

OXFORD CAMBRIDGE AND RSA EXAMINATIONS**Advanced GCE****PHYSICS A****2825/05**

Telecommunications

Thursday

26 JANUARY 2006

Morning

1 hour 30 minutes

Candidates answer on the question paper.

Additional materials:

Electronic calculator

Candidate Name	Centre Number	Candidate Number												
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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.
- 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	15	
2	19	
3	16	
4	12	
5	8	
6	20	
TOTAL	90	

This question paper consists of 14 printed pages and 2 blank pages.

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,	$g = 9.81 \text{ m s}^{-2}$

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,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel,

$$C = C_1 + C_2 + \dots$$

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,

$$x = x_0 e^{-\lambda t}$$

$$t_{1/2} = \frac{0.693}{\lambda}$$

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,

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

Answer **all** the questions.

- 1 Fig.1.1 shows a block diagram of a demonstration set up by a teacher to show the processes of analogue-to-digital conversion (ADC) and digital-to-analogue conversion (DAC). The periodic signal from the signal generator is regularly sampled and digitised by the ADC and transmitted along the multicore cable to the DAC and oscilloscope.

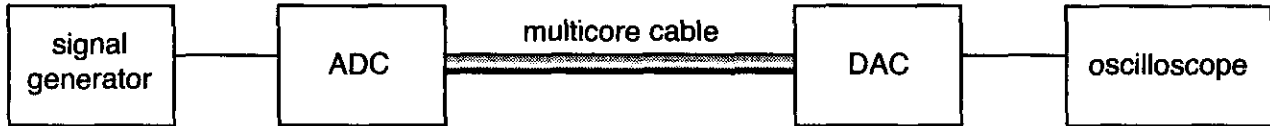


Fig. 1.1

The trace observed on the oscilloscope is shown in Fig.1.2.

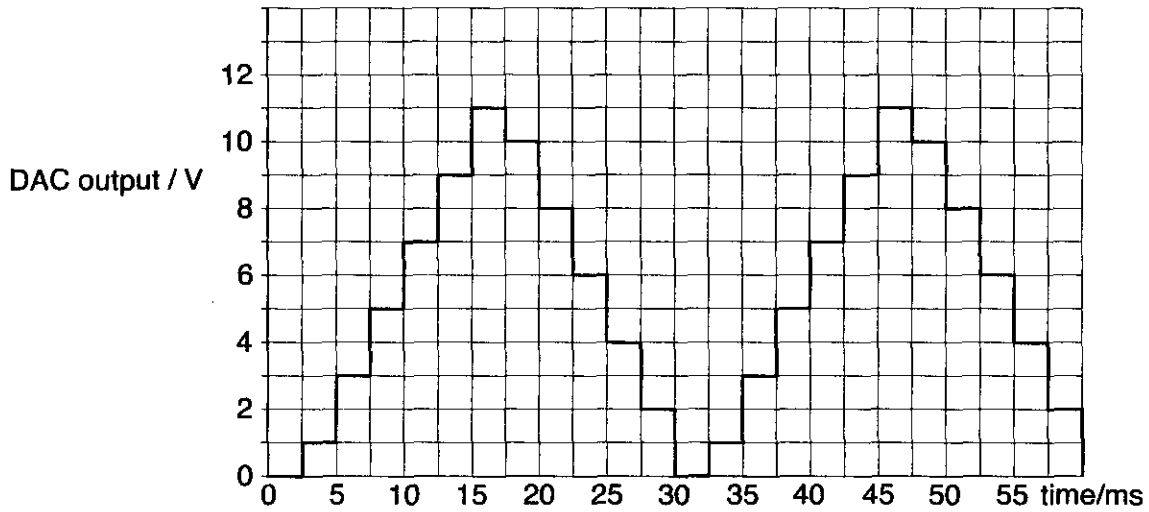


Fig. 1.2

- (a) Use Fig.1.2 to calculate the following and explain what information you used to arrive at your answer in each case.

- (i) the frequency of the signal generator

.....

signal frequency = Hz [2]

- (ii) the sampling frequency of the ADC

.....

sampling frequency = Hz [2]

(iii) the minimum number of separate wires in the multicore cable

.....
.....

number of wires =[3]

(b) Explain how the trace observed on the oscilloscope changes when

(i) the sampling frequency of the ADC is increased but the number of bits into which the signal is converted stays the same

.....
.....[2]

(ii) the number of bits into which the signal is converted is increased but the sampling frequency of the ADC stays the same.

.....
.....[1]

(c) (i) State **two** reasons why a digitised signal is not normally transmitted in parallel by a multicore cable when the distance of transmission is very large.

1.
2.[2]

(ii) Explain how the parallel output from the ADC is transmitted over long distances to the DAC.

.....
.....
.....
.....[3]

[Total: 15]

2 (a) Fig. 2.1 shows an operational amplifier with inputs **A** and **B** and output **C**.

