OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/05

Telecommunications

Wednesday **26 JANUARY 2005** Morning 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.
- 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	12	
2	13	
3	11	
4	12	
5	9	
6	13	
7	20	
TOTAL	90	

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

SP (NF/AR) S69612/5

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

Answer **all** the questions.

1 Fig. 1.1 shows an arrangement to measure the voltage gain of an amplifier.

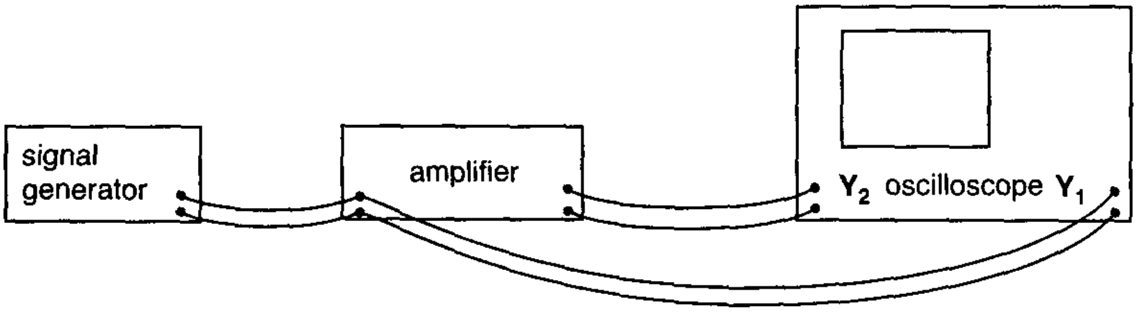

Fig. 1.1

Fig. 1.2 shows the settings and traces on the dual-beam oscilloscope for a signal of one particular frequency from the signal generator. The top trace is the amplifier input signal $\mathbf{Y_1}$ and the bottom trace is the amplifier output signal $\mathbf{Y_2}$.

