OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/03

Materials

Friday **1 FEBRUARY 2002** Afternoon 1 hour 30 minutes

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

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.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	9	
2	8	
3	10	
4	9	
5	12	
6	22	
7	20	
TOTAL	90	

This question paper consists of 15 printed pages and 1 blank page.

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Registered Charity Number: 1066969

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

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,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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,	$= 10 \lg\left(\frac{I}{I_0}\right)$

[Turn over

Answer **all** the questions.

1 **(a)** Explain, in terms of the forces acting on the atoms, what is meant by *equilibrium separation* in describing the spacing of two neighbouring atoms in a solid.

....

....

....[2]

(b) **(i)** On the axes of Fig. 1.1 sketch a graph to show the variation with separation *x* of the resultant force *F* between the pair of atoms in **(a)**. Indicate on the *F*-axis whether a positive force represents attraction or repulsion of the atoms. [3]

(ii) Label the point **E** on your graph corresponding to equilibrium separation. [1]

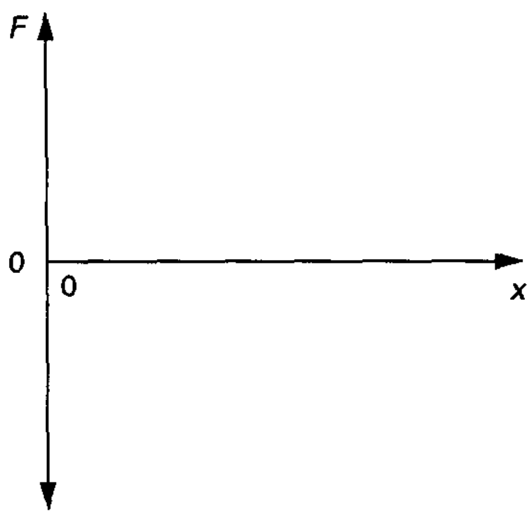

Fig. 1.1

(iii) The solid is stretched and the pair of atoms increase their separation. When the stretching forces are removed the atoms return to their equilibrium separation. Explain why.

....

....

....[1]

(iv) State and explain whether your graph suggests that the solid obeys Hooke's law for small changes in separation of the atoms.

....

....

....[2]

[Total : 9]

For Examiner's Use

2 **(a)** Distinguish between *single-crystal* and *polycrystalline* materials, stating one example of each type.

single crystal ....

....

example ....

polycrystalline ....

....

example .... [4]

(b) The lines in Fig. 2.1 represent some crystal planes in a section of a crystal. Fig. 2.2 shows the same crystal planes after the forces **F** have been applied as shown.

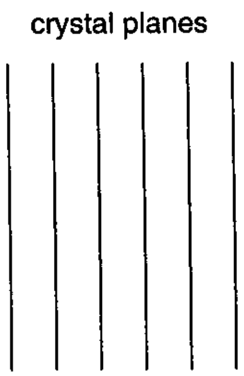

Fig. 2.1

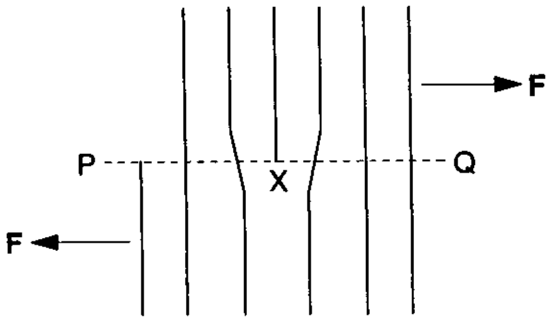

Fig. 2.2

Name the features represented by

(i) the dashed line PQ ....

(ii) the point X. .... [2]

(c) The forces **F** in Fig. 2.2 are increased. Sketch an arrangement of the crystal planes which results from this increase.

[2]

[Total : 8]

For Examiner's Use

3 (a) When a metal wire carries an electric current, *free electrons* move through the wire with a *drift velocity*. Explain what is meant by

(i) *free electrons*

....[1]

(ii) *drift velocity*.

....

