OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2825/05

Telecommunications

Thursday **26 JUNE 2003** 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.
- 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	7	
2	17	
3	12	
4	10	
5	10	
6	14	
7	20	
TOTAL	90	

This question paper consists of 16 printed pages.

SP (AT/SLC) S29229/5

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

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For Examiner's Use

Answer **all** the questions.

1 (a) Fig. 1.1 shows the voltage spectrum of an amplitude modulated (AM) waveform.

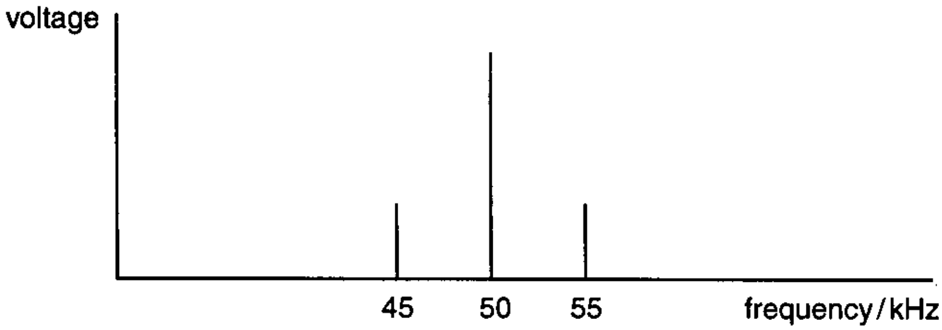

Fig. 1.1

(i) Show that the carrier period is 20 μs.

[1]

(ii) Calculate the period of the modulating signal.

period = ... μs [1]

(iii) On the axes of Fig. 1.2, draw the amplitude modulated waveform as a function of time and explain how it has been produced.

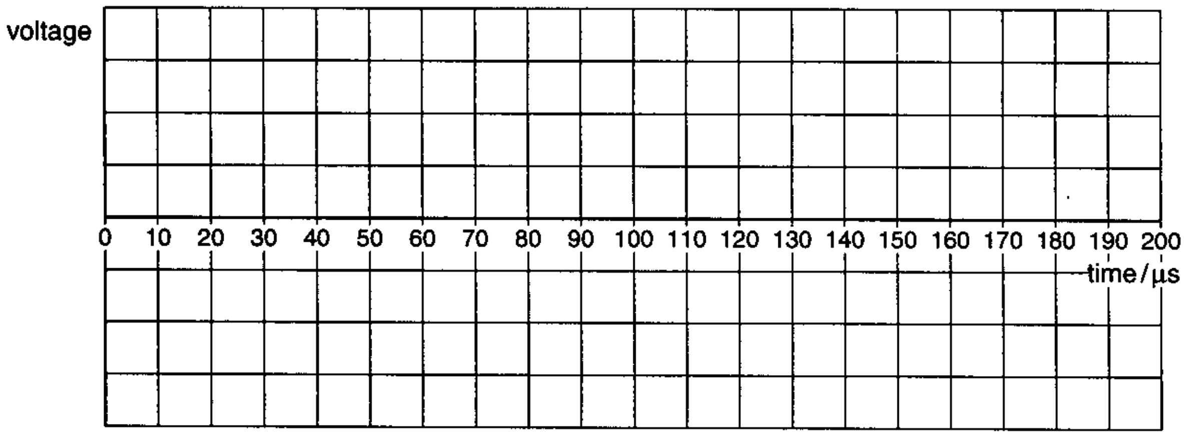

Fig. 1.2

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....[3]

For Examiner's Use

(b) Fig. 1.3 shows the voltage spectrum of a signal formed by simply adding together two sinusoidal waveforms.

