OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Friday **21 JUNE 2002** Afternoon 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 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	11	
3	10	
4	12	
5	11	
6	18	
7	12	
QWC	4	
TOTAL	90	

This question paper consists of 16 printed pages.

SPA (SLC/PW) S09223/7

Registered Charity Number: 1066969

[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 toy car runs down a length of flexible plastic track. In each of three trials the track is shaped differently as shown in Figs. 1.1, 1.2 and 1.3 but the top of the track is always the same vertical height above the ground. The car is released from rest at the top of the track for each trial. Assume that any frictional effects are negligible.

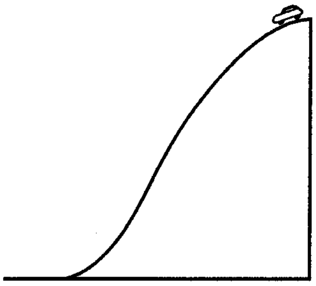

Fig. 1.1

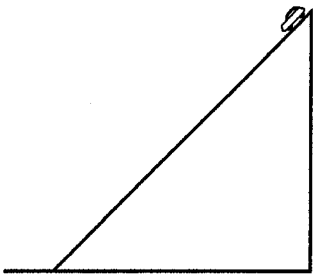

Fig. 1.2

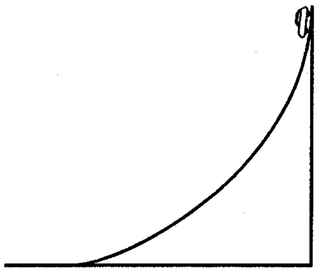

Fig. 1.3

(a) State and explain whether or not the car has the same speed at the end of the track in each trial.

....

....

....

.... [2]

(b) In Fig. 1.2 the length of the track is 1.2 m and it makes an angle of 45° to the ground. The mass of the car is 0.050 kg. Calculate

(i) the change in gravitational potential energy of the car in a trial

energy change = ... J [3]

(ii) the speed of the car at the end of the track.

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

For Examiner's Use

(c) The car continues along the floor until it collides with a toy brick. Just before it hits the brick, its speed is 3.0 m s^{-1}. It rebounds at two thirds of its speed.
The contact time is 0.2 s.

(i) Calculate the change of momentum of the car in the impact. State your answer with a suitable unit.

momentum change = ...[3]

(ii) Calculate the average force on the brick during the impact.

force =...................................N [2]

[Total : 12]

For Examiner's Use

2 **(a)** Define the *capacitance* of a capacitor.

....

....[1]

(b) A capacitor C of capacitance 500 μF is connected either to a 12 V battery or to a resistor R through a switch S, as shown in Fig. 2.1. The capacitor is initially uncharged and connected across R.

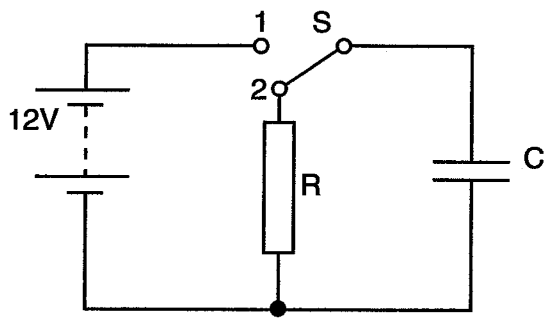

Fig. 2.1

(i) Describe the movement of charge in the circuit which takes place after the switch S is moved from position 2 into position 1.

....

....

....[1]

(ii) Calculate the final charge stored on the capacitor.

charge = ... μC [1]

For Examiner's Use

(c) The switch is moved back to position 2 so that the capacitor discharges through the resistor R. Fig. 2.2 shows the variation with time t of current I during the discharge.

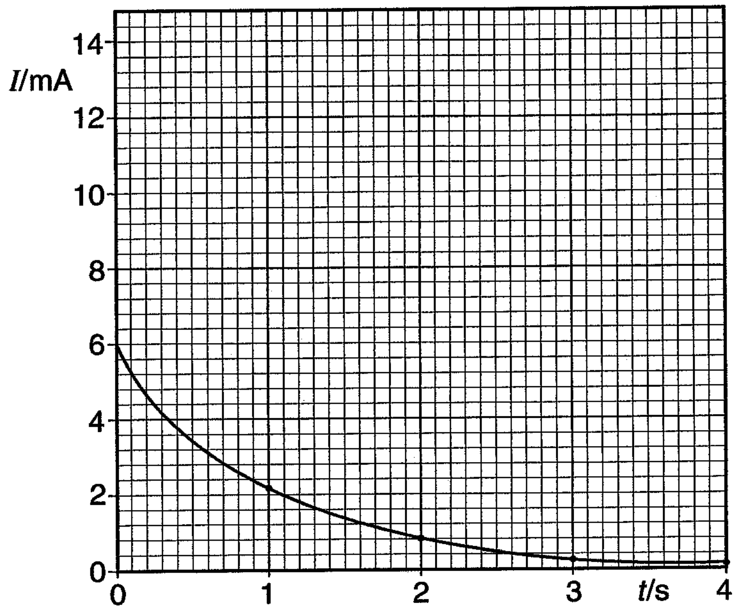

Fig. 2.2

(i) Use data from the graph and Fig. 2.1 to calculate a value for the resistance of R.

resistance = ... Ω [2]

(ii) Determine the time constant of the circuit.

time constant = ... s [1]

(iii) The curve of Fig. 2.2 can be described in the form $I = I_0 e^{-t/RC}$. Substitute values into the equation to give an expression for I in terms of t.

