THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE
PHYSICS A
Telecommunications

2825/05

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Tuesday 16 June 2009
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

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 five questions concern Telecommunications. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**15**	
2	**19**	
3	**13**	
4	**15**	
5	**8**	
6	**20**	
TOTAL	**90**	

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,	$n = \dfrac{1}{\sin C}$
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,	$= \sqrt{(1 - \dfrac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\dfrac{I}{I_0} \right)$

Answer **all** the questions.

1 An AM waveform is composed of a carrier of frequency 40 kHz modulated by a sine wave of frequency 4 kHz.

(a) State the meaning of AM.

.... **[1]**

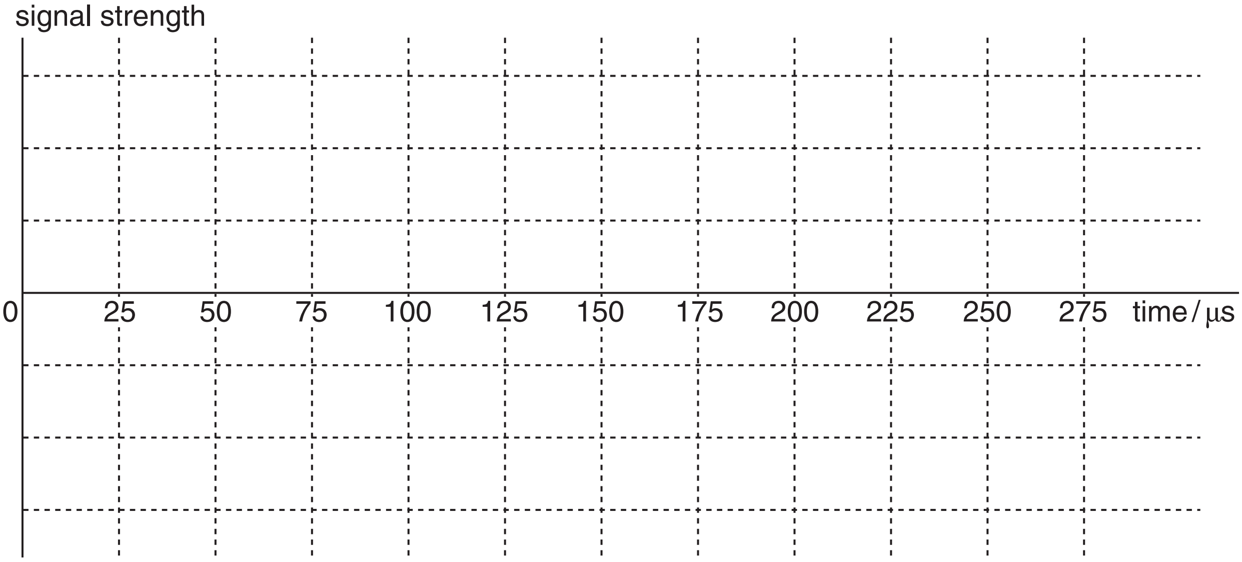
(b) **(i)** Show that the time period of the carrier is between 20 μs and 30 μs.

[2]

(ii) Show that the time period of the audio signal is 250 μs.

[1]

(iii) On the axes of Fig. 1.1, sketch a graph to show how the AM signal varies with time.



[4]

Fig. 1.1

(c) State the waveband which could accommodate this AM signal.

.... **[1]**

(d) **(i)** On the axes of Fig. 1.2, draw the frequency spectrum of the AM waveform of Fig. 1.1. Label the x-axis with an appropriate quantity and mark important values on this axis.

....

[4]

Fig. 1.2

(ii) Calculate the bandwidth of the signal and give an appropriate unit in your answer.

bandwidth = ... unit .... **[2]**

[Total: 15]

2 A signal source generates an electrical analogue signal which is to be transmitted to a receiver.

Fig. 2.1 shows a coaxial copper cable making a simple electrical link between the source and the receiver.

Fig. 2.1

(a) The maximum length of the coaxial cable is governed by the minimum value of the signal-to-noise ratio which can be allowed at the receiver.

(i) State what is meant by *noise* in telecommunications.

.... **[1]**

(ii) State and explain how the signal-to-noise ratio changes as the length of the coaxial cable increases.

....