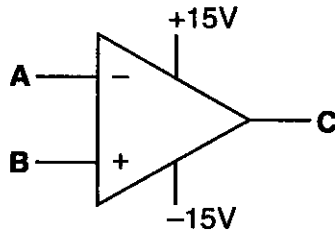


Fig. 2.1

(i) Making reference to the open-loop gain and the voltages V_A at **A**, V_B at **B** and V_C at **C**, explain why the op-amp is called a *difference* amplifier.

.....
[2]

(ii) The open-loop gain of the op-amp is 1.0×10^5 . Complete the following tables to show how V_C depends on V_A and V_B .

V_A/V	V_B/V	V_C/V
+3.5	+2.5	

V_A/mV	V_B/mV	V_C/V
-1.54	-1.54	

V_A/mV	V_B/mV	V_C/V
+2.85	+2.87	

[3]

Fig. 2.2 shows a circuit built around the op-amp of Fig. 2.1.

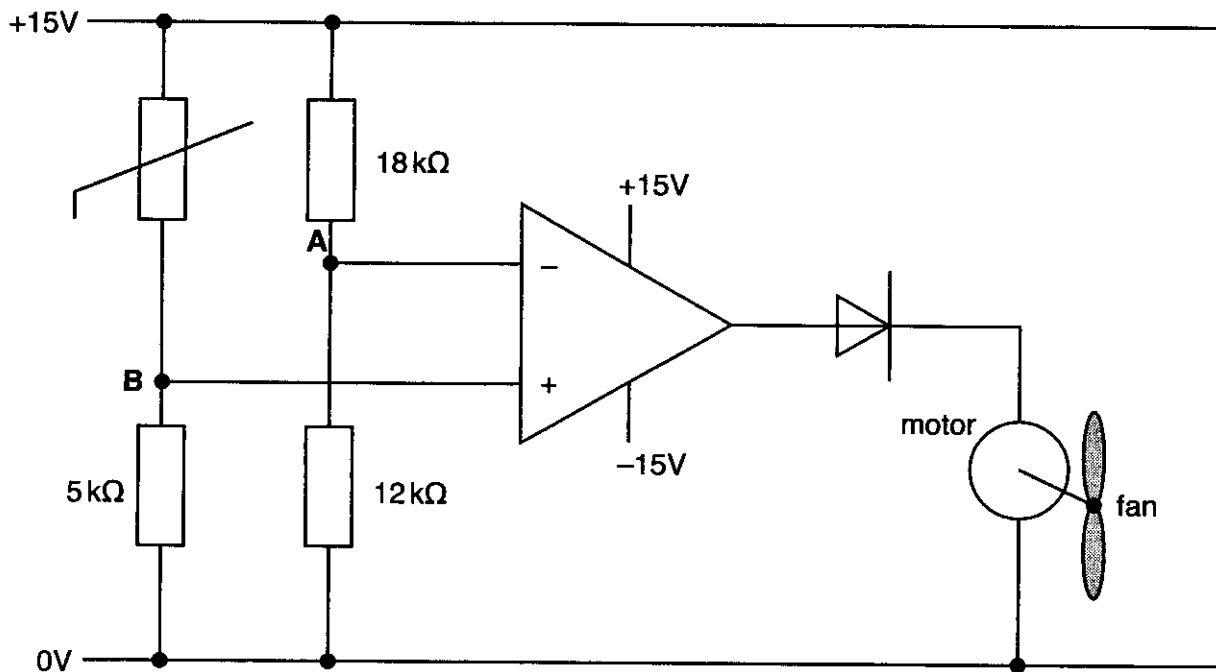


Fig. 2.2

(b) Calculate the voltage V_A at point A.

$V_A = \dots\dots\dots V$ [2]

(c) (i) In the circuit of Fig. 2.2, there is a thermistor. Put a circle around this component. [1]

(ii) The thermistor has a negative temperature coefficient. Explain what this means.

.....
..... [1]

(iii) Calculate the resistance of the thermistor which will make V_B equal to V_A .

resistance =k Ω [3]

(d) The motor which drives the fan is rated at 15 V and 150 mW. Explain why such a low power motor is used in the circuit.

.....
..... [2]

(e) Explain why the diode is necessary in this circuit.

.....
..... [2]

(f) Explain how the circuit functions.

.....
.....
..... [3]

[Total: 19]

- 3 Suppose the BBC is to set up a new radio station which can be received by everyone in the UK.
The new station could broadcast nationwide using AM on the LF waveband or FM on the VHF waveband.

(a) Explain what is meant by *AM* and *FM*.

AM.....
.....[2]

FM.....
.....[2]

(b) State and explain **two** reasons why music broadcast using FM on VHF sounds better than the same music broadcast using AM on LF.

1.
.....
2.
.....[4]

(c) By considering the problems of nationwide coverage, explain why it would be much cheaper to use AM on LF than FM on VHF.