.... [1]

(iv) Explain how you could use Fig. 2.2. to verify the charge calculated in **(b)(ii)**.

....

....

.... [2]

(v) The resistor R is replaced by one of half the resistance. Sketch on Fig. 2.2 the discharge curve you would predict. [2]

[Total : 11]

[Turn over

For Examiner's Use

3 (a) Explain the terms *internal energy* and *specific heat capacity* of a body.

internal energy ....

....[2]

specific heat capacity ....

....[1]

(b) A night storage heater can be considered as a stack of bricks which is warmed in the night by electric power and then cools down in the day heating a room. Calculate the energy given out by such a heater of mass 600 kg, as it cools from 70°C to 30°C. The specific heat capacity of brick = $1.1 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$.

energy = ... J [3]

(c) Estimate the internal energy of the air in a room of volume 24 m^3 at a temperature of about 20°C. Assume that the air behaves as an ideal gas at atmospheric pressure. Here are some useful formulae and data. *There are several ways to make this estimate. You do NOT need to use all of the information.*

formulae:
$pV = nRT$ is the equation of state of n moles of an ideal gas
kinetic energy of n moles of an ideal gas = $\frac{3}{2} nRT$

data:
$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
density of air = 1.3 kg m^{-3}
molar mass of air = $0.030 \text{ kg mol}^{-1}$
atmospheric pressure = $1.0 \times 10^5 \text{ Pa}$

internal energy = ... J [4]

[Total : 10]

For Examiner's Use

4 Two very small identical conducting balls, each of mass 8.0 x 10^{-4} kg, are suspended from a single point by insulating threads of negligible mass as shown in Fig. 4.1. Each sphere has been given the same charge of 3.0 x 10^{-8} C so that they repel each other and are in equilibrium with their centres a distance 6.0 x 10^{-2} m apart.

data:
$(4\pi\varepsilon_0)^{-1}$ = 9.0 x 10^9 m F^{-1}
g = 9.8 N kg^{-1}

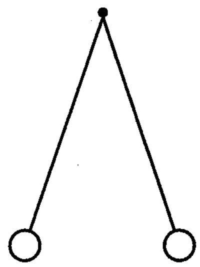

Fig. 4.1

(a) **(i)** On Fig. 4.1 draw two arrows, each labelled F_e, to show the direction of the electrostatic force on each ball. [1]

(ii) Show that the value of F_e is about 2.3 x 10^{-3} N.

[2]

(b) Each ball experiences three forces. On Fig. 4.1 draw and label arrows to represent the other two main forces acting on one ball. [1]

(c) Using the data above, calculate the angle between the threads.

angle = ... ° [4]

(d) The gravitational force F_g between the two balls is much smaller than the electrostatic force F_e between them. Calculate $\frac{F_g}{F_e}$.

$\frac{F_g}{F_e}$ = ...[4]

[Total : 12]

[Turn over

For Examiner's Use

5 **(a)** Complete the table below for the three types of ionising radiations.

radiation	nature	range in air	penetration ability
α			0.2 mm paper
β	electron		
γ		several km	

[3]

(b) Describe briefly with the aid of a sketch an absorption experiment to distinguish between the three radiations listed above.

....

....

....

....

....

....[3]

For Examiner's Use

(c) Rutherford suggested that the isotopes of uranium had equal numbers of atoms, when the Earth was formed. The half lives of two isotopes of uranium are shown in the table below.

isotope	$^{235}_{92}U$	$^{238}_{92}U$
half life / 10^9 years	0.75	4.5

(i) Assuming Rutherford's suggestion is correct, calculate the ratio

$$\frac{\text{number of } ^{235}_{92}U \text{ atoms}}{\text{number of } ^{238}_{92}U \text{ atoms}}$$

at a time 4.5 x 10^9 years after the Earth was formed.

ratio = ...[3]

(ii) The present day value for this ratio is 0.0072. Suggest without detailed calculation why this theory therefore puts the age of the Earth between 6.0 x 10^9 and 7.5 x 10^9 years.

....

....

....

....

....

....[2]

[Total : 11]

6 Fig. 6.1 shows a section of an electro-mechanical oscillator. The coil inside the oscillator is attached by a spring to the casing, so that the coil can move freely to the left and right in the space between the poles of a permanent magnet. A cross-section through the magnet and coil is shown in Fig. 6.2. The coil and magnet are being viewed from the right of Fig. 6.1.

