OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Monday **27 JANUARY 2003** 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	12	
3	13	
4	12	
5	12	
6	12	
7	16	
TOTAL	90	

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

MML 2847 3/02 S33782/5

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

Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a ball of mass 0.050 kg resting on the strings of a tennis racket held horizontally.

Fig. 1.1

(i) Draw and label the **two** forces acting on the ball. [2]

(ii) Each of these forces has a corresponding equal and opposite force according to Newton's third law of motion. Describe these equal and opposite forces and state the objects on which they act.

....

....

....

....

....

.... [4]

(iii) Calculate the difference in magnitude between the two forces on the ball when the racket is accelerated upwards at $2.0\,\mathrm{m\,s^{-2}}$.

force = ... N [2]

For Examiner's Use

(b) The ball is dropped from rest at a point 0.80 m above the racket head. The racket is fixed rigidly. Assume that the ball makes an elastic collision with the strings and that any effects of air resistance are negligible.

Calculate

(i) the speed of the ball just before the impact

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

(ii) the momentum of the ball just before impact

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

(iii) the change in momentum of the ball during the impact

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

(iv) the average force during the impact for a contact time of 0.050 s.

force = ... N [1]

[Total: 13]

[Turn over

2 Fig. 2.1 shows an airtrack glider of mass 0.40 kg held by two stretched springs. When the glider is pulled 0.050 m to the left and released, it oscillates freely without friction.

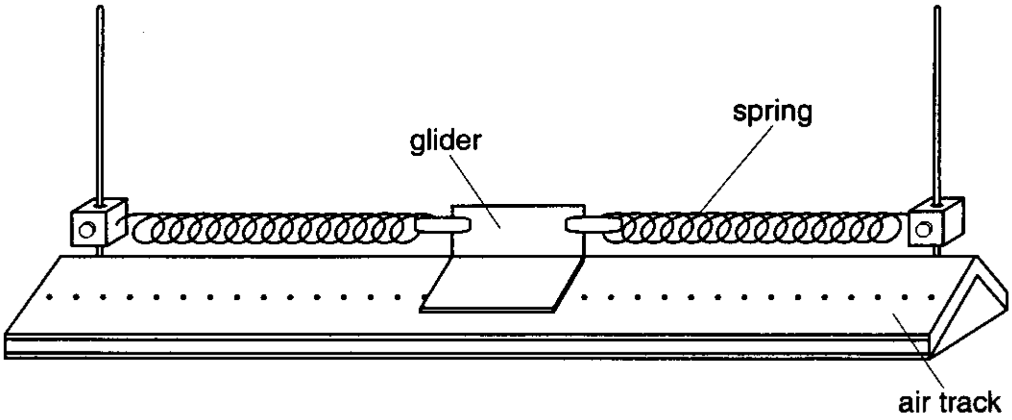

Fig. 2.1

Fig. 2.2 shows the variation of the elastic strain energy stored in the springs with the displacement *x* from the equilibrium position. Note that the strain energy is 70 mJ when the glider is not oscillating.

