RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Friday **20 JANUARY 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	12	
2	13	
3	14	
4	11	
5	10	
6	14	
7	16	
TOTAL	90	

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

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

For Examiner's Use

Answer **all** the questions.

1 A cricketer throws a cricket ball of mass 0.16 kg.

(a) Fig. 1.1 shows how the force on the ball from the cricketer's hand varies with time. The ball starts from rest and is thrown horizontally.

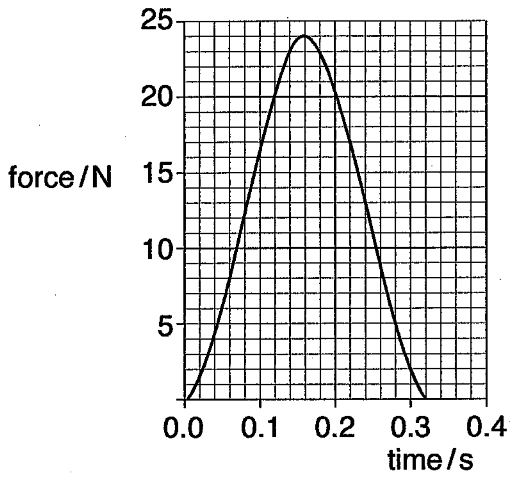

Fig. 1.1

(i) Estimate the area under the graph.

area = ... N s [1]

(ii) The area under the graph represents a change in a physical quantity for the ball. State the name of this quantity.

....[1]

(iii) Calculate the speed of the ball, mass 0.16 kg, when it is released.

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

(iv) Calculate the **maximum** horizontal acceleration of the ball.

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

For Examiner's Use

(b) The ball bounces several times on a hard surface. The maximum height to which it rises after each bounce is given in the table below.

bounce number, n	maximum height, h/m
1	0.71
2	0.33
3	0.16

The data given in the table fit a relationship for the variation in maximum height with bounce number of the form

$$h = 1.5\,e^{-kn}$$

where k is a constant.

(i) State the name of this form of relationship.

....[1]

(ii) Calculate the value of k.

k = ... [2]

(iii) What is the height from which the ball was thrown?

height = ... m [1]

(iv) Show that the loss of kinetic energy of the ball at the second bounce is about 0.6 J. Assume that the horizontal speed of the ball is unchanged.

[2]

[Total: 12]

[Turn over

2 This question is about a mass-spring system.

Fig. 2.1 shows a mass attached to two springs. The mass moves along a horizontal tube with one spring stretched and the other compressed. An arrow marked on the mass indicates its position on a scale. Fig. 2.1 shows the situation when the mass is displaced through a distance x from its equilibrium position. The mass is experiencing an acceleration a in the direction shown. Fig. 2.2 shows a graph of the **magnitude** of the acceleration a against the displacement x.

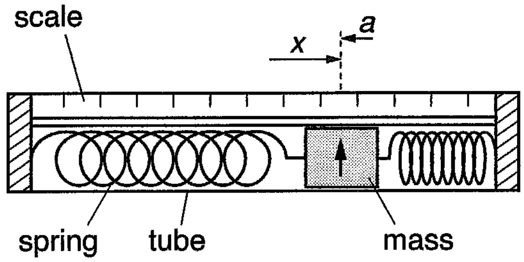

Fig. 2.1

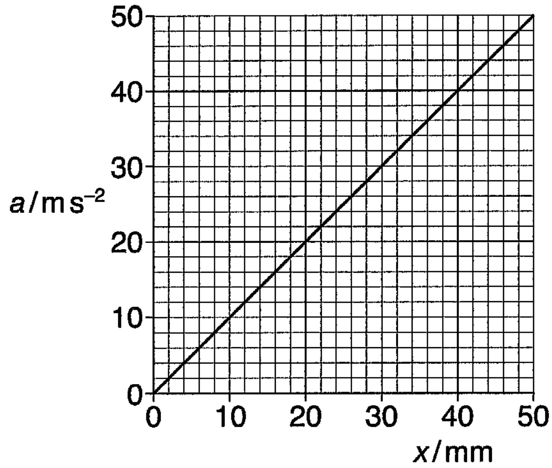

Fig. 2.2

(a) (i) State **one** feature from each of Fig. 2.1 and 2.2 which shows that the mass performs harmonic motion when released.

....

....

....[2]

(ii) Use data from Fig. 2.2 to show that the frequency of simple harmonic oscillations of the mass is about 5 Hz.