.... **[2]**

(b) An identical signal source and receiver can be linked by an optic fibre. However, when an optic fibre is used to carry the same analogue signal, energy transformations must be performed by transducers **X** and **Y**. This is shown in Fig. 2.2.

Fig. 2.2

State the names of the transducers **X** and **Y** which perform these energy transformations.

(transmitter) **X** ....

(receiver) **Y** .... **[2]**

(c) In the transmission systems shown in Fig. 2.1 and Fig. 2.2 the following data applies:

output power of each signal source	760 mW
noise in each receiver	4.8 μW
minimum signal-to-noise ratio at input of each receiver	27 dB
attenuation of coaxial cable	6.4 dB km^{-1}
attenuation of optic fibre	0.47 dB km^{-1}
efficiency of each of the transducers **X** and **Y**	12%

(i) Show that the lowest acceptable signal power at the input to either receiver is about 2 mW.

[3]

(ii) Calculate the total attenuation in the coaxial cable.

coaxial attenuation = ... dB **[2]**

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

coaxial length = ... km **[1]**

(iv) By considering the outputs of transducers **X** and **Y**, calculate the attenuation in the optic fibre.

optic fibre attenuation = ... dB **[3]**

(v) Calculate the continuous length of optic fibre which can be used.

optic fibre length = ... km **[1]**

(d) State and explain **two** reasons why optic fibre transmission is preferable to coaxial cable transmission.

1. ....

....

2. ....

.... **[4]**

[Total: 19]

3 Fig. 3.1 shows an op-amp circuit which receives a sinusoidal input from a signal generator.

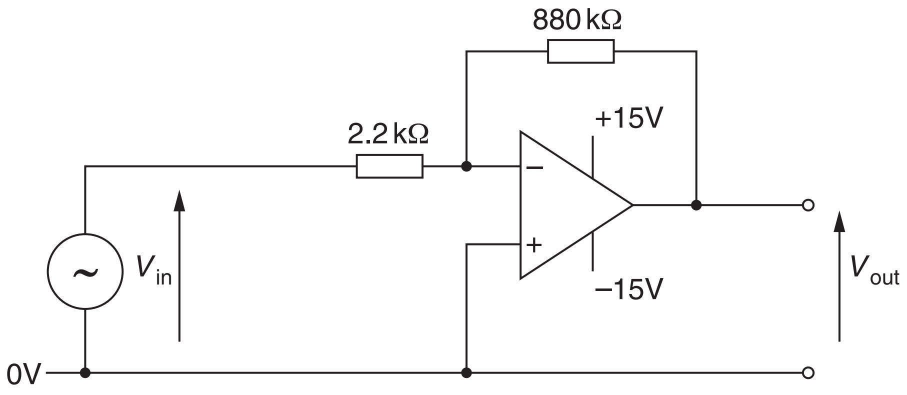


Fig. 3.1

A student is asked to investigate three features of the circuit:

- the phase of the output voltage relative to the input voltage
- the voltage gain of the amplifier
- the bandwidth of the amplifier.

(a) Name the other instrument the student will need (in addition to the signal generator and the dual power supply) to make the required measurements.
Mark points on Fig. 3.1 where connections to this instrument should be made.

....

....

.... **[2]**

(b) Explain, using sketch graphs on the axes below, what the student should observe regarding the *phases* of the output and input.

....

....

....

....

....

....

....

....

.... **[2]**

(c) **(i)** Calculate the voltage gain of the amplifier (show your working).

voltage gain = ... **[3]**

(ii) While measuring the gain experimentally, a problem arises if the student makes the value of V_{in} too high. Explain this problem and how it affects the gain.

....

....

.... **[2]**

(iii) Calculate the maximum value of V_{in} (show your working).

maximum input voltage = ... V **[2]**

(d) Explain briefly how the student should measure the bandwidth of the amplifier.

....

....

....

.... **[2]**

[Total: 13]

4 Fig. 4.1 shows one end of a straight length of multimode optic fibre into which two light rays have been launched by a light source.

