OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2824

Forces, Fields and Energy

Thursday **15 JUNE 2006** 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	**11**	
2	**12**	
3	**14**	
4	**11**	
5	**13**	
6	**13**	
7	**16**	
TOTAL	**90**	

This question paper consists of 18 printed pages and 2 blank pages.

SP (NF/CGW) S89416/6

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

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

current, $I = nAve$

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

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

For Examiner's Use

Answer **all** the questions.

1 This question is about pressing a red hot bar of steel into a sheet in a rolling mill.

(a) A bar of steel of mass 500 kg is moved on a conveyor belt at 0.60 m s^{-1}.
Calculate the momentum of the bar giving a suitable unit for your answer.

momentum = ... unit .... [2]

(b) From the conveyor belt, the bar is passed between two rollers, shown in Fig. 1.1. The bar enters the rollers at 0.60 m s^{-1}. The rollers flatten the bar into a sheet with the result that the sheet leaves the rollers at 1.8 m s^{-1}.

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Details: A diagram of a steel bar on a conveyor belt being passed between two rollers

Fig. 1.1

(i) Explain why there is a resultant horizontal force on the bar at the point immediately between the rollers.

....

....

....

....[2]

(ii) Draw an arrow on Fig. 1.1 at this point to show the direction of the force. [1]

(iii) The original length of the bar is 3.0 m. Calculate the time it takes for the bar to pass between the rollers.

time = ... s [1]

(iv) Calculate the magnitude of the resultant force on the bar during the pressing process.

force = ... N [3]

(c) To monitor the thickness of the sheet leaving the rollers, a radioactive source is placed below the sheet and a detector is placed above the sheet facing the source. State, with a reason, which radioactive emission would be suitable for this task. Assume that the thickness of the sheet is about 20 mm.

....

....

....

....[2]

[Total: 11]

For Examiner's Use

2 **(a)** Fig. 2.1 shows a graph of the variation of the gravitational field strength g of the Earth with distance r from its centre.

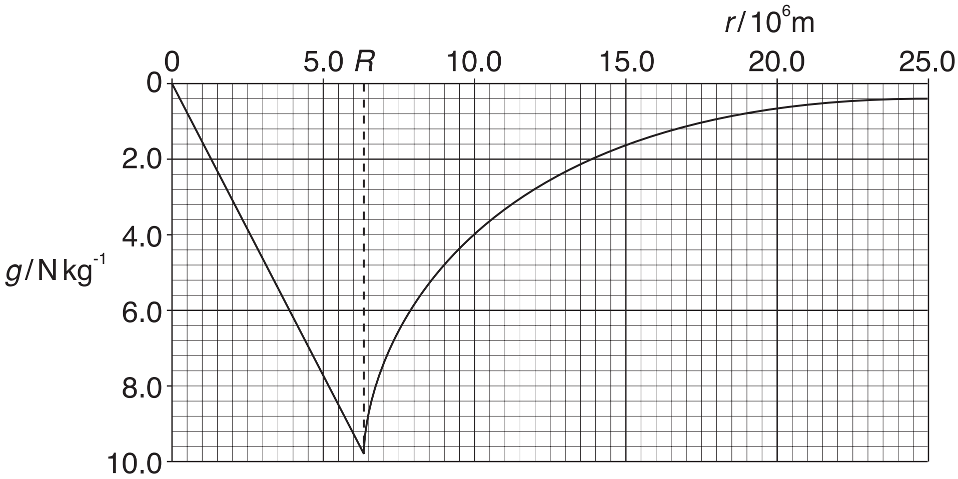

Fig. 2.1

(i) Define *gravitational field strength at a point*.

....

....[1]

(ii) Write down an algebraic expression for the gravitational field strength g at the surface of the Earth in terms of its mass M, its radius R and the universal gravitational constant G.

[1]

(iii) Use data from Fig. 2.1 and the value of G to show that the mass of the Earth is 6.0×10^{24} kg.

[2]

(iv) State which feature of the graph in Fig. 2.1 indicates that the gravitational field strength at a point below the surface of the Earth, assumed to be of uniform density, is proportional to the distance from the centre of the Earth.

....

....[1]

For Examiner's Use

(v) Calculate the **two** distances from the centre of the Earth at which $g = 0.098\,\mathrm{N\,kg^{-1}}$. Explain how you arrived at your answers.

distance 1 ....

