RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced Subsidiary GCE

PHYSICS A 2822

Electrons and Photons

Wednesday **12 JANUARY 2005** Morning 1 hour

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

Candidate Name	Centre Number	Candidate Number

TIME 1 hour

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 will be awarded marks for the quality of written communication where this is indicated in the 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	**12**	
2	**7**	
3	**12**	
4	**8**	
5	**11**	
6	**10**	
TOTAL	**60**	

This question paper consists of 12 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, $p = \frac{1}{3}\dfrac{Nm}{V}<c^2>$

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

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg \left(\dfrac{I}{I_0}\right)$

[Turn over

For Examiner's Use

Answer **all** the questions.

1 **(a)** State the difference between the directions of conventional current and electron flow.

....

....[1]

(b) In the space provided below, draw the symbol for a light-dependent resistor (LDR) and state how its resistance is affected by the intensity of light falling on it.

....

....

....

....[2]

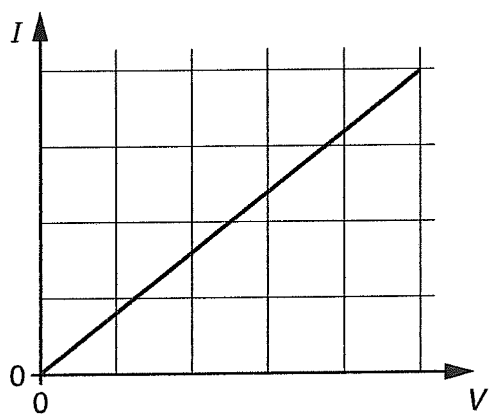
(c) State Ohm's law.

....

....

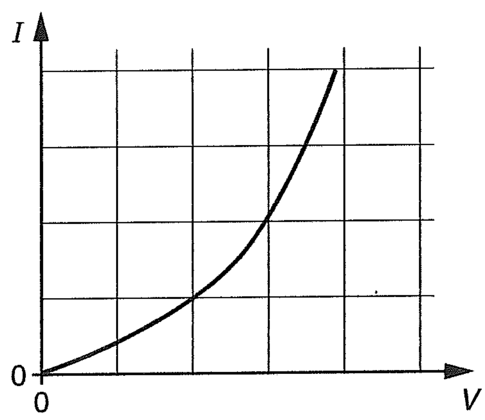
....[2]

(d) Current against voltage (*I*/*V*) characteristics are shown in Fig. 1.1a for a metallic conductor at a constant temperature and in Fig. 1.1b for a particular thermistor.



metallic conductor

Fig. 1.1a



thermistor

Fig. 1.1b

For Examiner's Use

(i) Sketch the variation of resistance R with voltage V for

1. the metallic conductor at constant temperature (draw this on Fig. 1.2a)
2. the thermistor (draw this on Fig. 1.2b). [3]

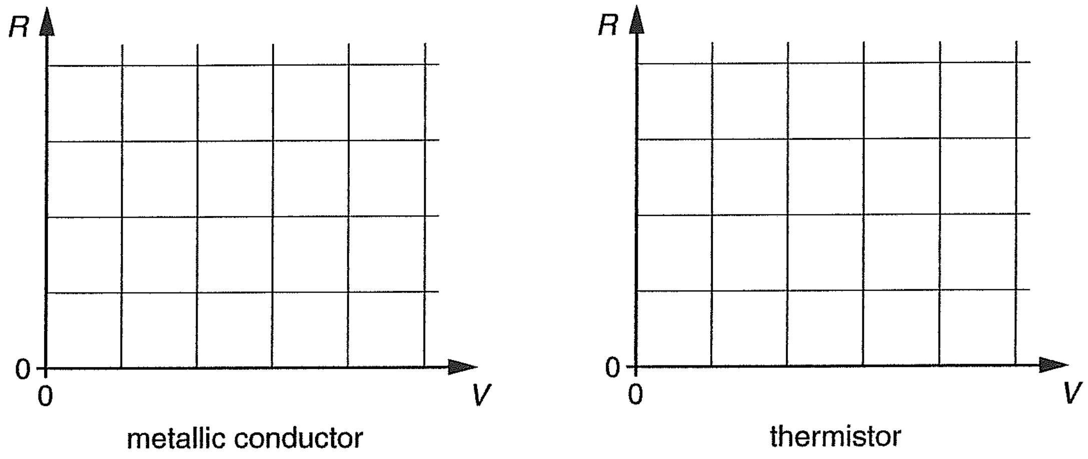


Fig. 1.2a **Fig. 1.2b**

(ii) State and explain the change, if any, to the graph of resistance against voltage for the metallic conductor

1. when the temperature of the metallic conductor is kept constant at a **higher** temperature

....

