OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **2825/03**

PHYSICS A

Materials

FRIDAY 25 JANUARY 2008 Morning

Time: 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials: Electronic calculator

CUP/T41113

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 blue or 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.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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	**12**	
2	**16**	
3	**12**	
4	**9**	
5	**12**	
6	**9**	
7	**20**	
TOTAL	**90**	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10\lg\left(\frac{I}{I_0}\right)$

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Answer **all** the questions.

1 **(a)** State

(i) an example of a substance which has a single-crystal molecular structure ....

(ii) an example of a substance which has a polycrystalline molecular structure ....

(iii) a difference between the microstructures of single-crystal and polycrystalline materials.

....

....[3]

(b) State

(i) the molecular structure of metallic glass ....[1]

(ii) **two** factors which make a magnetic metallic glass energy-efficient when used for the core of a transformer.

1. ....

....

2. ....

....[2]

(c) In Figs. 1.1 and 1.2 the dotted circles represent atoms in layer P of a close-packed crystal structure. The complete circles represent atoms in layer Q placed on top of those in layer P.

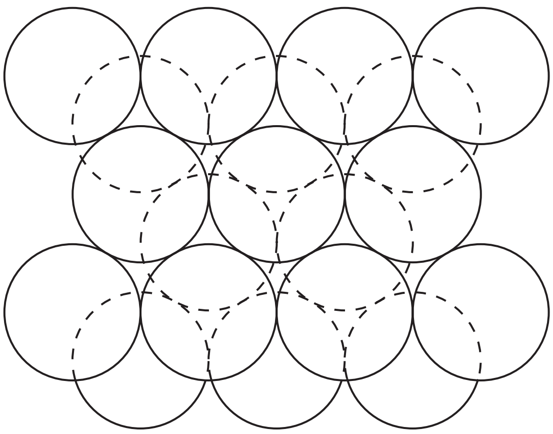

Fig. 1.1

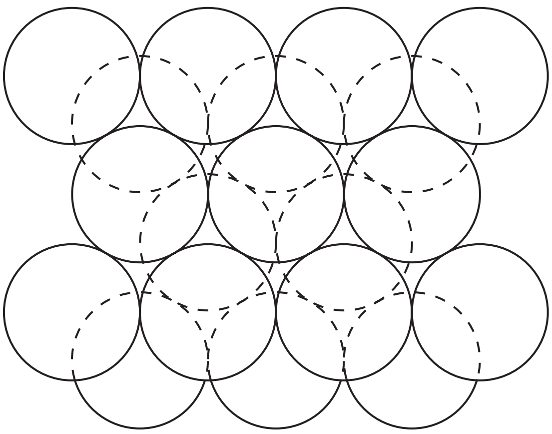

Fig. 1.2

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A further layer R of atoms is placed on top of layer Q. On Figs. 1.1 and 1.2, mark with the symbol **X** the **centres** of at least **three** atoms in layer R so that

(i) Fig. 1.1 represents a hexagonal close-packed structure

(ii) Fig. 1.2 represents a cubic close-packed structure.

[2]

(d) Metallic beryllium has a hexagonal close-packed crystal structure, in which the volume of the atoms is 74% of the total volume occupied by the solid. The mass and radius of a beryllium atom are 1.50×10^{-26} kg and 1.13×10^{-10} m respectively. Calculate the density of beryllium metal.

density = ... $kg\,m^{-3}$ [4]

[Total: 12]

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2 The graph in Fig. 2.1 shows the variation with separation x of the force F between an adjacent pair of atoms in a metal.

