OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2824**

PHYSICS A

Forces, Fields and Energy

MONDAY 22 JANUARY 2007 *Morning*

Time: 1 hour 30 minutes

Additional materials: Electronic Calculator

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate number in the boxes above.
- *Answer **all** the questions.*
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

INFORMATION FOR CANDIDATES

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 90.
- 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	**12**	
4	**14**	
5	**13**	
6	**13**	
7	**15**	
TOTAL	**90**	

This document consists of **18** printed pages and **2** blank pages.

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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, $p = \frac{1}{3} \dfrac{Nm}{V} \langle c^2 \rangle$

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

Answer **all** the questions.

1 This question is about an alpha particle making a head on collision with a gold nucleus.

(a) **(i)** When the alpha particle is at a large distance from the gold nucleus it has a kinetic energy of 7.6×10^{-13} J. Show that its speed is about 1.5×10^{7} m s^{-1}.

mass of alpha particle = 6.6×10^{-27} kg

[2]

(ii) As the alpha particle approaches the gold nucleus, it slows down and the gold nucleus starts to move, Fig. 1.1.

Fig.1.1

Explain this and explain how it is possible to calculate the speed of the gold nucleus.

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.... [3]

(iii) Fig.1.2 shows the alpha particle and the gold nucleus at the distance of closest approach. At this instant the gold nucleus is moving with speed V and the alpha particle is stationary.

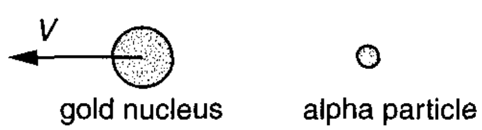

Fig. 1.2

Calculate the speed V of the gold nucleus.

mass of gold nucleus = 3.0×10^{-25} kg

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

(iv) The alpha particle bounces back. Its final speed approximately equals its initial speed of approach. Assume that the mean force on the nucleus is 9.0 N during the interaction. Estimate the time of the collision.

time = ... s [2]

(b)

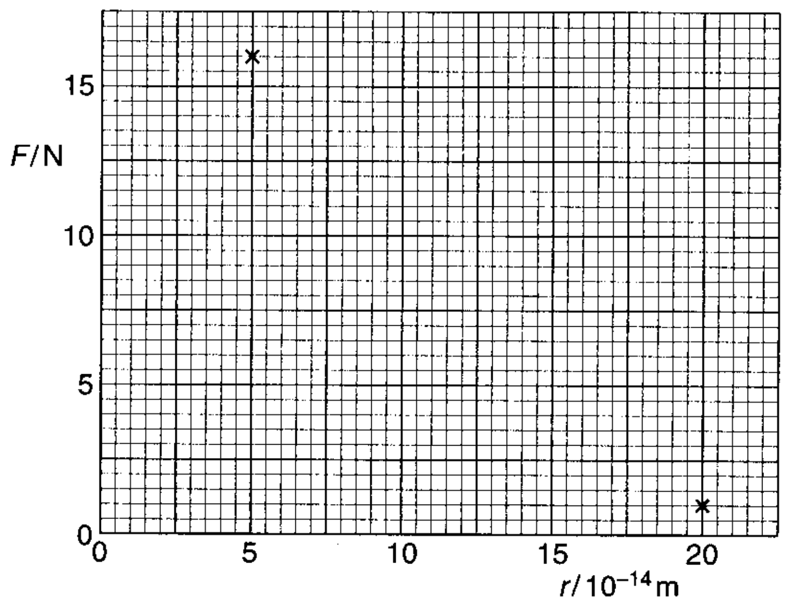

Fig. 1.3

(i) Fig. 1.3 shows two points on the graph of the electrostatic repulsive force F between the alpha particle and nucleus against their separation r. The particle and the nucleus are being treated as point charges. Use data from the graph to calculate the values of the force at distances $r = 10 \times 10^{-14}$ m and 15×10^{-14} m.

F at 10×10^{-14} m =................N

F at 15×10^{-14} m =................N [3]

(ii) Plot the two points on the graph and draw the curve. [1]

[Total: 13]

2 **(a)** Explain what is meant by the *internal energy* of a gas.

