RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A **2825/05**

Telecommunications

Thursday **27 JUNE 2002** 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 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	**8**	
2	**7**	
3	**9**	
4	**16**	
5	**16**	
6	**14**	
7	**20**	
TOTAL	**90**	

This question paper consists of 16 printed 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,	$n = \dfrac{1}{\sin C}$
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,	$p = \frac{1}{3}\dfrac{Nm}{V}<c^2>$
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,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg\left(\dfrac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows an oscilloscope screen displaying a signal which has been formed by adding a sine wave to a square wave.

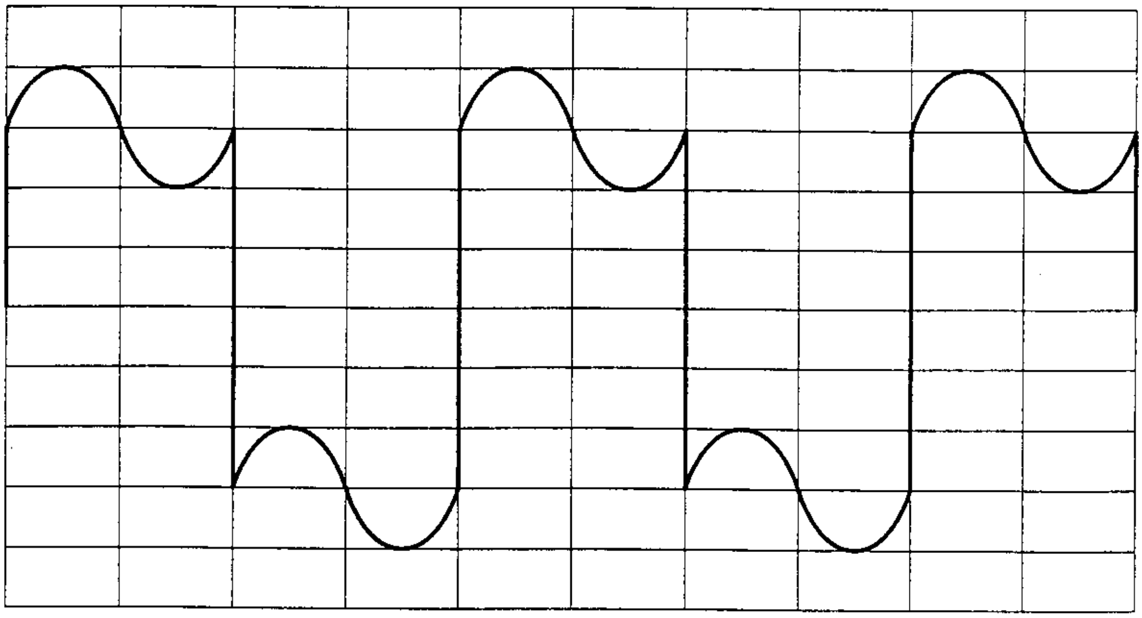

Fig. 1.1

The oscilloscope settings are 2 V per division vertically and 0.125 ms per division horizontally.

(a) Calculate the amplitude and frequency of the sine wave.

amplitude = ... V

frequency = ... kHz
[3]

(b) Calculate the amplitude and frequency of the square wave.

amplitude = ... V

frequency = ... kHz
[2]

For Examiner's Use

(c) The signal of Fig. 1.1 may be displayed as a function of frequency. Draw the resulting frequency spectrum on the axes of Fig. 1.2. [3]

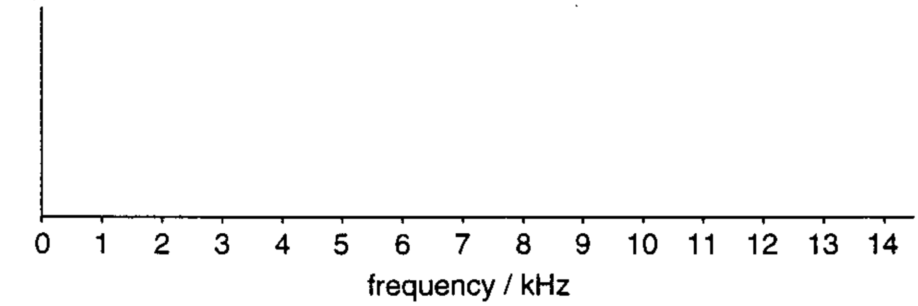

Fig. 1.2

[Total : 8]

2 Fig. 2.1 shows a block diagram of an amplitude-modulated radio receiver. The signal is picked up by the aerial and heard on the loudspeaker.