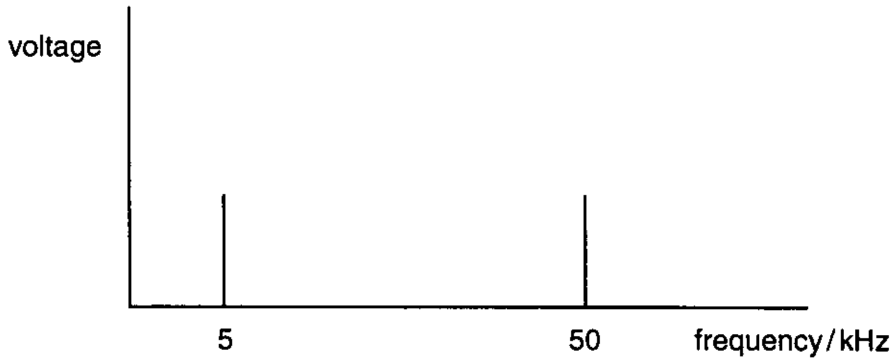
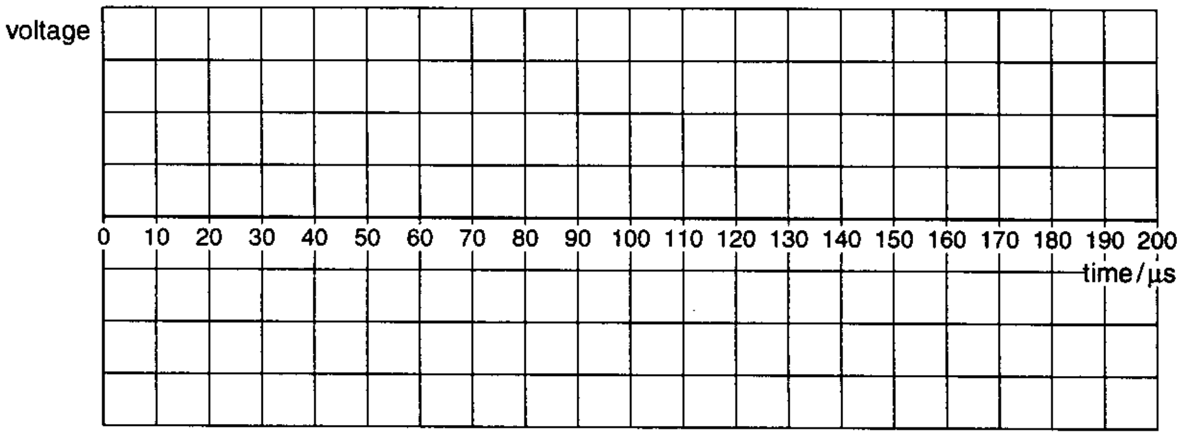


Fig. 1.3

On the axes of Fig. 1.4, draw this waveform as a function of time.



[2]

Fig. 1.4

[Total: 7]

[Turn over

For Examiner's Use

2 A teacher decides to set up a demonstration to show how a few metres of optic fibre can carry a speech signal from one end of a laboratory to the other. She uses a microphone which generates a signal of ± 25 mV. At the receiving end of the fibre, the output signal is emitted from a high resistance loudspeaker. She has available operational amplifiers together with other basic electronic components.

(a) **(i)** Fig. 2.1 is an incomplete diagram of the transmitting end of the fibre. Using the figure as a guide, draw a suitable input system for the optic fibre. The microphone, op-amp and optic fibre are shown. State all resistor values and justify them with calculations.