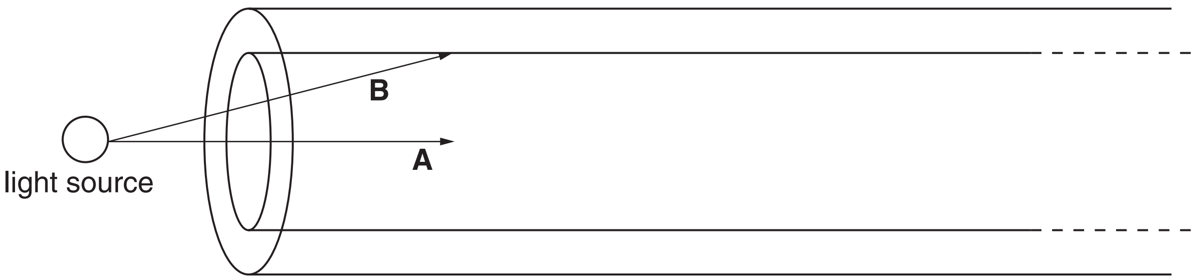


Fig. 4.1

The refractive index of the core is 1.50 while the refractive index of the cladding is 1.48.

(a) **(i)** State what is meant by the refractive index of a transparent medium in terms of the speed of light.

.... **[1]**

(ii) State why the refractive index of the core is made greater than that of the cladding.

....

.... **[1]**

(b) **(i)** State what is meant by the critical angle between two transparent media.

....

.... **[1]**

(ii) The behaviour of a light ray at an angle i_1 in a medium of refractive index n_1 emerging at an angle i_2 into a medium of refractive index n_2 is governed by the equation

$$n_1 \sin i_1 = n_2 \sin i_2.$$

Use this equation to show that the critical angle for a light ray in the core of the fibre of Fig. 4.1 is about 80°.

[2]

(c) The length of the fibre in Fig. 4.1 is 24 km.

(i) Calculate how long ray **A** will take to travel directly along the centre of the fibre.

time = ... μs **[3]**

(ii) Ray **B** strikes the core / cladding boundary at the critical angle.
Show that the factor by which this ray travels further than ray **A** is about 1.014.

[2]

(iii) Calculate how long ray **B** will take to travel by repeated reflections along the fibre.

time = ... μs **[1]**

(d) Fig. 4.2 shows a graph of a series of pulses, each of duration 1 μs, separated by a time τ. These pulses enter the fibre of Fig. 4.1.

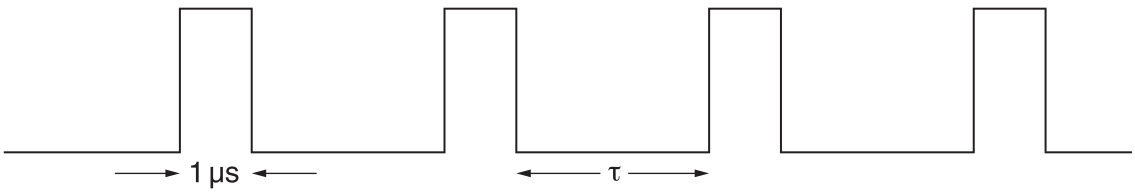


Fig. 4.2

Each 1 μs pulse produces many rays which enter the fibre core at various angles.

(i) Use your results in **(c)** to calculate the duration of each pulse as it exits the fibre.

pulse duration on exit = ... μs **[3]**

(ii) Hence calculate the highest pulse frequency which can be input to the fibre.

highest frequency = ... Hz **[1]**

[Total: 15]