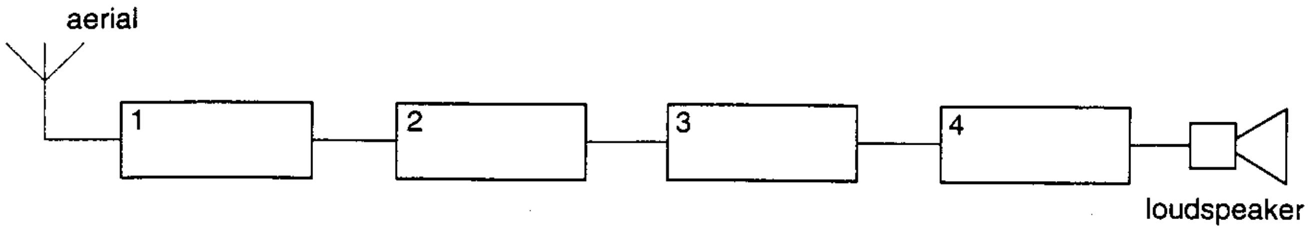

Fig. 2.1

State the name and explain the function of each of the four elements shown.

1. ....

....

....

2. ....

....

....

3. ....

....

....

4. ....

....

....

[7]

[Total : 7]

For Examiner's Use

3 Fig. 3.1 shows the circuit diagram of an inverting amplifier being operated from ±15 V power supply lines.

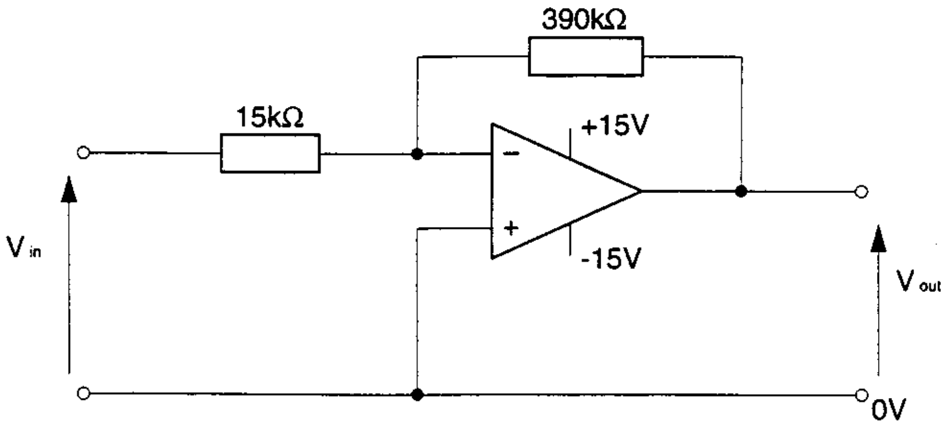

Fig. 3.1

When the op-amp output is not saturated, the inverting input is referred to as a virtual earth.

(a) State the potential of a virtual earth input.

potential = ... V [1]

(b) By referring to the open-loop voltage gain of the op-amp, explain why the inverting input has this potential.

....

....

....

....[3]

(c) Calculate the voltage gain of the amplifier circuit of Fig. 3.1.

voltage gain = ... [2]

(d) Explain what is meant by saturation in an amplifier.

....

....[1]

(e) Calculate the maximum input voltage the amplifier can amplify before saturation sets in.

maximum input voltage = ... V [2]

[Total : 9]

[Turn over

For Examiner's Use

4 A coaxial cable is to be used to carry telephone signals between a small local exchange and a trunk exchange. The maximum input power to the cable is 24 W and there is a constant noise power in the cable of 1.9 μW. The exchanges are separated by 4.5 km and there are no amplifiers between them. The signal-to-noise ratio must not be allowed to fall below 35 dB.

(a) Calculate

(i) the lowest signal power which can be allowed to reach the trunk exchange

power = ... W [2]

(ii) the maximum allowable attenuation caused by the cable.

attenuation = ... dB [2]

(b) The attenuation per kilometre produced by this cable varies with the frequency of the signal according to the graph of Fig. 4.1.

