OCR RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A **2825/03**

Materials

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 Materials. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	14	
2	8	
3	9	
4	14	
5	11	
6	14	
7	20	
TOTAL	90	

This question paper consists of 16 printed pages.

SP (NH/CG) S29230/7

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

[Turn over

For Examiner's Use

Answer **all** the questions.

1 **(a)** State the molecular structure of the following materials.

glass ....

metal ....

[2]

(b) **(i)** State what is meant by the terms

grain boundary

....[1]

dislocation.

....[1]

(ii) State the type of fault introduced into a crystal structure by an impurity atom.

....[1]

(c) Copper readily undergoes plastic behaviour when sufficient force is applied.
Explain this behaviour in terms of the presence of dislocations in the copper.

....

....

....

....[3]

(d) Brass is an alloy of copper and zinc.

(i) Suggest why brass less easily undergoes plastic behaviour.

....

....

....[2]

(ii) State a use of brass for which copper, due to its plastic behaviour, would not be suitable.

....[1]

For Examiner's Use

(d) The ice of a glacier is 30 m deep. Owing to the pressure at this depth, the ice undergoes plastic behaviour.

(i) Calculate the pressure exerted by a vertical cylinder of ice of cross-sectional area 1.0 m^2 and depth 30 m. The density of ice is 920 $kg\,m^{-3}$.

pressure = ... Pa [2]

(ii) Suggest how the presence of ice showing plastic properties contributes to the behaviour of the glacier.

....

....[1]

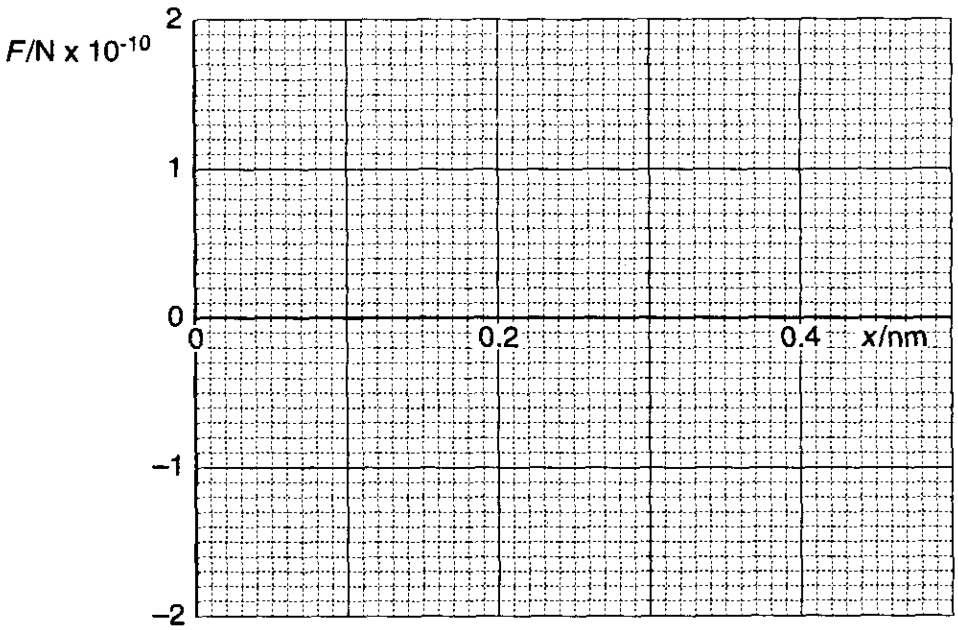
[Total: 14]

[Turn over

For Examiner's Use

2 The resultant force F between two atoms in a metal depends on their separation x. For a particular pair of atoms, the equilibrium separation is 0.22 nm. The maximum resultant attractive force between the atoms is -1.5×10^{-10} N when their separation is 0.26 nm.

(a) Sketch a graph of F against x on the axes of Fig. 2.1.



[4]

Fig. 2.1

(b) A thin wire is made of this metal. A slice of the wire cut through the area of cross-section and one atom thick contains 2.5×10^{13} atoms.

(i) Calculate the theoretical maximum breaking force of the wire.

breaking force = ... N [2]

(ii) Suggest **two** reasons why the actual breaking force of the wire would be less than the value calculated in **(i)**.

1. ....

....

2. ....

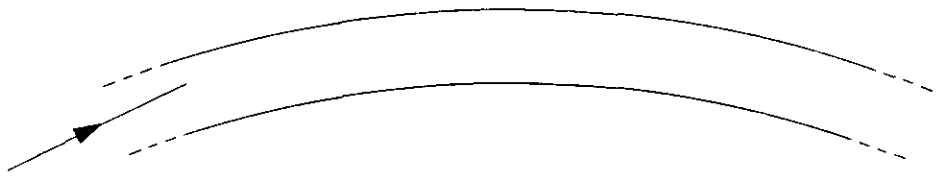
....

