OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Tuesday **20 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 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	13	
2	10	
3	15	
4	12	
5	12	
6	12	
7	16	
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's Use

Answer **all** the questions.

1 **(a)** **(i)** Define *work*.

....

.... [2]

(ii) Show that power P is given by

$$P = Fv$$

where F is the force applied and v is the velocity.

....

....

.... [2]

(b) A cyclist pedalling along a horizontal road provides 200 W of power to the rear wheel, reaching a steady speed of $5.0\,m\,s^{-1}$. The total mass of cycle and cyclist is 120 kg.

Calculate

(i) the total kinetic energy of the cycle and cyclist

energy = ... J [2]

(ii) the total force resisting forward motion

force = ... N [2]

(iii) the distance travelled before coming to a halt when the cyclist stops pedalling. Assume the total resistive force is constant.

distance = ... m [2]

For Examiner's Use

(c) The cyclist reaches a hill of gradient 1 in 30. See Fig. 1.1.

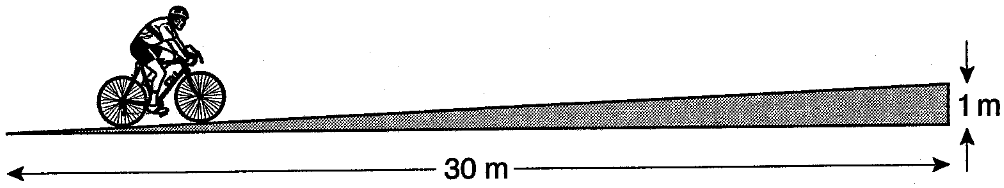

Fig. 1.1

The cyclist pedals harder to maintain a speed of $5.0\,m\,s^{-1}$. Assume that the total resistive force is unchanged.

Calculate the new power provided to the rear wheel.

power = ... W [3]

[Total: 13]

2 **(a)** Very high temperatures, for example, the temperature of the solar corona at half a million degrees, are often stated without a complete unit, i.e. degrees Celsius or kelvin.

Suggest why it is unnecessary to give degrees Celsius or kelvin in this case.

....

....

....

.... [2]

(b) Describe how the concept of an absolute zero of temperature arises from

(i) the ideal gas laws

....

....

....

.... [2]

(ii) the kinetic theory of an ideal gas.

....

....

....

.... [2]

(c) Two students attempt the same experiment to find how air pressure varies with temperature. They heat identical sealed glass flasks of air, to be considered as an ideal gas, in an oil bath. The flasks are heated from 300 K to 400 K. The pressure in flask A rises from atmospheric pressure, p_0, as expected, but the pressure in flask B remains at p_0 because the rubber bung is defective and air leaks out of the flask.

(i) Calculate the pressure in flask A at 400 K in terms of p_0.

pressure = ... [2]

For Examiner's Use

(ii) Calculate the fraction, *f*, of gas molecules in flask B compared to flask A at 400 K.

$$f = \frac{\text{number of gas molecules in B at 400 K}}{\text{number of gas molecules in A at 400 K}}$$

f = ... [2]

[Total: 10]

For Examiner's Use

3 **(a)** Define *electric field strength* at a point in space.

....

.... [2]

(b) Fig. 3.1 shows two point charges of equal magnitude, 1.6×10^{-19} C, and opposite sign, held a distance 8.0×10^{-10} m apart at points **A** and **B**. The charge at **A** is positive.

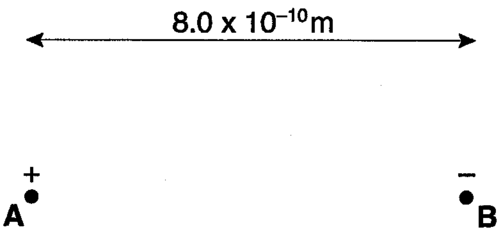

Fig. 3.1

(i) On Fig. 3.1, draw electric field lines to represent the field in the region around the two charges. [3]

(ii) Calculate the magnitude of the electric field strength at the mid point between the charges. Give a suitable unit for your answer.

electric field strength = ... unit .... [5]

For Examiner's Use

(c) Imagine two equal masses, connected by a light rigid link, carrying equal but opposite charges. This is a system called *a dipole*. Fig. 3.2 and Fig. 3.3 show the dipole placed in different orientations between two uniformly and oppositely charged plates.