5 Fig. 5.1 shows a radio-wave transmitter **T** located in the middle of a school laboratory.

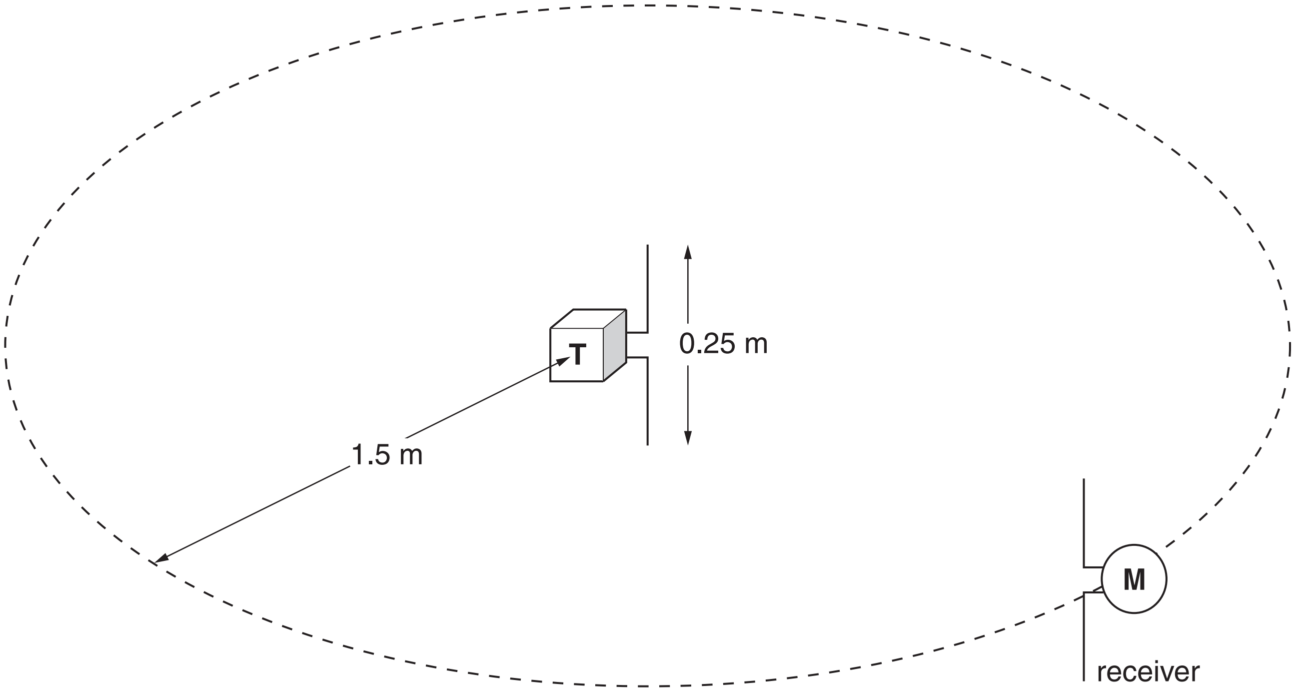


Fig. 5.1

Electromagnetic waves radiate from the transmitter via a vertical half-wave dipole aerial of length 0.25 m.
A receiver consists of a matched dipole aerial connected to a meter **M** which measures the signal-strength.

(a) Calculate the transmission frequency of the radio-waves.

transmission frequency = ... MHz **[2]**

(b) The receiver is moved around the horizontal circle of radius 1.5 m keeping the receiving dipole vertical.

State and explain what will be observed on the meter **M**.

....

....

.... **[2]**

(c) The receiver now remains in the position shown in Fig. 5.1. The receiving dipole is then rotated through 360° about the horizontal axis through its centre and the centre of the transmitting aerial. State and explain what will be observed on the meter **M** as the dipole rotates.

....

....

....

....

.... **[3]**

(d) The receiving dipole is now kept vertical but is moved directly away from the transmitter. State what will be observed on the meter **M** as it is moved.

....

....

.... **[1]**

[Total: 8]

6 A Physics student receives a present of a torch which requires neither batteries nor a filament light bulb. The basic arrangement of the torch is shown in Fig. 6.1 and has the following features:

- a rechargeable capacitor instead of batteries
- a fixed coil of wire through which a powerful magnet can move inside the body of the torch
- a circuit board with diodes and the rechargeable capacitor

The capacitor can be charged by making the magnet move back and forth through the coil.
The capacitor can be discharged through an LED to provide the light.