[2]

[Total: 8]

For Examiner's Use

3 **(a)** A ray of light passes through a curved optic fibre without escaping into the surrounding air. Explain why and illustrate your answer by completing the diagram.



....

....[2]

(b) An optic fibre contains some metal impurity atoms. Explain, using band theory, why the metal atoms lead to a reduction in the intensity of light transmitted by the fibre.

....

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....[3]

(c) *Rayleigh scattering* also leads to a reduction in the intensity of light transmitted by an optic fibre.

(i) State the cause of Rayleigh scattering.

....[1]

(ii) Visible light of wavelength 500 nm and infra-red of wavelength 1500 nm pass through equal lengths of the same optic fibre. 10% of the power of the visible light is lost through Rayleigh scattering. Calculate the percentage power loss of the infra-red through the same cause.

% power loss = ... [3]

[Total: 9]

[Turn over

For Examiner's Use

4 **(a)** The current I through a wire is given by the expression $I = nAve$.

(i) Explain the meaning of n.

....[1]

(ii) Calculate the value of n for a semiconductor in which $I = 3.6\,\text{mA}$, $v = 80\,\text{m s}^{-1}$ and $A = 8.2 \times 10^{-6}\,\text{m}^2$.

n = ... m^{-3} [2]

(iii) The value of n for copper is about 10^9 times greater than that for the semiconductor. Briefly explain why in terms of band theory.

....

....

....

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....[2]

(b) A thermistor is an intrinsic semiconductor. The graph in Fig. 4.1 shows how the resistance R of a thermistor varies with temperature θ.

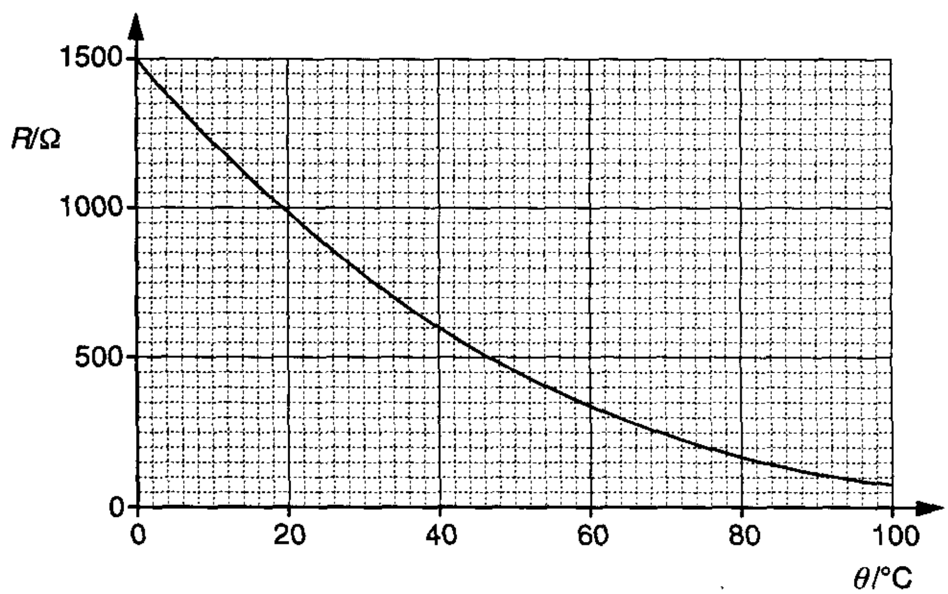

Fig. 4.1

For Examiner's Use

(i) The thermistor is connected to a 6.0 V battery. Calculate the current through the thermistor if its temperature is maintained at

0 °C

current = ... A

50 °C.

current = ... A
[3]

(ii) Neglecting thermal expansion, describe what happens to the atoms and number of charge carriers in the thermistor as the temperature rises. Hence explain how these changes lead to a decrease in resistance.

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....

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....

....[4]

(c) To make a thermometer, the thermistor in **(b)** is connected to a battery with an ammeter in series. The ammeter is calibrated to read temperatures in the range 0 °C to 100 °C rather than current. Describe qualitatively the scale of the meter. Explain your answer.

....

....

....

....

....[2]

[Total: 14]

For Examiner's Use

5 **(a)** Fig. 5.1 shows a voltmeter connected to a slab of semiconductor. A Hall voltage, to be measured by the voltmeter, is to be set up between the upper and lower faces of the slab.

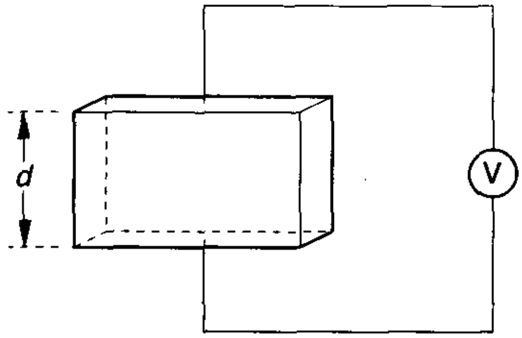


Fig. 5.1

(i) Show on Fig. 5.1 a battery connected to the slab and the direction of the required magnetic field. [2]

(ii) State a necessary precaution in the connection of the voltmeter such that the Hall voltage reading is accurate.

