RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2826/01

Unifying Concepts in Physics

Thursday **17 JUNE 2004** Morning 1 hour 15 minutes

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

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 15 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.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	5	
3	16	
4	10	
5	17	
TOTAL	60	

This question paper consists of 12 printed pages.

SP (CW/SLM) S59686/5

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

[Turn over

Answer **all** the questions.

1 Make reasoned estimates of the following, giving your answer in SI units. A wide range of answers will be accepted provided they are consistent with your reasoning.

(a) The power of an electric kettle.

....

....

....[2]

(b) **(i)** The speed of a good sprinter.

....

....[2]

(ii) The speed of a car on a motorway.

....

....[1]

(iii) The kinetic energy of a good sprinter.

....

....[2]

(c) The resistance of a domestic light bulb when it is on.

....

....[2]

(d) The number density (number per unit volume) of molecules in the atmosphere, given that the density of air is about 1 kg m^{-3}.

....

....

....

....[3]

[Total: 12]

For Examiner's Use

2 Name the quantities which are defined below. They are all rates of change with time.

(a) The rate of change of displacement is the ....[1]

(b) The rate of change of electrical charge is the ....[1]

(c) The rate of change of velocity is the ....[1]

(d) The rate of change of the number of radioactive nuclei is the ....[1]

(e) The rate of doing work is the ....[1]

[Total: 5]

For Examiner's Use

3 **(a)** Outline **two** experiments which can be done to show that there are three different types of radiation from naturally occurring radioactive materials.

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....[5]

The apparatus for an experiment which showed that alpha particles are helium nuclei is illustrated in Fig. 3.1. It is a pipette, evacuated and sealed at one end, with the other end connected to a rubber U-tube filled with mercury. A strong alpha source, with an activity of 7.7×10^9 Bq and a very long half-life, is placed in the pipette.

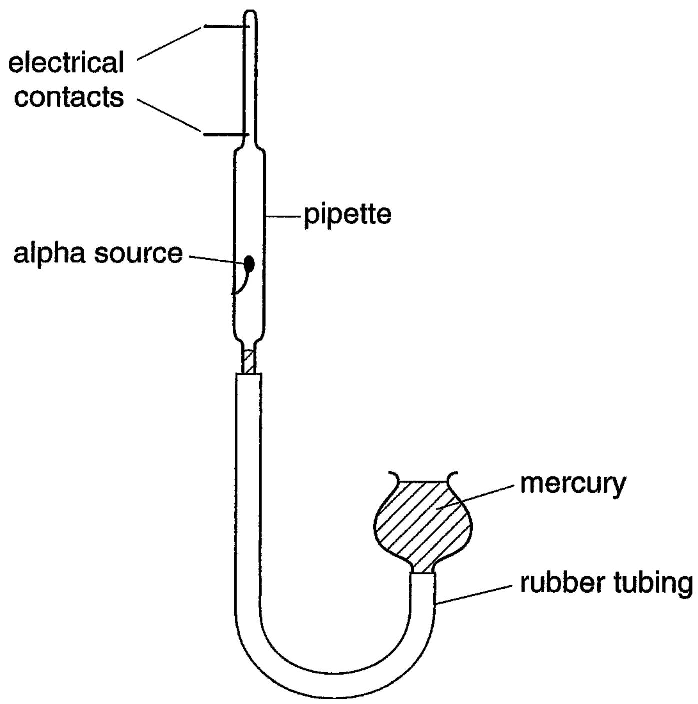


Fig. 3.1

For Examiner's Use

(b) **(i)** Show that the number of alpha particles which are emitted by the source in six weeks is 2.8×10^{16}.

....

....[1]

(ii) Why does your calculation in **(i)** depend on knowing that the alpha source has a long half-life?

....[1]

(iii) Calculate the number of moles of helium which have been formed during the six weeks.

number of moles = ... [2]

(iv) To become helium atoms, each alpha particle must gain two electrons. Where could 5.6×10^{16} electrons come from?

