THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Health Physics

2825/02

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator
- Ruler (cm/mm)

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 Health Physics. 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	20	
2	10	
3	13	
4	15	
5	12	
6	20	
TOTAL	**90**	

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,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
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,	$= 10 \lg \left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 An eye has a cornea-retina distance of 1.90 cm. It has a far point and near point at distances of 60.0 cm and 15.0 cm respectively from the cornea. Fig. 1.1 shows a cross-section of the eye (not to scale) together with an object situated beyond the far point of the eye.

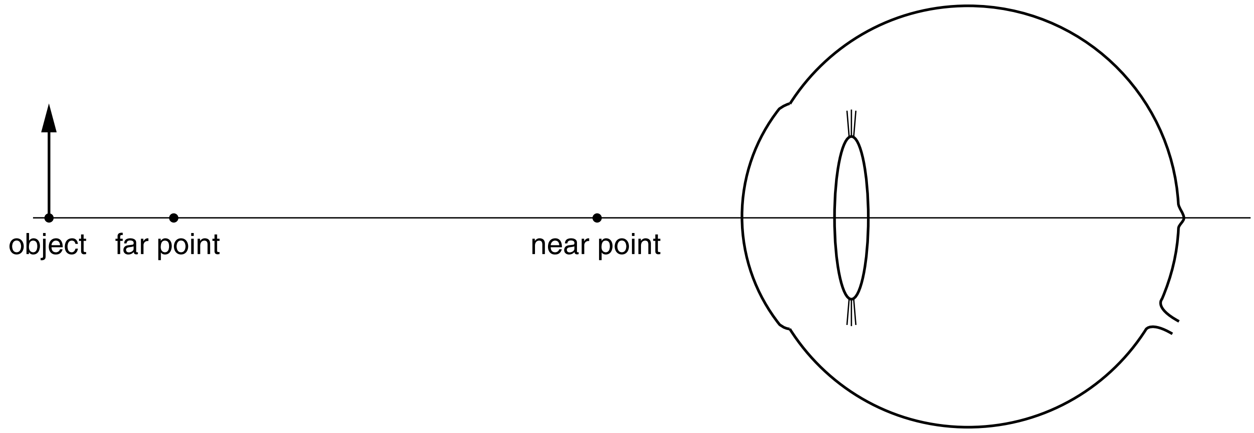

Fig. 1.1

(a) On Fig. 1.1 use a ruler to draw lines to show the paths of **two** rays from the top of the object to the retina of the eye. **[2]**

(b) Describe the vision of a person with these far and near points compared to that of a person with normal vision.

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.... **[4]**

(c) State

(i) the type of lens required to correct the defect described above

.... **[1]**

(ii) the effect on the two rays drawn in **(a)** when the corrective lens is inserted in front of the cornea.

....

.... **[1]**

(d) For this part of the question, assume that all of the refraction in the eye takes place at the front surface of the cornea.

(i) Calculate the power of the eye in **(a)** when it is focused on an object situated at its far point.

power = ... D **[3]**

(ii) Calculate the power of the lens required to correct the defect of the eye in **(a)**.

power = ... D **[4]**

(iii) The eye in Fig. 1.1 has a near point at 15 cm. State and explain how this distance will change when the corrective lens is placed in front of the eye. No calculation is required.

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.... **[3]**

(e) Patients who suffer from the eye defect described above often also suffer from astigmatism. Explain the meaning of the term *astigmatism* and give a possible cause.

....

....

.... **[2]**

[Total: 20]

2 The principle of moments may be applied to lever systems within the body in order to calculate the magnitudes of muscle forces necessary to move loads. State an example of a lever system in the body which has a mechanical advantage (MA) less than 1. Explain how the principle of moments may be applied to your lever system to calculate the MA. Illustrate your answer with a labelled diagram and include a numerical calculation of the MA. Make sensible estimates of body dimensions and loads.