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....[2]

(b) A bicycle tyre has a volume of $2.1 \times 10^{-3}\,m^3$. On a day when the temperature is 15 °C the pressure of the air in the tyre is 280 kPa. Assume that air behaves as an ideal gas.

(i) Calculate the number of moles *n* of air in the tyre.

n = ... mol [3]

(ii) The bicycle is ridden vigorously so that the tyres warm up. The pressure in the tyre rises to 290 kPa. Calculate the new temperature of the air in the tyre. Assume that no air has leaked from the tyre and that the volume is constant.

temperature = ... °C [3]

(iii) Calculate, for the air in the tyre, the ratio

$$\frac{\text{internal energy at the higher temperature}}{\text{internal energy at 15°C}} .$$

ratio = ...

Justify your reasoning.

....

....[2]

[Total: 10]

3 The electric motor in a washing machine rotates the drum containing the clothes by means of a rubber belt stretched around two pulleys, one on the motor shaft and the other on the drum shaft, as shown in Fig. 3.1.

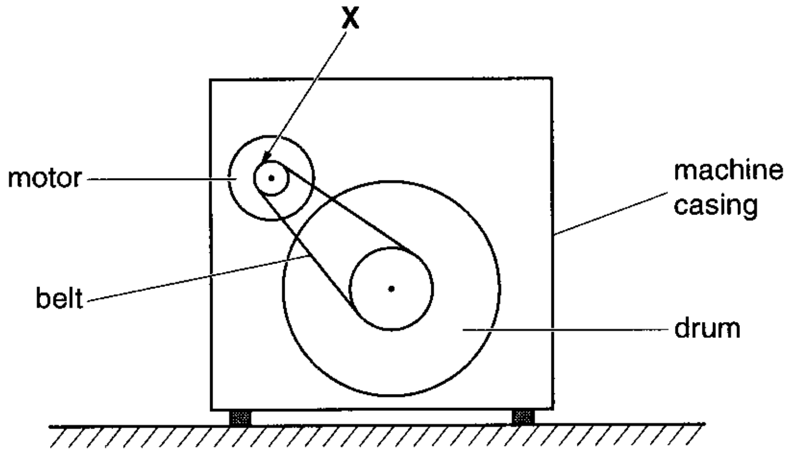

Fig. 3.1

(a) The motor pulley of radius 15 mm rotates at 50 revolutions per second. Calculate

(i) the speed of the belt

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

(ii) the centripetal acceleration of the belt at point **X**.

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

(iii) When the motor speed is increased, the belt can start to slip on the motor pulley. Explain why the belt slips.

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.... [2]

(b) When the drum is rotated at one particular speed, a metal side panel of the machine casing vibrates loudly. Explain why this happens.

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....[2]

(c) A fault develops in the motor, causing the coil to stop rotating. Magnetic flux from the electromagnet of the motor still links with the now stationary coil. Fig. 3.2 shows how the flux linkage of the coil varies with time.