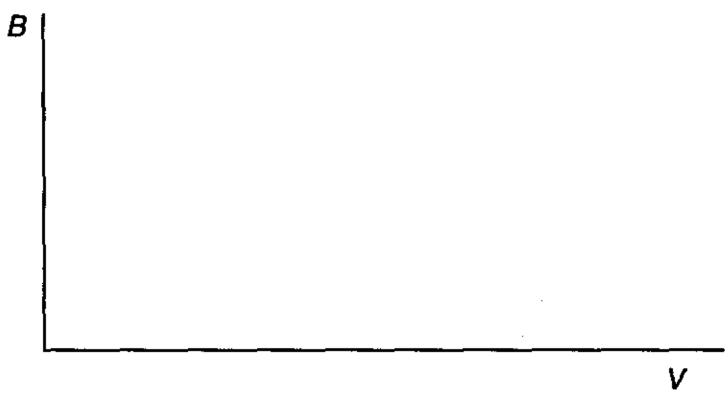
....

....[1]

(b) The height, *d*, of the slab in Fig. 5.1 is 8.0 mm. The drift velocity of charge carriers in the slab is 60 m s^{-1}. A Hall voltage of 0.028 V is measured.
Calculate the flux density of the magnetic field.

flux density = ... T [3]

(c) The slab in Fig. 5.1, with the battery and voltmeter, forms the basis of a Hall probe. Sketch a graph on the axes below to show the relationship between the Hall voltage *V* generated, and the flux density *B* of the magnetic field.



[1]

(d) **(i)** A long solenoid carries a current. The flux density of the magnetic field at the centre of the axis of the solenoid is to be measured.

Describe

the orientation of the probe

....

....

how the position of the probe is achieved in practice.

....

....

[2]

(ii) Describe how the measurement in **(d)(i)** could be modified so that the result excludes the effect of the Earth's magnetic field.

....

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....

....[2]

[Total: 11]

6 **(a)** **(i)** Suggest why the magnetic field set up by a single iron atom is similar in form to that set up by a current in a circular loop of wire.

....

....[1]

(ii) A magnetic domain in iron may contain 10^{14} atoms. Explain why a magnetic domain has a strong magnetic field.

....

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....[2]

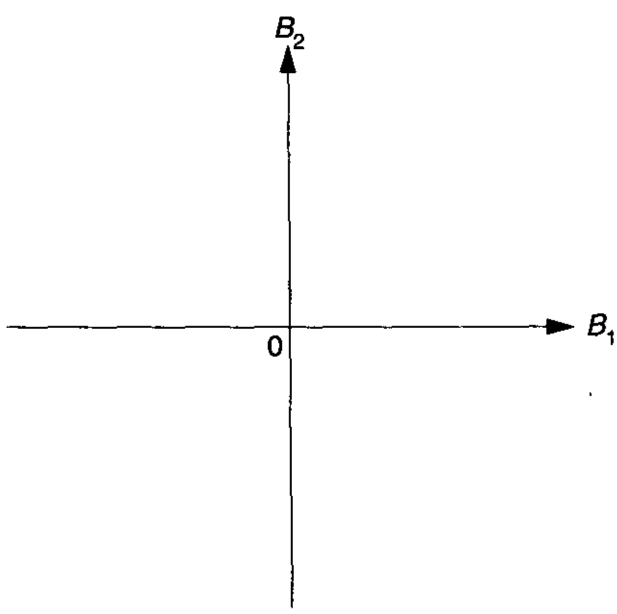
(b) B_1 is the flux density of a magnetic field causing the magnetisation of a magnetic material. B_2 is the flux density within the material. B_1 and B_2 are shown on the axes of the graph in Fig. 6.1.

On Fig. 6.1 sketch the hysteresis loops of

(i) a soft magnetic material, labelling this loop S,

(ii) a hard magnetic material, labelling this loop H.

The graphs should make clear the essential differences between the two types of material.



[4]

Fig. 6.1

For Examiner's Use

(c) Discuss energy losses from the cores of transformers and explain, with reference to your graphs in **(b)**, why soft, rather than hard, magnetic materials are used to make the cores of transformers.

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....[7]

[Total: 14]

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]

For Examiner's Use

(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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....[2]

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

....

....

....

....[3]

[Total: 20]

Jun03/erratum26

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/03

Materials

Thursday **26 JUNE 2003** Morning 1 hour 30 minutes

ERRATUM NOTICE

For the attention of the Examinations Officer

Please read the following correction to candidates at the start of the examination.

Turn to page **5** and look at **Question 1(d)** which begins 'The ice of a glacier is 30 m deep.... .

This question has been labelled incorrectly.

This question should be numbered **Question 1(e)**.