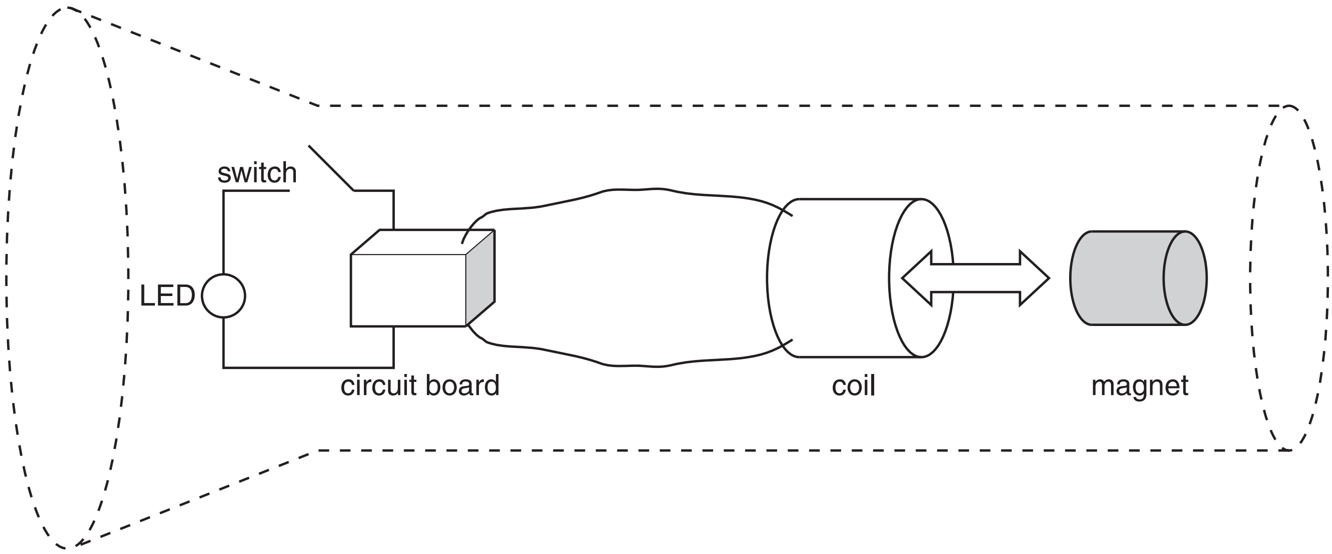


Fig. 6.1

To charge the capacitor in the circuit board, the torch is repeatedly inverted. In this way, the magnet is lifted through a vertical height *h* and then allowed to fall through the coil. It is then lifted through *h* again and allowed to fall. The process is shown in Fig. 6.2.

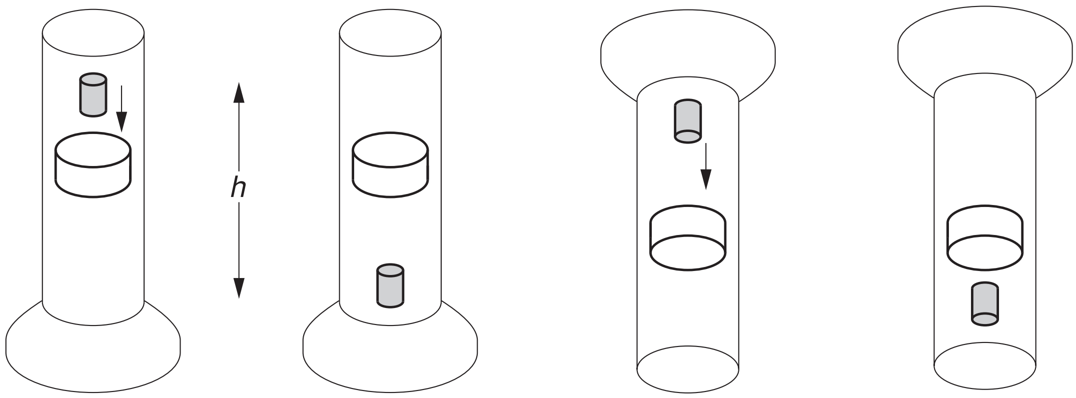


Fig. 6.2

(a) The mass of the magnet is 240 g and the height *h* through which it falls is 6.0 cm.

(i) Calculate the loss in gravitational potential energy in each fall.

loss in GPE = ... J **[2]**

(ii) Calculate the work done on the magnet in making 84 inversions.

work done = ... J **[1]**

(iii) Explain why the total work done by the student will be much greater than your answer to **(ii)**.

....

.... **[1]**

(b) The energy stored in the capacitor after 84 inversions is 10.5 J.
The mean power dissipation of the LED in the torch is 55 mW.

Calculate how long the light will operate after the 84 inversions.

time = ... s **[2]**

(c) To find out more about the torch, the student connects a voltmeter and data logger to the coil when the magnet falls through it. The magnet is released from rest at time **A** and finishes at rest at time **C**. The resulting induced e.m.f. is shown in Fig. 6.3.