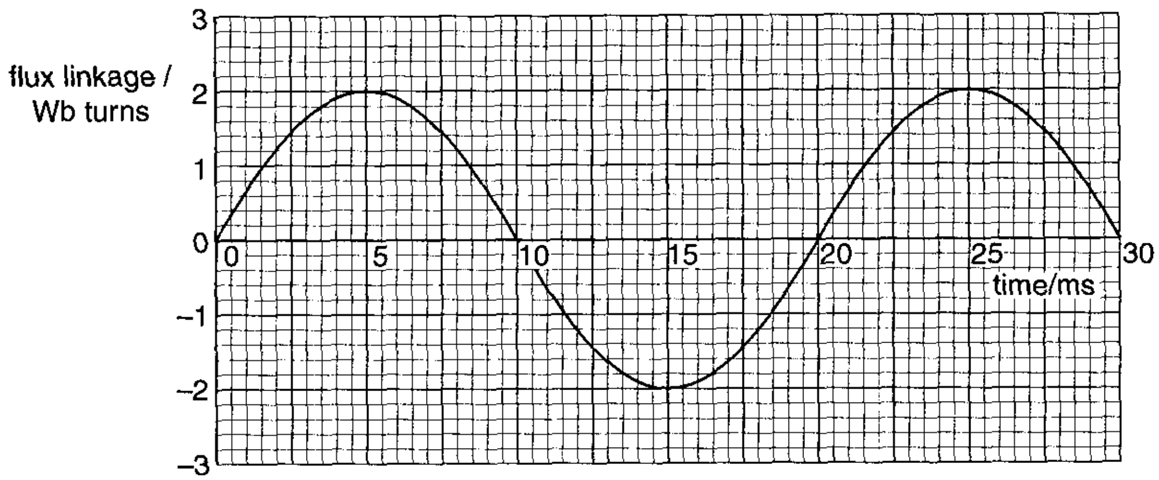

Fig. 3.2

(i) Using Fig. 3.2 state a time at which the e.m.f. induced across the ends of the coil is

1 zero .... ms

2 a maximum. .... ms [2]

(ii) Use the graph of Fig. 3.2 to calculate the peak value of the e.m.f. across the ends of the coil.

peak e.m.f. = ... V [2]

[Total: 12]

4 Fig. 4.1 shows a football balanced above a metal bench on a length of plastic drain pipe. The surface of the ball is coated with a smooth layer of an electrically conducting paint. The pipe insulates the ball from the bench.

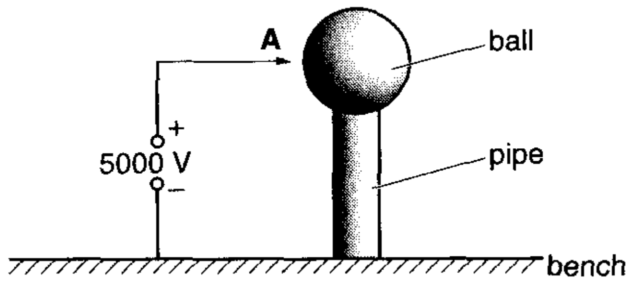

Fig. 4.1

(a) The ball is charged by touching it momentarily with a wire **A** connected to the positive terminal of a 5000 V power supply. The capacitance C of the ball is 1.2×10^{-11} F. Calculate the charge Q_0 on the ball. Give a suitable unit for your answer.

Q_0 = ……………unit ……..[3]

(b) The charge on the ball leaks slowly to the bench through the plastic pipe, which has a resistance R of $1.2 \times 10^{15}\ \Omega$.

(i) Show that the time constant for the ball to discharge through the pipe is about 1.5×10^4 s.

[1]

(ii) Show that the initial value of the leakage current is about 4×10^{-12} A.

[1]

(iii) Suppose that the ball continues to discharge at the constant rate calculated in **(ii)**. Show that the charge Q_0 would leak away in a time equal to the time constant.

[2]

(iv) Using the equation for the charge Q at time t

$$Q = Q_0 e^{-t/RC}$$

show that, in practice, the ball only loses about 2/3 of its charge in a time equal to one time constant.

[2]

(c) The ball is recharged to 5000V by touching it momentarily with wire **A**. The ball is now connected in parallel via wire **B** to an uncharged capacitor of capacitance 1.2×10^{-8} F and a voltmeter as shown in Fig. 4.2.

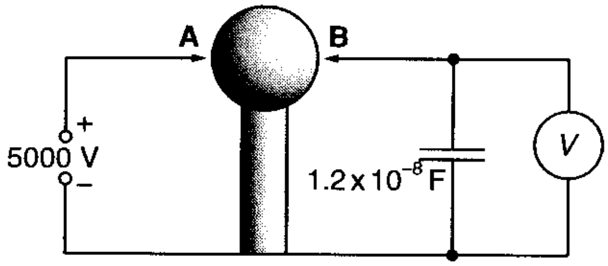

Fig. 4.2

(i) The ball and the uncharged capacitor act as two capacitors in parallel. The total charge Q_0 is shared instantly between the two capacitors. Explain why the charge left on the ball is $Q_0/1000$.