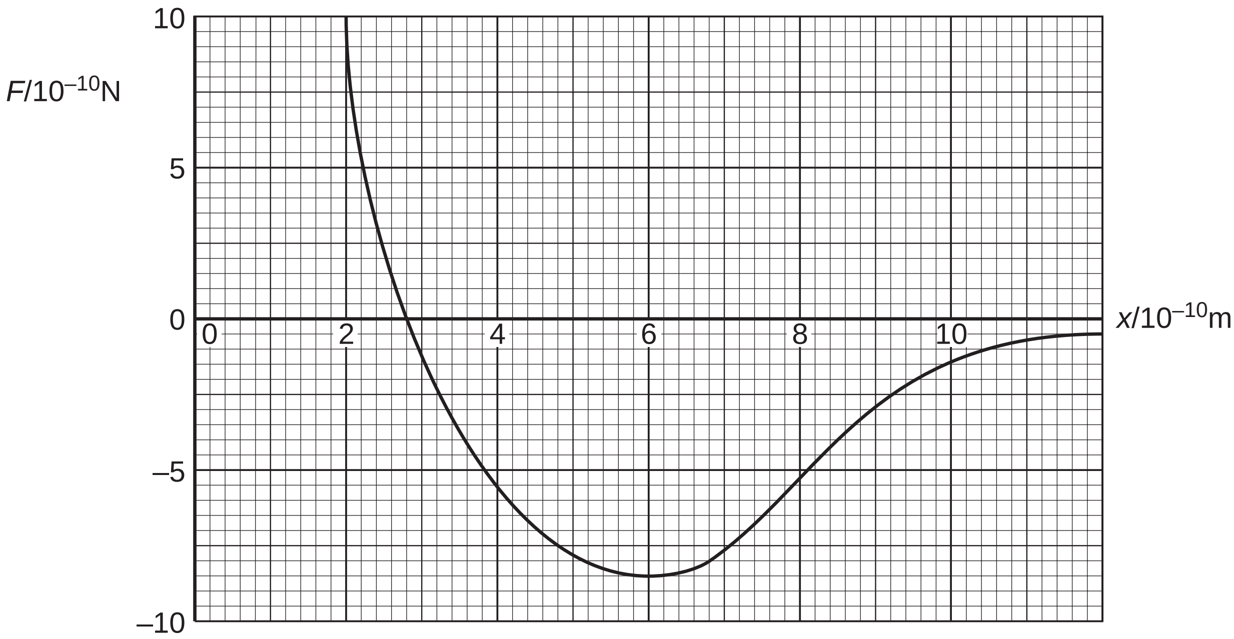

Fig. 2.1

(a) State

(i) the equilibrium separation of the atoms in the metal separation = ... m [1]

(ii) the maximum attractive force between the atoms. force = ... N [1]

(b) The metal is used to make a wire. Explain how the graph shows that the wire obeys Hooke's law for small stretching or compressing forces.

....

....

....[2]

(c) The wire has a cross-sectional area of $1.8 \times 10^{-7}\,\text{m}^2$.

(i) Show that the number of atoms in any plane perpendicular to the length of the wire is about 3×10^{12}.

[3]

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(ii) Estimate the force required to break the wire.

force = ... N [1]

(iii) The actual force required to break the wire would be much smaller than the estimate in **(ii)**. Explain why, addressing the following issues:

- the assumptions made in determining the estimate
- the arrangement of atoms in the wire
- what happens when an increasing force is applied to the wire.

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....[8]

[Total: 16]

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3 A cylindrical specimen of germanium is 12 mm long and has a cross-sectional area of $7.5\,mm^2$. In an experiment the ends of the cylinder are connected to an electrical power supply using copper wire of cross-sectional area $0.80\,mm^2$. When the voltage across the germanium is 6.0 V the current through the circuit is 6.3 mA.

(a) Calculate

(i) the resistance of the cylinder

resistance = ... Ω [1]

(ii) the conductivity of germanium.

conductivity = ... $\Omega^{-1}\,m^{-1}$ [3]

(b) At the temperature of this experiment, the charge carrier densities of copper and germanium are $7.8 \times 10^{28}\,m^{-3}$ and $4.3 \times 10^{21}\,m^{-3}$ respectively. Calculate the ratio

$$\frac{\text{drift velocity of charge carriers in copper}}{\text{drift velocity of charge carriers in germanium}}.$$

ratio = ... [3]

(c) With the same voltage across the germanium, but at a slightly higher temperature, the current in the circuit is significantly higher. Use band theory to explain why. Consider the effect of the increased temperature on the copper wire and the germanium specimen.

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....[5]

[Total: 12]

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4 **(a)** The superconducting transition temperature of a niobium-titanium alloy is 10 K. State the meaning of *superconducting transition temperature*.

....[1]

(b) In medical diagnosis using magnetic resonance imaging (MRI), a uniform magnetic field of flux density of about 1 T is required in a space large enough to be occupied by an adult human body. This field can be produced by a current in a solenoid surrounding the space. The magnetic flux density B along the axis of a solenoid is given by the expression

$$B = \frac{1.3 \times 10^{-6} NI}{L}$$

where N is the number of turns, I is the current, and L is the length of the solenoid.

(i) A solenoid of 15 000 turns and length 2.1 m produces a magnetic field of flux density 1.0 T along its axis. Show that the current in the solenoid is about 110 A.

[1]

(ii) State and explain **two** practical problems if the solenoid is made of copper wire.

....

....

....

....

....[4]

(iii) In practice, the wire of the solenoid is made of thin filaments of niobium-titanium alloy embedded in copper, as shown in Fig. 4.1. In operation the solenoid is surrounded by liquid helium. Copper does not become a superconductor.

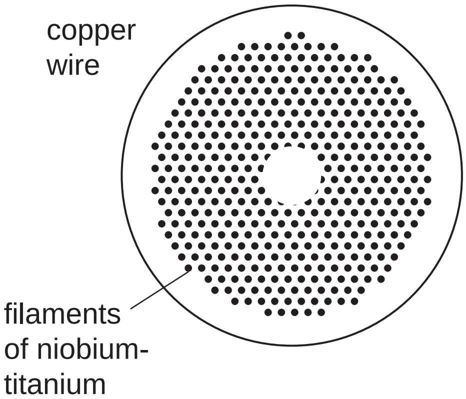

Fig. 4.1

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Suggest

1 why there is negligible current in the copper

....

....[1]

2 a situation which could arise in which the copper has an important function.

....

....

....

....

....[2]

[Total: 9]

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5 **(a)** Explain

(i) how, due to the properties of electrons, the atoms of some elements are magnetic dipoles

....