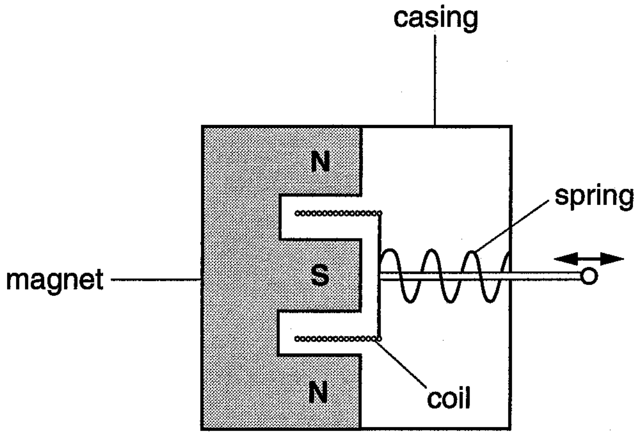

Fig. 6.1

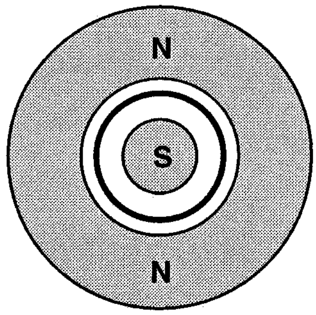

Fig. 6.2

(a) (i) On Fig. 6.2 draw lines with arrows to represent the magnetic field between the poles. [1]

(ii) Draw an arrow on the coil to indicate the direction of the current which will cause the coil to move upwards, that is, out of the plane of the examination paper. [1]

(iii) Write down an expression for the force F on a wire of length l carrying a current I at right angles to a magnetic field of flux density B.

....[1]

(iv) Calculate the force on the coil when there is a current of 80 mA in the coil. The flux density of the magnetic field at the coil is 0.40 T. The length of the wire in the coil is 15 m.

force = ... N [2]

(b) An alternating current in the coil forces the coil to oscillate in simple harmonic motion at a frequency of 50 Hz with an amplitude of 2.0 mm.

(i) On Fig. 6.3 below sketch a graph of the variation with time t of displacement x of the coil over an interval of 40 ms. [3]

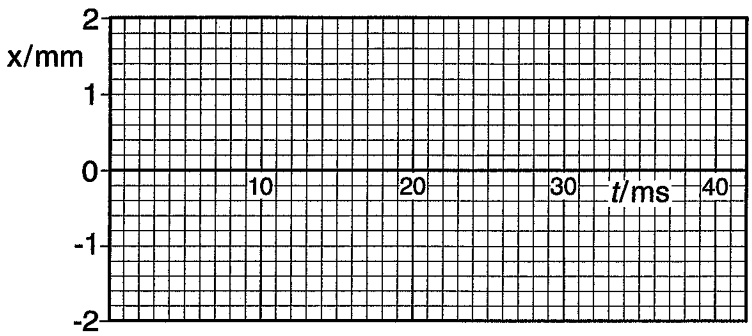

Fig. 6.3

(ii) Show that the maximum acceleration of the coil is about 200 m s^{-2}.

[3]

(iii) Hence calculate

1 the maximum force on the coil, of mass 0.020 kg

force = ... N [1]

2 the maximum current in the coil.

current = ... A [2]

(c) The amplitude of vibration of the coil varies with frequency as shown in Fig. 6.4. The alternating current in the coil of the oscillator is maintained at a constant maximum value.

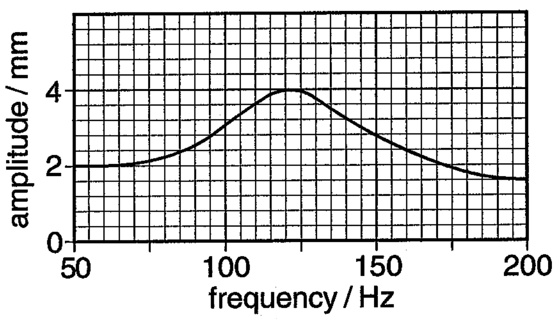

Fig. 6.4

(i) State the term used to describe this effect.

.... [1]

(ii) Estimate the value of the natural frequency of oscillation of the coil.

frequency = ... Hz [1]

(iii) Predict how the shape of the curve in Fig. 6.4 will change when the damping within the oscillator is reduced.

....

....

.... [2]

[Total : 18]

[Turn over

For Examiner's Use

7 (You will be awarded marks for the quality of written communication in your answer to question 7.)

(a) Describe briefly one scattering experiment to investigate the size of the nucleus of the atom. Include a description of the properties of the incident radiation which makes it suitable for this experiment.

....

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....[6]

For Examiner's Use

(b) **(i)** Give one difference and one similarity between a fusion reaction and a fission reaction.

difference ....

....

similarity ....

....[2]

(ii) Describe the process of the fission of a $^{235}_{92}U$ nucleus, induced by a neutron.

....

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....

....

....

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....[4]

[Total : 12]

Quality of written communication [4]