....

....[2]

distance 2 ....

....

....[2]

(b) A spacecraft on a journey from the Earth to the Moon feels no resultant gravitational pull from the Earth and the Moon when it has travelled to a point 0.9 of the distance between their centres. Calculate the mass of the Moon, using the value for the mass of the Earth in **a(iii)**.

mass = ... kg [3]

[Total: 12]

3 The external wing mirror of a large vehicle is often connected to the body of the vehicle by a long metal arm. See Fig. 3.1. The wing mirror assembly sometimes behaves like a mass on a spring, with the mirror oscillating up and down in simple harmonic motion about its equilibrium position. The graph of Fig. 3.2 shows a typical oscillation.

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Details: A diagram of a wing mirror attached to the body of a vehicle by a long metal arm

Fig. 3.1

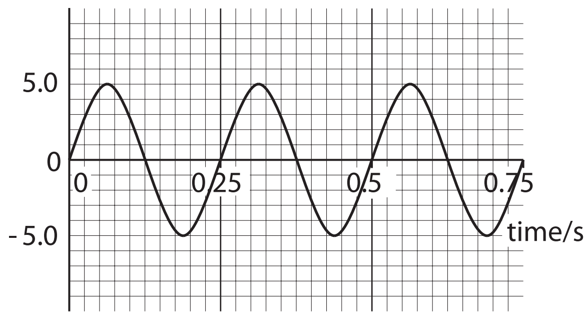

Fig. 3.2

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

....

....

....[2]

(ii) Calculate the frequency of oscillation of the wing mirror.

frequency = ... Hz [2]

(iii) Calculate the maximum acceleration of the wing mirror.

acceleration = ... m s^{-2} [3]

For Examiner's Use

(b) With the vehicle at rest and the engine running slowly at a particular number of revolutions per second, the wing mirror oscillates significantly, whereas at other engine speeds the mirror hardly moves.

(i) Explain how this phenomenon is an example of resonance.

....

....

....

....

....

....

....[3]

(ii) Suggest, giving a reason, **one** change to the motion of the mirror

1 for a mirror of greater mass

....

....

....

....[2]

2 for a metal arm of greater stiffness.

....

....

....

....[2]

[Total: 14]

For Examiner's Use

4 This question is about the discharge of combinations of capacitors.

In Figs. 4.1 and 4.2, the capacitors are charged through a 10 kΩ resistor from a 10 V d.c. supply when the switch **S** is connected to **X**. They discharge when the switch is moved to **Y**. The ammeters A_1, A_2, A_3 and A_4 monitor the currents in the circuits. Initially, the switch is connected to **X** and the capacitors are fully charged.

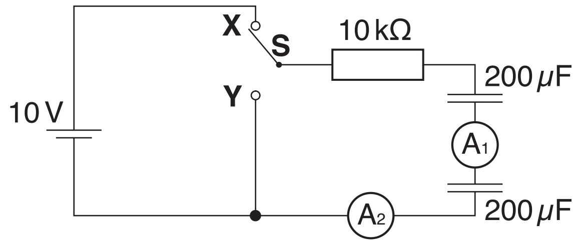

Fig. 4.1

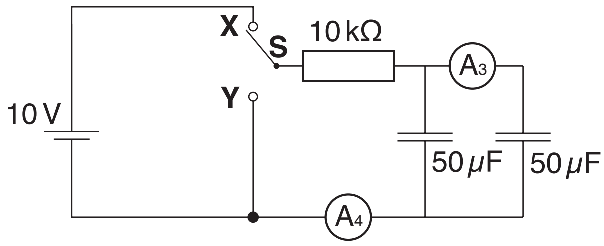

Fig. 4.2

(a) State

(i) the voltage across each capacitor in Fig. 4.1 .... V [1]

(ii) the voltage across each capacitor in Fig. 4.2 .... V [1]

(b) **(i)** Calculate the total charge stored in the circuit of Fig. 4.2.

charge = ... C [2]

(ii) Explain why the total charge stored in the circuit of Fig. 4.1 is the same as in the circuit of Fig. 4.2.

....

....

....

