THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A **2825/03**

Materials

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Thursday 28 January 2010
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 six questions concern Materials. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

Examiner's Use Only:			
1			
2			
3			
4			
5			
6			
7			
Total			

OCR is an exempt Charity

DC (SJH) 16857/9

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,	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_{\mathrm{e}} = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_{\mathrm{p}} = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J K^{-1}\ mol^{-1}}$
the Avogadro constant,	$N_{\mathrm{A}} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
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 **(a)** In terms of the behaviour of atoms, distinguish between *elastic* and *plastic* behaviour in a solid.

....

....

....

.... **[2]**

(b) Fig. 1.1 shows a two-dimensional view of part of a perfect cubic crystal. The circles represent atoms. The arrows labelled **F** represent forces to be applied to the section of crystal.

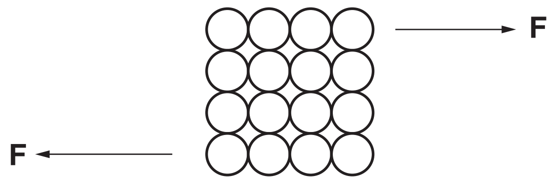

Fig. 1.1

Draw diagrams to show a possible arrangement of the atoms in Fig. 1.1 when

(i) the forces **F** are small and the crystal is deformed elastically

[2]

(ii) the forces **F** are larger and the crystal is deformed plastically.

[3]

(c) (i) State what is meant by a *dislocation*.

....

.... **[1]**

(ii) When a strong enough stretching force is applied to a copper wire, the wire undergoes plastic extension. Explain this behaviour in terms of the presence of dislocations.

....

....

....

.... **[2]**

[Total: 10]

2 The graph in Fig. 2.1 shows the variation with separation x of the resultant force F between two neighbouring atoms in a metal wire.

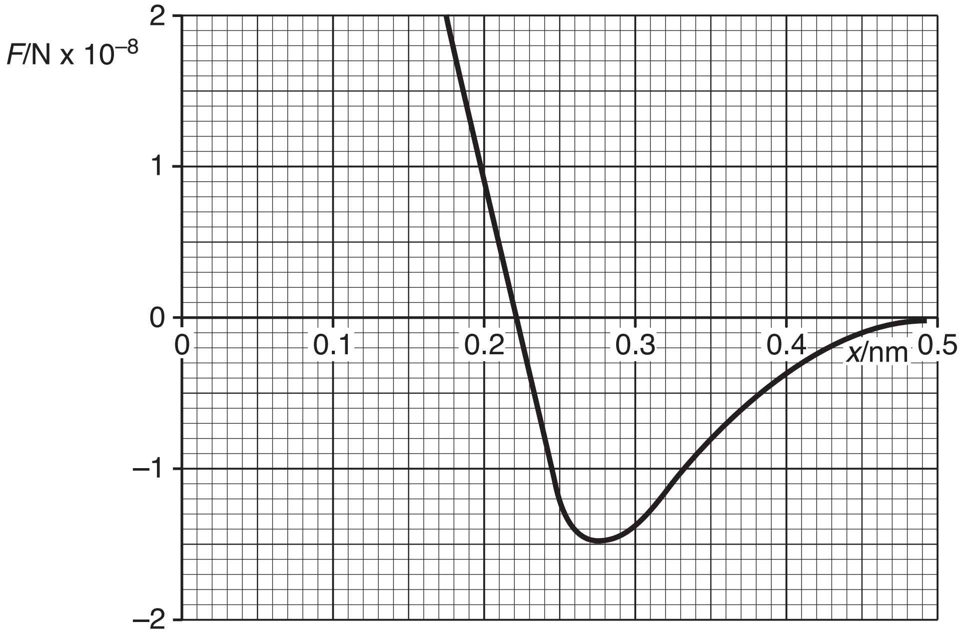

Fig. 2.1

(a) Using Fig. 2.1, state

(i) the equilibrium separation x_e of the atoms x_e = ... nm **[1]**

(ii) the maximum resultant attractive force F_{max} between the atoms.

F_{max} = ... N **[1]**

(b) (i) Calculate the gradient k of the graph at equilibrium separation.

k = ... N m^{-1} **[3]**

(ii) The Young modulus E of the material of the wire is given by the expression $E = -\dfrac{k}{x_e}$.

Calculate E, stating the unit of your answer.

E = ... unit .... **[2]**

(c) (i) The number of atoms occupying a cross-section of the wire is 4.8×10^{12}. Calculate the theoretical maximum breaking force of the wire.

