THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE
PHYSICS A
Materials

2825/03

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 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 six questions concern Materials. 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	14	
2	15	
3	11	
4	10	
5	10	
6	10	
7	20	
TOTAL	90	

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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,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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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,	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dots$
capacitors in parallel,	$C = C_1 + C_2 + \dots$
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,	$= \sqrt{} \left(1 - \dfrac{v^2}{c^2}\right)$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\dfrac{I}{I_0}\right)$

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Turn over

Answer **all** the questions.

1 **(a)** The graph in Fig. 1.1 shows the variation with separation x of the resultant force F between a pair of atoms in a solid.

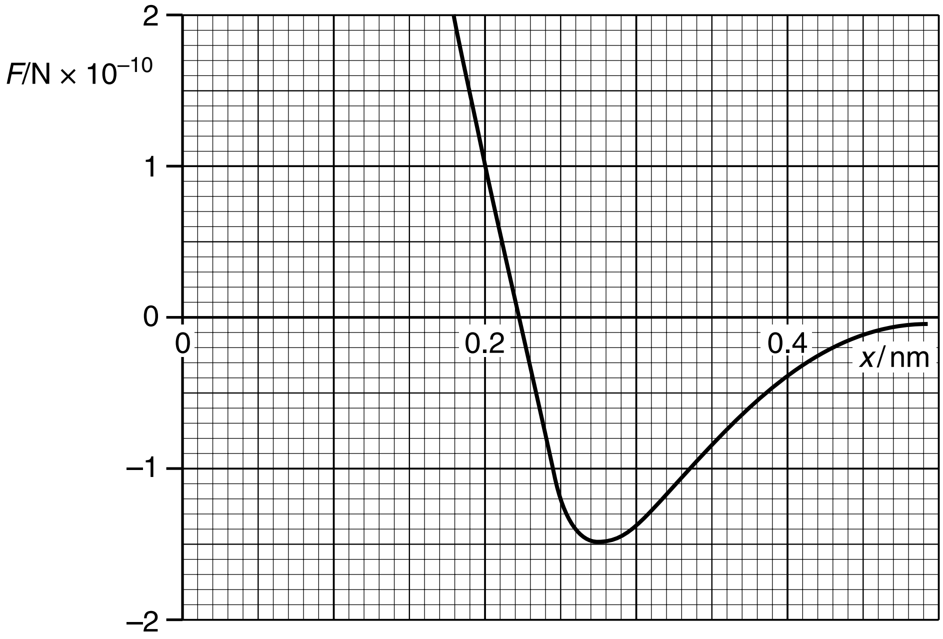

Fig. 1.1

State

(i) the equilibrium separation of the atoms

separation = ... m **[1]**

(ii) the resultant **repulsive** force between the atoms when they are displaced from the equilibrium position by 0.03 nm.

resultant force = ... N **[1]**

(b) A metal wire has a cross-sectional area of $1.8 \times 10^{-7}\,m^2$. The atoms of the metal have an equilibrium separation of $2.8 \times 10^{-10}\,m$.

(i) Make an estimate to show that the number of atoms occupying a plane perpendicular to the axis of the wire is somewhere between 2×10^{12} and 3×10^{12}.

[3]

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(ii) The maximum attractive force between the metal atoms is 4.8×10^{-11} N. Calculate the theoretical value of the tensile force needed to break the wire.

force = ... N **[2]**

(c) Discuss the assumptions made in the calculations of **(b)(i)** and **(b)(ii)**. Suggest why these assumptions are likely to be invalid and state the effect upon the force needed to break the wire.

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.... **[7]**

[Total: 14]

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2 **(a)** Describe the motion of free electrons

(i) in a metal

....

....

.... **[3]**

(ii) in a metal wire carrying an electric current.

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.... **[3]**

(b) A metal wire of cross-sectional area A contains n free electrons per m^3. When the wire carries a current I, the drift velocity of free electrons in the wire is v. The electronic charge is e.

(i) Explain what is meant by *drift velocity*.

....

.... **[1]**

(ii) Show that the current in the wire is given by the expression $I = nAve$.

....

....

....

.... **[3]**

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(c) An aluminium power cable has a cross-sectional area of $1.6 \times 10^{-4}\,m^2$. The potential difference between two points 0.60 m apart on the cable is 0.013 V. The electrical conductivity of aluminium $3.5 \times 10^{7}\,\Omega^{-1}\,m^{-1}$. Aluminium contains 5.0×10^{28} free electrons per m^3.

(i) Show that the current in the cable is about 120 A.

[3]

(ii) Calculate the drift velocity of free electrons in the cable.

drift velocity = ... $m\,s^{-1}$ **[2]**

[Total: 15]

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3 **(a)** **(i)** State **three** types of point defect which may occur in crystal structures.

1. ....

2. ....

3. .... **[3]**

(ii) Name or describe a laboratory model used to show the presence of point defects in crystal structures.