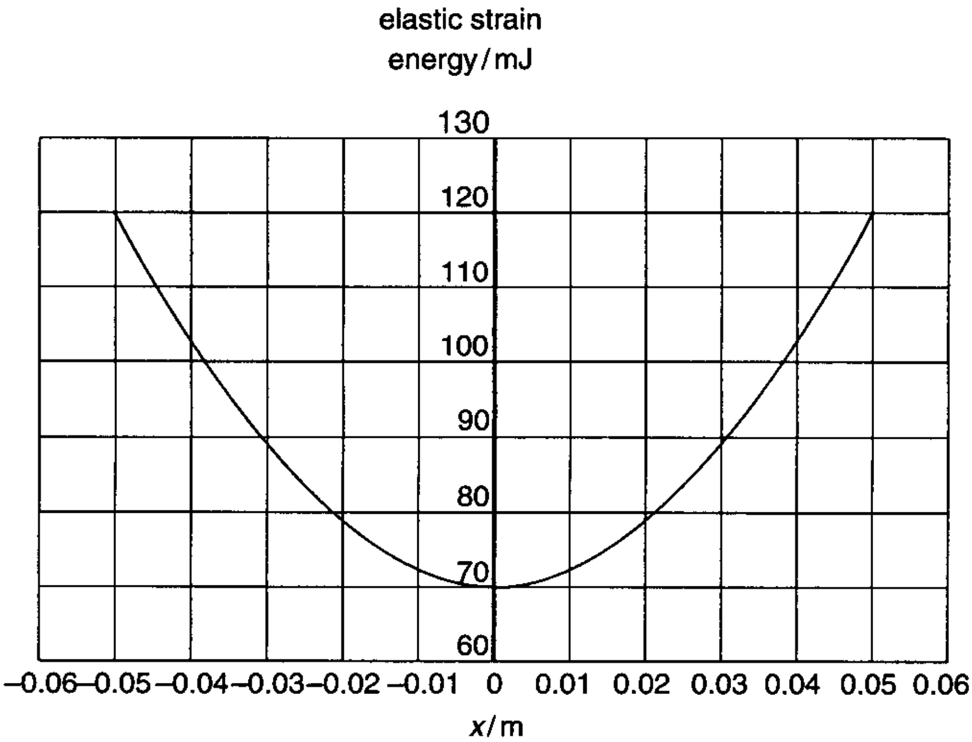

Fig. 2.2

(a) Write down

(i) the total energy stored in the system when oscillating .... mJ [1]

(ii) the maximum kinetic energy of the glider .... mJ [2]

For Examiner's Use

(b) **(i)** Show that the maximum speed of the glider is 0.50 m s^{-1}.

[2]

(ii) Use Fig. 2.2 or otherwise to find the amplitude of oscillation required to halve the maximum speed of the glider. Show your reasoning.

amplitude = ... m [2]

(c) The equation of motion of the glider relating its acceleration a in m s^{-2} to its displacement x in m is

$$a = -110\,x$$

(i) Use this equation to show that the period of oscillation is 0.60 s.

[2]

(ii) Use the data from **(b)(i)** and **(c)(i)** to sketch on Fig. 2.3 the velocity-time graph for the glider. It is released at x = 0.050 m at t = 0. [3]

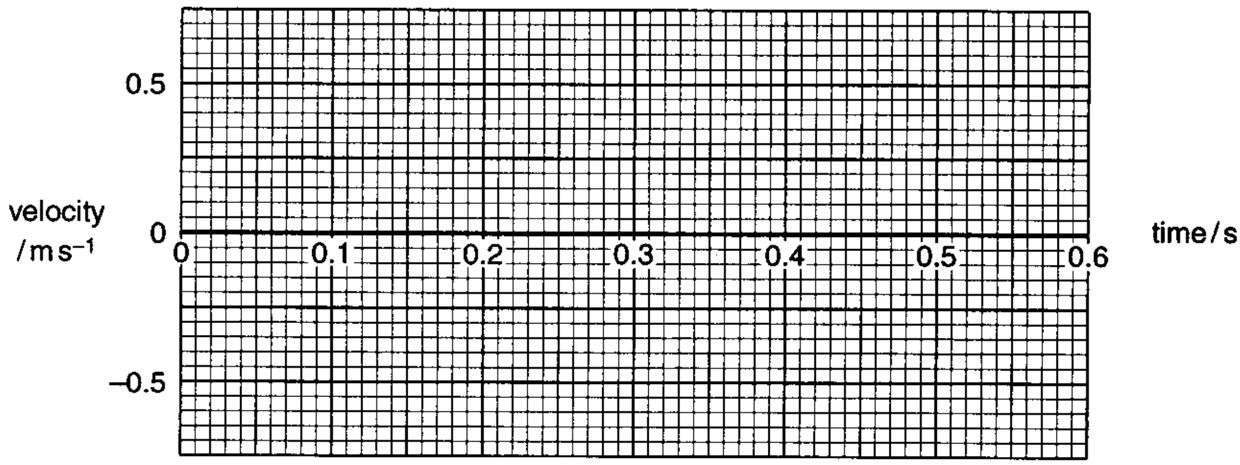

Fig. 2.3

[Total: 12]

[Turn over

3 This question is about gravitational fields. You may assume that all the mass of the Earth, or the Moon, can be considered as a point mass at its centre.

(a) It is possible to find the mass of a planet by measuring the gravitational field strength at the surface of the planet and knowing its radius.

(i) Define gravitational field strength, *g*.

....

.... [1]

(ii) Write down an expression for *g* at the surface of a planet in terms of its mass *M* and radius *R*.

[1]

(iii) Show that the mass of the Earth is 6.0×10^{24} kg.

radius of the Earth = 6400 km

[1]

(b) **(i)** Use the data below to show the value of *g* at the Moon's surface is about $1.7\,N\,kg^{-1}$.

mass of Earth = 81 x mass of Moon
radius of Earth = 3.7 x radius of Moon

[2]

For Examiner's Use

(ii) Explain why a high jumper who can clear a 2 m bar on Earth should be able to clear a 7 m bar on the Moon. Assume that the high jump on the Moon is inside a 'space bubble' where Earth's atmospheric conditions exist.

....

....

....

....