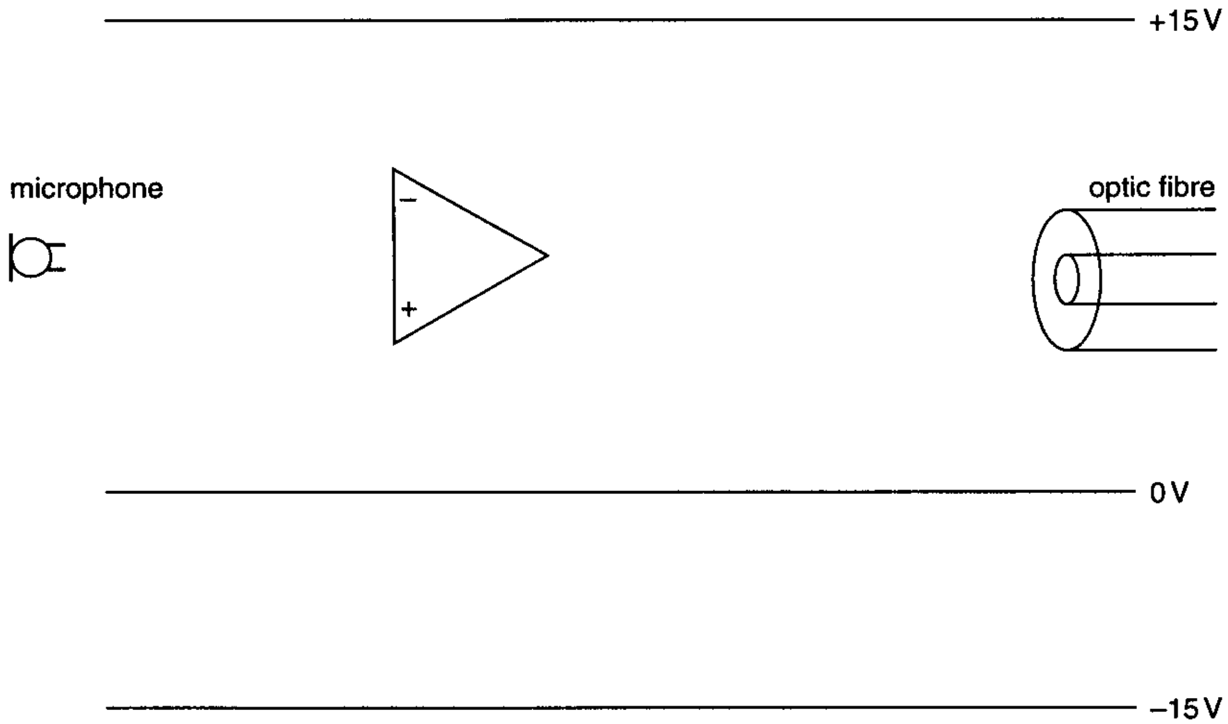


Fig. 2.1

[7]

(ii) Explain how your system works.

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....[2]

For Examiner's Use

(b) (i) Fig. 2.2 is an incomplete diagram of the receiving end of the fibre. Using the figure as a guide, draw a suitable output system for the light signal emerging from the optic fibre. The loudspeaker, op-amp and optic fibre are shown. State all resistor values and justify them with calculations.

