OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2824

Forces, Fields and Energy

Monday **28 JANUARY 2002** Morning 1 hour 30 minutes

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

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 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	11	
2	13	
3	13	
4	14	
5	10	
6	13	
7	12	
QWC	4	
TOTAL	90	

This question paper consists of 15 printed pages and 1 blank page.

SPA (SLC/PW) S08708/6

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

[Turn over

For Examiner's Use

1 (a) (i) Define the *momentum* of a body.

....[1]

(ii) A body, initially at rest, explodes into two unequal fragments of mass m_1 and m_2. Mass m_1 has a velocity v_1 and mass m_2 has a velocity v_2. Using the principle of conservation of momentum, derive an expression for v_1/v_2.

[2]

(b) An isolated nucleus of mass 4.0×10^{-25} kg is initially at rest. It decays, emitting an alpha particle of mass 6.7×10^{-27} kg with kinetic energy of 1.2×10^{-14} J.

(i) Show that the speed of the alpha particle is about 2×10^6 m s^{-1}.

[2]

(ii) Calculate the momentum of the alpha particle.

momentum = ...kg m s^{-1} [1]

(iii) Hence find the speed of the recoiling nucleus.

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

(c) Before the decay described in **(b)** the nucleus is at point P on Fig. 1.1.

• P

Fig. 1.1

(i) Place a small cross on Fig. 1.1 at a possible position, to full scale, of the alpha particle 8.0×10^{-9} s after the emission. [1]

(ii) Indicate with an arrow, starting at P, the direction of movement of the recoiling nucleus. [1]

(iii) Estimate how far the recoiling nucleus has moved in 8.0×10^{-9} s.

distance = ...mm [1]

[Total : 11]

For Examiner's Use

2 Fig. 2.1 shows a ball at rest, hanging on a vertical thread from a fixed support, S.

Fig. 2.1

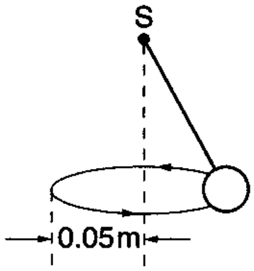

Fig. 2.2

(a) On Fig. 2.1 draw and label arrows to represent the two forces acting on the ball. [2]

(b) Fig. 2.2 represents the ball moving in a circle about a vertical axis through S. On Fig. 2.2 draw and label arrows to represent the two forces acting on the ball. Explain how they provide the force to make the ball move in a circular path.

....

....

....

....[3]

(c) The ball has a mass of 0.020 kg and moves in a circle of radius 0.050 m at 1.2 revolutions per second. Assume that the thread supporting the ball has negligible mass. Calculate

(i) the speed of the ball

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

(ii) the magnitude of the force which keeps the ball moving in a circular path.

force = ... N [3]

(d) Predict and explain the difference in the path of the ball when it is rotating at a higher speed.

....

....

....

....[3]

[Total : 13]

[Turn over

For Examiner's Use

3 **(a)** Define *simple harmonic motion.*

....

....

....

....[2]

(b) Fig. 3.1 shows a mass suspended from a spring beside a ruler. When the mass is pulled down and released, it oscillates with simple harmonic motion. Fig. 3.2 shows the variation of the position of the mass with time, starting at the moment of release.

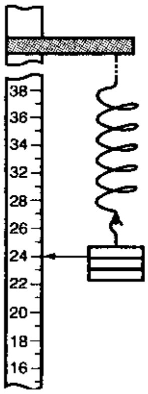

Fig. 3.1

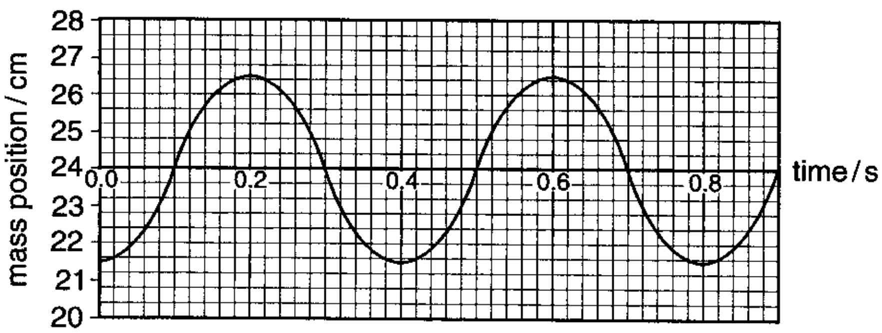

Fig.3.2

(i) Use Fig. 3.2 to determine,

1 the amplitude of the oscillation

amplitude = ...m [2]

2 the frequency of the oscillation.

frequency= ....Hz [2]

(ii) Hence find the maximum acceleration of the mass.

acceleration = ... m s^{-2} [2]

(iii) Use Fig. 3.2. to state a time at which

1 the mass has maximum speed

time = ... s [1]

2 the mass has maximum acceleration.

time= .... s [1]

(c) On the axes of Fig. 3.3 sketch the variation with time *t* of the acceleration *a* of the mass. Add a suitable scale on the *y*-axis.

