OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A **2825/03**

Materials

Monday **27 JUNE 2005** Afternoon 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	**12**	
2	**11**	
3	**14**	
4	**12**	
5	**10**	
6	**11**	
7	**20**	
TOTAL	**90**	

This question paper consists of 19 printed pages and 1 blank page.

SP (NF/AR) S72322/5

[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,	$= 10 \lg\left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 The mass of a titanium atom is 7.98×10^{-26} kg. At normal temperatures, titanium has a hexagonal close-packed crystal structure and a density of $4510\,kg\,m^{-3}$.

(a) Explain what is meant by *close-packed.*

....[1]

(b) Calculate

(i) the volume occupied by 1 kg of titanium

volume = ... m^3 [2]

(ii) the number of atoms in 1 kg of titanium.

number = ... [2]

(c) The radius of a titanium atom is 1.46×10^{-10} m. Show that

(i) the volume of a titanium atom, assumed to be spherical, is $1.30 \times 10^{-29}\,m^3$

[2]

(ii) in titanium the space occupied by the atoms themselves is 74 % of the total volume.

[2]

For Examiner's Use

(d) At 883 °C, the crystal structure of titanium becomes body-centred cubic. Suggest and explain the changes of density which occur as titanium is heated from normal temperatures to 900 °C.

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....[3]

[Total: 12]

For Examiner's Use

2 **(a)** Sketch a graph to show the variation with separation *x* of the resultant force *F* between two atoms in a solid. Label the regions of attraction and repulsion on the force axis.

[3]

For Examiner's Use

(b) Discuss the nature of the forces between two atoms in a solid and how the resultant force arises.
With reference to your graph in **(a)**

- consider the equilibrium separation of atoms
- explain the elastic behaviour of a solid.

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....[8]

[Total: 11]

3 **(a)** **(i)** What is the phase (solid, liquid or gas) of an element when the electronic energy levels are

sharp and well-defined

....

broadened into bands?

....
[1]

(ii) Describe how the electronic energy levels of atoms of an element change from sharp distinct levels to broad bands as the phase changes.

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....[3]

(b) **(i)** Draw a labelled diagram to illustrate the terms *valence band, conduction band* and *energy gap.*

[3]

(ii) Explain, using band theory, the differing electrical properties of insulators, intrinsic semi-conductors and metals.

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For Examiner's Use

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....[7]

[Total: 14]

For Examiner's Use

4 **(a)** A metal wire of cross-sectional area A carries a current I. The metal contains n free electrons per unit volume. The mean drift velocity of these electrons is v. Derive an expression for the current I in terms of A, n, v and e, the electronic charge.

[3]

(b) Fig. 4.1 shows a length of metal foil, of width d and thickness t, carrying a current I, in a magnetic field of flux density B. The directions of I and B are shown by arrows.

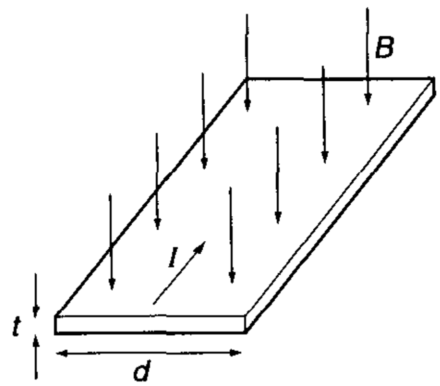

Fig. 4.1

The concentration of free electrons in the metal is $8.7 \times 10^{28}\,\text{m}^{-3}$. Given that $I = 25\,\text{mA}$, $B = 0.15\,\text{T}$, $t = 0.050\,\text{mm}$ and $d = 8.0\,\text{mm}$, calculate

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

drift velocity = ... m s^{-1} [2]

(ii) *the Hall voltage across the foil.*

Hall voltage = ... V [3]

For Examiner's Use

(iii) On Fig. 4.1, mark two points, **X** and **Y**, to which a voltmeter could be connected to measure this Hall voltage. [1]

(c) Explain, with reference to your calculations in **(b)**, why a Hall probe incorporates a thin slice of semiconductor rather than a metal foil of similar dimensions.

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....[3]

[Total: 12]

5 **(a)** A transformer is assumed to be 100% efficient in its operation. The primary coil is connected to a 230 V a.c. source. The secondary coil is connected to a 50 Ω resistor. The potential difference across the resistor is 12 V a.c.

Calculate

(i) the current through the 50 Ω resistor

current = ... A [2]

(ii) the current in the primary circuit.

current = ... A [2]

(b) (i) State **two** features of a transformer core which maximise the transformer's efficiency.

1. ....

2. ....
[2]

(ii) For **one** of the features described in **(i)** state and explain how an increase in the frequency of the current in the transformer affects the efficiency.

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....[4]

[Total: 10]

6 **(a)** Explain, using band theory, why metals are opaque to visible light.

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....[3]

(b) An insulator has an energy gap between its valence and conduction bands of 2.40 eV. Show that this insulator is transparent to visible light of wavelength 550 nm.

[4]

(c) Visible and infra-red beams of radiation travel the same distance through a glass fibre. Both beams undergo a loss in intensity through Rayleigh scattering.

(i) State and explain which of these radiations loses a greater percentage of its intensity.

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....[2]

(ii) The wavelengths of the visible and infra-red beams are 600 nm and 1200 nm respectively. The visible beam loses 72 % of its intensity per km of fibre. Calculate the corresponding loss for the infra-red beam.

intensity loss = ... % [2]

[Total: 11]

7 The London Eye, Fig. 7.1, is the largest observation wheel ever built. It has 32 egg-shaped capsules attached to the outside of the rim of the wheel. Each capsule holds up to 25 passengers and completes one revolution in 30 minutes.