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

(ii) State **two** reasons why the actual value of the force required to break the wire is less than your answer in **(i)**.

1. ....

....

2. ....

.... **[2]**

[Total: 11]

3 **(a)** The electrical conductivity of a semiconductor is $1.7\,\Omega^{-1}\,m^{-1}$. A cylindrical specimen of the semiconductor is 8.0 mm long and 1.2 mm in radius. Calculate the current through the specimen when a potential difference of 2.5 V is applied across its ends.

current = ... A **[3]**

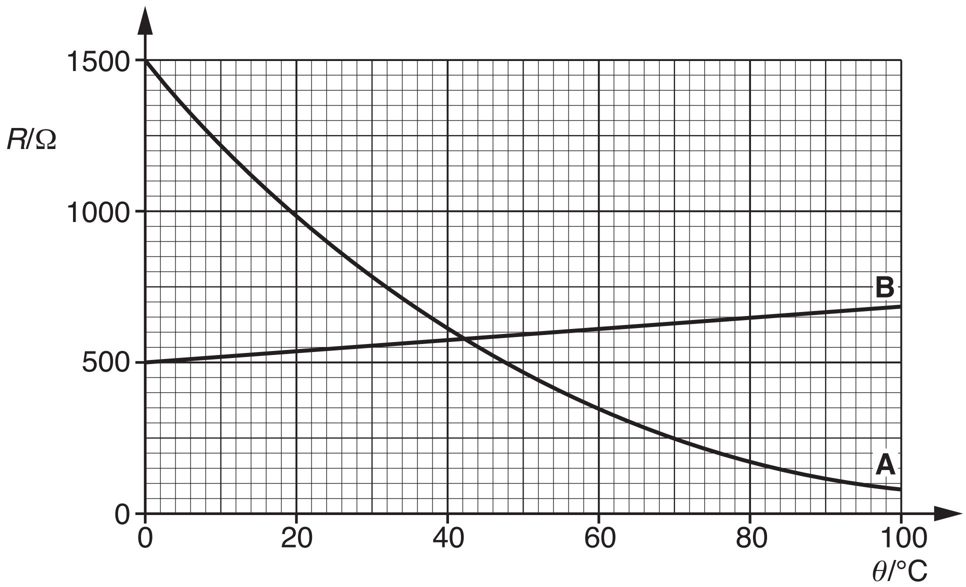

Fig. 3.1

(b) The graphs in Fig. 3.1 show the variation with temperature θ of the resistance R of two different conductors. Graph **A** refers to a specimen of semiconductor. Graph **B** refers to a specimen of the metal platinum. In both specimens current is due only to the flow of free electrons.

(i) In terms of band theory and the behaviour of free electrons and atoms, explain the changes in resistance with temperature of the semiconductor and the platinum.

....

....

....

....

....

....

....

....

....

....

....

.... **[7]**

(ii) The change of resistance of the semiconductor and platinum with temperature can both be used to measure temperature in the range 0–100 °C. Suggest, on the basis of the graphs in Fig. 3.1, a disadvantage of using

1 the change in resistance of the semiconductor

.... **[1]**

2 the change in resistance of platinum.

.... **[1]**

[Total: 12]

4 Fig. 4.1 shows a strip of metal foil of width d and thickness t. The foil carries a current I in a magnetic field of flux density B. The directions of I and B are shown by arrows. The number of free electrons per cubic metre of the metal is n.

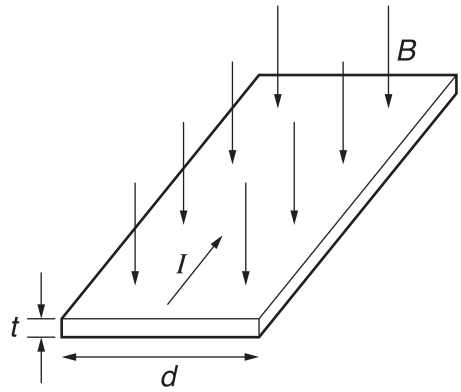

Fig. 4.1

(a) Derive an expression for the drift velocity v of free electrons in the foil in terms of I, n, d, t and e, the electronic charge.

[4]

(b) Given that $I = 25\,\text{mA}$, $n = 8.7 \times 10^{28}\,\text{m}^{-3}$, $d = 7.5\,\text{mm}$, $t = 0.080\,\text{mm}$ and $B = 0.25\,\text{T}$, calculate

(i) the drift velocity v of free electrons in the foil

v = ... m s^{-1} **[2]**

(ii) the Hall voltage across the foil.