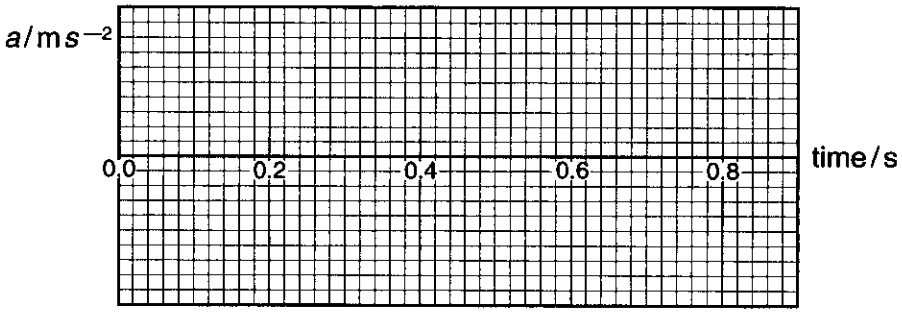

Fig. 3.3

[3]

[Total : 13]

4 Fig. 4.1 shows two horizontal parallel metal plates, 1.2×10^{-2} m apart, connected to a 600 V power supply.

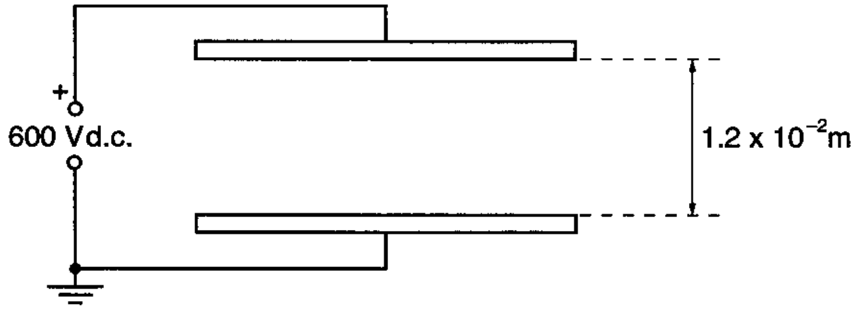

Fig. 4.1

(a) (i) On Fig. 4.1 draw lines to represent the electric field between the central region of the plates. [2]

(ii) Calculate the electric field strength between the plates, expressing your answer with a suitable unit.

electric field strength = ...[3]

(b) (i) Explain how the plates act as a capacitor.

....

....[1]

(ii) The capacitance of the plates is 1.0×10^{-12} F. Calculate

1 the charge stored on the plates

charge =..................................C [1]

2 the energy stored in the charged capacitor.

energy = ...J [2]

(c) A tiny sphere of weight 3.3×10^{-14} N has acquired a charge so that it is held in equilibrium midway between the plates by the electric field. See Fig. 4.2.

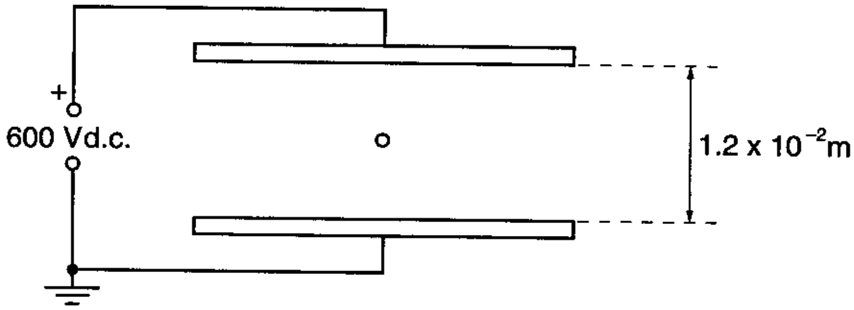

Fig. 4.2

(i) State the magnitude and direction of the electric force on the sphere.

magnitude = ...N

direction = ... [1]

(ii) Calculate the magnitude of the charge on the sphere.

charge =..................................C [2]

(iii) The voltage between the plates is doubled suddenly. Describe the motion of the sphere.