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....[3]

(ii) Hence or otherwise calculate the initial reading V on the voltmeter.

V = ... V [2]

[Total: 14]

5 This question is about the electron beam inside a television tube.

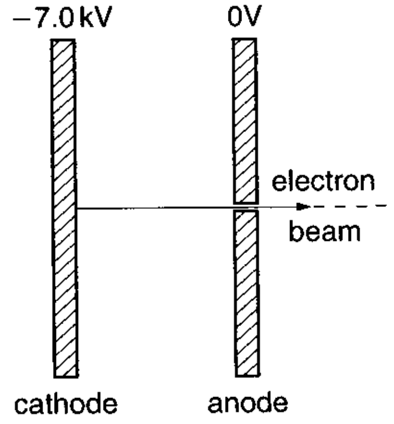

Fig. 5.1

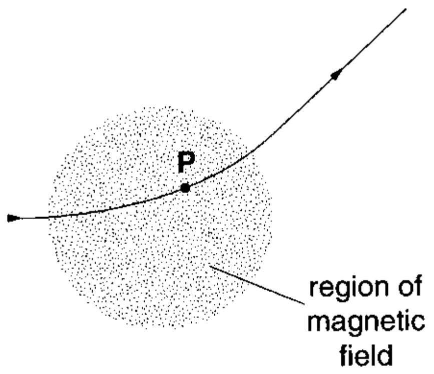

Fig. 5.2

(a) Fig. 5.1 shows a section through a simplified model of an electron gun in an evacuated TV tube.

(i) On Fig. 5.1 draw electric field lines to represent the field between the cathode and the anode. [2]

(ii) The electrons, emitted at negligible speed from the cathode, are accelerated through a p.d. of 7.0 kV. Show that the speed of the electrons at the anode is about $5.0 \times 10^7\,\text{m s}^{-1}$.

[2]

(b) Some electrons pass through a small hole in the anode. They enter a region of uniform magnetic field shown by the shaded area in Fig. 5.2. They follow a circular arc in this region before continuing to the TV screen.

(i) Draw an arrow through the point labelled **P** to show the direction of the force on the electrons at this point. [1]

(ii) State the direction of the magnetic field in the shaded area. Explain how you arrived at your answer.

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....[2]

(iii) Calculate the radius of the arc of the path of the electron beam when the value of the magnetic flux density is 3.0×10^{-3} T.

radius = ... m [4]

(c) The region of uniform magnetic field is created by the electric current in an arrangement of coils. Suggest how the end of the electron beam is swept up and down the TV screen.

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.... [2]

[Total: 13]

6 This question is about the decay of an isotope of bismuth, $^{212}_{83}Bi$.

(a)

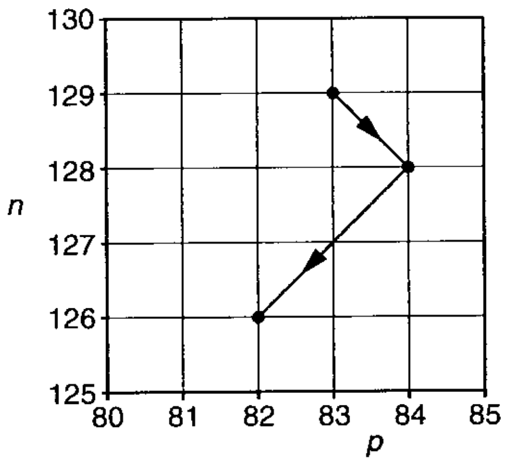

Fig. 6.1

Fig. 6.1 shows a small region of the chart of neutron number *n* against proton number *p*. An isotope of bismuth, Bi, decays to an isotope of lead, Pb, in two stages along the path shown by the two arrows on Fig. 6.1.
Complete the nuclear equations which describe these two decays.