....[2]

For Examiner's Use

(c) Fig. 4.3 shows how the reading I on ammeter A_2 in the circuit of Fig. 4.1 varies with time t as the capacitors discharge, after the switch is moved from **X** to **Y** at $t = 0$.

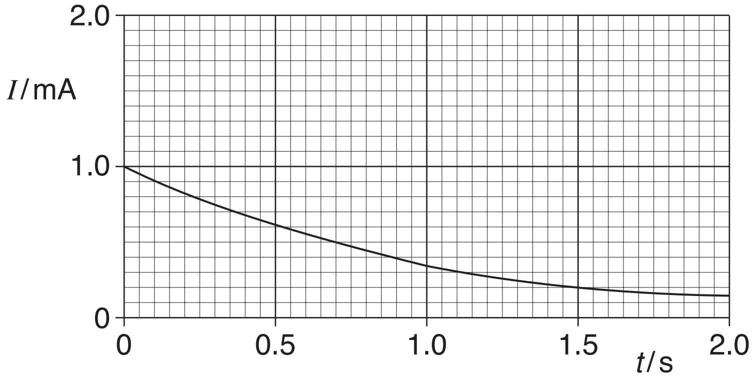

Fig. 4.3

(i) Describe how and explain why the reading on ammeter A_1 varies, if at all, over the same time interval.

....

....

....[2]

(ii) Sketch curves on Fig. 4.3 to show how you expect the readings on ammeters A_3 and A_4 to vary with time from $t = 0$, when the switch is moved from **X** to **Y** in Fig. 4.2. Label your curves $\mathbf{A_3}$ and $\mathbf{A_4}$ respectively. [3]

[Total: 11]

For Examiner's Use

5 A nitrogen atom is initially stationary at point **P** in Fig. 5.1, midway between two large horizontal parallel plates in an evacuated chamber. The nitrogen atom becomes charged. There is an electric field between the plates. Ignore any effects of gravity.

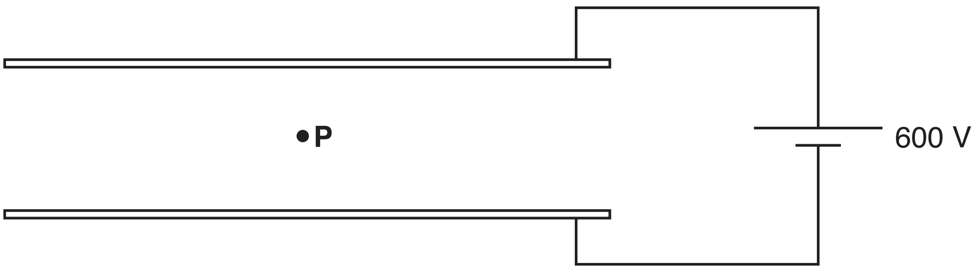

Fig. 5.1

(a) The direction of the electric force on the nitrogen ion is vertically downwards. State with a reason the sign of the charge on the ion.

....

....

....[1]

(b) The voltage between the plates is 600 V. At the instant that the ion, charge 1.6×10^{-19} C and mass 2.3×10^{-26} kg, reaches the lower plate, show that

(i) the kinetic energy of the ion is 4.8×10^{-17} J

[2]

(ii) the speed of the ion is 6.5×10^{4} m s^{-1}.

[2]

(c) The electric field strength between the plates is 4.0×10^{4} N C^{-1}. Calculate the separation of the plates.

separation = ... m [2]

(d) The ion passes through a hole in the lower plate at a speed of $6.5 \times 10^4\ \mathrm{m\,s^{-1}}$. It enters a region of uniform magnetic field of flux density 0.17 T perpendicularly into the plane of Fig. 5.2.