Hall voltage = ... V **[3]**

(c) A Hall probe used to measure the flux density of a magnetic field uses a strip of semiconductor rather than one made of metal. Explain why.

....

....

.... **[3]**

[Total: 12]

5 **(a)** The primary coil of a transformer is connected to the 230 V mains supply. The 12 V output of the secondary coil is connected to a bulb which draws a current of 2.5 A. The transformer operates with an efficiency of 96 %. Calculate

(i) the power supplied to the bulb from the output of the transformer

power = ... W **[2]**

(ii) the current in the primary coil.

current = ... A **[3]**

(b) State and explain the features of a transformer which maximise the transformer's efficiency.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[8]**

[Total: 13]

6 **(a)** Infra-red radiation of wavelength 1.3 μm is incident on an insulator with a band-gap of 0.80 eV.

(i) Calculate the energy of a single photon of this radiation.

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

(ii) Determine, with necessary calculations, whether this radiation will pass through or be absorbed by the insulator.

....

.... **[3]**

(b) Use band theory to explain why

(i) a white-light source appears white when viewed through a sheet of window glass

....

....

.... **[2]**

(ii) the same white-light source appears red when viewed through a sheet of red glass

....

....

.... **[2]**

(iii) a metal sheet is opaque to visible and infra-red radiation.

....

....

....

.... **[3]**

[Total: 12]

7 A householder wants to reduce the amount of mains energy used in his home, in order to combat global warming. He plans to install a device which is powered by a renewable energy source.

He considers three options:

A an array of photoelectric cells mounted on his house roof

B a solar panel mounted on the house roof for heating water by solar radiation

C an aerogenerator attached by a short pole to the house chimney.

Option A: Photoelectric cells

Photoelectric cells consist of two layers of different semiconductor materials in contact with each other. When a cell is exposed to solar radiation an e.m.f. is created. See Fig. 7.1. The cells are arranged in an array as shown in Fig. 7.2.

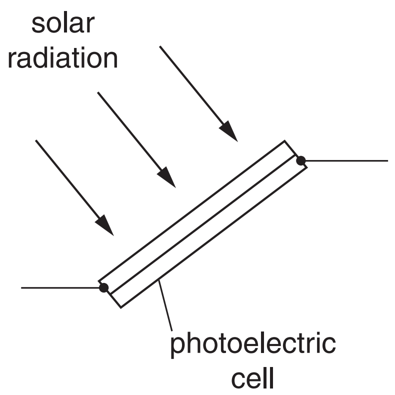

Fig. 7.1

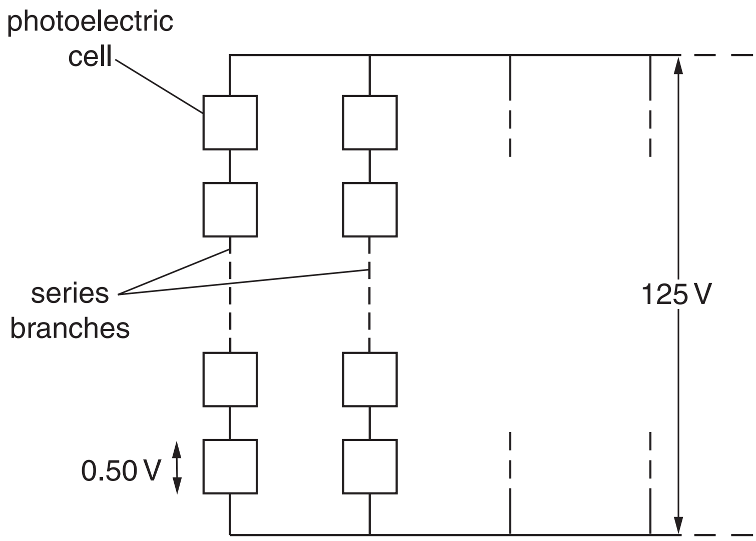

Fig. 7.2

intensity of solar radiation falling on the house	=	$800\,\mathrm{W\,m^{-2}}$
voltage output of each cell for this intensity	=	$0.50\,\mathrm{V}$
efficiency of each photoelectric cell	=	10 %
surface area of each photoelectric cell	=	$5.0\,\mathrm{cm^2}$
required output from photoelectric cell array	=	$125\,\mathrm{V}$

(a) (i) Calculate the total area of photoelectric cells needed to generate 1000 W of electrical power.

area = ... $\mathrm{m^2}$ **[2]**

(ii) Show that the number of photoelectric cells needed is 25 000.

[1]

(iii) The photoelectric cells are arranged as in Fig. 7.2.