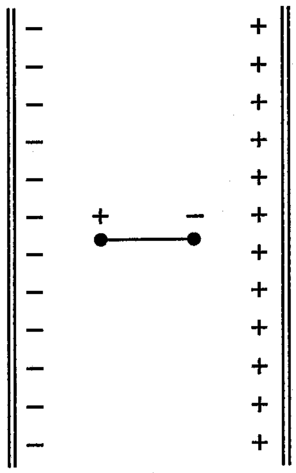

Fig. 3.2

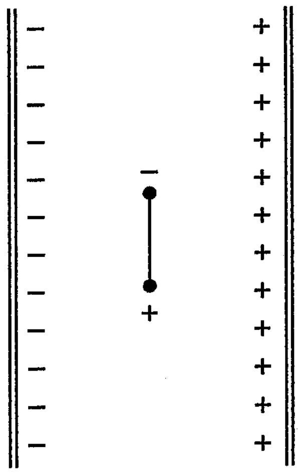

Fig. 3.3

Any effects of gravity are negligible.

(i) Describe the electric forces acting on the charges by drawing suitable arrows on the diagrams.

(ii) Explain the motion, if any, of the dipole when it is released from rest

in Fig. 3.2

....

....

....

in Fig. 3.3.

....

....

....

....

[5]

[Total: 15]

[Turn over

For Examiner's Use

4 Fig. 4.1 shows two capacitors, **A** of capacitance *C*, and **B** of capacitance 2 *C*, connected in parallel. Fig. 4.2 shows them connected in series. The capacitors can be connected by a two-way switch S either to a d.c. supply, of e.m.f. *V*, or to a voltmeter.

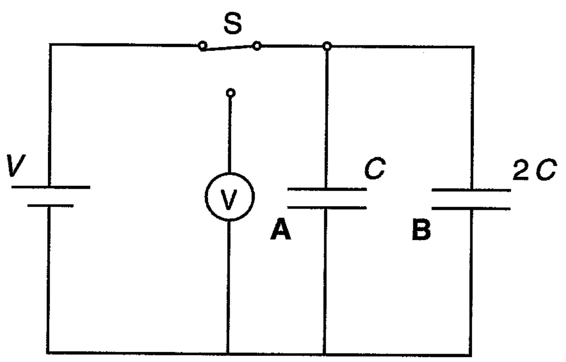

Fig. 4.1

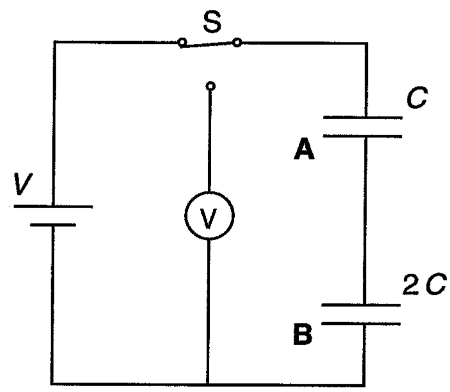

Fig. 4.2

(a) In terms of *C*, find the total capacitance of the capacitors

(i) when connected as in Fig. 4.1

capacitance = ... [1]

(ii) when connected as in Fig. 4.2.

capacitance = ... [2]

(b) For the circuit shown in Fig. 4.1, find

(i) in terms of *V*, the voltage across capacitor **A**

voltage = ... [1]

(ii) in terms of *V* and *C*, the total charge stored on the capacitors.

charge = ... [2]

(c) For the circuit shown in Fig. 4.2, find, in terms of V and C, the total energy stored in the two capacitors.

energy = ... [2]

(d) The switch S is changed to connect the charged capacitors to the voltmeter in both circuits.

(i) Explain why the capacitors will discharge, although possibly very slowly.

....

....

.... [2]

(ii) State which system will discharge more rapidly. Give a reason for your answer.

....

....

.... [2]

[Total: 12]

[Turn over

For Examiner's Use

5 **(a)** The radioactive nuclide $^{238}_{92}U$ decays by alpha-particle emission. The newly formed nuclide X is also unstable and decays by a different radioactive emission to a third nuclide Y. Y then decays to become another isotope of uranium, $^{234}_{92}U$.