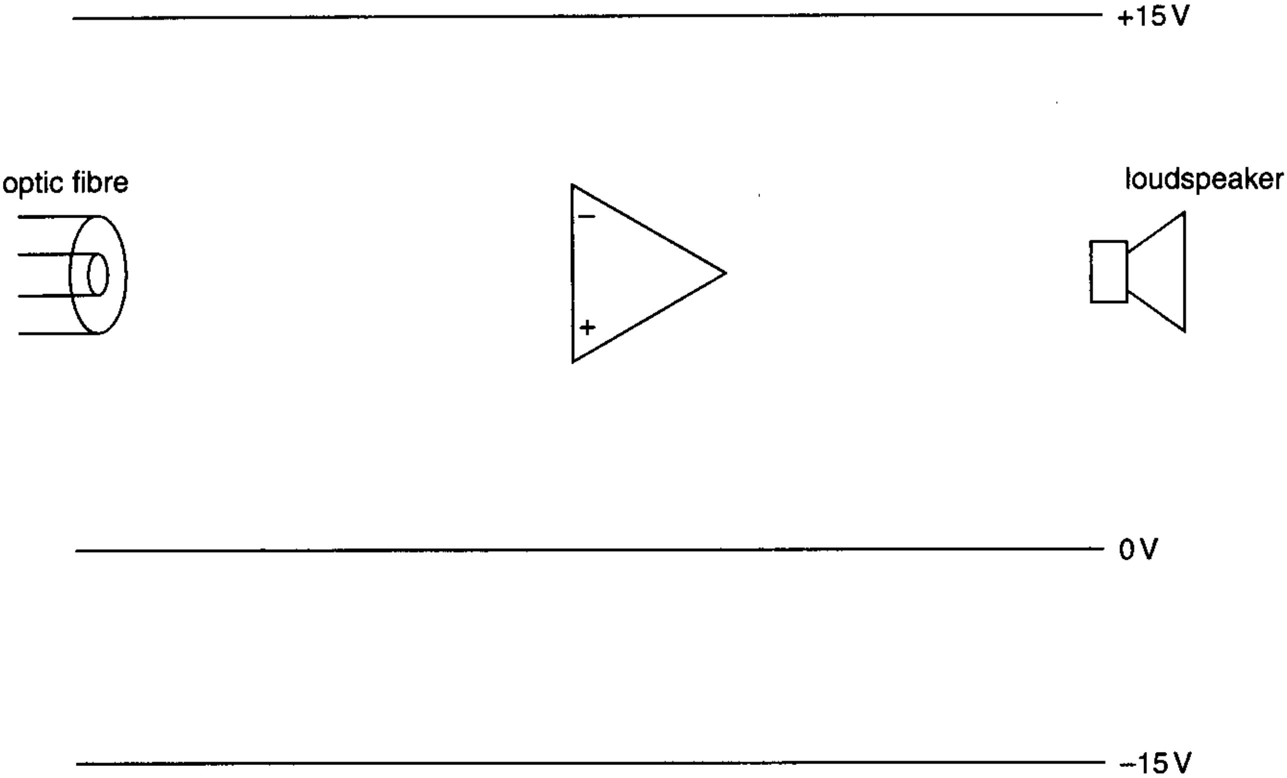

Fig. 2.2

[7]

(ii) Explain how your system works.

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....[1]

[Total: 17]

[Turn over

For Examiner's Use

3 Fig. 3.1 shows the process by which an analogue signal is sampled by an analogue-to-digital converter (ADC) before being connected to a parallel to serial converter which transmits the individual bits, one at a time, along the transmission line. At the other end of the transmission line, the bits arrive at a serial to parallel converter where they are prepared for the digital-to-analogue converter (DAC) which reproduces the original analogue signal.

Fig. 3.1

Fig. 3.2 shows the signal output of the DAC as a function of time.

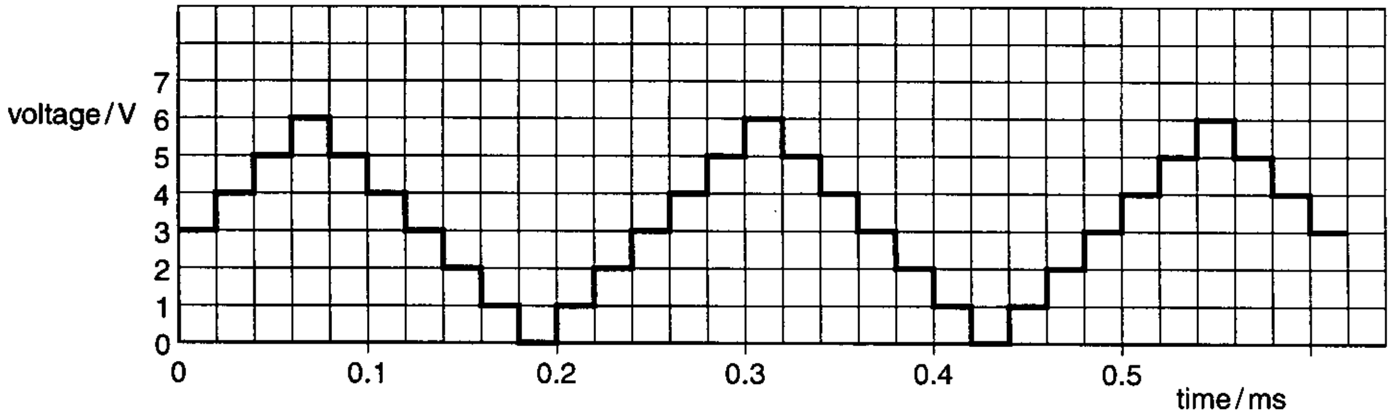

Fig. 3.2

(a) Use data from Fig. 3.2 to calculate

(i) the sampling frequency of the ADC

sampling frequency = ... Hz [2]

(ii) the fundamental frequency of the signal.

signal frequency = ... Hz [1]

For Examiner's Use

(b) State the most likely word length of the ADC (i.e. the number of bits into which each sample is converted). Explain your answer.

number of bits = ...