(i) $^{212}_{83}Bi \rightarrow {}^{---}_{84}Po + ------$ [2]

(ii) $^{---}_{84}Po \rightarrow {}^{---}_{82}Pb + ------$ [2]

(b) Imagine that you are given a sample of $^{212}_{83}Bi$ mounted on a stand. You are asked to verify experimentally that the two decays in **(a)(i)** and **(ii)** occur. Outline briefly the experiment that you would perform.

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....[4]

(c) The decay constant for $^{212}_{83}Bi$ is $0.0115\,min^{-1}$.

(i) Show that the initial activity of a sample containing 1.00×10^{-9} g of the isotope is about $3 \times 10^{10}\,min^{-1}$.

[3]

(ii) Calculate the half-life of the isotope.

half-life = ...min [1]

(iii) Assume that only one decay in a million is detected in an experiment to measure the half-life. Draw a graph on the axes of Fig. 6.2 of the count rate against time that you would expect to observe. [1]

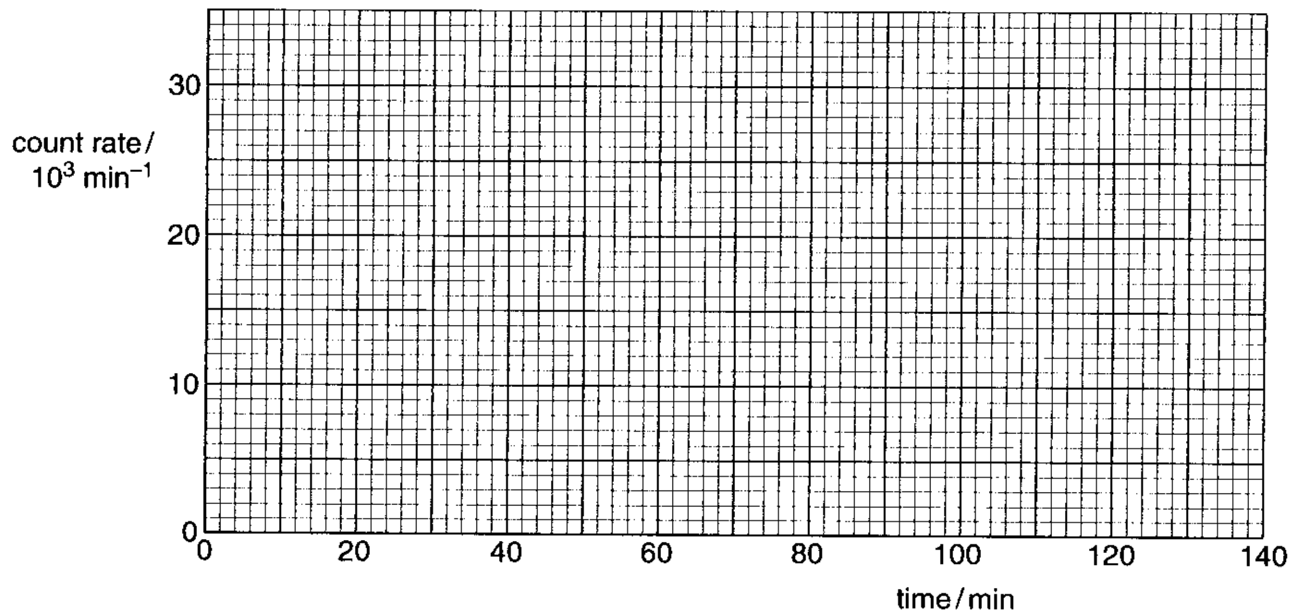

Fig.6.2

[Total: 13]

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

(a) Describe the processes of fission and fusion of nuclei. Distinguish clearly between them by highlighting **one** similarity and **one** difference between the two processes. State the conditions required for each process to occur in a sustained manner.

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(b) The fission of a uranium-235 nucleus releases about 200 MeV of energy, whereas the fusion of four hydrogen-1 nuclei releases about 28 MeV. However the energy released in the fission of one kilogramme of uranium-235 is less than the energy released in the fusion of one kilogramme of hydrogen-1. Explain this by considering the number of particles in one kilogramme of each.

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Quality of Written Communication [4]

[Total: 15]

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