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.... **[10]**

[Total: 10]

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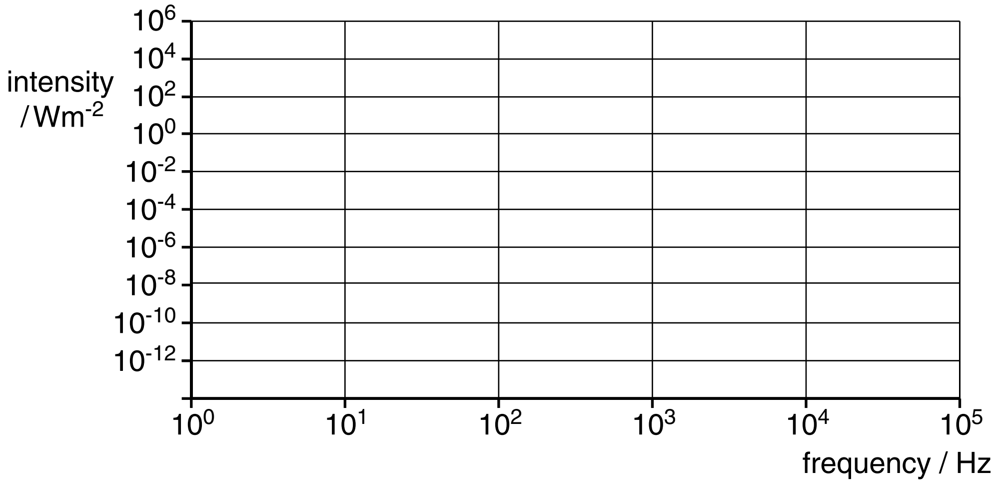
3 **(a)** On Fig. 3.1 sketch an intensity-frequency graph to show how the threshold of hearing for a person with normal hearing varies across the audible range of frequencies. Label this graph **N**.



[4]

Fig. 3.1

(b) An audiogram is a chart which allows the identification of hearing loss across the audible range of frequencies. In order to produce an audiogram, a patient is exposed to a sound at a given frequency which is just detectable by a normal person (0 dB on the audiogram). If this is not detectable by the patient, the intensity level is increased until it is just detectable.

Fig. 3.2 is an audiogram for a person with normal hearing.

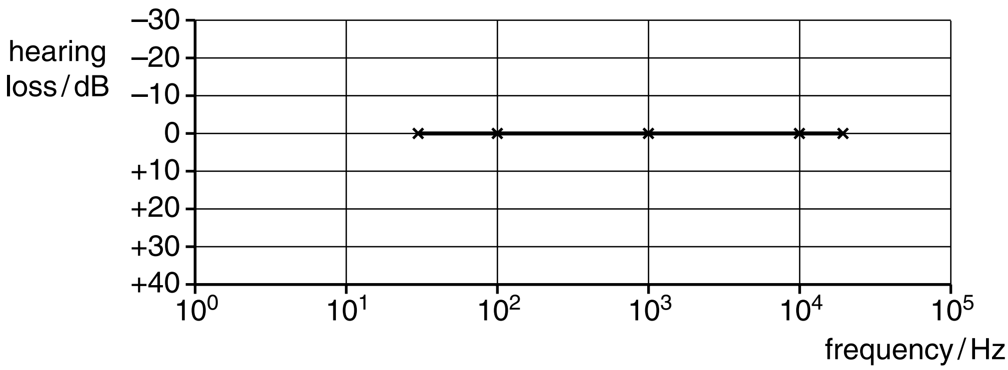


Fig. 3.2

Fig. 3.3 is an audiogram for a person who has a +30 dB hearing loss at a frequency of 1000 Hz. This means that the intensity level needs to be increased by +30 dB for the sound to be just detected at 1000 Hz.