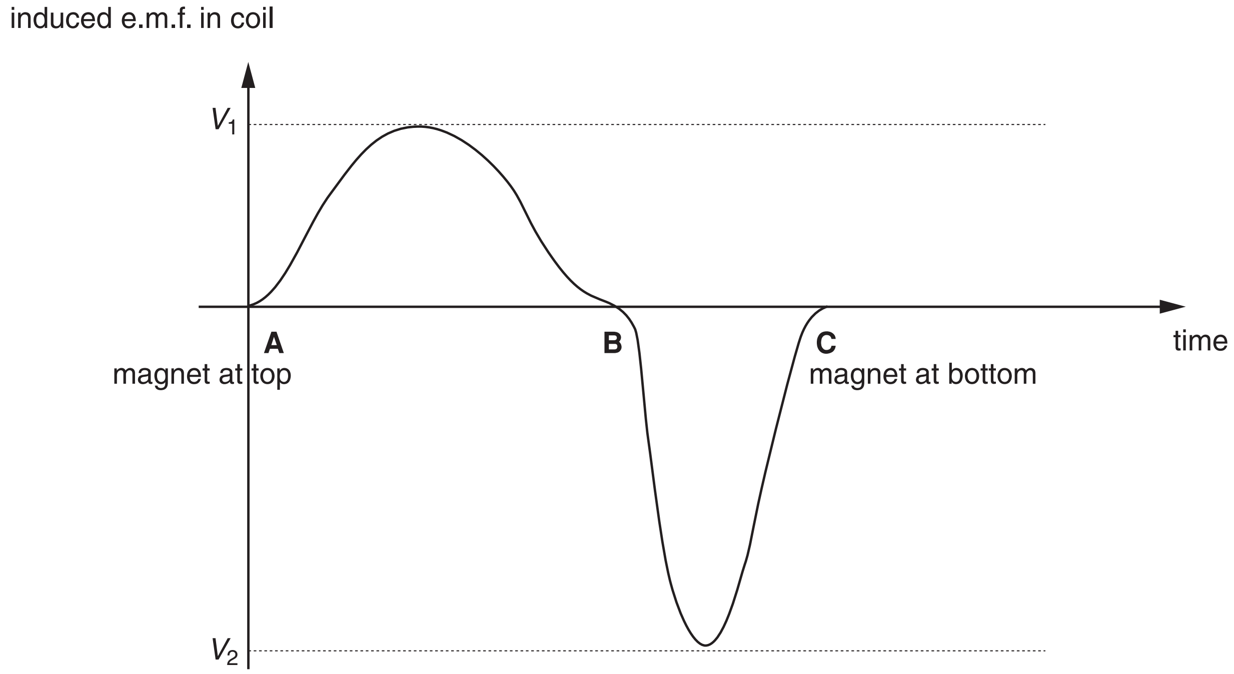


Fig. 6.3

Explain the following:

(i) The time **AB** in the positive region is greater than the time **BC** in the negative region.

....

.... **[2]**

(ii) Why an e.m.f is induced in the coil.

....

.... **[1]**

(iii) The peak induced e.m.f. V_1 is less than the peak induced e.m.f. V_2.

....

.... **[2]**

(iv) The induced e.m.f. consists of a positive voltage region and a negative voltage region.

....

.... **[1]**

(d) The characteristics of the magnet, coil and capacitor are as follows:

- magnetic flux ϕ emerging from one pole of magnet — 0.54 mWb
- number of turns N on coil — 420
- resistance R of coil and circuit — 28 Ω
- capacitance C of capacitor — 88 mF

(i) The average current I charging the capacitor during the positive voltage time interval **AB** is given by

$$I = \frac{Q}{t}$$

where Q is the total charge which has flowed and t is the time interval **AB**.

The mean induced e.m.f. E is given by

$$E = \frac{N\phi}{t}.$$

1 Show that the total charge Q is given by

$$Q = \frac{N\phi}{R}.$$

[2]

2 Show that the charge Q on the capacitor at time **B** is about 8 mC.

[1]

(ii) Explain why diodes are necessary between the coil and the capacitor.

....

.... **[1]**

(iii) Explain why a charge of about 16 mC is stored on the capacitor after one fall of the magnet.

....

.... **[1]**

Question 6 continues on the next page.

(iv) Show that 10.5 J of energy are stored in the capacitor after the student makes 84 inversions.
You may assume the capacitor is initially uncharged and that the diodes are ideal.

[3]

[Total: 20]

END OF QUESTION PAPER

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

PLEASE DO NOT WRITE ON THIS PAGE