The wheel of diameter 122 m, is driven by a drive system based on tyres gripping the edge of the wheel rim. 16 rubber tyres each supply a tangential force of 12.5 kN to the rim. The tyres are pressed against the rim by hydraulic cylinders.

The design engineers used computer simulations to predict all of the stresses on the structure. These programs modelled the effect of metal fatigue as well as wind and temperature changes over the whole structure. All of the 80 cables between the rim of the wheel and the hub (centre) remain under tension as the wheel rotates. The system acts like a large bicycle wheel suspended in the air.

As the wheel rotates, the tension in each cable changes. The wheel and support as a whole has a natural frequency of oscillation and it is important that the combination is not set in oscillation by the wind.

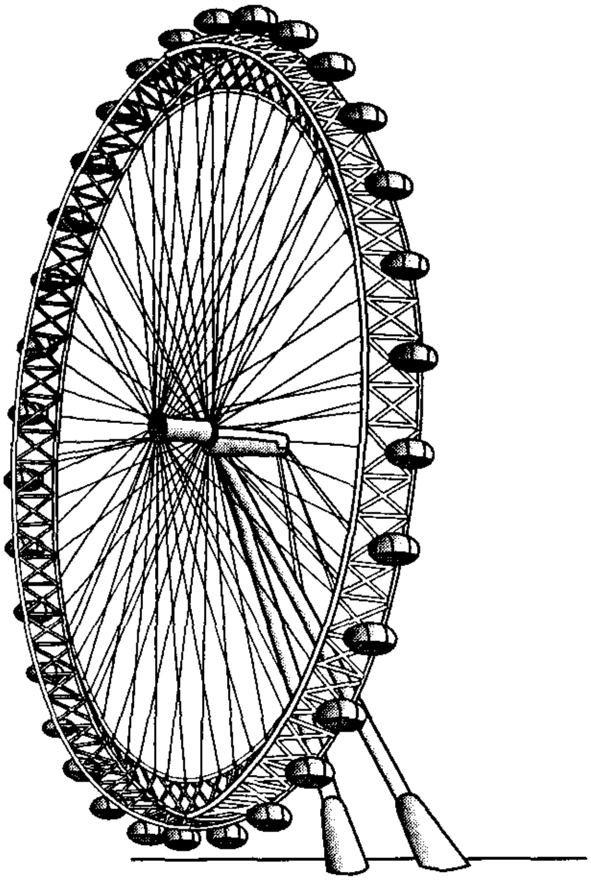

Fig. 7.1

For Examiner's Use

(a) **(i)** Calculate the linear speed of the wheel rim when it is turning normally.

speed = ... $m\,s^{-1}$ [2]

(ii) Calculate the total force exerted by the drive system.

force = ... N [1]

(iii) Calculate the work done in moving the wheel through one revolution.

work done = ... J [2]

For Examiner's Use

(iv) Calculate the useful power needed for the wheel to turn at the rate of one revolution every 30 minutes.

power = ... W [2]

(v) The wheel turns at a constant speed. Energy is converted as a result of

- friction in the bearings
- friction between the tyres and the rim
- electrical energy supplied to the motor.

Apply the conservation of energy for the rotating wheel and discuss which of the above produces useful work in rotating the London Eye.

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.... [5]

For Examiner's Use

(b) The London Eye behaves like a large bicycle wheel suspended in the air. Fig. 7.2(i) shows the front wheel and fork of a stationary bicycle wheel which is in contact with the ground. Fig. 7.2(ii) shows the front wheel and fork of the same bicycle when lifted off the ground.

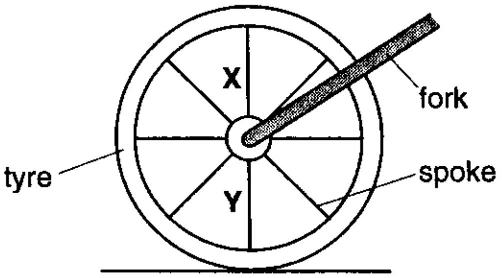

Fig. 7.2(i)

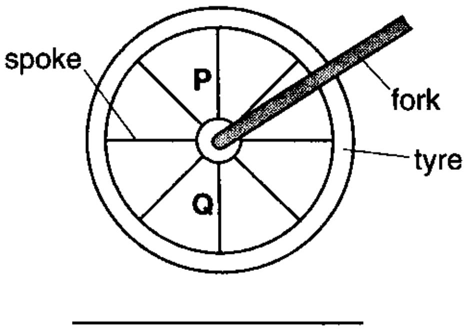

Fig. 7.2(ii)

Assume all spokes are always in tension.
Compare, giving a reason in each case, the magnitude of

(i) the tension in the spokes **X** and **Y**

....

....

(ii) the tension in the spokes **P** and **Q**.

....

....
[2]

(c) This question is concerned with the effect of the wind on the London Eye.

(i) In a storm the wind may exert a horizontal force of 1800 kN on the wheel support, causing it to deflect horizontally by 90 cm. Calculate a value for the spring constant k of the wheel support.

k = ...N m^{-1} [2]

[Turn over

For Examiner's Use

(ii) The natural frequency f of oscillation of the wheel is given by the equation

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

where m is the mass of the system.
Calculate the fundamental natural frequency f of oscillation of the wheel support when m is 9.5×10^5 kg.

f = ... Hz [2]

(iii) The wind may cause fluctuations at the frequency calculated in **(c)(ii)**. What problem might this cause and how may this problem be overcome?

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....

....
[2]

[Total: 20]

END OF QUESTION PAPER