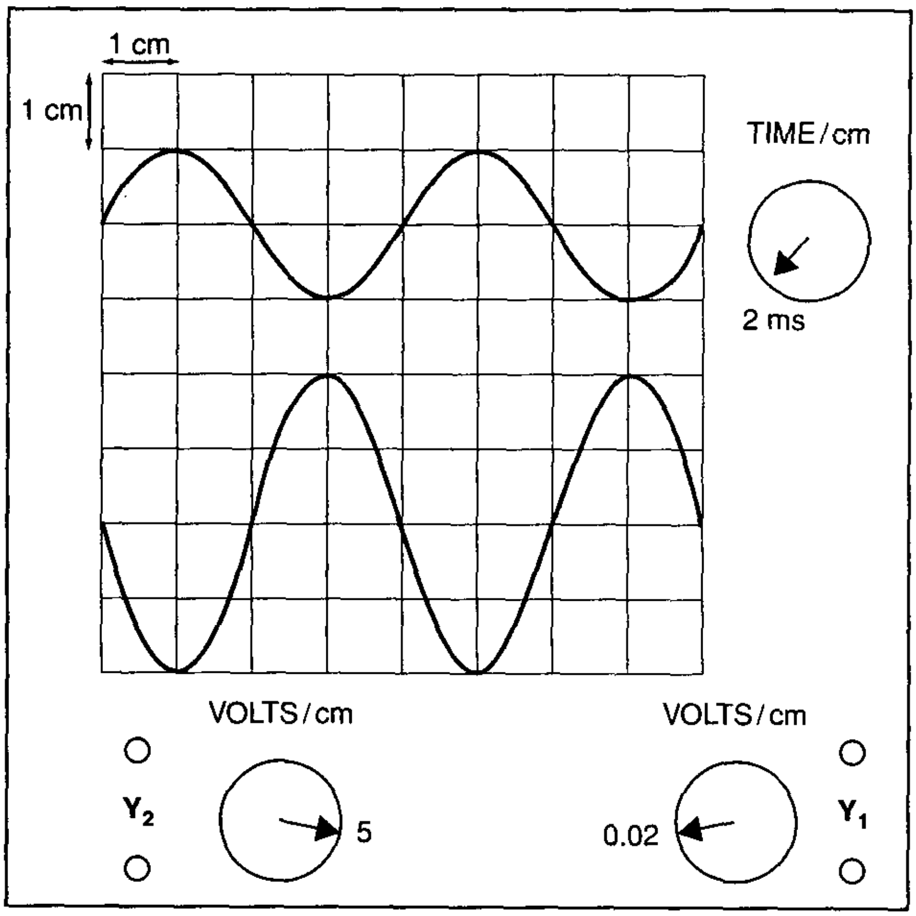

Fig. 1.2

For Examiner's Use

(a) From Fig. 1.2 calculate

(i) the peak voltage of the output signal

peak output = ... V [1]

(ii) the peak voltage of the input signal

peak input = ... V [1]

(iii) the voltage gain of the amplifier

voltage gain = ... [2]

(iv) the frequency of the input signal.

frequency = ... Hz [2]

(b) State **one** characteristic of the amplifier evident from an observation of Fig. 1.2.

....[1]

(c) In the space below, draw a circuit diagram for an op-amp amplifier which has the same gain as the amplifier of Fig. 1.1. Label resistors with appropriate values.

[5]

[Total: 12]

[Turn over

For Examiner's Use

2 (a) For satellite television systems, parabolic dishes are essential. One dish is used for transmission from a satellite while another is used for reception on Earth.

In the space below, complete the diagram to show how the two dishes would be set up for this purpose.

- Label clearly the **radiating source** and the **receiving element**. Also draw several ray paths to illustrate how electromagnetic waves travel from the source to the receiver.

transmitter

[5]

(b) Explain why dishes are essential for the transmission and reception of satellite television signals and why the dishes are parabolic.

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....[5]

For Examiner's Use

(c) Explain why dishes are **not** used for **terrestrial** television broadcasts.

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....[3]

[Total: 13]

For Examiner's Use

3 A new radio station is to be set up in a large city to broadcast the discussions at council meetings. Each member of the city council who speaks does so into a microphone.

(a) Explain why it is not practical for the radio station to amplify the AF signal from the microphone and send it directly to an aerial for transmission.

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....[3]

(b) Describe **two** methods by which the signal from the microphone can be processed so that the voices can be broadcast. Draw diagrams to illustrate your answers.

method 1

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method 2

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[6]

For Examiner's Use

(c) By considering the range of the transmissions, suggest why it would be better if the new radio station used the VHF waveband for its broadcast rather than the LF waveband.

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....[2]

[Total: 11]

For Examiner's Use

4 Fig. 4.1 shows how the attenuation in a cable varies with the frequency of input signal.

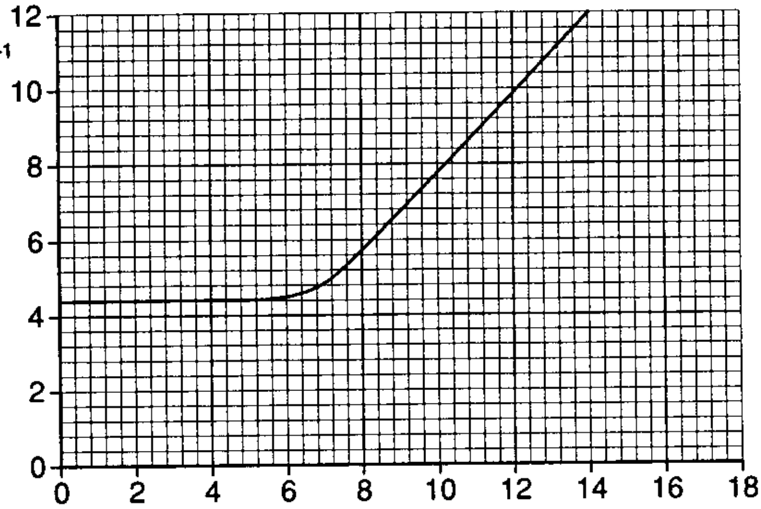

Fig. 4.1

(a) State what is meant by *attenuation*.