[3]

(iii) The mass oscillates in damped harmonic motion before coming to rest. On the axes of Fig. 2.3, sketch a graph of the damped harmonic oscillation of the mass, from an initial displacement of 25.0 mm. [3]

For Examiner's Use

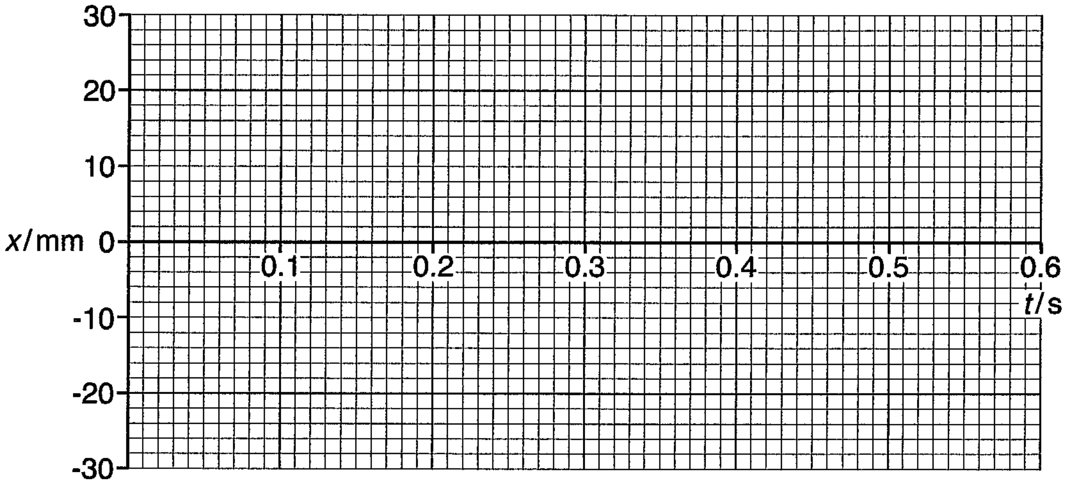

Fig. 2.3

(b) The mass-spring system of Fig. 2.1 can be used as a device to measure acceleration, called an accelerometer. It is mounted on a rotating test rig, used to simulate large g-forces for astronauts. Fig. 2.4 shows the plan view of a long beam rotating about axis **A** with the astronaut seated at end **B**, facing towards **A**. The accelerometer is parallel to the beam and is fixed under the seat 10 m from **A**.

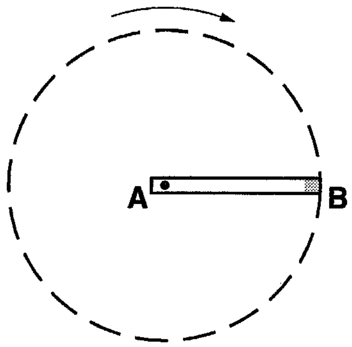

Fig. 2.4

(i) When the astronaut is rotating at a constant speed, the arrow marked on the mass has a constant deflection. Explain why.

....

....

....[2]

(ii) Calculate the speed v of rotation of the astronaut when the deflection is 50 mm.

v = ... $m\,s^{-1}$ [3]

[Total: 13]

For Examiner's Use

3 This question is about electric forces.

A very small negatively-charged conducting sphere is suspended by an insulating thread from support **S**. It is placed close to a vertical metal plate carrying a positive charge. The sphere is attracted towards the plate and hangs with the thread at an angle of 20° to the vertical as shown in Fig. 3.1.

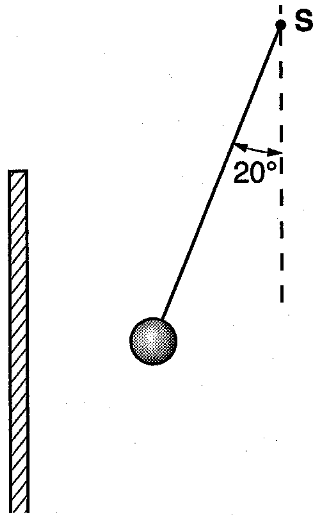

Fig. 3.1

(a) Draw at least **five** electric field lines on Fig. 3.1 to show the pattern of the field between the plate and the sphere. [3]

(b) The sphere of weight 1.0×10^{-5} N carries a charge of -1.2×10^{-9} C.

(i) Show that the magnitude of the attractive force between the sphere and the plate is about 3.6×10^{-6} N.

[3]

(ii) Hence show that the value of the electric field strength at the sphere, treated as a point charge, is 3.0×10^{3} in SI units. State the unit.

unit for electric field strength is .... [3]

For Examiner's Use

(c) The plate is removed. Fig. 3.2 shows an identical sphere carrying a charge of $+1.2 \times 10^{-9}$ C, mounted on an insulating stand. It is placed so that the hanging sphere remains at 20° to the vertical.