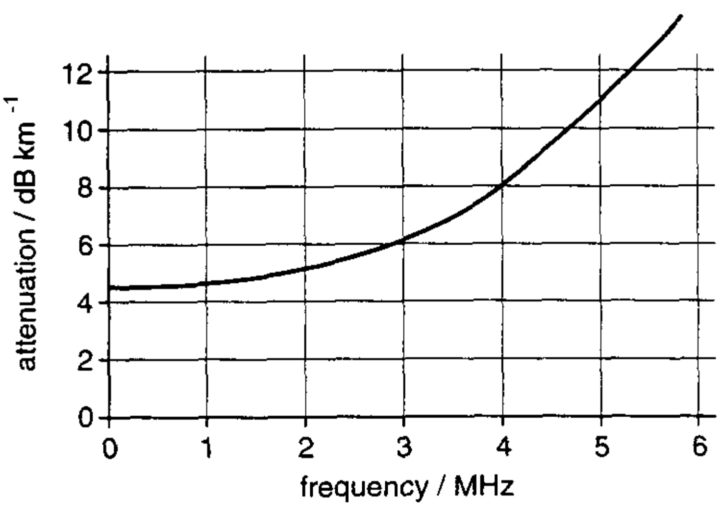

Fig. 4.1

Show that the maximum frequency which can be used to communicate signals between the exchanges is 4 MHz.

....

....

....[2]

For Examiner's Use

(c) At the local exchange, each telephone call is restricted to the frequency range between 300 Hz and 3.4 kHz. Calculate the bandwidth of each telephone call.

bandwidth = ... kHz [1]

(d) At the local exchange there are two ways of multiplexing to allow several calls to share the coaxial cable.

(i) One way is for each call to amplitude modulate one of a number of carriers which have a frequency in the range 10 kHz to 4 MHz (the maximum allowed in the cable). The different AM carrier frequencies are then added together and sent down the cable. This process is called frequency-division multiplexing (f.d.m.). Estimate the maximum number of calls which can be carried between the two exchanges in this way. Explain your working.

maximum number of calls = ...

....

....[3]

(ii) The second way uses time-division multiplexing (t.d.m.). Each call is sampled 8000 times per second and each sample is composed of 8 bits. Assuming that each bit lasts for 0.25 μs (the period of the 4 MHz frequency), estimate the maximum number of calls which can be carried in this way. Explain your working.

maximum number of calls = ...

....

....[3]

(iii) Compare your answers to **(i)** and **(ii)** and suggest why modern exchanges use t.d.m. to multiplex calls even though f.d.m. allows a greater number of calls to share the same cable.

....

....

....

....[3]

[Total : 16]

[Turn over

5 Fig. 5.1 shows the design for a simple communication system which two students are considering setting up between their houses, A and B, which are 250 m apart.

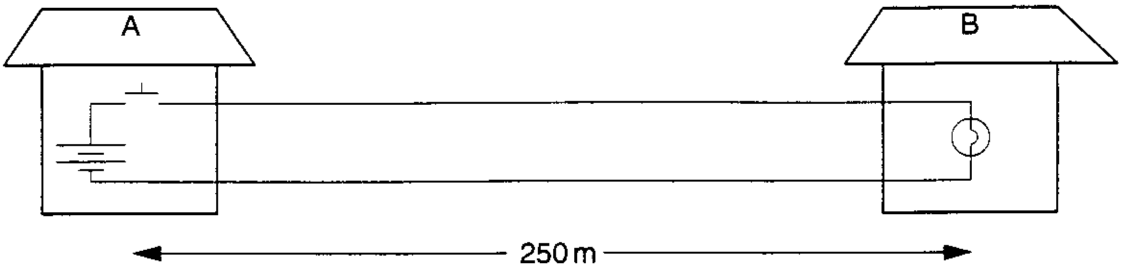

Fig. 5.1

Their first idea is for house A to contain a battery and house B to contain a lamp. By pressing the push switch in house A, the light bulb in house B is to light. The two students intend to devise a lamp on/off code which will allow each letter of the alphabet to be coded uniquely. The lamp in house B is rated at 12 V, 24 W. The copper cable which is to link the two houses has a cross-sectional area of 0.20 mm^2 and a resistivity of $1.8 \times 10^{-8}\,\Omega\,m$.

