OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2825/03**

PHYSICS A

Materials

THURSDAY 21 JUNE 2007 Afternoon

Time: 1 hour 30 minutes

Additional materials: Electronic calculator.

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate Number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

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	**15**	
2	**8**	
3	**11**	
4	**14**	
5	**11**	
6	**11**	
7	**20**	
TOTAL	**90**	

This document consists of **16** printed pages.

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, $= \surd\,(1 - \dfrac{v^2}{c^2})$

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)** Describe the arrangement of atoms in

(i) an amorphous material

.... [1]

(ii) a **close-packed** crystalline material.

....

.... [2]

(b) **(i)** Sketch on Fig. 1.1 a graph to show the relationship between the tensile force *F* applied to a copper wire and the extension *x* produced. Continue the graph to the breaking point of the wire. [1]

Fig. 1.1

(ii) Label your graph in Fig. 1.1 to show the regions where the wire is undergoing

1 elastic deformation

2 plastic deformation. [2]

(c) Describe what happens to the positions of atoms in copper when

(i) a force causing **elastic** deformation is applied and then removed

....

....

.... [2]

(ii) a force causing **plastic** deformation is applied and then removed.

....

....

.... [2]

(d) Copper has a close-packed crystalline structure. Theoretically, in such a material, the atoms themselves occupy 74% of the volume of the metal. The radius of a copper atom is 1.28×10^{-10} m.

(i) Calculate the number of atoms in $1\,m^3$ of copper.

number = ... [3]

(ii) State **two** reasons why the actual number of copper atoms in $1\,m^3$ of copper differs from your calculation in **(i)**.

1. ....

2. .... [2]

[Total: 15]

2 The arrangement in Fig. 2.1 shows a laboratory model to demonstrate the variation with separation of the resultant force between two atoms.

The trolleys **X** and **Y**, which run on an air-track with no friction, represent atoms. Bar magnets and compressible springs are fixed to the facing ends of the trolleys. Opposite poles of the magnets are facing each other as shown in Fig. 2.1. Initially the trolleys are held stationary. The trolleys are close enough for a magnetic force to act, but the springs are not touching.

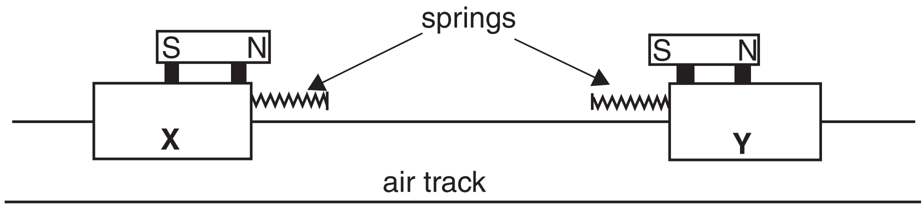

Fig. 2.1

The trolleys are now released.

- Describe and explain the subsequent motion of the trolleys.
- Explain how this model illustrates the behaviour of two neighbouring atoms in a solid.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... [8]

[Total: 8]

3 Red light of wavelength 650 nm is incident on the face of a light-dependent resistor (LDR).

The energy gap between the valence and conduction bands of the material of the LDR is 1.5 eV.

(a) Show that the energy of a photon of the red light is about 2 eV.

[3]

(b) Explain, using band theory,

(i) how the red light causes the LDR to become an electrical conductor

....

....

....

....

.... [3]

(ii) why the resistance of the LDR decreases as the intensity of the red light increases.

....

....

.... [2]

(c) **(i)** Calculate the maximum wavelength of radiation which this LDR could detect.

wavelength = ... nm [2]

(ii) In which region of the electromagnetic spectrum does this radiation lie?

.... [1]

[Total: 11]

4 **(a)** Describe the motion of the free electrons in a metal when there is an electric current in it. In your answer, distinguish between the root-mean-square (r.m.s.) speed and the drift velocity of these electrons.

....

....

....

....

....

....

....

.... [4]

(b) An experiment is carried out to determine the number density of free electrons in a slice of semiconductor used in a Hall probe. Fig. 4.1 shows a battery connected to the slice, of width *d* and thickness *t*. The arrows show the direction of a uniform magnetic field.

