier frequencies which the two radio amateurs could use.

from .... MHz to .... MHz [2]

(d) Draw a diagram of a dipole aerial which may be used for this system.
Calculate a typical length for this aerial.

length = ... m [3]

[Total: 9]

For Examiner's Use

2 A signal transmitted over long distances through a coaxial cable must be repeatedly amplified due to the effects of *attenuation* and *noise*.

(a) Explain what is meant by

(i) *attenuation*

....

(ii) *noise.*

....

[2]

(b) Explain why it is necessary to make repeated amplifications of the signal.

....

....

....[2]

(c) Calculate, using the data given below, the maximum uninterrupted distance through which a signal may be transmitted.

signal power input to cable = 15 W
attenuation of cable = 6.6 dB km^{-1}
noise power in cable = 15 μW
minimum signal-to-noise ratio = 27 dB

maximum distance = ... km [5]

[Total: 9]

[Turn over

For Examiner's Use

3 Fig. 3.1 shows a circuit set up to measure temperature using a voltmeter.

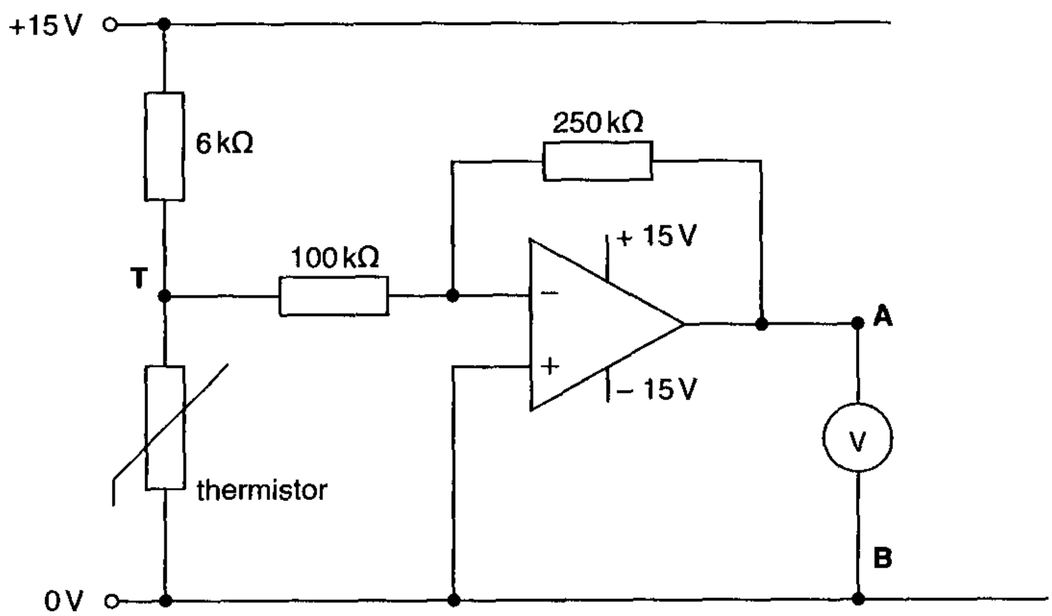

Fig. 3.1

The thermistor has a negative temperature coefficient and the d.c.voltmeter shows full scale deflection for a potential difference of 15V between **A** and **B**.

(a) State what is meant by a *negative temperature coefficient*.

....

....[1]

(b) Explain why the positive terminal of the voltmeter is connected to point **B**. Refer to the potential at point **T** in your answer.

....

....[2]

(c) At 50 °C, the thermistor has a resistance of 1.5 kΩ. For this temperature, calculate

(i) the current in the 6 kΩ resistor, giving a suitable unit for your answer

current = ... unit .... [3]

(ii) the potential at point **T**

potential = ... V [1]

(iii) the reading on the voltmeter.

reading = ... V [3]

(d) The temperature of the thermistor decreases. Explain how the voltmeter reading will change as the temperature continues to fall.

....

....

....

....[3]

(e) *Calculate the resistance of the thermistor at the lowest temperature that can be* measured by using this circuit.

thermistor resistance = ... Ω [3]

[Total: 16]

For Examiner's Use

4 Fig. 4.1 shows three different analogue signal sources 1, 2 and 3, connected to a circuit. This samples each one of the signals five times per second and converts each sample into a 4-bit digital signal. The circuit then transmits the three digital signals along a single optic fibre using time-division multiplexing.

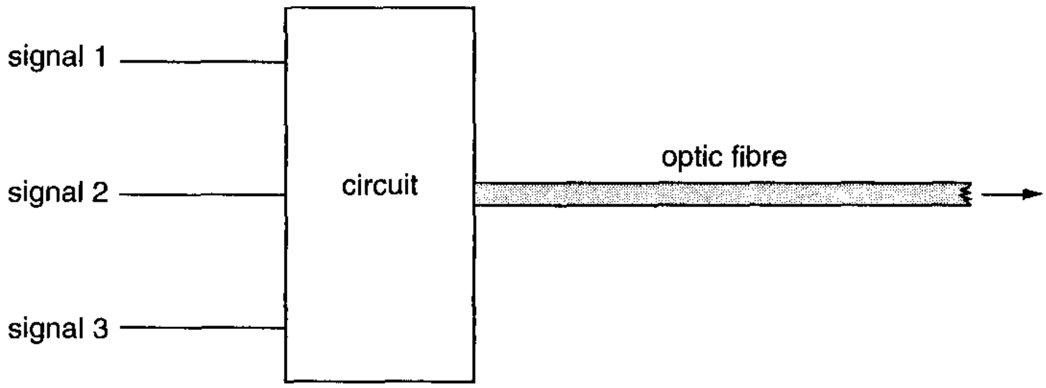

Fig. 4.1

(a) Calculate the maximum bit duration in the optic fibre which will allow this system to operate.

maximum duration = ... s [2]

(b) Calculate the maximum frequency of an analogue signal which may be recovered by this system.

maximum frequency = ... Hz [1]

For Examiner's Use

(c) Discuss how
- the three signals would be recovered at the other end of the optic fibre
- the system could be modified to transmit more than three signals.

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....[7]

For Examiner's Use

(d) A "snapshot" of 30 samples from the signals in a continuous section of the optic fibre (shown in two lengths for reasons of scale) is shown in Fig. 4.2.

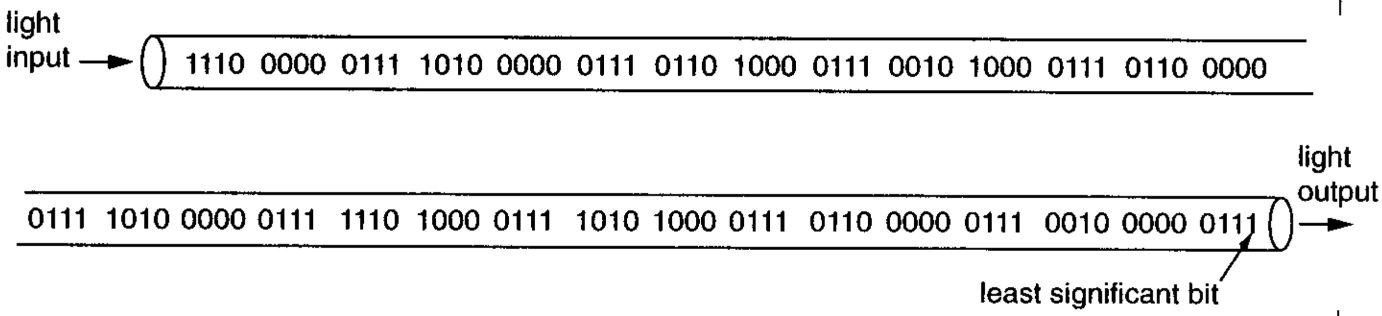
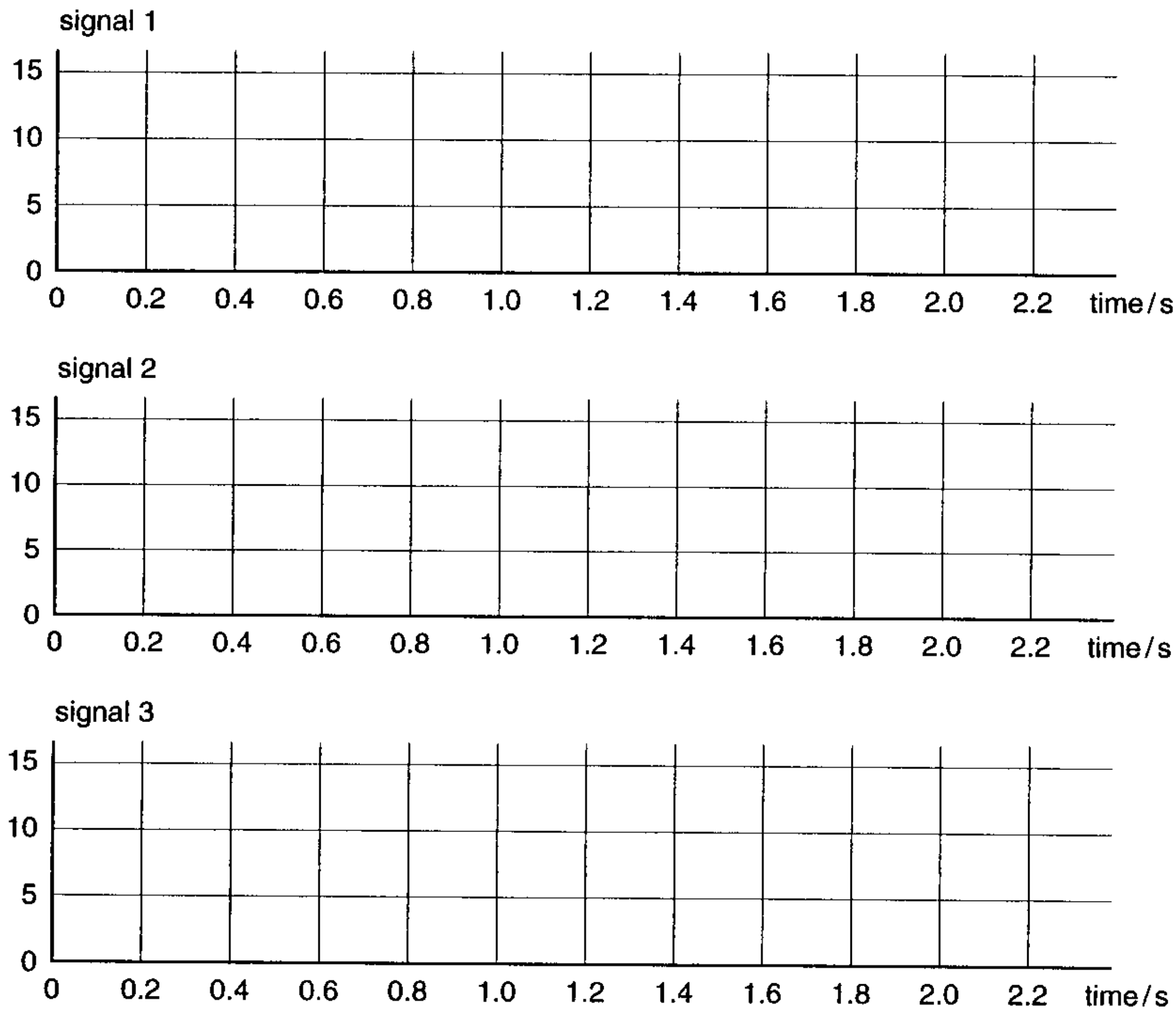