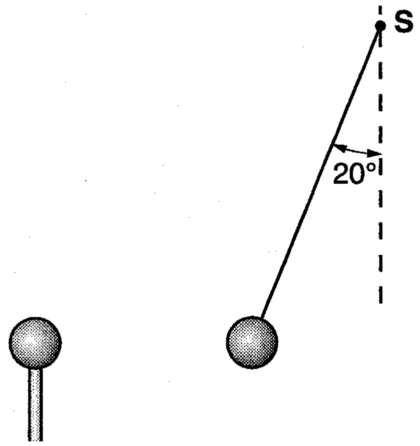

Fig. 3.2

Treating the spheres as point charges, calculate the distance *r* between their centres.

r = ... m [3]

(d) On Fig. 3.2, sketch the electric field pattern between the two charges. By comparing this sketch with your answer to **(a)**, suggest why the distance between the plate and the sphere in Fig. 3.1 is half of the distance between the two spheres in Fig. 3.2.

....

....

....[2]

[Total: 14]

4 The radioactive nickel nuclide $^{63}_{28}Ni$ decays by beta-particle emission with a half-life of 120 years.

(a) A copper nucleus is produced as the result of this decay. State the number of nucleons in the copper nucleus which are

protons ....

neutrons ....[2]

(b) Show that the decay constant of the nickel nuclide is $1.8 \times 10^{-10}\,s^{-1}$.

1 year = 3.2×10^{7} s

[1]

(c) A student designs an electronic clock, powered by the decay of nuclei of $^{63}_{28}Ni$. One plate of a capacitor of capacitance 1.2×10^{-12} F is to be coated with this isotope. As a result of this decay, the capacitor becomes charged. The capacitor is connected across the terminals of a small neon lamp. See Fig. 4.1. When the capacitor is charged to 90 V, the neon gas inside the lamp becomes conducting, causing it to emit a brief flash of light and discharging the capacitor. The charging starts again. Fig. 4.2 is a graph showing how the voltage V across the capacitor varies with time.

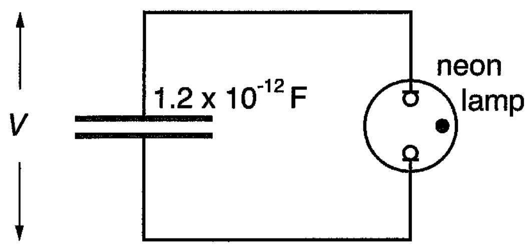

Fig. 4.1

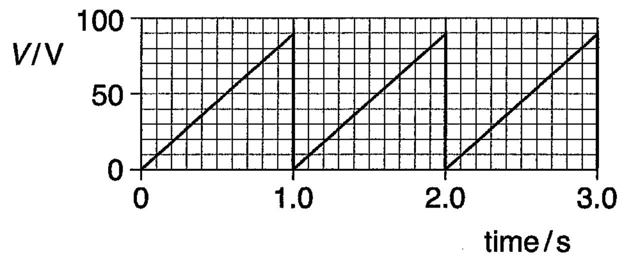

Fig. 4.2

(i) Show that the maximum charge stored on the capacitor is 1.1×10^{-10} C.

[2]

For Examiner's Use

(ii) When a nickel atom emits a beta-particle, a positive charge of 1.6×10^{-19} C is added to the capacitor plate. Show that the number of nickel nuclei that must decay to produce 1.1×10^{-10} C is about 7×10^{8}.

[2]

(iii) The neon lamp is to flash once every 1.0 s. Using your answer to **(b)**, calculate the number of nickel atoms needed in the coating on the plate.

number = ... [3]

(iv) State, giving a reason, whether or not you would expect the clock to be accurate to within 1% one year after manufacture.

....

....

....[1]

[Total: 11]

For Examiner's Use

5 This question is about forcing a liquid metal, such as molten sodium, through a tube.

(a) The liquid metal is in a tube of square cross-section, side w, made of electrically insulating material. See Fig. 5.1. Two electrodes are mounted on opposite sides of the tube and a magnetic field of flux density B fills the region between the electrodes. An electric current I passes across the tube between the electrodes, perpendicular to the magnetic field. The interaction between the current and the field provides the force to move the liquid.