....

....

2. when the length of the conductor is doubled but the material, temperature and the cross-sectional area of the conductor remain the same.

....

....

....[4]

[Total: 12]

For Examiner's Use

2 **(a)** The statement below defines an important quantity in magnetism.

The force on a conductor, per unit length, carrying a unit current and placed 90° to the magnetic field.

State this quantity.

....[1]

(b) Write a suitable equation and use it to show that the tesla (T) is the same as the $N\,m^{-1}\,A^{-1}$.

[1]

(c) Fig. 2.1 shows a current-carrying conductor placed at right angles to a uniform magnetic field.

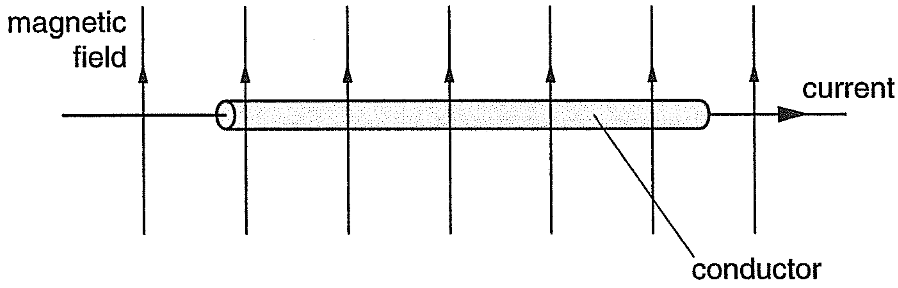


Fig. 2.1

(i) Explain how you can determine the direction of the force experienced by the current-carrying conductor using Fleming's left-hand rule.

....

....

....[1]

(ii) State the direction of the force experienced by the conductor shown in Fig. 2.1.

....[1]

(d) One of the world's strongest electromagnets creates a magnetic field that can provide a maximum force of 1.4 N per metre on a conductor carrying a current of 78 mA. Calculate the magnetic flux density of this electromagnet.

magnetic flux density = ...T [3]

[Total: 7]

3 **(a)** Define the *kilowatt-hour* (kW h).

....

....[1]

(b) On average, a student uses a computer of power rating 110 W for 4.0 hours every day. The computer draws a current of 0.48 A and its screen emits visible light of average wavelength 5.5×10^{-7} m.

(i) For a period of **one** week, calculate

1. the number of kilowatt-hours supplied to the computer

number of kW h = ...[2]

2. the cost of operating the computer.
(The cost of each kW h is 7.5p)

cost = ... p [1]

(ii) Calculate the electric charge drawn by the computer for a period of **one** week.

charge = ... C [3]

(iii) 1. Calculate the energy of each photon of wavelength 5.5×10^{-7}m emitted from the computer screen.

energy = ... J [3]

2. The power of the light emitted from the computer screen is 8.0 W. Calculate the total number of photons emitted per second from the computer screen.

number = ... s^{-1} [2]

[Total: 12]

4 Wave-particle duality suggests that an electron can exhibit both particle-like and wave-like properties. Fig. 4.1 shows the key features of an experiment to demonstrate the wave-like behaviour of electrons.