Fig. 4.2

(i) On the axes of Fig. 4.3, draw three labelled sketch graphs to show the variation with time of the three recovered analogue signals. Convert each 4-bit sample to the corresponding decimal value and assume the first sample to emerge is signal 1.



[6]

Fig. 4.3

(ii) Calculate the frequency of signal 2.

frequency = ... Hz [1]

[Total: 17]

For Examiner's Use

5 Fig. 5.1 shows a cross-section of a step-index multimode optic fibre.

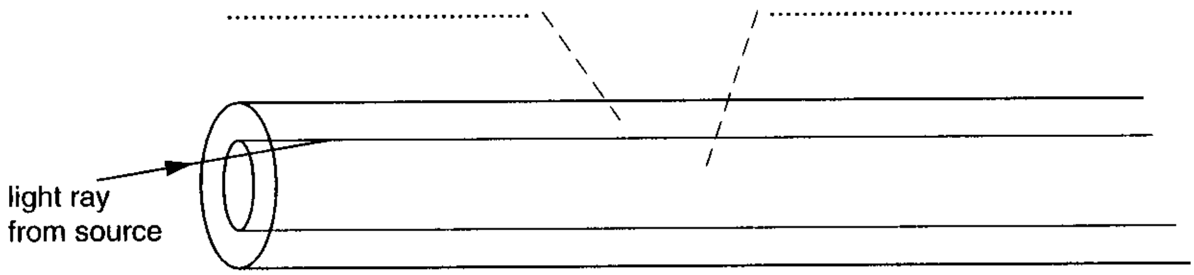


Fig. 5.1

(a) Label the sections of the fibre indicated by the dotted lines. [1]

(b) Explain why the fibre is called a *step-index* fibre.

....

....

....[2]

(c) On Fig. 5.1, continue the path of the light ray along the fibre. [1]

(d) This type of fibre produces multipath distortion when high frequency pulses of light are transmitted over long distances. Explain how this distortion is produced and describe how optic fibres are modified to reduce it.