....

....[3]

(c) Show that the rate at which bits are transferred along the transmission line is 150 k bits sec^{-1}.

[1]

(d) Calculate

(i) the maximum bit duration which will allow this system to operate

maximum bit duration = ... s [1]

(ii) the highest pulse frequency likely to occur in the transmission line.

highest pulse frequency = ... Hz [2]

(e) Suppose the bit duration is made much shorter than your answer to **(d)(i)**. Suggest an advantage gained by this change.

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....[2]

[Total: 12]

[Turn over

For Examiner's Use

4 **(a)** The diameter of the core of a step-index monomode optic fibre is 9 μm.
Explain why the diameter is made so small.

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....[2]

(b) Explain why a laser rather than a LED is used to inject light into a monomode optic fibre.

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....[1]

(c) A 25 mW signal enters a continuous 40 km length of step-index monomode optic fibre cable.
The attenuation in the fibre is 0.25 dB km^{-1}.

(i) Show that the signal power emerging from the receiving end of the fibre is 2.5 mW.

[3]

(ii) Calculate the light intensity in the core at the receiving end of the fibre.

light intensity = ... W m^{-2} [2]

(iii) The ratio of the signal power to the noise power (signal-to-noise ratio) in the receiver is 35 dB.
Calculate the noise power at the receiver.

noise power = ... W [2]

[Total: 10]

For Examiner's Use

5 (a) A normal telephone call made through the Public Switched Telephone Network (PSTN) may be termed a *connection oriented* system. When the PSTN is used for Internet links, however, the system becomes a *connectionless system*.

Making reference to the switching involved and the use of protocols, explain the difference between using the PSTN for a normal telephone call and using the PSTN to transfer Internet data.

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(b) The availability of the Internet resulted in social and economic change. Briefly describe **four** of these changes.

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[Total: 10]

6 Fig. 6.1 shows a TV transmitter on a hill top overlooking a lake. At the far end of the lake is an apartment building in which each floor has a TV set with a simple dipole aerial.