....

....

....[2]

[Total : 14]

For Examiner's Use

5 **(a)** An aircraft is flying horizontally at a constant speed v close to the North Pole. Fig. 5.1 shows the aircraft viewed from above. The vertical component B of the Earth's magnetic field is indicated by crosses.

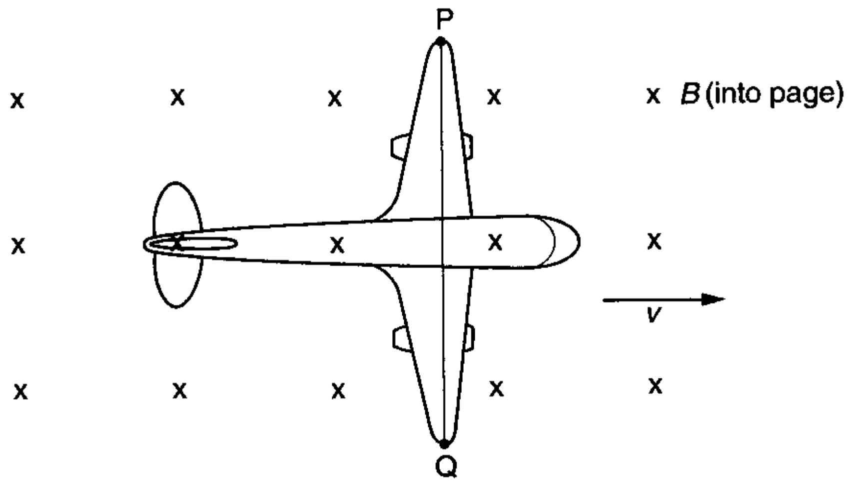

Fig. 5.1

(i) A wire stretches from wing tip P to wing tip Q. Each free electron, charge $-e$, in the wire experiences a force along the wire. Write down an expression for this force.

....[1]

(ii) On Fig. 5.1 mark with an arrow the direction of this force. [1]

(iii) Explain why a steady voltage is induced between the wing tips.

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For Examiner's Use

(b) The vertical component *B* of the Earth's magnetic field is 5.0×10^{-5} T. The aircraft is flying at 200 m s^{-1}. The distance PQ between the wing tips is 40 m.

(i) Calculate the force exerted by the magnetic field on each electron in the wire.

force = ... N [2]

(ii) Hence, or otherwise, calculate the voltage induced between the wing tips.

voltage = ... V [3]

[Total : 10]

[Turn over

For Examiner's Use

6 Carbon-14 is a radioactive isotope of carbon which decays by β^- emission with a *half life* of 5700 years.

(a) **(i)** Explain the meaning of the term *half life*.

....

....[1]

(ii) What is the composition of a $^{14}_{6}C$ nucleus?

....[2]

(b) $^{14}_{6}C$ is produced when a nitrogen nucleus $^{14}_{7}N$ first absorbs a neutron in the atmosphere and then the resulting nuclide emits a proton.

(i) State the nuclear reaction equation for the production of $^{14}_{6}C$ from $^{14}_{7}N$.

....[2]

(ii) Write down the stable nuclide into which $^{14}_{6}C$ decays by β^- emission.

....[2]

(c) Living plants absorb carbon dioxide from the atmosphere, a small quantity of which contains $^{14}_{6}C$. The β^- activity A_0 from a living plant remains constant but once the plant dies, the activity decays according to the expression

$$A = A_0 \, e^{-\lambda t}$$

where A is the activity at time t.

Calculate

(i) the decay constant λ for $^{14}_{6}C$

decay constant = ...y^{-1} [2]

(ii) the quantity $f = \dfrac{\text{the activity after 40 000 years}}{\text{the initial activity } A_0}$

f = ... [2]

(d) 'For objects over 40 000 years old the ${}^{14}_{6}C$ β^- emission becomes indistinguishable from the background count'. Explain the implications of this statement, making clear the meaning of the term *background count*.

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....[2]

[Total : 13]

7 **(a)** (*In this question, 4 marks are available for the quality of written communication.*)

Explain what is meant by *internal energy*. Suggest how the internal energy of a *real* gas differs from that of an *ideal* gas.

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....[4]

Question 7 continued over the page.

[Turn over

For Examiner's Use

(b) Describe the changes which occur to the *internal energy* and the *state of matter* as a gas is cooled from room temperature to near absolute zero. Include in your answer, where appropriate, a description of the changes on the molecular scale.

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[Total : 12]

Quality of written communication [4]