(i) Explain the meaning of the term *isotope*.

....

.... [1]

(ii) Write down suitable symbols in the form $^{238}_{92}U$ for

an α-particle ....

a β-particle .... [2]

(iii) Show how $^{238}_{92}U$ can become the isotope $^{234}_{92}U$ after three decays.

[3]

(b) **(i)** The radioactive decay law can be written in the form

$$N = N_0 e^{-\lambda t}.$$

Explain the meaning of each of the following symbols.

N ....

N_0 ....

λ ....

.... [3]

For Examiner's Use

(ii) The uranium isotope $^{235}_{92}U$ was present at the formation of the Earth. Since then, the nuclei of this isotope have been decaying according to the decay law.

Calculate the fraction *f* of the original quantity of $^{235}_{92}U$ which remains on the Earth today.

half-life of $^{235}_{92}U = 7.1 \times 10^8$ y

age of the Earth = 4.6×10^9 y

f = ... [3]

[Total: 12]

For Examiner's Use

6 Read the short passage before answering the questions below.

Fig. 6.1 shows a section of a mass spectrometer. A beam of identical positively-charged ions, all travelling at the same speed, enters an evacuated chamber through a slit **S**. A uniform magnetic field directed vertically out of the plane of the diagram causes the ions to move along the semicircular path **SPT**. The beam exits the chamber through the slit at **T**.

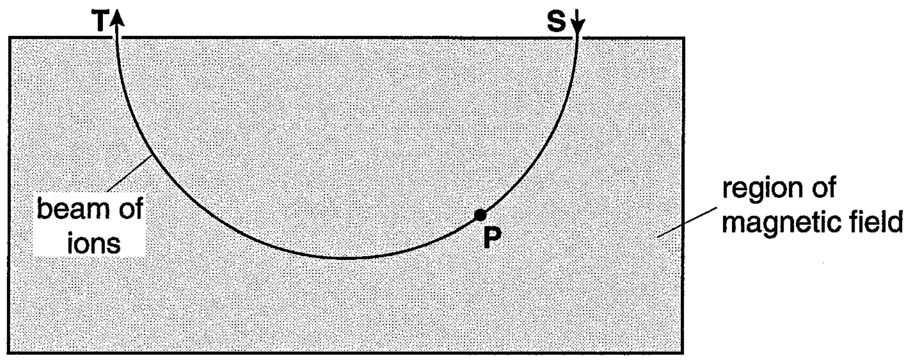

Fig. 6.1

(a) **(i)** On Fig. 6.1, draw an arrow to indicate the direction of the force on the ion beam at **P**. [1]

(ii) Name the rule you would use to verify that the ions are positively charged.

....

.... [1]

(iii) Explain why the ions follow a circular path in the chamber.

....

....

....

.... [2]

(b) Describe and explain the changes to the path of the ions for a beam of ions of greater mass but the same speed and charge.

....

....

....

....

.... [3]

For Examiner's Use

(c) The speed of the singly charged ions is $3.0 \times 10^5\,\mathrm{m\,s^{-1}}$ in the magnetic field of flux density 0.60 T. The mass of each ion is 4.0×10^{-26} kg.

(i) Show that the force on each ion in the beam in the magnetic field is about 3×10^{-14} N.

[2]

(ii) Calculate the radius of the semicircular path.

radius = ... m [3]

[Total: 12]

For Examiner's Use

7 In this question, four marks are available for the quality of written communication.

(a) Explain the meaning of the term *resonance*.

State **two** examples of oscillating systems in which resonance occurs; one being useful or beneficial and the other being a nuisance or harmful. Explain their practical significance. You may use diagrams in your answer.

State how the oscillation is driven in each case.

.... [7]

For Examiner's Use

(b) Describe how damping in vibrating systems affects their resonant properties. Give an example of a practical resonant system where **two** of the damping effects that you describe could be observed. A space has been left for you to draw suitable sketch graph(s), if you wish to illustrate your answer.

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.... [5]

Quality of Written Communication [4]

[Total: 16]

END OF QUESTION PAPER

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