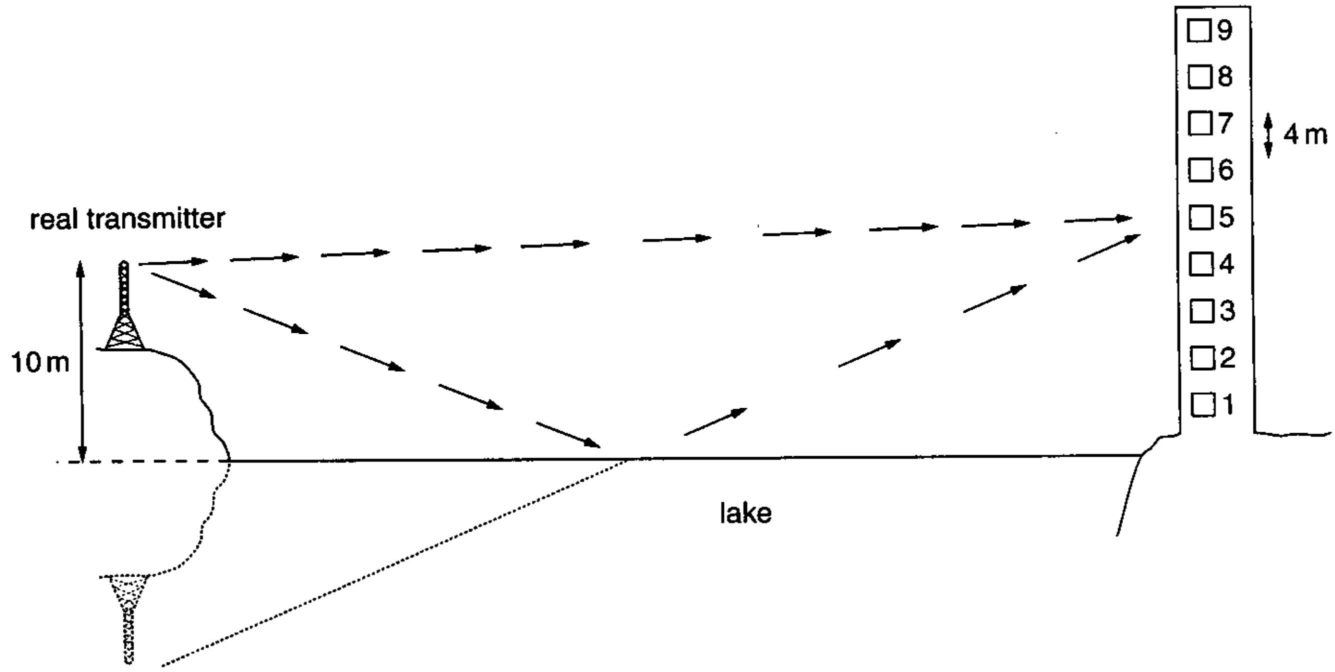

Fig. 6.1

Each TV aerial may receive waves directly from the transmitter as well as by reflection from the surface of the lake. Thus, the receiving aerial effectively "sees" two coherent sources, one the real transmitter and the other its mirror image in the lake.

The situation shown in Fig. 6.1 results in floors 1, 3, 5, 7 and 9 receiving a strong signal while the floors 2, 4, 6 and 8 receive a weak signal.

The TV transmitter uses a carrier frequency of 600 MHz and is located 10 m above the lake surface level. Floors in the apartment building are separated by 4 m.

(a) Calculate the wavelength of the waves. Give an appropriate unit for your answer.

wavelength = ... unit .... [2]

(b) Explain why the even numbered floors receive a weak signal while the odd numbered floors receive a strong signal.

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.... [3]

(c) Calculate

(i) the separation of the real and mirror image wave sources.

separation = ... m [1]

(ii) the distance across the lake from the transmitter to the apartment building. Show your working. **Note that the diagram is not to scale.**

distance = ... m [4]

(d) When the weather is very poor and the lake surface is choppy, all the floors in the apartment building receive a similar strength signal. Explain this observation and describe what modifications can be made to cause all floors to receive an equally strong signal in all weathers. You may draw a diagram if you wish.

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.... [4]

[Total: 14]

[Turn over

For Examiner's Use

7 Electric vehicles offer many advantages over those powered by internal combustion engines. However, they suffer from one overwhelming problem – storing the energy. In spite of massive research into battery technology, the traditional lead-acid car battery is still best for storing energy. It can hold 20 times more energy per kg than its nearest competitor, the nickel-cadmium rechargeable cell.

A typical lead-acid battery has the following properties.

storage capacity = 0.75 kW h
volume = $7.0 \times 10^{-3}\,m^3$
mass = 16 kg
terminal voltage = 12 V

Petrol has the following properties.

energy available = $50\,MJ\,kg^{-1}$
density = $700\,kg\,m^{-3}$

(a) Suggest **two possible** advantages of electric vehicles over conventional petrol powered vehicles.

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....[2]

(b) The storage capacity of a battery is often quoted in ampere-hours. This is the number of hours for which a fully charged battery can supply a current of 1 A. Use the data to estimate the capacity in ampere-hours of a typical lead-acid battery.

capacity = ... ampere-hour [3]

(c) A bank of lead-acid batteries of total mass 960 kg is used to power a car.

(i) Calculate the total energy (in MJ) available.

energy = ... MJ [3]

(ii) The drag force on the car at $25\,m\,s^{-1}$ is 300 N. Estimate how far it could travel at this speed on a level road using the energy stored in these batteries.

distance = ... m [3]

(d) **(i)** Calculate the mass and volume of petrol that provides the same energy as the 960 kg of lead-acid batteries.

mass of petrol = ... kg

volume of petrol = ...m^3 [4]

(ii) The volume of petrol calculated in **(d)(i)** is very small.

Explain why, in practice, a greater volume of petrol is needed to travel the distance calculated in **(c)(ii)**.

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(e) Discuss the significance of your answers for the future adoption of electric vehicles rather than petrol vehicles.

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....[3]

[Total: 20]