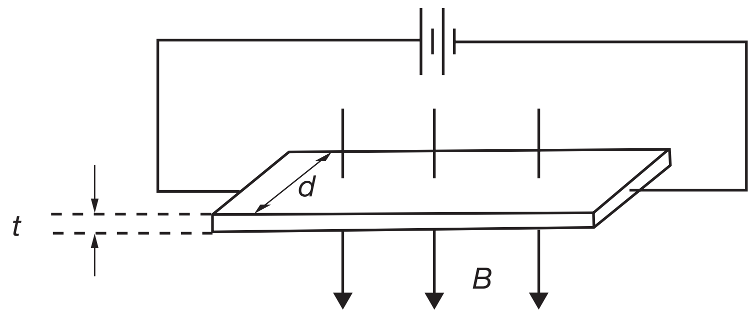

Fig. 4.1

(i) Show on Fig. 4.1 where a voltmeter needs to be connected to measure the Hall voltage. [1]

(ii) The measurements obtained in the experiment are as follows:

current through the Hall slice = 200 mA
Hall voltage = 16 mV
width of Hall slice, d = 5.0 mm
thickness of Hall slice, t = 1.2 mm
flux density of magnetic field = 0.065 T

1 Show that the drift velocity of the free electrons in the Hall slice is about $50\,\mathrm{m\,s^{-1}}$.

[2]

2 Calculate the number density of free electrons in the Hall slice, stating the unit of your answer.

number density = ... unit .... [3]

(c) The experiment in **(b)** is repeated with the same current and magnetic field but with the laboratory at a significantly higher temperature. Discuss changes in the magnitude of the number density, the drift velocity and the Hall voltage.

....

....

....

....

....

....

.... [4]

[Total: 14]

5 **(a)** A transformer with an efficiency of 96% develops a power of 200 W in a resistor connected to the secondary coil.

(i) Write down an expression for the efficiency of a transformer.

.... [1]

(ii) Calculate the power loss in the transformer.

power loss = ... W [2]

(b) State **two** causes of power loss **in the core** of a transformer. For each cause explain

- the reason for the power loss
- the effect on the power loss when the frequency of the input voltage is increased.

Cause 1 ....

....

....

....

....

....

....

....

Cause 2 ....

....

....

....

....

....

....

.... [8]

[Total: 11]

6 Fig. 6.1 shows the colour, wavelength and photon energy of light emitted by three sources.

colour	wavelength/nm	photon energy/eV
red	650	1.91
green	550	2.26
blue	450	2.76

Fig. 6.1

(a) Explain why

(i) an insulator may be transparent to all three colours

....

....

.... [2]

(ii) metals are opaque to all three colours.

....

....

.... [3]

(b) An insulator with an energy band gap of 2.1 eV is placed in the path of the light from all three sources. No other light source is present. An observer looks through the insulator towards the sources. State and explain the appearance of the insulator.

....

....

....

.... [3]

(c) In passing through a block of glass, the intensity of all three colours is reduced by Rayleigh scattering. The intensity of the blue light is reduced by 5.0%. Calculate the reduction in intensity of the red light.

reduction = ... % [3]

[Total: 11]

7 The suspension system for road vehicles can be modelled using springs and masses. The natural frequency of oscillation *f* for a mass *m* supported by a spring is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where *k* is the spring constant.

(a) **(i)** A spring is found to compress by 40 mm when loaded with a mass of 5000 kg. Show that the spring constant *k* is $1.2 \times 10^6\,\mathrm{N\,m^{-1}}$.

[2]

(ii) A 5000 kg mass is supported by four such springs as shown in Fig. 7.1.

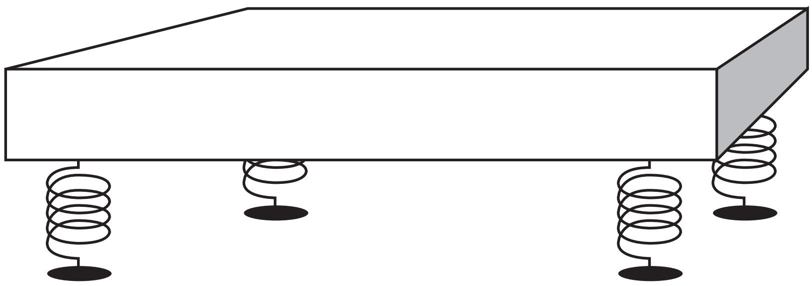

Fig. 7.1

Calculate the natural frequency of oscillation of the mass.

natural frequency = ... Hz [2]

(b) The suspension systems of large lorries require springs made from rods which may be several centimetres thick. Steel rod of this diameter would snap if bent into shape at room temperature. To prevent this the rod is 'hot-coiled': it is heated from 20 °C to 1000 °C before being wound into a spring.