.... [3]

(c) The distance between the centres of the Earth and the Moon is 3.8×10^8 m. Assume that the Moon moves in a circular orbit about the centre of the Earth. Estimate the period of this orbit to the nearest day.

mass of Earth = 6.0×10^{24} kg
1 day = 8.6×10^4 s

period = ... day [5]

[Total: 13]

4 Fig. 4.1 shows two large parallel insulated capacitor plates, separated by an air gap of 4.0×10^{-3} m. The capacitance of the arrangement is 200 pF. The plates are connected by a switch to a 2000 V d.c. power supply. The switch is closed and then opened.

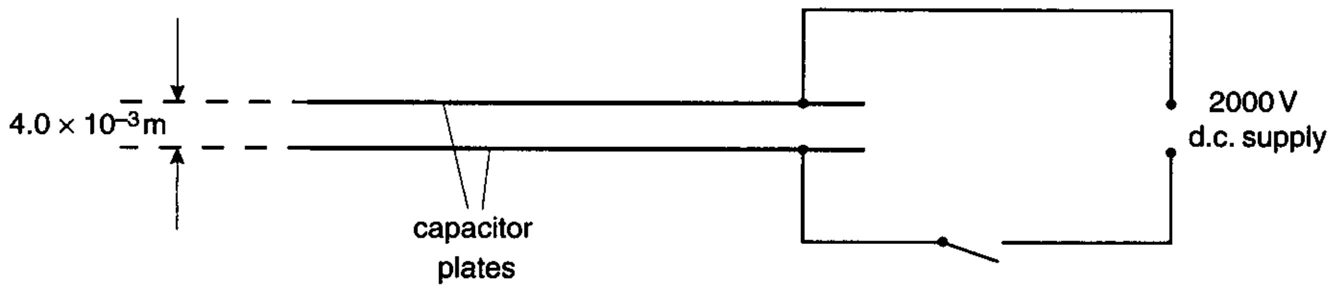

Fig. 4.1

(a) Calculate

(i) the magnitude of the electric field strength between the plates giving a suitable unit for your answer

electric field strength = ... unit .... [2]

(ii) the magnitude in μC of the charge on each plate

charge = ... μC [3]

(iii) the energy in μJ stored in the capacitor.

energy = ... μJ [3]

(b) With the switch remaining open, the plates are pulled apart until their separation is doubled. The capacitor maintains the same charge. The electric field strength between the plates is unchanged. State the new

(i) voltage between the plates

voltage = ... V [1]

(ii) capacitance of the plates

capacitance = ... pF [1]

(iii) energy stored in the capacitor.

energy = ... μJ [1]

(c) The energy stored in the capacitor has increased. State the source of this energy.

....

....

.... [1]

[Total: 12]

5 The radioactive nuclide of plutonium, $^{239}_{94}Pu$, decays by alpha-particle emission with a half-life of 2.4 x 10^4 years. The alpha-particle energy is 8.2 x 10^{-13} J.

(a) **(i)** For a $^{239}_{94}Pu$ nucleus, state the number of

protons ....

neutrons .... [1]

(ii) For the nucleus produced as the result of the decay, state the number of

protons ....

neutrons .... [2]

(b) Calculate the decay constant of the plutonium nuclide.

1 year = 3.2 x 10^7 s

decay constant = ... s^{-1} [1]

(c) A small power source to generate 2.5 W is to be made from the plutonium isotope.

(i) Show that the rate of decay of the plutonium must be at least 3 x 10^{12} Bq.

[2]

(ii) Calculate the number of plutonium atoms needed to provide this activity.

number = ... [2]

For Examiner Use

(iii) Calculate the mass of plutonium in the source.

mass = ... kg [2]

(d) Another isotope of plutonium, $^{238}_{94}Pu$, also decays by alpha-particle emission but with a half-life of 86 y. The alpha-particle energy is 8.8×10^{-13} J.

State **one** advantage and **one** disadvantage of using ^{238}Pu instead of ^{239}Pu in the power source.

advantage ....

....

.... [1]

disadvantage ....

....

.... [1]

[Total: 12]

6 Fig. 6.1 shows a simple transformer used for demonstrations in the laboratory. It consists of two coils linked by a laminated soft iron core. The primary coil is connected to a signal generator and the secondary coil to a voltage sensor, interface and computer. The number of turns on the secondary coil is double that on the primary coil.