....[1]

(b) Several uninterrupted kilometres of the cable is used to transmit an audio signal. Use Fig. 4.1 to explain what will be heard at the receiving end when the input signal is

(i) music with the full range of audio frequencies

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....[2]

(ii) speech restricted to a maximum frequency of 3 kHz.

....

....

....[2]

For Examiner's Use

(c) The cable of Fig. 4.1 is used to transmit speech restricted to frequencies below 3 kHz. The input power to the cable is 1.33 W and the noise power in the cable is a constant 4.2 μW. The signal-to-noise ratio must not fall below 28 dB.

(i) Calculate the lowest acceptable signal power in the cable.

lowest power = ... mW [2]

(ii) Calculate the total attenuation of the signal at the point of lowest acceptable signal power.

total attenuation = ... dB [2]

(iii) Calculate the maximum uninterrupted length of cable which can be used.

length = ... km [1]

(iv) Explain quantitatively what must be done to allow the signal to be transmitted through a distance of 24 km and arrive at the other end with the same 1.33 W power with which it left the transmitter.

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....[2]

[Total: 12]

[Turn over

For Examiner's Use

5 Fig. 5.1 shows part of a drawing of a length of **monomode** step-index optic fibre.

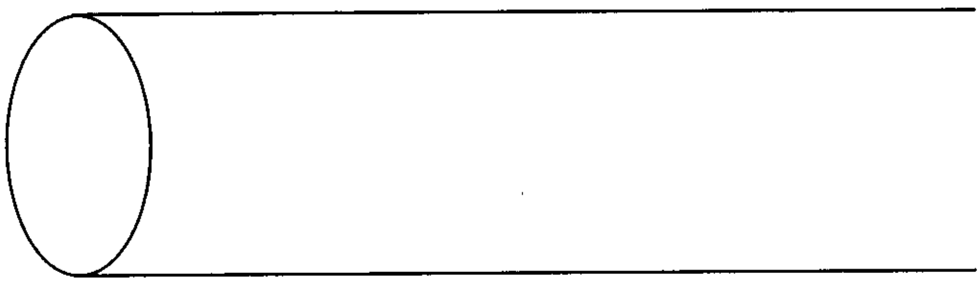

Fig. 5.1

(a) Complete and label the drawing to show the relative sizes of the different sections of the fibre. [2]

(b) Draw and label the path of a typical light ray down the fibre. [1]

(c) State the name of the component used to launch a light signal into the fibre and the name of the component used to detect the light signal at the other end.

input ....

output .... [2]

(d) Monomode fibre is used in preference to multimode fibre for the transmission of long-distance digital signals by the telecommunications industry. Explain this by contrasting the behaviour of signals in each type of fibre.

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....[4]

[Total: 9]

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[Turn over

For Examiner's Use

6 In the original telephone system of 1876, every subscriber was connected to every other subscriber by a pair of wires. This limited the use to simple voice communication within a single building. Today, the telephone has spread worldwide as a result of three major developments; these are the invention of the exchange, the use of multiplexing and the use of digital electronics.

(a) Discuss each of these three developments.

invention of the exchange

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....[3]

the use of multiplexing

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....[2]

For Examiner's Use

the use of digital electronics

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....[4]

(b) Highlight the differences between the original and the modern telephone systems in terms of the use by society.

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....[4]

[Total: 13]

7 Although the idea for the airbag was first suggested more than fifty years ago, it has only been a compulsory safety feature in the modern motor car since 1998. When a car experiences a serious head-on collision, the seat belt is designed to restrain the driver's body. However, without the cushioning effect of an airbag, the inertia in the driver's head will cause it to carry on moving at the speed of the car until it is stopped by the steering wheel or the windscreen. When activated, the airbag must be fully inflated before the driver's head reaches it so that the head hits a soft target.

One early system stored the gas for the airbag in a cylinder under the driver's seat. When the deceleration of the car was sufficiently large, a sensor caused an electrical circuit to operate and open a valve so that the compressed gas could rush into the airbag on the steering wheel.

The sensor used a steel ball and spring in a cylinder as shown in Fig. 7.1.