1 State the number of cells in **one** series branch. ....

2 State the number of branches in parallel. ....

[2]

(iv) Calculate the current through each photoelectric cell.

current = ... A **[2]**

Option B: Solar Panel

Solar radiation passes through a layer of glass and is absorbed by tubes of water. Cool water flows into the tubes and is heated. Hot water flows out and is led to an insulated storage tank.

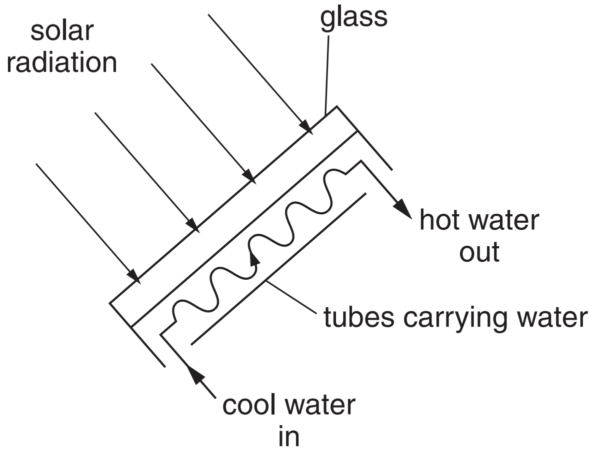

Fig. 7.3

intensity of solar radiation falling on the house	=	$800\,\text{W m}^{-2}$
efficiency of solar panel	=	70 %
incoming water temperature	=	20 °C
outgoing water temperature	=	75 °C
specific heat capacity of water	=	$4200\,\text{J kg}^{-1}\,\text{K}^{-1}$

(b) (i) Calculate the area of the solar panel needed for the water to gain 1000 J of heat energy per second.

area = ... m^2 **[2]**

(ii) Calculate the rate in kg s^{-1} at which water must flow through the tubes in order to emerge at 75 °C.

rate = ... kg s^{-1} **[3]**

Option C: Aerogenerator

This consists of a fan that rotates in the wind, and an electrical generator.

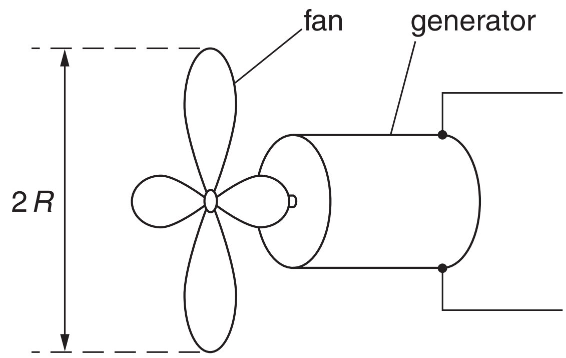

Fig. 7.4

efficiency of aerogenerator	=	40 %
wind speed	=	$5.0\ \mathrm{m\,s^{-1}}$
density of air	=	$1.3\ \mathrm{kg\,m^{-3}}$

(c) The air flowing through the fan in 1 second is a body of air having a cylindrical shape, of diameter $2R$ and length v where v is the speed of the air. See Fig. 7.5.

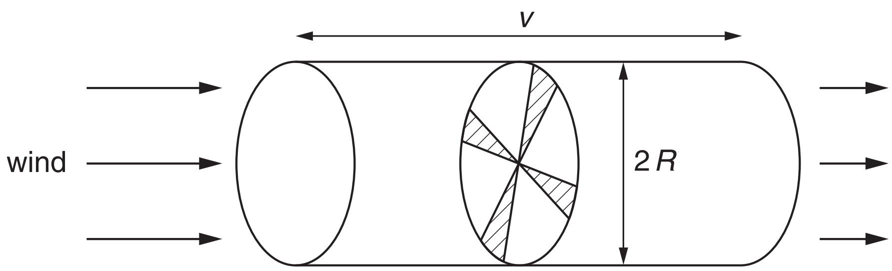

Fig. 7.5

The aerogenerator supplies 1000 J of electrical energy from this air in 1.0 second. This is 40 % of the initial kinetic energy of the air.

(i) Show that the initial kinetic energy of the cylinder of air is 2500 J.

[1]

(ii) Calculate the mass of this cylinder of air.

mass = ... kg **[2]**

(iii) Calculate the radius R of the aerogenerator fan.

R = ... m **[2]**

(d) The householder needs to make a choice.
Comment on the appropriateness or otherwise of **one** of these energy-generating processes for the house.

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[3]**

[Total: 20]

END OF QUESTION PAPER

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

PLEASE DO NOT WRITE ON THIS PAGE