....[2]

(ii) what is meant by a *magnetic domain*.

....

....[1]

(b) The arrowed regions in Fig. 5.1 represent magnetic domains in a section of an unmagnetised iron bar. The arrows in the domains show their direction of magnetisation.
Show in Fig. 5.2 how the domains change when a weak external magnetic field is applied
In the direction of the arrow labelled **B**.

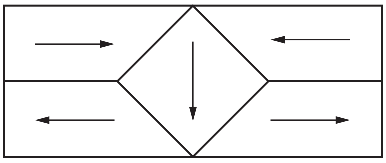
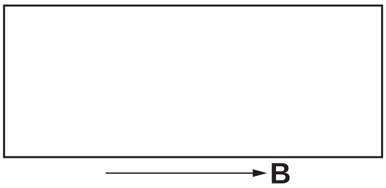


Fig. 5.1



[2]

Fig. 5.2

(c) **(i)** On the axes of Fig. 5.3, B_0 is the flux density of a magnetising field, and B is the flux density within an iron specimen. On Fig. 5.3 sketch and label the hysteresis curves of hard and soft iron. [3]

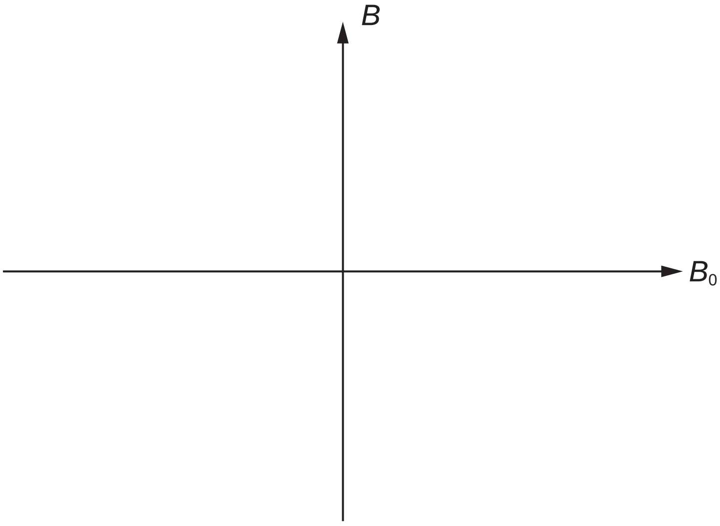


Fig. 5.3

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(ii) Use your graphs in Fig. 5.3, with suitable labelling, to explain why

1 hard iron is the better material to make a permanent magnet

....

....

....[2]

2 soft iron is more easily demagnetised than hard iron.

....

....

....[2]

[Total: 12]

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6 **(a)** The photon energy of infra-red radiation used in optic-fibre communication is 1.3×10^{-19} J. Calculate the wavelength of this radiation.

wavelength = ... m [2]

(b) Explain the advantages of using infra-red from a laser rather than from an LED for optic-fibre communication.

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....[7]

[Total: 9]

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7 The normal temperature of a healthy human body is 37 °C. When an adult person at this temperature is at rest, energy from food is required to maintain normal internal body activity (the basal metabolic rate). On average this energy is supplied to the body at the rate of 75 W. When involved in physical activity, extra energy from food is used. 20% of this extra energy is needed to do mechanical work; the remaining 80% heats the body and has to be dissipated. The energy available from 1 g of food in the form of carbohydrate is about 1.7×10^4 J.

(a) A meal provides a person with 250 g of carbohydrate.

(i) Estimate the period of rest in hours which is provided for by this intake of food.

period of rest = ... hour [2]

(ii) Suggest why the temperature of the person's body remains steady during this period.

....

....

....[2]

(b) A mountaineer of mass 70 kg climbs a mountain to a vertical height of 800 m above the starting point in 1.5 hours. Calculate

(i) the gain in potential energy of the mountaineer

potential energy gain = ... J [2]

(ii) the mass of carbohydrate used to provide this gain in potential energy

mass = ... g [1]

(iii) the minimum total mass of carbohydrate used by the mountaineer.

mass = ... g [3]

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(c) A marathon runner, of mass 65 kg, competes on a day when the temperature of the environment is 40 °C. The rate of heating of the runner's body is 900 W.

(i) Calculate the rate of temperature rise of the runner's body. Assume that the body has a specific heat capacity of 4200 $J\,kg^{-1}\,K^{-1}$.

rate of temperature rise = ... $K\,s^{-1}$ [2]

(ii) Explain why the runner's body cannot lose heat to the surrounding air by the processes of conduction, convection and radiation.

....

....

....[2]

(iii) The runner maintains normal body temperature by using heat from the body to evaporate water (sweat) from the surface of the skin. The heat required to vaporise 1 kg of water is 2.4×10^6 J. Calculate the mass of water evaporated from the skin in 2.5 hours of running.

mass = ... kg [2]

(iv) To minimise harm to the body **during the race**, state and explain **two** precautions the runner should take.

1. ....

....

....

2. ....

....

....[4]

[Total: 20]

END OF QUESTION PAPER

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