....[1]

(b) A copper wire with a cross-sectional area of $1.2 \times 10^{-6}\,m^2$ is connected into a circuit with a constant voltage source. The current in the wire is 1.5 mA. The concentration of free electrons in copper is $8.7 \times 10^{28}\,m^{-3}$. Calculate the drift velocity of electrons in this wire.

drift velocity = ... $m\,s^{-1}$ [3]

(c) The temperature of the copper wire in **(b)** is raised. No other change is made to the circuit. State and explain the effect of the temperature rise on the current in terms of the behaviour of atoms and free electrons in the wire.

....

....

....

....[3]

(d) The current through a strip of semiconductor with a similar cross-section to that of the copper wire in **(b)** is 1.5 mA.

(i) State how the drift velocity of free electrons in the semiconductor differs from that in the copper wire.

....

(ii) Explain this difference in terms of free electron concentration.

....

....

....[2]

[Total : 10]

For Examiner's Use

4 **(a)** Describe the arrangement of the magnetic domains within a specimen of iron when

(i) the iron is unmagnetised ....

....

(ii) the iron is magnetised. ....

.... [2]

(b) A solenoid of many turns of copper wire is wound around a steel bar. The steel is ***initially unmagnetised***. B_i is the flux density of the magnetic field due to the current in the solenoid causing magnetisation of the bar. B is the flux density of the magnetic field within the bar.

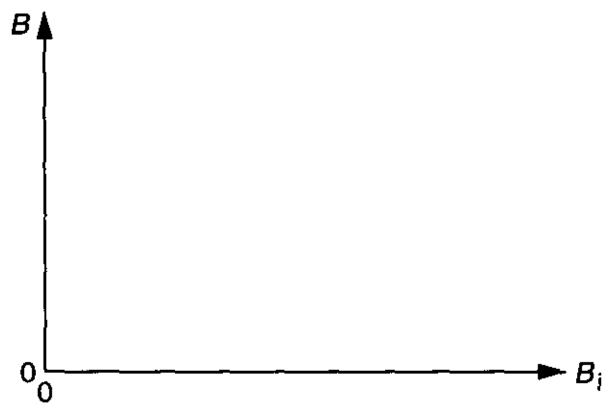

Fig. 4.1

On the axes of Fig. 4.1 sketch a graph to show how B is related to B_i as the current in the solenoid is

(i) increased from zero so that the steel reaches saturation,

(ii) then reduced to zero. [3]

(c) Energy losses from the core of a transformer reduce the efficiency of the transformer. State and explain how energy losses are minimised by

(i) the choice of material of which the core is made

....

....

....[2]

(ii) the structure of the core.

....

....

....[2]

[Total : 9]

[Turn over

For Examiner's Use

5 **(a)** Explain, using band theory, why glass is transparent to visible light.

....

....

....

....

....[3]

(b) For electromagnetic radiation of a given wavelength, the refractive index *n* of a medium is given by the expression:

$$n = \frac{\text{speed of the radiation in air}}{\text{speed of the radiation in the medium}}$$

(i) Electromagnetic radiation travels more slowly in glass than in air. What do you conclude from this about the numerical value of *n* for glass?

....[1]

(ii) As the wavelength of electromagnetic radiation decreases, its speed in glass decreases. Describe how *n* varies with the wavelength.

....[1]

(c) **(i)** State what is meant by *Rayleigh scattering* of light.

....[1]

(ii) State the cause of Rayleigh scattering in glass.

....

....[1]

(iii) Suggest why Rayleigh scattering is one of the reasons for using infra-red rather than visible light for transmission in optic fibre communication systems.

....

....

....[2]

(d) The spectral bandwidths (range of wavelengths) of the light emitted by a light emitting diode (LED) and by a laser are 20 nm and less than 10^{-3} nm respectively. Use these data to suggest and explain a reason why a laser, rather than an LED, may be chosen to generate signals for transmission along optic fibres.

....

....

....

....[3]

[Total : 12]

For Examiner's Use

6 (a) (i) Draw labelled diagrams to show how the energy-band structure of a metal and an intrinsic semiconductor differ.

metal semiconductor [2]

(ii) State and explain how the electrical conductivity of a semiconductor varies as its temperature is raised.

....

....

....

....[3]

(b) Cadmium sulphide is a semiconductor. A light-dependent resistor (LDR) made of this material has a resistance in the dark of about 1 MΩ, which falls to less than 1 kΩ in daylight.
These resistances are to be measured by an ammeter-voltmeter method.

(i) Draw a suitable circuit, powered by a 3 V battery.

(ii) What approximate value would you expect the ammeter to read when the LDR is

1 in the daylight ....

2 in the dark? ....
[5]

(c) Suggest the mechanism by which light falling on an LDR causes the resistance to be reduced.

....

....

....[2]

(d) For a thermistor, $R = R_0 e^{-K\theta}$, where R is the resistance at temperature θ, R_0 is the resistance at 0 °C and K is a constant.

In an experiment the data in Fig. 6.1 were obtained.

θ/°C	R/kΩ	ln (R/kΩ)
0	140	4.9
20	66	
40	31	
60	14	
80	6.8	
100	3.2	

Fig. 6.1

(i) Complete the table in Fig. 6.1. [2]

(ii) Plot a graph of ln (R/kΩ) against θ on the grid provided in Fig. 6.2. [3]

(iii) Use your graph to evaluate K and state its unit.

K = ... [5]

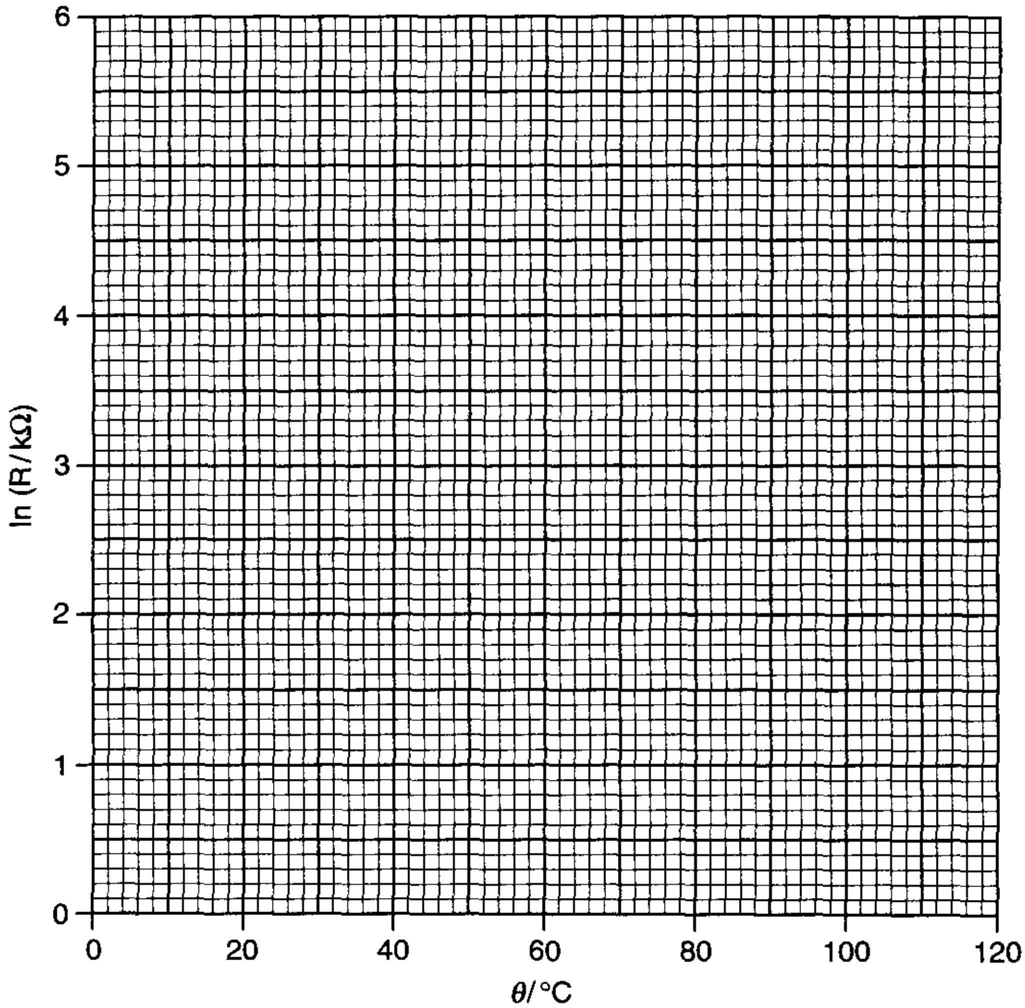

Fig. 6.2

[Total : 22]

7 A couple who find modern life too stressful decide to move to a Scottish island which has no mains electricity supply.

There are two ways in which they could provide a power supply. One method is to lay a long-distance supply cable from another island which has mains electricity. The other method is to equip themselves with an aerogenerator and rechargeable batteries.

One disadvantage of using a long-distance supply cable is that the potential difference available at the user's end of the cable is less than the p.d. at the supply end of the cable. Because of this and the cost of laying a sufficiently thick cable, they decide to use an aerogenerator and batteries.

Rechargeable 12 V batteries are available and these will provide a reservoir of energy which can be increased by adding extra batteries. However, a battery will deliver only 80% of the energy stored in it.

The island is usually windy so they plan to keep the batteries charged by means of the aerogenerator. This consists of a rotating propeller of diameter 1.5 m, which drives a generator. The overall efficiency of the aerogenerator is 40%. It works by converting into electrical energy some of the kinetic energy of the air passing through the propeller. The average wind speed on the island is 8.0 m s^{-1}. This means that all the air inside a cylinder 8.0 m long, of diameter 1.5 m, passes through the propeller in 1 second. This is illustrated in Fig. 7.1.

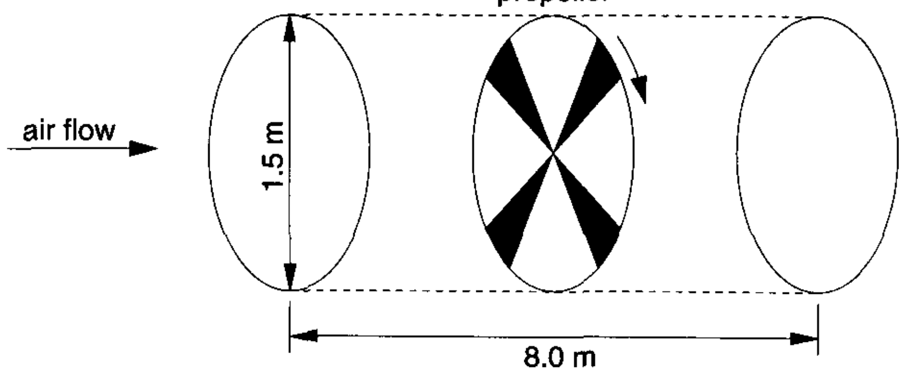

Fig. 7.1

Although the island is normally windy, there are periods of calm. Meteorological information suggests that the longest such period would be 40 hours. The couple estimate that their average power requirement during these periods would be 160 W.

Additional information:

amount of energy stored by one rechargeable battery	= 7.0×10^6 J
density of air	= 1.3 kg m^{-3}

(a) Explain why the p.d. available to the user of a long mains cable would be less than the p.d. at the supply end of the cable.

....

....

....

....[3]

(b) Suggest why it is not possible for the aerogenerator to achieve an efficiency of 100%.

....

....

....

....

....

....[2]

(c) **(i)** Show that the mass of air contained in a cylinder of diameter 1.5 m and length 8.0 m is approximately 18 kg.

[2]

(ii) Calculate the kinetic energy of 18 kg of air travelling at 8.0 m s^{-1}.

energy = ... J [2]

[Turn over

For Examiner's Use

(iii) Hence calculate the average power output of the aerogenerator.

power = ... W [1]

(d) Calculate the average time taken by the aerogenerator to recharge one battery fully.

time = ... s [2]

(e) **(i)** State what form of energy is stored by a battery.

....[1]

(ii) Give **one** reason why the energy delivered by a battery is less than the energy input.

....

....

....[1]

For Examiner's Use

(f) **(i)** Calculate the greatest amount of energy which needs to be delivered by the batteries during a 40 hour period of calm weather.

energy = ... J [2]

(ii) Calculate the total energy which the set of batteries must be capable of storing.

energy = ... J [2]

(iii) Calculate the minimum number of rechargeable batteries that will be needed.

[2]

[Total : 20]

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