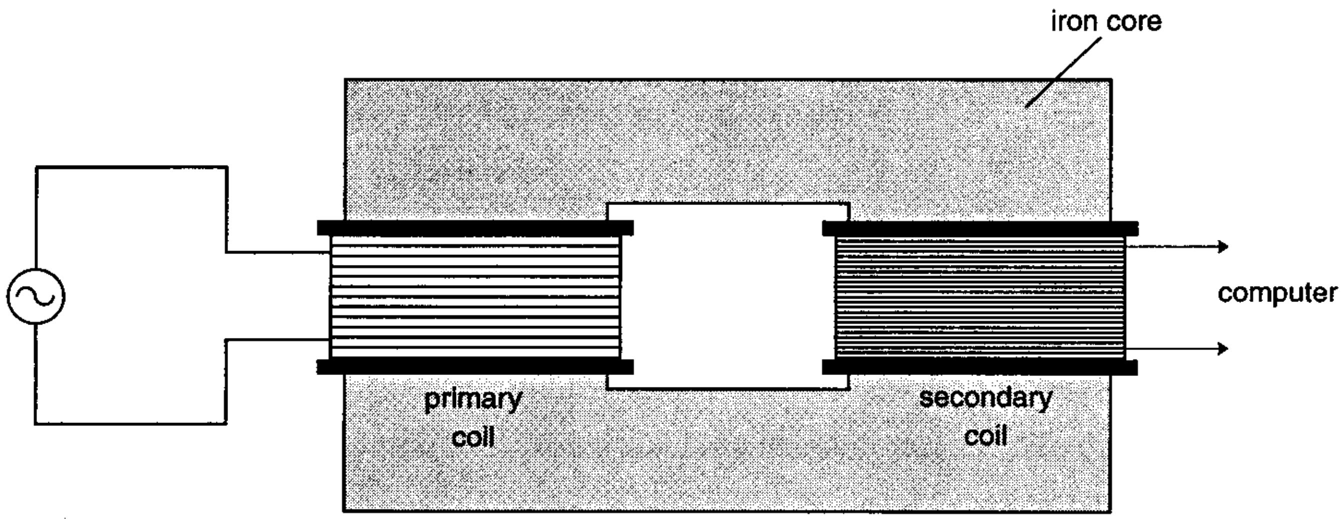

Fig. 6.1

(a) **(i)** Draw on Fig. 6.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) Define the term *magnetic flux*.

....

....

.... [2]

(iii) Explain how *magnetic flux linkage* differs from *magnetic flux*.

....

....

.... [2]

For Examiner's Use

(iv) Use Faraday's law of electromagnetic induction to explain why an alternating current is necessary in the primary coil for a voltage to be detected across the secondary coil.

....

....

....

....

....

.... [3]

(b) Fig. 6.2 shows the computer screen in the demonstration where the number of turns on the secondary coil is double that on the primary coil.

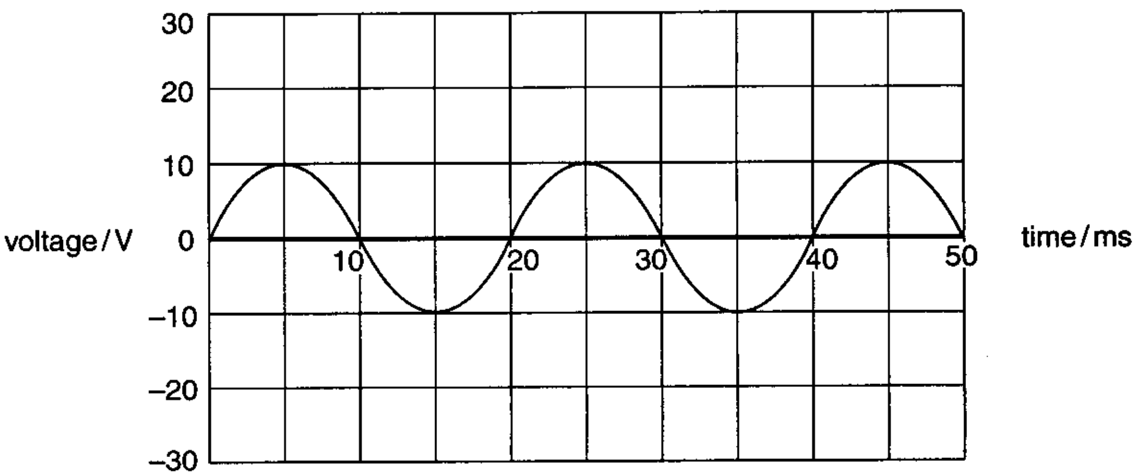

Fig. 6.2

(i) Show that the frequency of the supply is 50 Hz.

[1]

(ii) Calculate the amplitude of the **supply** voltage.

amplitude = ... V [2]

[Total: 12]

[Turn over

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

(a) Describe the structure of the atom and the nature of its constituents.

....

....

....

....

....

....

....

....

....

....

....

.... [4]

(b) Describe briefly **one** piece of experimental evidence for each of the following statements.

(i) Atomic radii are about 10^{-10} m.

....

....

....

....

....

....

....

....

....

.... [4]

For Examiner Use

(ii) Nuclear radii are about 10^{-14} m.

....

....

....

....

....

....

....

....

....

....

....

.... [4]

Quality of Written Communication [4]

[Total: 16]

BLANK PAGE