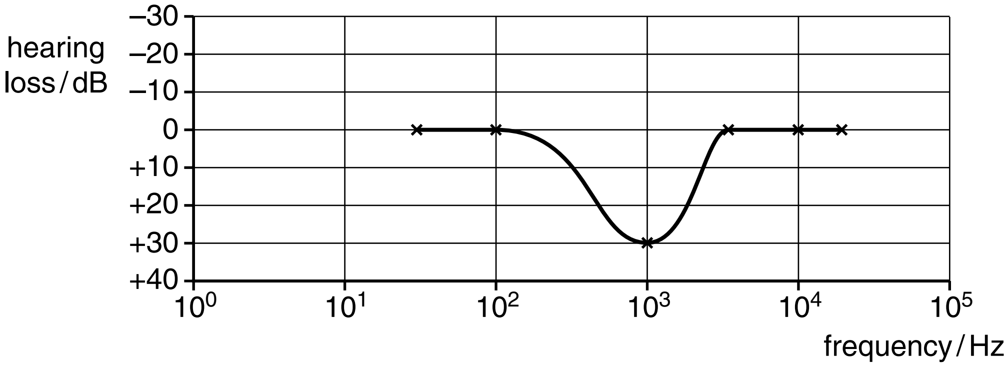


Fig. 3.3

(i) On Fig. 3.1, sketch the intensity-frequency graph to show the threshold of hearing for this person. Label this graph **P**. **[4]**

(ii) Suggest why there is a negative dB scale on the graph of Fig. 3.2.

....

.... **[2]**

(c) Fig. 3.4 shows an audiogram for a patient who has noise-induced deafness.

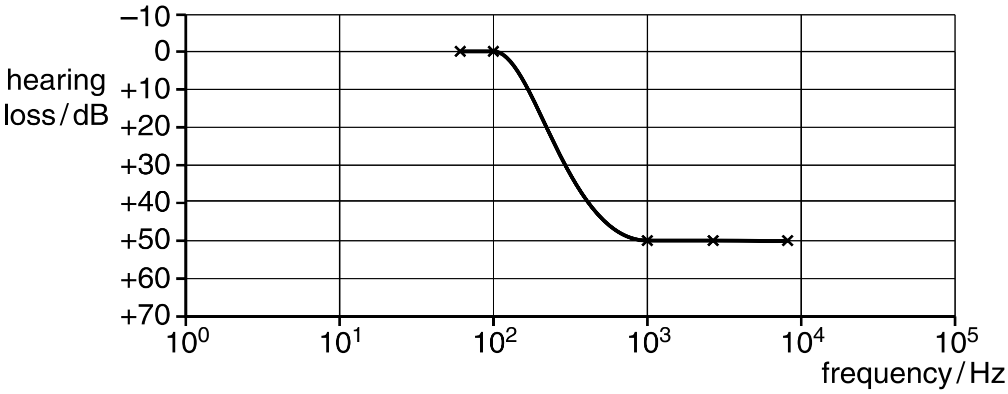


Fig. 3.4

Calculate the sound intensity required for the patient who experiences noise-induced deafness to just detect a sound at a frequency of 1000 Hz.

sound intensity = ... $W\,m^{-2}$ **[3]**

[Total: 13]

4 **(a)** Explain the use of coherent and incoherent bundles of optical fibres in endoscopes. In your answer you should state and explain the mechanism by which light travels from one end of an optic fibre to the other.

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.... **[5]**

(b) The carbon dioxide laser is commonly used in the treatment of cervical cancer in which surface-lying tumours are vapourised. Energy is delivered to the site in short pulses by a laser the power of which may be varied between 1 and 300 W. Pain is experienced by the patient if the duration of a laser pulse exceeds 200 ms.

For a particular treatment, the energy required at the tumour in each pulse is 0.80 J. The duration of a pulse is to be 4.0% of the time interval before pain is experienced.

Calculate

(i) the power needed by the laser

power = ... W **[3]**

(ii) the intensity of the laser at the site of the tumour if the diameter of the laser beam is 0.4 mm and the beam is normal to the tumour.

intensity = ... $W\,m^{-2}$ **[3]**

(c) Use your knowledge of the advantages of laser surgery to suggest and explain **two** reasons why patients are normally not required to remain overnight in hospital after such a procedure.

....

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....