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....[7]

[Total: 11]

For Examiner's Use

6 Fig. 6.1 shows a diagram of the Earth spinning on its axis.

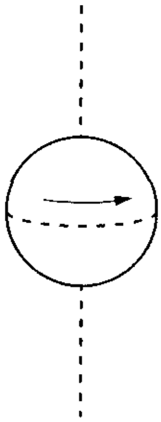

Fig. 6.1

(a) On Fig. 6.1, draw the path followed by a geostationary satellite. Your answer should show the direction of rotation and be approximately to scale. [2]

(b) State the orbital period of a satellite in a *geostationary orbit*.

period = ... [1]

(c) Explain why parabolic dishes are essential when communicating with geostationary satellites.

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....[4]

(d) State **one** use of geostationary satellites.

....[1]

[Total: 8]

For Examiner's Use

7 A student is concerned to keep fit and equally concerned to minimise the use of electricity from the national grid. The student decides to combine the two issues and designs the system shown in Fig. 7.1. The chain on the exercise bicycle turns a d.c. generator which passes a current through a heating coil immersed in a hot water tank. The idea is that the student exercises for a certain length of time and instead of simply "wasting" energy in pedalling, the energy is used to heat the water necessary for a shower when finished.

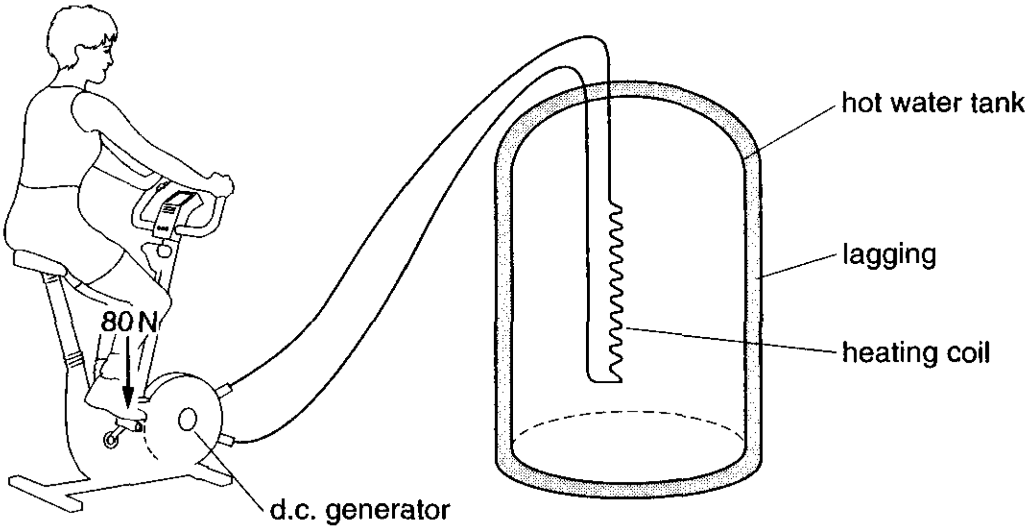

Fig. 7.1

The specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(a) The water enters the hot water tank at a temperature of 8 °C and is required to be heated to 38° C for an acceptable shower. The shower lasts for 5 minutes during which time the water flows at a rate of 0.15 kg s^{-1}. Calculate

(i) *the mass of water used during the shower*

mass of water = ... kg [2]

(ii) the energy required to heat the water for the shower.

energy = ... J [2]

[Turn over

For Examiner's Use

(b) When pedalling on the exercise bicycle, each foot spends half the cycle doing work and the other half relaxing. While doing work, an average tangential force of 80 N is applied to each pedal. The pedal is positioned at a radius of 20 cm from the axle and the student maintains 1.3 revolutions per second.

(i) Show that the work done by the student during one revolution of the pedals is about 100 J.

[2]

(ii) Calculate the power produced by the student while pedalling.

power = ... W [1]

(iii) Calculate the total number of revolutions of the pedals required before the energy expended by the student equals that required to heat the water.

number of revolutions = ... [1]

(iv) Calculate the time for which the student must pedal in order to deliver the heat energy required.

time = ... hour [2]

For Examiner's Use

(c) The d.c. generator being driven by the exercise bicycle has an internal resistance of $1.2\,\Omega$ and produces an e.m.f. of 24 V while delivering a current of 5A.

(i) Show that the resistance of the heater element in the hot water tank is $3.6\,\Omega$.

[3]

(ii) Calculate the length of heater wire required if the element is made from resistance wire of resistivity $1.5 \times 10^{-7}\,\Omega\,\text{m}$ and cross-sectional area $0.32\,\text{mm}^2$.

length .... m [3]

(d) In practice, the student would have to pedal for an even longer time than your answer to **(b)(iv)**. By considering energy losses, give reasons for this. Include some calculations in your answer.

....

....

....

....

....[4]

[Total: 20]

END OF QUESTION PAPER