The method of heating is electrical, using a supply of 50 V, which passes a current of 12 000 A through the steel rod. Large contacts at each end of the rod are necessary and these are water-cooled (see Fig. 7.2).

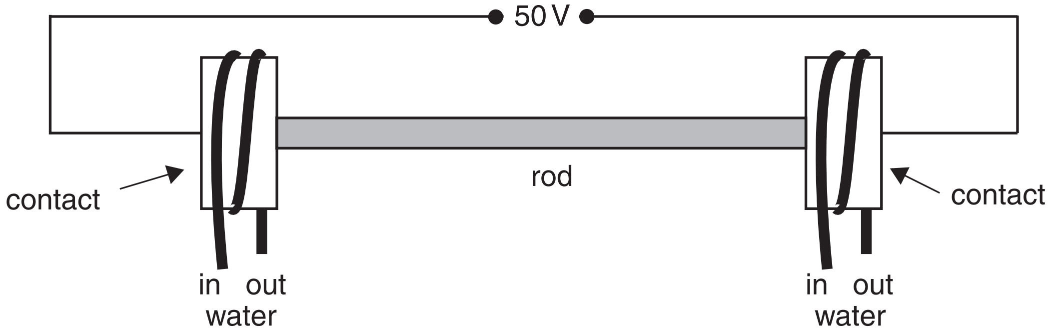

Fig. 7.2

(i) Calculate the resistance of the rod, assuming that the voltage across it is 50 V.

resistance = ... Ω [1]

(ii) Show that the electrical power generated in the rod is 600 kW.

[1]

The mass of the rod is 15 kg.

The specific heat capacity of steel is 420 J kg^{-1} K^{-1}.

(iii) Calculate the energy required to heat the rod from 20 °C to 1000 °C.

energy = ... J [2]

(iv) Calculate the minimum time required to heat the rod to 1000 °C.

minimum time = ... s [2]

(c) In practice the time taken to reach 1000 °C is greater than the value found in **(b)(iv)**. Consequently, the total energy supplied is found to vary according to the time taken for the heating process. The relationship between the energy supplied and time taken is shown in Fig. 7.3.

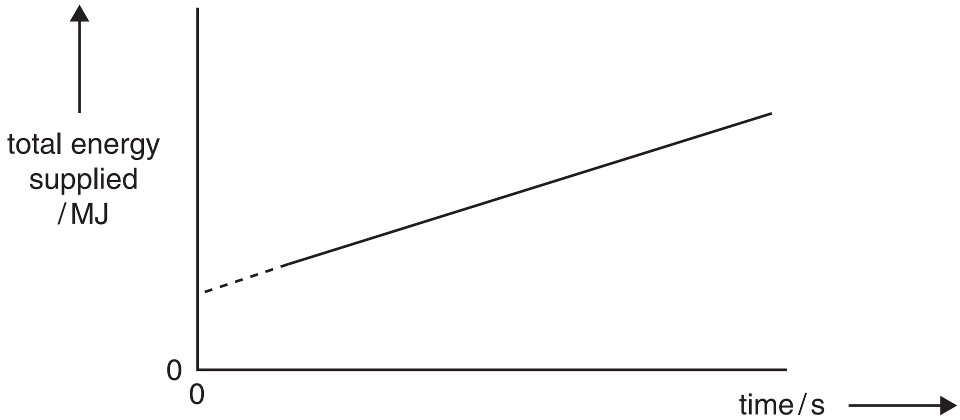

Fig. 7.3

Discuss **two** ways in which energy is lost from the rod during heating and explain the trend shown by the graph in Fig. 7.3.

....

....

....

....

....

.... [3]

(d) A spring is made from a steel rod of the same length but with **twice** the radius.

Suggest, **with reasons**, how the following will change.

(i) The resistance of the rod.

....

....

....

.... [2]

(ii) The time taken to heat the rod from 20 °C to 1000 °C, using the same voltage across the rod.

....

....

....

....

.... [3]

(iii) The natural frequency of the mass-spring system in **(a)**.

....

....

....

.... [2]

[Total: 20]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE