OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/03

Materials

Monday **26 JANUARY 2004** 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 provided 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.
- The first six questions concern Materials. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	11	
2	9	
3	12	
4	9	
5	16	
6	13	
7	20	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

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

For Examiner Use

Answer **all** the questions.

1 **(a)** State the molecular structure of

aluminium ....

glass. ....[2]

(b) State **two** types of close-packed crystal structures.

1. ....

2. ....[2]

(c) A bubble raft on the surface of a liquid represents the arrangement of atoms in a crystal plane of a solid. Fig. 1.1 shows a photograph of a bubble raft.

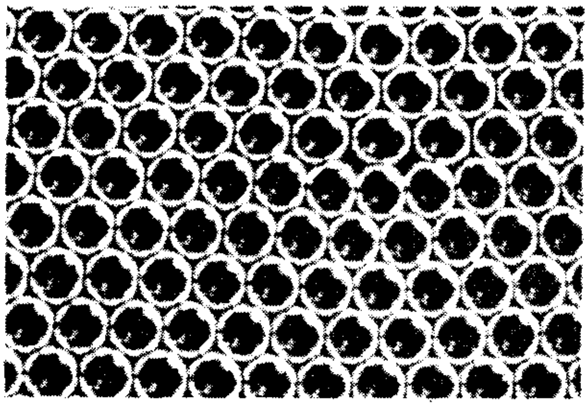

Fig. 1.1

From careful observation of Fig. 1.1, locate the position of a dislocation in the crystal plane. Draw a cross (X) on Fig. 1.1 to indicate where the bubble raft represents the start of this dislocation. [1]

(d) **(i)** Discuss any part that dislocations play in the deformation of a thin copper rod up to and beyond its elastic limit.

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....[4]

For Examiner's Use

(ii) Brass is an alloy of copper and zinc. Suggest why a thin brass rod does **not** show plastic behaviour.

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....[2]

[Total: 11]

For Examiner's Use

2 The resultant repulsive force F between a pair of atoms in an elastic solid varies with the separation r of the atoms. The table below gives values of F for selected values of r.

$r/10^{-10}$ m	2.80	2.85	2.90	2.95	3.00
$F/10^{-9}$ N	1.10	0.50	0.00	– 0.30	– 0.50

(a) Plot the graph of F against r on the axes of Fig. 2.1. [2]

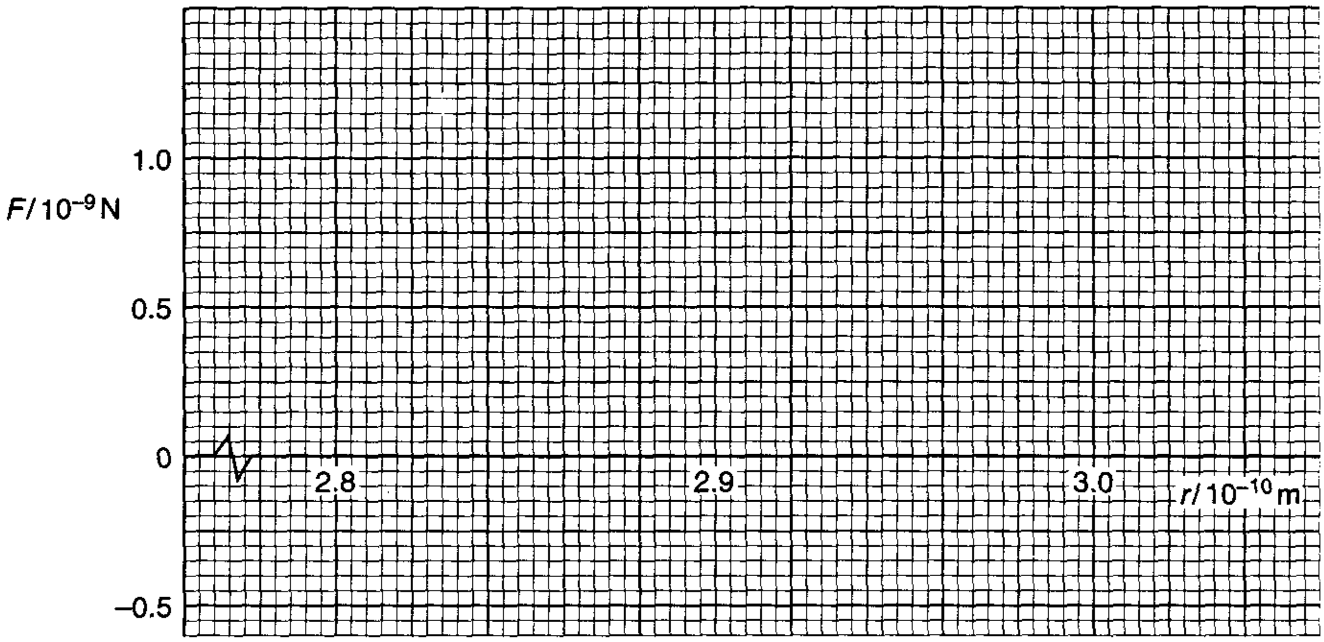

Fig. 2.1

(b) State the significance of

(i) r_0, the value of r where $F = 0$

....[1]

(ii) negative values of F.

....[1]

(c) **(i)** Determine the gradient k of the graph at $r = r_0$.

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

For Examiner's Use

(ii) The Young modulus E of the solid is given by the expression $E = -\dfrac{k}{r_0}$.
Calculate E.
Give a suitable unit for your answer.

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

[Total: 9]

3 **(a)** Fig. 3.1 shows a small filament bulb close to the face of a light dependent resistor (LDR). An experiment is carried out to investigate how the current through the LDR varies as the power supplied to the bulb is changed.
Draw the necessary circuits connected to the bulb and to the LDR. [4]

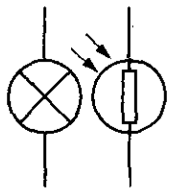

Fig. 3.1

(b) The results of the experiment in **(a)** show that the current through the LDR, made of intrinsic semiconductor, increases as the power to the bulb increases.
Explain this increase in terms of band theory.

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....[4]

(c) The material of the LDR in **(b)** has an energy gap of 2.4 eV.

(i) Calculate the wavelength of light from the bulb which just allows conduction through the LDR.

wavelength = ... m [3]

(ii) Explain why this is the **maximum** wavelength that allows conduction.

....

....[1]

[Total: 12]

For Examiner's Use

4 (a) Explain what is meant by the *transition temperature* of a superconductor.

....

....[1]

(b) The transition temperatures of the earliest known superconductors were less than 10 K. Recently manufactured superconducting materials have transition temperatures above 100 K. Suggest why this is a significant development.

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....[2]

(c) Some electromagnets use superconductors in their structure. Describe the part played by superconductors in the function of such electromagnets. Discuss the practical and economic advantages of using these electromagnets.

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....[6]

[Total: 9]

5 **(a)** Describe, in terms of domain theory, **two** processes which occur within an iron bar when it is magnetised.

1. ....

....

2. ....

....[4]

(b) An alternating supply delivers a current of 0.025 A at 12 V to the primary coil of a transformer. A 20 Ω resistor is connected to the secondary coil.

(i) The current in the secondary circuit is 0.110 A.
Calculate for the transformer

the power input

power input = ... W [1]

the power output

power output = ... W [2]

the efficiency.

efficiency = ... % [2]

(ii) The frequency of the supply is increased. The power input is kept constant. The current in the secondary coil falls to 0.105 A.
Calculate the new efficiency of the transformer.

efficiency = ... % [2]

(c) **(i)** State and explain **one** cause of power loss in the **core** of a transformer.

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....[3]

For Examiner's Use

(ii) Using your answer to **(c)(i)**, explain why the power loss in the core increases as the frequency of the supply is increased.

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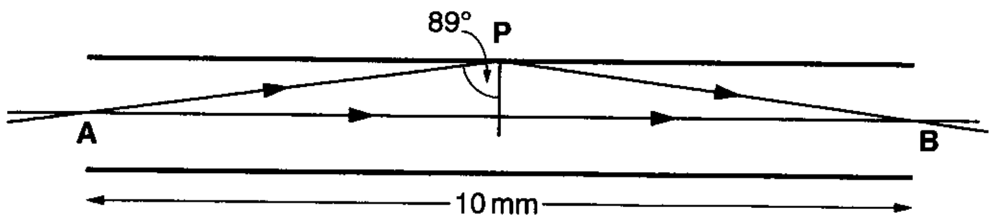
....[2]

[Total: 16]

For Examiner Use

6 **(a)** Fig. 6.1 shows a section of optic fibre of length 10 mm. A light pulse of a single wavelength is projected into this section of fibre. One ray passes along the axis of the fibre through **A** and **B**.
Another ray travelling through **A** and **B** undergoes total internal reflection at **P** at an angle of incidence of 89°.



not to scale

Fig. 6.1

(i) Show that the difference in path length of the two rays in the 10 mm length of fibre is about 0.0015 mm.

difference = ... mm [2]

(ii) The rays continue through a 1.0 km length of fibre. Calculate the difference in arrival time of the two rays at the end of this length of fibre. The speed of light in the fibre is $2.1 \times 10^{8}\,\text{m s}^{-1}$.

time difference = ... s [3]

(b) Fig. 6.2 (i) shows the shape of the light pulse, described in **(a)**, projected into the optic fibre.
Fig. 6.2 (ii) shows the shape of the pulse emerging from the end of the 1.0 km length of fibre.

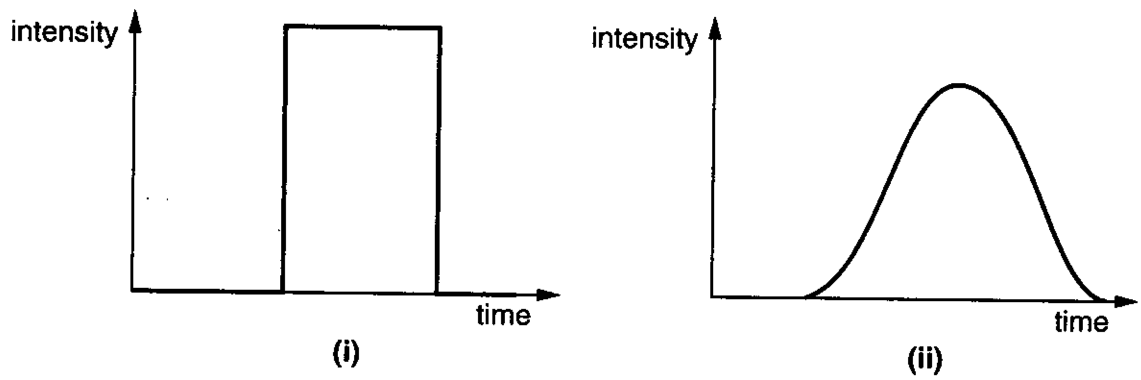


Fig. 6.2

For Examiner's Use

Explain the shape and size of the emerging pulse, and suggest a change which could be made to the fibre which would reduce the distortion.

For communication purposes, infra-red pulses, rather than visible light, are transmitted along optic fibres. Discuss what effect using infra-red would have on the emerging pulse. The refractive index for infra-red is about 1% less than that for visible light.

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[Total: 13]

7 Scintillation counters have been widely used to detect particles in high energy physics experiments. A scintillation counter consists of a sheet of plastic scintillator material coupled to a photomultiplier tube, as shown in Fig. 7.1.

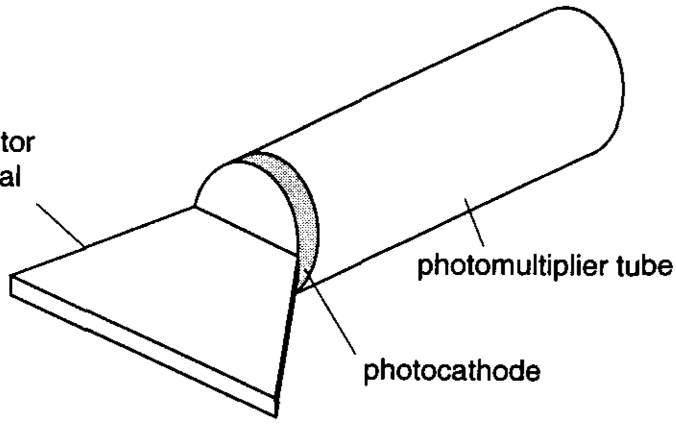


Fig. 7.1

The scintillator material produces a tiny flash of light when struck by a high energy particle. This light undergoes total internal reflection within the scintillator material until it reaches the photocathode of the photomultiplier tube. Fig. 7.2 shows this and also the internal structure of the photomultiplier tube.

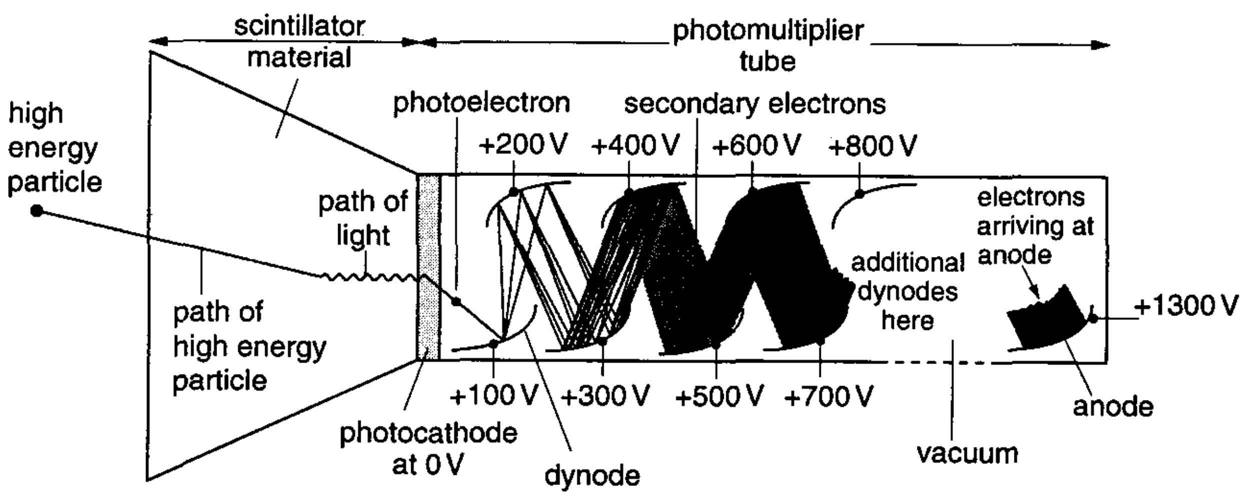


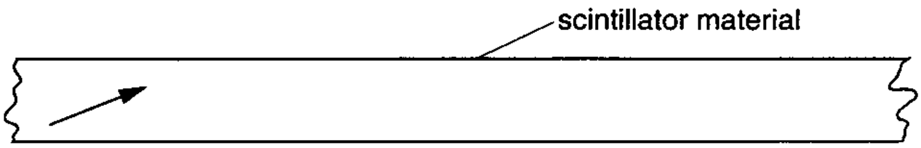
Fig. 7.2

When the flash of light reaches the photocathode, the photoelectric effect causes an electron, called a photoelectron, to be emitted from the photocathode. This electron is attracted by a potential difference between the photocathode and the first curved plate, called a dynode. When the electron hits the first dynode, with 100 eV energy in this case, several *secondary* electrons are emitted. These are accelerated to the next dynode, where the process is repeated. The pulse of charge at the final dynode, called the anode, can be measured by an electronic system.

For Examiner's Use

(a) The diagram below shows a section of the scintillator viewed from the side.

(i) Explain, with the aid of the diagram, how the light may be transmitted along the scintillator by total internal reflection.



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....[3]

(ii) The scintillator material has a refractive index of 1.58. Calculate the critical angle *C* for this material in air.

critical angle = ...° [2]

(b) In a particular experiment, a single high energy particle loses 1.5 MeV of energy in the scintillator material and in losing this energy produces 1.0×10^4 photons of wavelength 413 nm.

(i) Show that the energy of one photon of wavelength 413 nm is about 3.0 eV.

[2]

(ii) What percentage of the particle's energy loss has been converted into light in the scintillator material?

percentage = ...% [2]

[Turn over

For Examiner Use

(c) The photocathode is coated with potassium which has a work function ϕ of 2.2 eV.

(i) Calculate the threshold wavelength for potassium.

threshold wavelength = ... nm [2]

(ii) Why would zinc, which has a work function of 4.3 eV, be unsuitable for the photocathode coating?

....

....[1]

(iii) Calculate the maximum speed v_{max} of the photoelectrons emitted from the potassium photocathode.

v_{max} = ... m s^{-1} [3]

(d) **(i)** In the photomultiplier tube, there are 13 dynodes, including the anode, and 3 secondary electrons are emitted at each dynode per incident electron. Calculate the number of electrons received at the anode for one electron leaving the photocathode.

number = ... [2]

(ii) This pulse of electrons lasts 3.0×10^{-9} s. Calculate the average current during this pulse.

average current = ... A [3]

[Total: 20]

END OF QUESTION PAPER

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