(a) Calculate

(i) the current required to operate the lamp

current = ... A [2]

(ii) the total resistance of the cables which link the two houses

resistance = ... Ω [3]

(iii) the emf of the battery required in house A. Give your answer with an appropriate unit.

emf = ... [3]

(b) Calculate the efficiency of the system (i.e. the ratio of the power delivered to the lamp to the power delivered by the battery when the switch is pushed).

efficiency = ... [1]

(c) The code for each letter of the alphabet is to be composed of a mixture of short or long light pulses (about 0.5 second and 1 second respectively). Estimate the time required to transmit a message of 50 letters. Explain your working.

time = ... s

....

....

....[3]

(d) **(i)** The two students now consider using an optic fibre cable instead of a copper cable. On Fig. 5.2 draw a diagram of the components they now require to make their simple communication system operate.

Fig. 5.2

(ii) State **two** advantages of the optic fibre system over the copper cable system.

....

....

....

....

....[4]

[Total : 16]

6 During the past decade, huge numbers of people in the UK have become subscribers to mobile telephone networks. Using portable handsets, they can now make a telephone call from almost anywhere in the country to almost anywhere in the world.

(a) By making reference to the processes of transmission and reception and the frequencies involved, explain

(i) why the aerial on a mobile phone handset is relatively small

....

....

....

....[2]

(ii) why the power transmitted from a handset must be relatively small

....

....

....

....[2]

(iii) how the system operates to allow the users to make a call from almost anywhere

....

....

....

....

....

....[5]

For Examiner's Use

(iv) why there are some areas in the country where the handset is not effective.

....

....

....

....[2]

(b) Suggest **three** reasons why the use of the mobile phone has become so widespread and popular with all sections of society.

1. ....

....

2. ....

....

3. ....

....

[3]

[Total : 14]

7 The following passage is based on a scientific article.

Power stations are normally most efficient when running under full load. The variation in demand over a day means that there must be capacity to meet peak demand, but much of this will be out of use for most of the day. This is wasteful of capital equipment when it is standing idle and of the fuel needed to run the station up to full demand and down at times of minimum demand.

The demand shown for January in Fig. 7.1 below is met for most of the day by power stations which are called *base load* stations. It has been suggested that during periods of peak demand, hydroelectric stations may be used to top-up the supply. The water for the hydroelectric stations is pumped into reservoirs at times when the *base load* stations' output is greater than demand. This is called a 'pumped storage' system.