.... **[4]**

[Total: 15]

5 Fig. 5.1 shows the absorption factor f for air, bone and muscle for incident X-ray photons of energy 80 keV and 200 keV. The absorption factor f is defined by the equation

absorbed dose in a substance = $f \times$ exposure.

	f / J C^{-1} for 80 keV photons	f / J C^{-1} for 200 keV photons
air	34	34
bone	100	42
muscle	37	37

Fig. 5.1

(a) Calculate the absorbed dose in bone and muscle for X-rays of photon energy 80 keV. The exposure is 0.014 μC kg^{-1}. Give a unit for your answer.

(i) bone

absorbed dose = ... unit .... **[3]**

(ii) muscle

absorbed dose = ... unit .... **[1]**

(b) Calculate the energy delivered to 0.50 kg of bone for an exposure of 0.014 μC kg^{-1} due to X-rays of photon energy 80 keV.

energy = ... J **[2]**

(c) Suggest and explain which photon energy should be employed to produce a conventional X-ray image of a broken bone.

....

....

.... **[2]**

(d) When considering the damage to living tissue exposed to ionising radiation, the dose equivalent is calculated.

(i) Explain why an absorbed dose of alpha radiation is more damaging than a similar absorbed dose of X-rays.

....

....

....

.... **[2]**

(ii) Calculate the dose equivalent for the absorbed dose of X-rays in bone calculated in **(a)(i)** above if the quality factor of the X-ray source is 1.2. Give a unit for your answer.

dose equivalent = ... unit .... **[2]**

[Total: 12]

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.

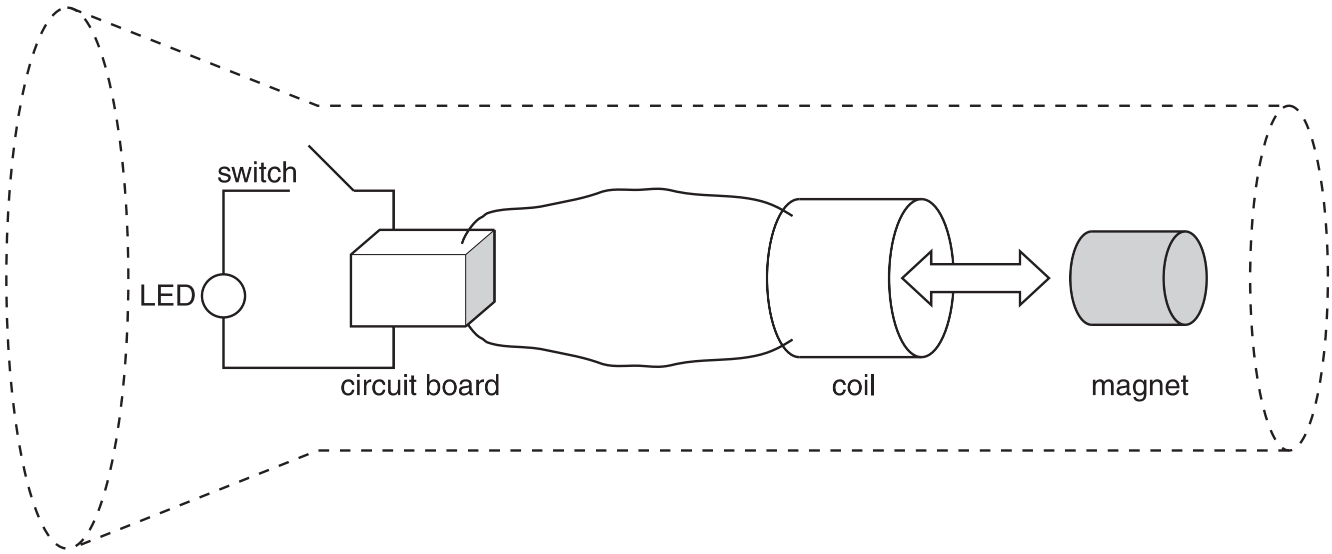

Fig. 6.1

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.