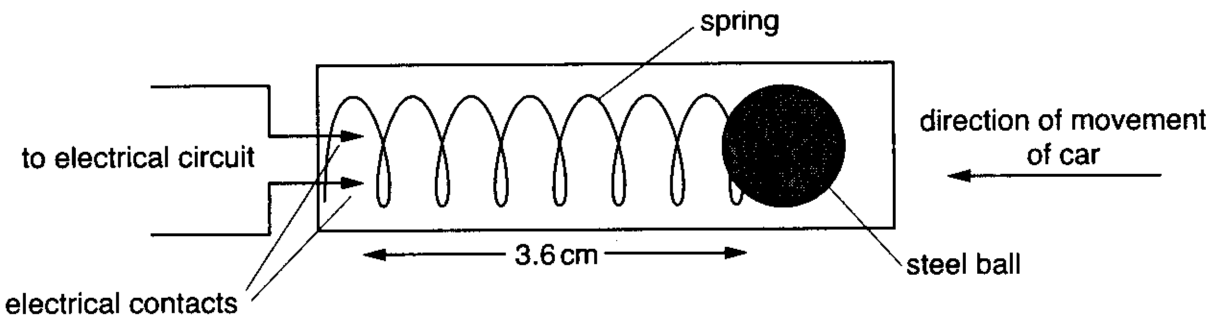

Fig. 7.1

When the car was being driven normally, the spring kept the steel ball apart from the two electrical contacts inside the cylinder. But if the deceleration became large enough, the inertia of the free ball compressed the spring and the ball touched the two contacts, thus activating the electrical circuit.

The method of storing compressed gas in a cylinder was not very reliable because some cylinders slowly leaked gas and so all had to be checked regularly.

The modern method of inflating an airbag is to generate the gas chemically by activating an electrical heater or detonator in an explosive chemical mixture. The heating starts a very rapid chemical reaction which produces nitrogen for the airbag. This means that the folded airbag along with chemicals and heater can all be located together in a compact container and positioned anywhere inside the car.

Consider the following data for a car running head-on into an immovable object.

initial velocity of car	= 54 km hr^{-1}
final velocity of car	= 0
car front crumple distance	= 1.25 m
distance from head to windscreen	= 0.96 m

(a) Show that the car's speed in m s^{-1} just before hitting the object is 15 m s^{-1}.

[2]

For Examiner's Use

(b) Calculate

(i) the deceleration of the car during the collision (assumed to be constant)

deceleration = ... $m\,s^{-2}$ [2]

(ii) the time taken for the car to crumple to rest.

time = ... s [2]

(c) The data for a ball and spring sensor is given below.

mass of ball	= 0.12 kg
spring constant	= $30\,N\,m^{-1}$
distance to be compressed	= 3.6 cm

Calculate

(i) the force necessary to compress the spring by 3.6 cm

force = ... N [2]

(ii) the deceleration which the force in **(c)(i)** would cause in a mass of 0.12 kg.

deceleration = ... $m\,s^{-2}$ [1]

(d) When the airbag was fully inflated from a storage cylinder, the bag had a volume of $0.060\,m^3$, with the gas inside at a pressure of 250 kPa. If the storage cylinder had a volume of $3.0 \times 10^{-4}\,m^3$, calculate the stored gas pressure, assuming the gas was ideal and at constant temperature.

pressure = ... Pa [2]

[Turn over

(e) Suppose that the pressure inside the cylinder dropped by 20% over a period of 4 weeks. Assuming the mean temperature of the cylinder is 17 °C, calculate the average number of gas molecules leaving per second during this time.

number leaving per second = ... [4]

(f) The data for a modern airbag is given below.

energy required for reaction to start	= 0.96 J
heater wire cross sectional area	= $2.75 \times 10^{-8}\,m^2$
heater wire length	= 2.2 cm
resistivity of heater wire	= $1.5 \times 10^{-6}\,\Omega\,m$
battery voltage	= 12 V

(i) Show that the resistance of the heater filament is 1.2 Ω.

[2]

(ii) Hence calculate the time taken for the heater to start the chemical reaction.

time to start = ... s [3]

[Total: 20]

END OF QUESTION PAPER