.... **[1]**

(b) Explain how the presence of *dislocations* and *slip planes* are relevant to the plastic behaviour of a material.

....

....

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.... **[3]**

(c) **(i)** Using circles of equal size to represent atoms, sketch **two** layers of atoms in a close-packed crystal structure.

[2]

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(ii) Describe, with reference to your sketch in **(i)**, how a third layer of atoms can be added to form

1 a hexagonal close-packed structure

....

.... **[1]**

2 a cubic close-packed structure.

....

.... **[1]**

[Total: 11]

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4 **(a)** Magnetic resonance imaging, used in medical investigations, requires a human body to be exposed to a uniform magnetic field of very high flux density for extended periods of time. Superconducting material is involved in the production of this magnetic field. Explain

- the construction of the system which produces the field
- how the system is used to produce the field
- why superconductors rather than conventional conductors are preferred for the production of this field.

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.... **[8]**

(b) A Hall probe is used to measure the flux density of the magnetic field in **(a)**. The width of the germanium wafer of the probe is 6.5 mm. The drift velocity of charge carriers in the wafer is 36 $m\,s^{-1}$. The voltmeter connected to the probe reads 0.28 V. Calculate the flux density of the field.

flux density = ... T **[2]**

[Total: 10]

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5 **(a)** Metallic glass has a higher resistivity than iron and a hysteresis loop of smaller area than iron. State and explain the advantages of using metallic glass rather than iron as the core of a high-frequency transformer.

....

....

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....

.... **[4]**

(b) A power supply of frequency 500 Hz is connected to the primary coil of a transformer.
A resistor connected to the secondary coil dissipates 25 W. The power losses in the core of the transformer are 0.18 W due to hysteresis and 0.12 W due to eddy currents. The efficiency of the transformer is 98%.

(i) Show that the power loss due to heating of the transformer coils is about 0.21 W.

[3]

(ii) The table below shows the power losses from the transformer when operating at 500 Hz.
Complete the table with the values for the power losses if the transformer operates at 1500 Hz with the primary coil current unchanged.

frequency (Hz)	power loss in coils (W)	hysteresis power loss (W)	eddy current power loss (W)
500	0.21	0.18	0.12
1500			

[3]

[Total: 10]

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6 **(a)** A ruby laser emits light of wavelength 694 nm. Each photon of this light arises from a transition between energy levels in chromium atoms in the laser material. Calculate the energy difference, in electron-volts, of the two energy levels involved in the transition.

energy difference = ... eV **[3]**

(b) A helium-neon laser emits light of wavelength 632 nm. In passing through a certain length of optic fibre this light loses 1.5% of its intensity due to Rayleigh scattering. Calculate the % loss in intensity due to Rayleigh scattering for the ruby laser light in **(a)** in the same piece of optic fibre.

loss in intensity = ... % **[3]**

(c) For communication purposes, infra-red from a laser is used rather than visible light from a laser.
State and explain why

(i) infra-red is used

....

....

.... **[2]**

(ii) a laser source is used.

....

....

.... **[2]**

[Total: 10]

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7 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. 7.1 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.

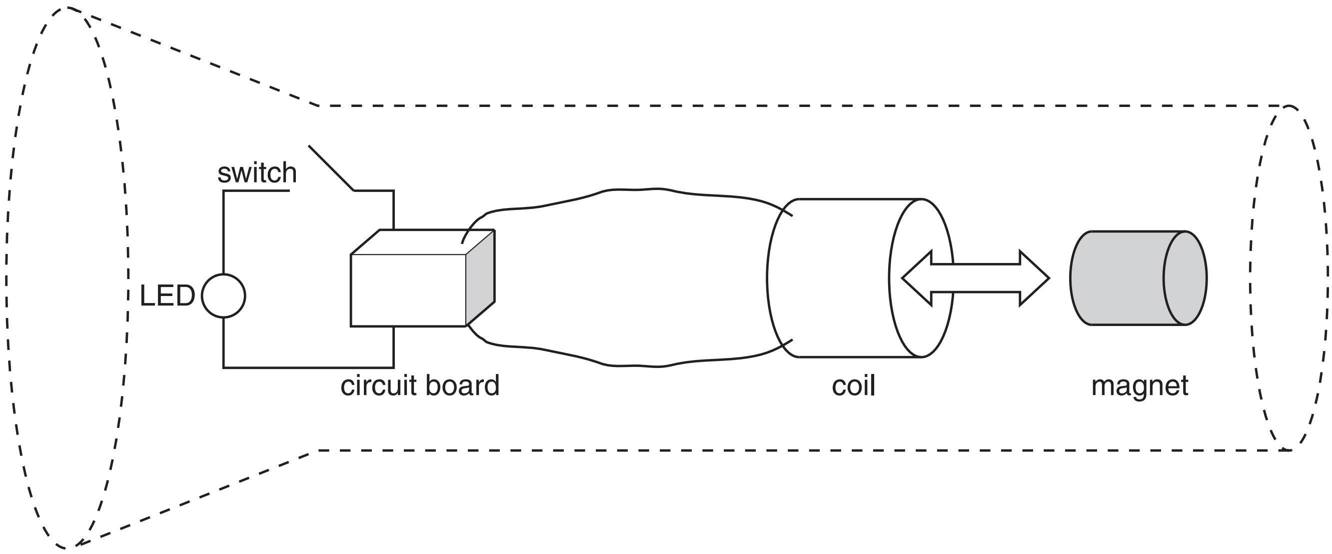

Fig. 7.1

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. 7.2.