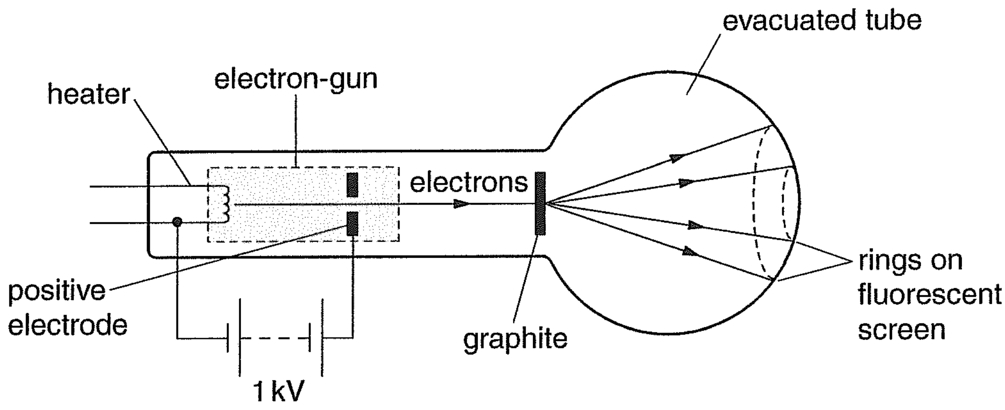


Fig. 4.1

The electrons are accelerated to high speeds by the electron-gun. These high speed electrons pass through a thin layer of graphite (carbon atoms) and emerge to produce rings on the fluorescent screen.

(a) In this question, two marks are available for the quality of written communication.

Use the ideas developed by de Broglie to explain how this experiment demonstrates the wave-like nature of electrons. Suggest what happens to the appearance of the rings when the speed of the electrons is increased.

....

....

....

....

....

....

....

....

....

....

....[5]

Quality of Written Communication [2]

For Examiner's Use

(b) Suggest how, within the electron-gun, this experiment provides evidence for the particle-like property of the electrons.

....

....[1]

[Total: 8]

Question 5 is over the page

For Examiner's Use

5 **(a)** Both electromotive force (e.m.f.) and potential difference (p.d.) may be defined as 'energy per unit charge'. With reference to energy transfers, state **one** major difference between e.m.f. and potential difference.

....

....[1]

(b) State Kirchhoff's first law.

....

....

....[2]

(c) Fig. 5.1 shows an electrical circuit in which the voltmeter has an infinite resistance.

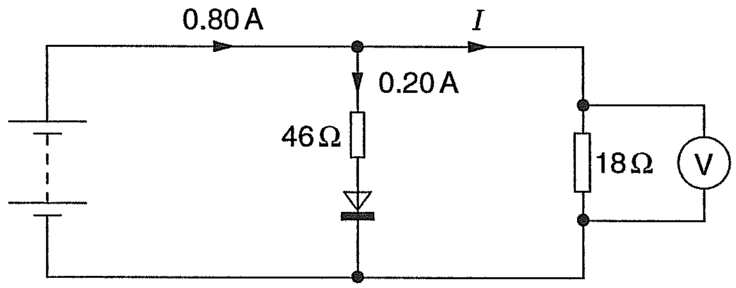


Fig. 5.1

Calculate

(i) the current I in the 18 Ω resistor

I = ... A [1]

(ii) the voltmeter reading

reading = ... V [2]

(iii) the resistance of the diode

resistance = ... Ω [3]

(iv) the power dissipated by the diode.

power = ... W [2]

[Total: 11]

Question 6 is over the page

For Examiner's Use

6 (a) Electrons are emitted from the surface of zinc when it is exposed to ultraviolet radiation.

(i) Name this phenomenon.

....[1]

(ii) State a typical value for the wavelength of ultraviolet radiation in metres.

....[1]

(b) Electromagnetic radiation incident on a metal plate releases energetic electrons from its surface. The metal plate is placed in an evacuated chamber. The energy of each photon is 2.8 eV. The metal has a work function energy of 1.1 eV.

(i) Explain what is meant by the *work function energy* of the metal.

....

....[1]

(ii) State the speed of the photons.

....[1]

(iii) For an electron emitted from the surface of the metal, calculate

1. its maximum kinetic energy in joules

energy = ... J [3]

2. its maximum speed.

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

(iv) State the change, if any, to your answer for the maximum speed of an electron emitted from the surface of the metal when the intensity of the incident electromagnetic radiation is doubled.

....

....[1]

[Total: 10]

END OF QUESTION PAPER