....[1]

(v) The volume of the pipette in which the helium is stored is $0.000050\,m^3$ and its temperature is 20 °C. Use the ideal gas equation to calculate the pressure of the helium at the end of the six weeks.

pressure = ... Pa [3]

(c) The pressure calculated in **(b)(v)** is very small, so at this stage the level of the mercury in the right hand tube is raised. This forces all the helium into the top, narrow part of the pipette, and so raises the pressure. This narrow part is fitted with two electrical contacts and when a high voltage is connected across them, the helium glows. It becomes a (dim) fluorescent lamp. State a possible range of values for the wavelength of the helium light. Suggest how it could be confirmed that this emitted light is from helium.

....

....

....

....

....

....[3]

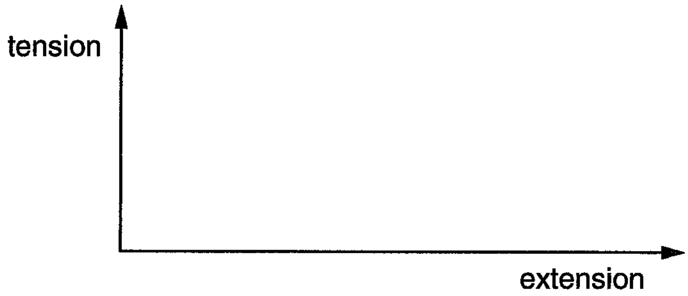
[Total: 16]

[Turn over

For Examiner's Use

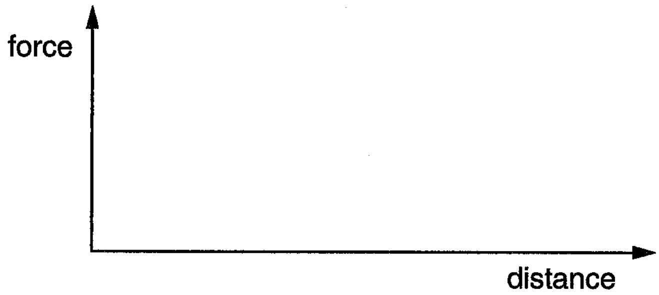
4 On the axes drawn, sketch graphs to show how the following quantities vary with distance.

(a) the tension in an elastic band



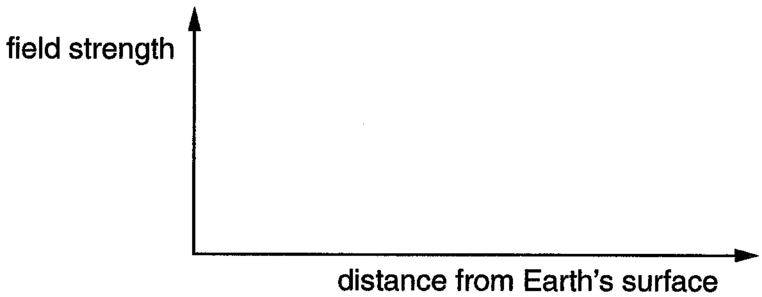
[2]

(b) the force required to pull up a weed from the ground



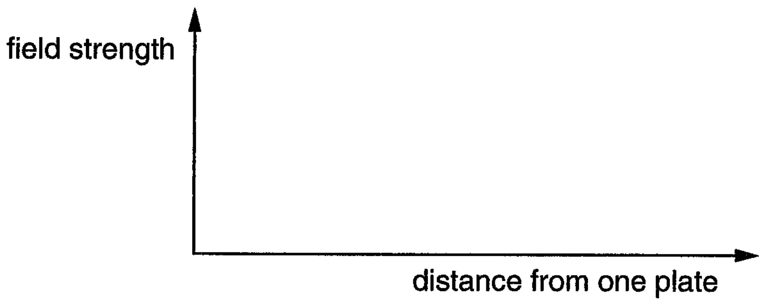
[2]

(c) the gravitational field strength as the distance from the Earth's surface increases