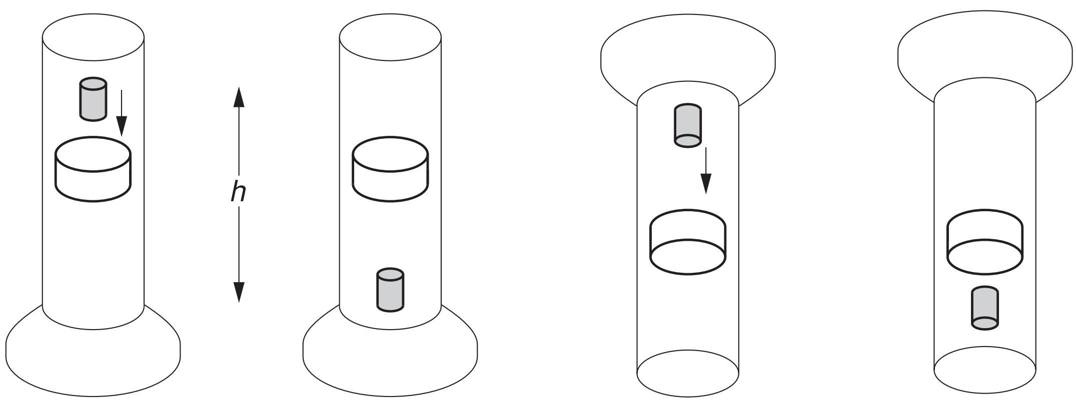

Fig. 6.2

(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.

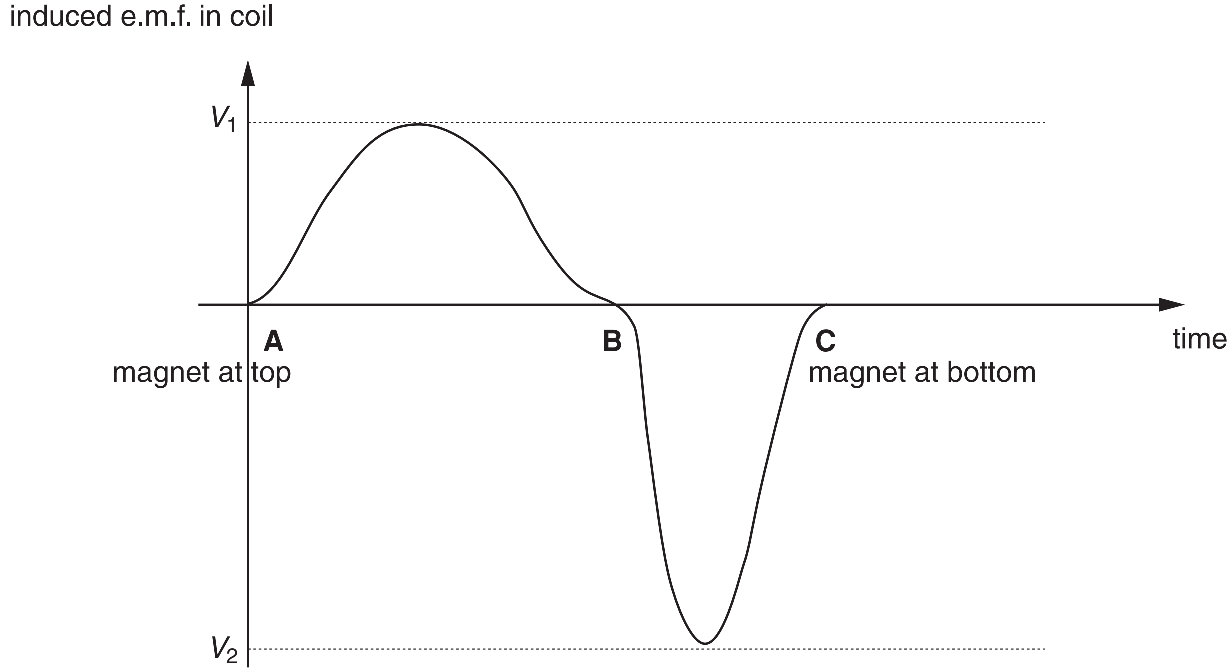

Fig. 6.3

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

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