.....
.....
.....
.....
.....[4]

(d) Draw the diagram of a dipole aerial for use on the VHF waveband. Calculate the length of your dipole for a typical VHF frequency. Show your working.

length = m [4]

[Total: 16]

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- 4 Fig. 4.1 shows two telephone exchanges linked by optic fibre. Between the two exchanges there are four amplifiers, equally spaced, as shown. A fifth and final amplifier is located inside exchange 2.



Fig. 4.1

The amplifiers are necessary to prevent the signal-to-noise ratio from falling below 34 dB.

- (a) Explain what is meant by *noise* in a telecommunications system.

.....
[1]

- (b) Explain why the signal-to-noise ratio falls as the length of the optic fibre increases.

.....
[2]

- (c) Exchange 1 outputs a signal power of 22 mW into the optic fibre.
 The fibre has an attenuation of 0.30 dB km⁻¹.
 The noise power at the input of each amplifier is 0.28 μW.
 Signal-to-noise ratio at the input of each amplifier is 34 dB.

- (i) Show that the signal power at the input of each amplifier is 0.70 mW.

[2]

- (ii) Calculate the attenuation in each section of optic fibre.

attenuation =dB [2]

(iii) Calculate the separation of the two exchanges.

separation = km [2]

(d) The refractive index of the core of the optic fibre is 1.5. Calculate the **minimum** time which a light signal could spend travelling between the two exchanges.

minimum time = ms [3]

[Total: 12]

- 5** Nowadays, almost all A-level students in the UK own a mobile phone yet very few have any idea of how the mobile phone network operates. Imagine you are to give a talk on the subject to a group of Physics students who are not studying this module. In the space below, set out the main features you would bring out in your talk to explain the principles of operation of the mobile telephone network. Include in your answer some comments on the frequencies used.

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[Total: 8]

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Turn over for Question 6

6 This question is about the design and use of Christmas tree lights.

Design of bulbs

An engineer intends to design light bulbs for use in a set of Christmas tree lights to be powered by a 240 V mains supply.

Each bulb, when operating normally, will use 0.50 W and will have a filament 6.0 mm long, made of tungsten.

resistivity of tungsten at normal working temperature = $1.1 \times 10^{-6} \Omega \text{ m}$

(a) State **one** advantage of connecting these bulbs in parallel, rather than in series.

.....
.....
..... [1]

(b) Suppose the bulbs are connected in **parallel**. Calculate

(i) the current through each bulb

current = A [2]

(ii) the resistance of each bulb filament

resistance = Ω [2]

(iii) the radius of each bulb filament.

radius = m [3]

(iv) Hence suggest why these bulbs are impractical.

.....
.....
..... [1]

Use of bulbs

A householder has two sets of Christmas tree lights.

Set A consists of 24 bulbs, each of resistance $200\ \Omega$, connected in series.

Set B consists of 48 bulbs, each of resistance $50\ \Omega$, connected in series.

All bulbs fail when their power dissipation reaches $0.75\ \text{W}$.

(c) **Set A** is connected to a $240\ \text{V}$ mains supply. Fig. 6.1 shows the wiring of four of these bulbs.

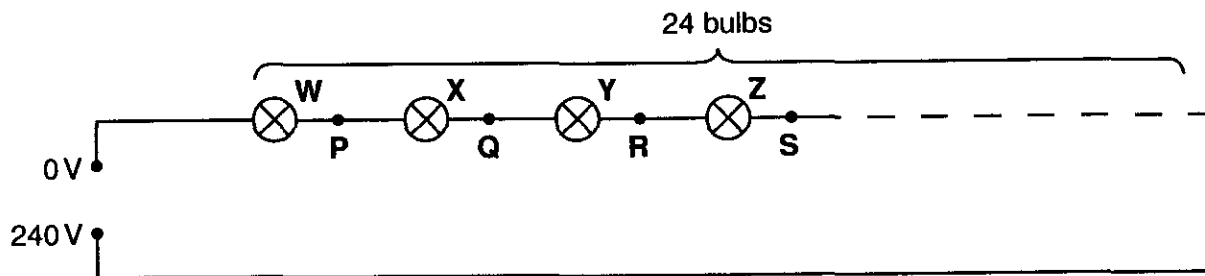


Fig. 6.1

During use, the filament of bulb **Y** fails and its resistance becomes infinite. In order to find which bulb has failed, the householder connects one terminal of a voltmeter to the $0\ \text{V}$ terminal of the mains and notes the voltmeter reading when its other terminal is connected successively to points **P**, **Q**, **R** and **S**.

Enter in the table the voltmeter reading for each connection.
Explain your answer.

connection	reading / V
P	
Q	
R	
S	

.....

.....

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.....

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.....

..... [4]

- (d) (i) The householder has no correct replacement bulbs for **Set A**. Each time a **Set A** bulb fails, it is replaced by a **Set B** bulb.
Explain why this is unsatisfactory and what will happen as more bulbs are replaced in this way.

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..... [3]

- (ii) Calculate how many bulbs from **Set A** can be replaced by **Set B** bulbs before the system fails altogether.
Assume that the resistance of each bulb is independent of the current.

number = [4]

[Total: 20]

END OF QUESTION PAPER