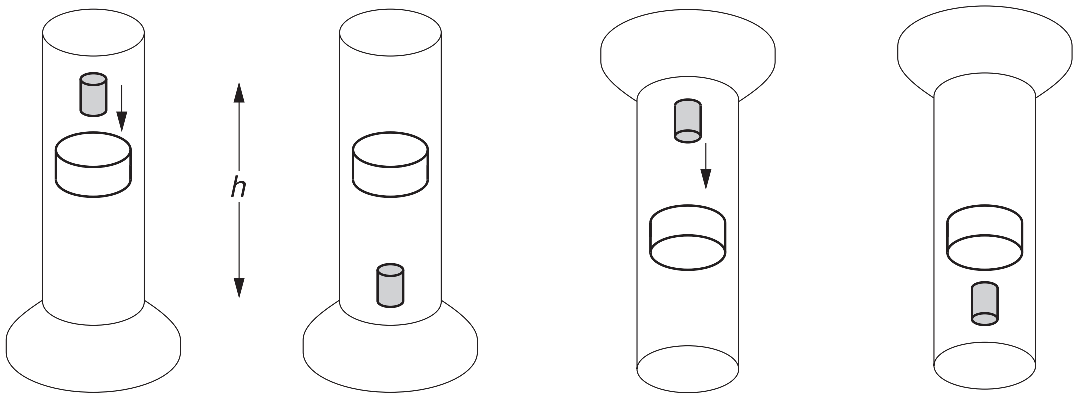

Fig. 7.2

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(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]**

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(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. 7.3.

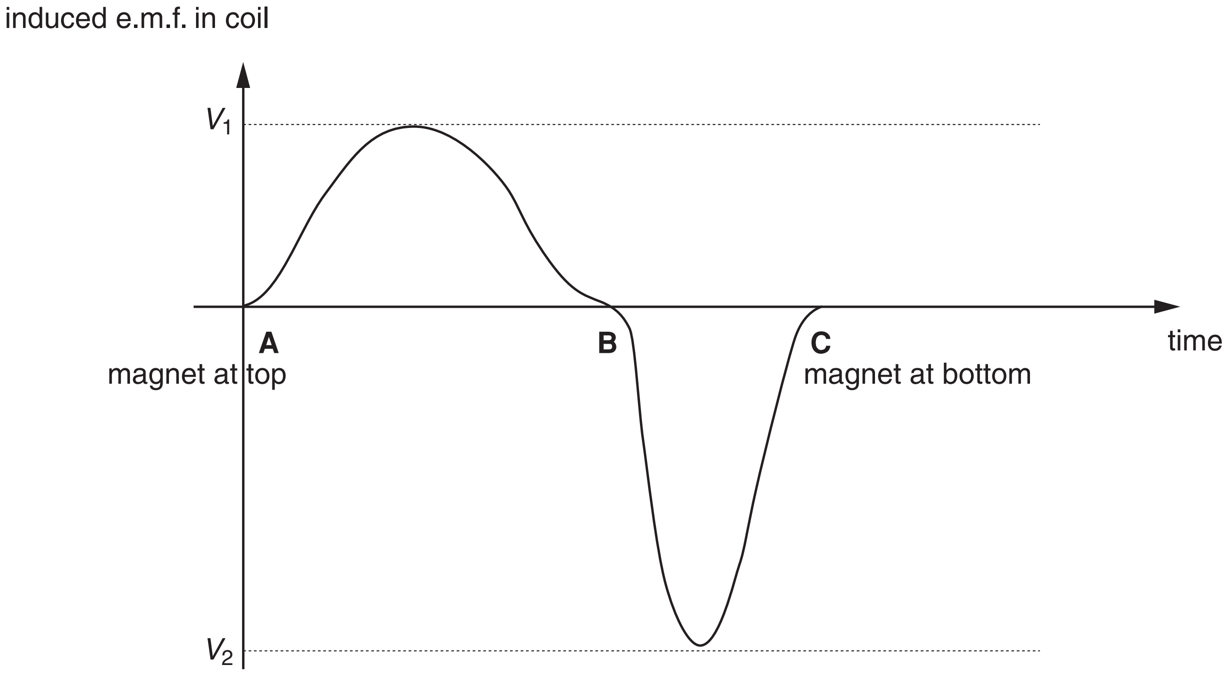

Fig. 7.3

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]**

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(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]**

(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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