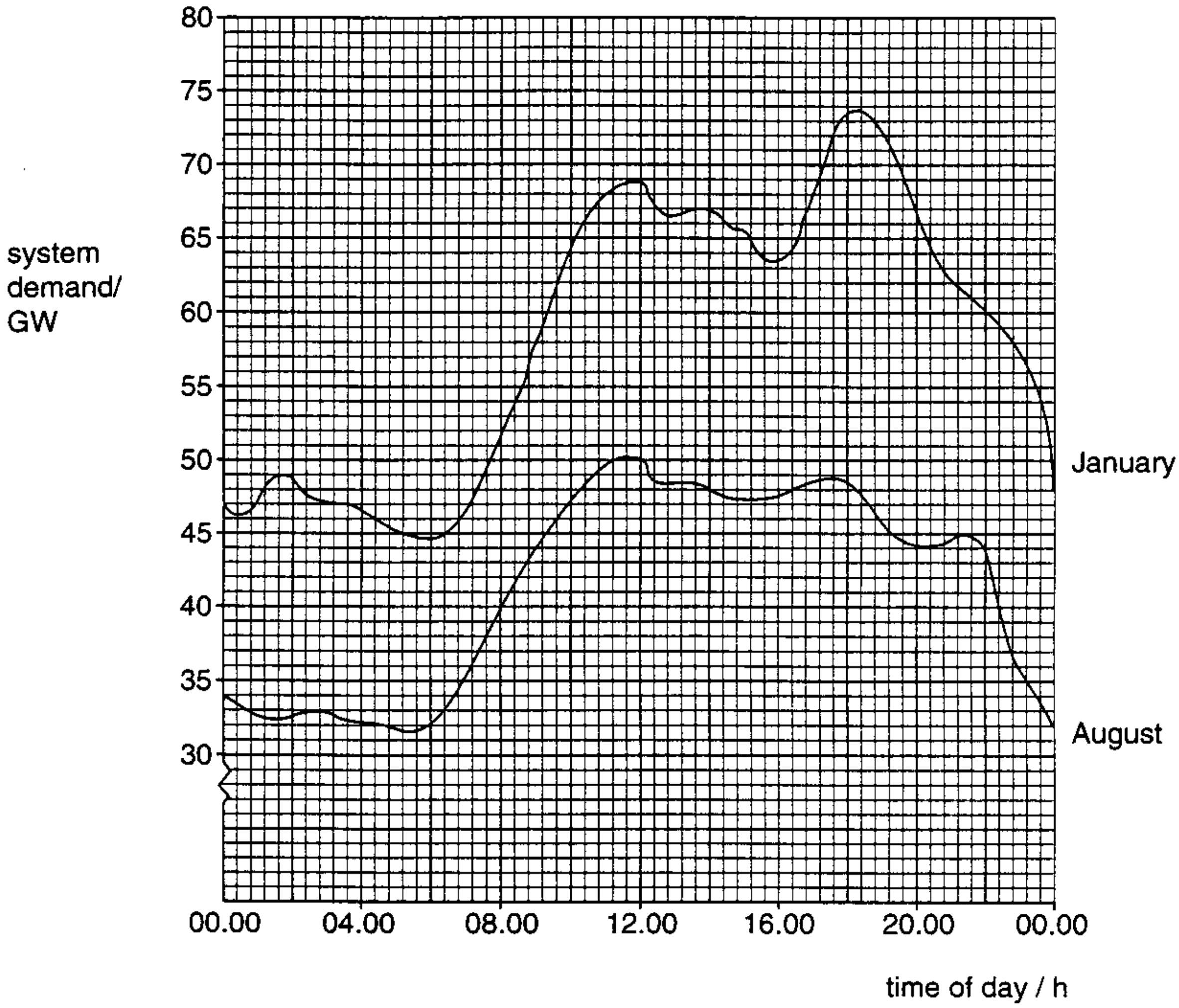

Fig. 7.1

Fig. 7.1 shows the average variation in demand for electrical energy from the electricity companies in the UK with time of day for January and August.

For Examiner's Use

Answer the following questions about this passage.

(a) State **four** major features of the graphs of Fig. 7.1 for January and August and suggest reasons for these features.

1. ....

....

2. ....

....

3. ....

....

4. ....

....
[4]

(b) Suggest **two** reasons why a *base load* coal-fired power station cannot simply be switched on or off when the demand suddenly changes.

....

....

....[2]

(c) **(i)** Use Fig. 7.1 to estimate the *base load* power for January, that would allow the system to meet the demand for 18 hours out of a 24 hour period.
Show this as a horizontal line labelled BL on Fig. 7.1.

(ii) Estimate the maximum power output of the hydroelectric power stations needed to meet the extra demand.

power = ... GW
[2]

[Turn over

For Examiner's Use

(d) Water in one of the hydroelectric power stations falls through a vertical distance of 100 m.

(i) Show that the minimum volume of water required per second to flow through the turbines to produce an output of 1.0 GW from the generator is about $1 \times 10^3\,m^3$. (The density of water = $1000\,kg\,m^{-3}$.)

[4]

(ii) Calculate the length of one side of a square reservoir of depth 35 m which would just supply water at a rate of $1.0 \times 10^3\,m^3\,s^{-1}$ for a continuous period of 4 hours.

length = ... m [4]

(iii) Comment on the feasibility of a number of such power stations to meet the extra requirements during periods of peak demand.

....

....[2]

(iv) Give **two** reasons why the actual volume of water required per second to produce an output of 1.0 GW is greater than that calculated in **(d)(i)**.

....

....

....[2]

[Total : 20]

Copyright Acknowledgements:

Question 7. Passage based on Question 24 in the 'Physics Nuffield Students' Guide', p.441, published by Addison Wesley & Longman.
Graph data based on SATIS no.601, 'Students' Guide', p.7 and 8, published by ASE, Hatfield, Herts.