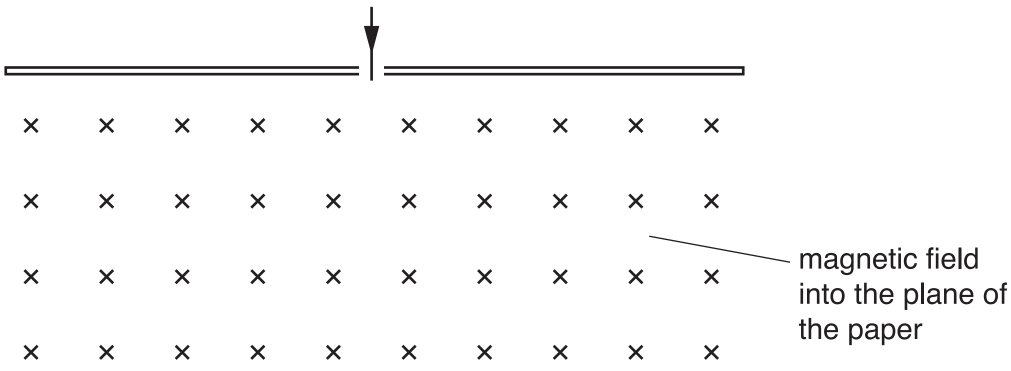

Fig. 5.2

(i) Sketch on Fig. 5.2 the semicircular path taken by the ion. [1]

(ii) Calculate how far from the hole the ion will collide with the plate. Use data from **(b)**.

distance = ... m [5]

[Total: 13]

[Turn over

For Examiner's Use

6 The radioactive radium nuclide $^{226}_{88}Ra$ decays by alpha-particle emission to an isotope of radon Rn with a half-life of 1600 years.

(a) State the number of

(i) neutrons in a radium nucleus ....[1]

(ii) protons in the radon nucleus resulting from the decay ....[1]

(b) The historic unit of radioactivity is called the curie and is defined as the number of disintegrations per second from 1.0 g of $^{226}_{88}Ra$. Show that

(i) the decay constant of the radium nuclide is $1.4 \times 10^{-11}\,s^{-1}$

1 year = 3.16×10^{7} s

[1]

(ii) 1 curie equals 3.7×10^{10} Bq.

[3]

(c) Use the data below to show that the energy release in the decay of a single nucleus of $^{226}_{88}Ra$ by alpha-particle emission is 7.9×10^{-13} J.

nuclear mass of Ra-226 = 226.0254 u
nuclear mass of Rn-222 = 222.0175 u
nuclear mass of He = 4.0026 u

[3]

(d) Estimate the time it would take a freshly made sample of radium of mass 1.0 g to increase its temperature by 1.0 °C. Assume that 80% of the energy of the alpha-particles is absorbed within the sample so that this is the energy which is heating the sample. Use data from **(b)** and **(c)**.

specific heat capacity of radium = 110 J kg^{-1} K^{-1}

time = ... s [4]

[Total: 13]

For Examiner's Use

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

This question is about electromagnetic induction.

(a) State Faraday's law of electromagnetic induction. Explain the terms *magnetic flux* and *magnetic flux linkage* which you may have used in your statement of the law.

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....[5]

(b) Fig. 7.1 shows a simple a.c. generator used for demonstrations in the laboratory. It consists of a magnet being rotated inside a cavity in a soft iron core. The output from the coil, wound on the iron core, is connected to an oscilloscope.

A diagram has been removed due to third party copyright restrictions

Details: A diagram showing a simple a.c. generator consisting of a rotating magnet inside a cavity in a soft iron core

Sketch on the grid of Fig. 7.2 a typical output voltage which would be seen on the oscilloscope screen. State and explain, using Faraday's law and/or the terms given in **(a)**, how doubling each of the following factors will alter this output voltage:

- the speed of rotation of the magnet
- the number of turns on the coil

Finally, explain how the output voltage would be different if the soft iron core were removed, leaving the magnet and coil in the same positions.

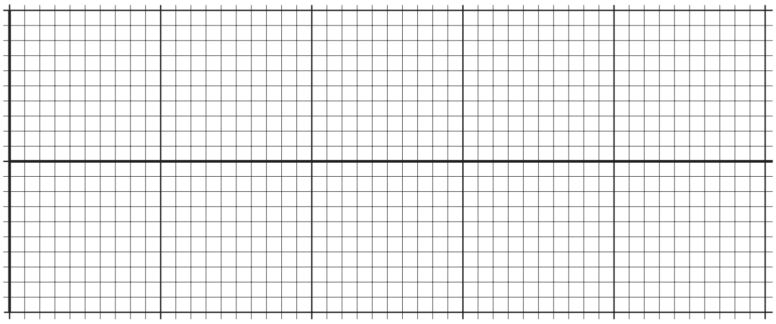

Fig. 7.2

....[7]

Quality of Written Communication [4]

[Total: 16]

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