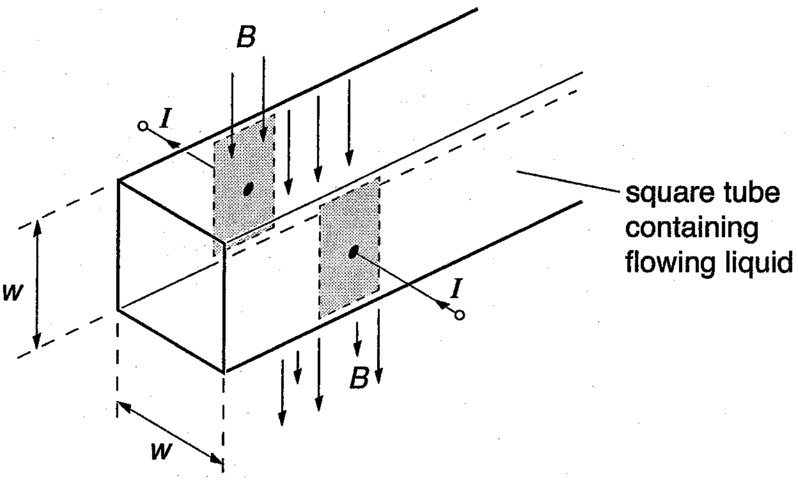

Fig. 5.1

(i) Draw on Fig. 5.1 an arrow labelled **F** to indicate the direction of the force on the liquid metal. Explain how you determined the direction.

....

....[2]

(ii) State a relationship for the force F in terms of the current I, the magnetic field B and the width w of the tube.

....[1]

(iii) Data for this device are shown below.

$B = 0.15\,\text{T}$
$I = 800\,\text{A}$
$w = 25\,\text{mm}$

Calculate the force on the liquid metal in the tube.

force = ... N [2]

For Examiner's Use

(b) To monitor the speed of flow of the liquid metal, a similar arrangement of electrodes and magnetic field is set up further down the tube. See Fig. 5.2. A voltmeter is connected across the electrodes instead of a power supply.

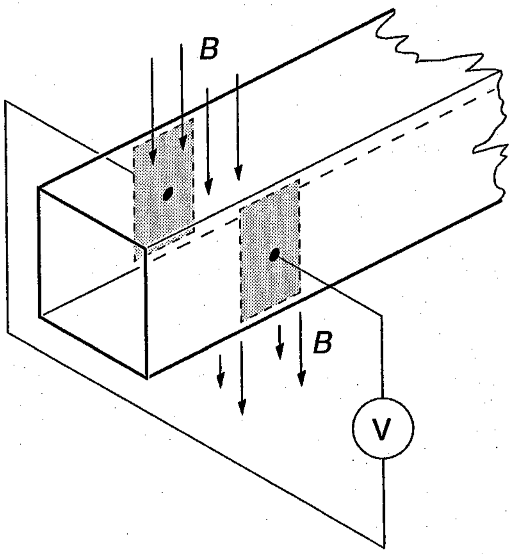

Fig. 5.2

(i) Explain, using the law of electromagnetic induction, why the voltmeter will register a reading which is proportional to the speed of flow of the metal.

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....[3]

(ii) State how and explain why the voltmeter reading changes when the magnetic flux density across the tube is doubled.

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....[2]

[Total: 10]

For Examiner's Use

6 **(a)** Explain the term *internal energy* and define *the specific heat capacity* of a body.

internal energy ....

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....[2]

specific heat capacity ....

....[1]

(b) Outline a method of measuring the specific heat capacity of aluminium.

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....[4]

(c) Consider a 2.0 kg block of aluminium. Assume that the heat capacity of aluminium is independent of temperature and that the internal energy is zero at absolute zero. Also assume that the volume of the block does not change over the range of temperature from 0 K to 293 K.

(i) Show that the internal energy of this block of aluminium at 20 °C is 540 kJ.

specific heat capacity of aluminium = 920 $J\,kg^{-1}\,K^{-1}$

[2]

For Examiner's Use

(ii) Hence show that the mean energy per atom in the 2.0 kg aluminium block at 20 °C is about 1.2×10^{-20} J.

molar mass of aluminium = 0.027 kg mol^{-1}

[3]

(iii) In 1819, Dulong and Petit measured the heat capacities of bodies made of different substances, and found that for one mole of each substance the molar heat capacity was about 25 J mol^{-1} K^{-1}. Starting from any of the data in **(i)** or **(ii)** show that this is true for aluminium.

[2]

[Total: 14]

[Turn over

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

This question is about helium nuclei.

(a) Describe the nature of alpha-particles and the main features of alpha-particle decay. Describe **one** experiment where alpha-particles have been used to learn about atomic structure. Explain how the experiment led to the discovery of the nucleus. A space has been left for you to draw suitable diagram(s), if you wish to illustrate your answer.

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....[7]

For Examiner's Use

(b) A method of producing helium nuclei is shown by the following nuclear equation.

$$4\,^{1}_{1}H \rightarrow \,^{4}_{2}He + 2\,^{0}_{1}e$$

Describe this process of fusion giving as much detail as you can.
Compare the energy release in this process with the energy released in alpha-particle decay.

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....[5]

Quality of Written Communication [4]

[Total: 16]

END OF QUESTION PAPER

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