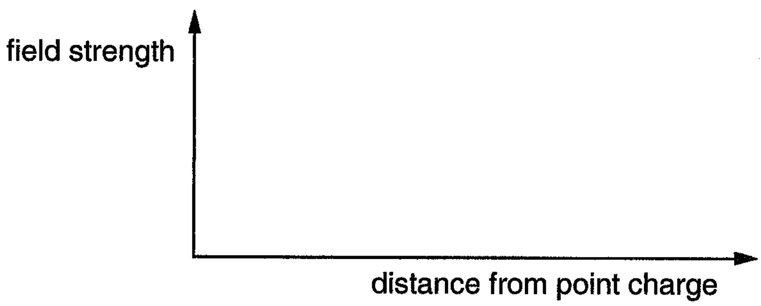
[2]

(d) the uniform electric field strength between charged parallel plates



[2]

(e) the electric field strength at a distance from a point charge



[2]

[Total: 10]

For Examiner's Use

5 Many homes have microwave cookers as well as conventional cookers. Microwaves of frequency 2450 MHz are used in them.

(a) (i) What type of waves are microwaves?

....[1]

(ii) Calculate the wavelength of microwaves of this frequency.

wavelength = ... m [2]

(b) The microwaves heat the food in the cooker because they cause water molecules in the food to oscillate with high amplitude at the same frequency as the microwaves. What name is given to this forced oscillation?

....[1]

(c) A 600 W microwave cooker is used to heat 0.20 kg of water from 20 °C to 100 °C. The specific heat capacity of water is $4200\ \text{J kg}^{-1}\ \text{K}^{-1}$. Calculate the time required for the heating.

time = ... s [2]

For Examiner's Use

(d) Microwave cookers are said to heat food quickly.

- Suggest why microwave cooking can be quicker than cooking in a conventional oven.
- Explain why a 1200 W ring (hotplate) heating 0.02 kg of water in a saucepan will take longer than the answer you obtained in **(c)**.
- Explain why it would be quicker to use a ring rather than a microwave oven if a large casserole needed to be heated up.

....

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....[5]

(e) The microwaves themselves are generated inside the cooker in a device known as a reflex klystron. In this klystron a beam of electrons from an electron gun pass up and down past a cylindrical cavity, as shown in Fig. 5.1. The electric fields of this beam cause stationary wave oscillations in the cavity in much the same way as a stream of air passing an organ pipe sets up stationary sound waves in the pipe.

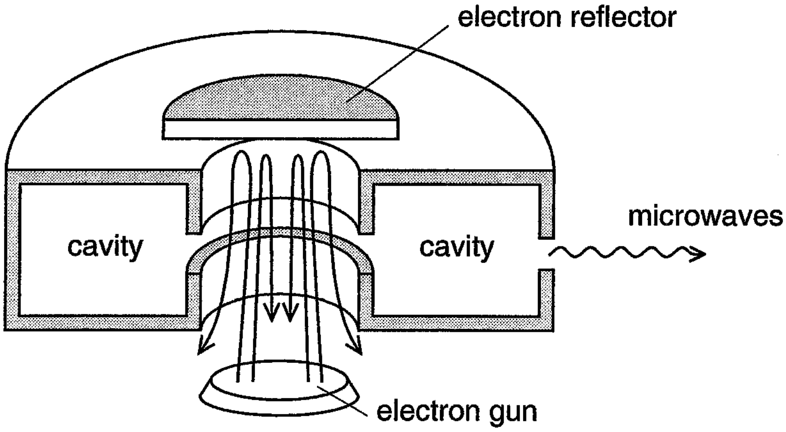

Fig. 5.1

For Examiner's Use

(i) What is meant by a *stationary* wave?

....

....

....

....[2]

(ii) One theory gives the radius r of the cylindrical cavity in terms of μ_0 the permeability of free space and ϵ_0 the permittivity of free space as

$$r = \frac{1}{\pi f \sqrt{\mu_0 \epsilon_0}}$$

where f, which equals 2450 MHz, is the microwave frequency. Use the values given on page 2 of this examination paper to find the radius of the klystron cavity used in microwave cookers.

radius = ... m [2]

(iii) What would be the effect on the size of microwave cookers if the frequency required was 245 MHz?

....[1]

(iv) Suggest the principle you would use in designing the electron reflector in the klystron in Fig. 5.1.

....

....[1]

[Total: 17]

END OF QUESTION PAPER