Centre Number	Candidate Number	Name

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

PHYSICS **9702/04**

Paper 4

May/June 2004

1 hour

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen in the spaces provided on the Question Paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
The number of marks is given in brackets [ ] at the end of each question or part question.
You may lose marks if you do not show your working or if you do not use appropriate units.

If you have been given a label, look at the details. If any details are incorrect or missing, please fill in your correct details in the space given at the top of this page.

Stick your personal label here, if provided.

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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,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

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Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

gravitational potential, $\phi = -\frac{Gm}{r}$

simple harmonic motion, $a = -\omega^2 x$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$
$v = \pm \omega \sqrt{(x_0^2 - x^2)}$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\epsilon_0 r}$

capacitors in series, $1/C = 1/C_1 + 1/C_2 + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

energy of charged capacitor, $W = \frac{1}{2}QV$

alternating current/voltage, $x = x_0 \sin \omega t$

hydrostatic pressure, $p = \rho g h$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

equation of continuity, $Av = \text{constant}$

Bernoulli equation (simplified), $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

Stokes' law, $F = Ar\eta v$

Reynolds' number, $R_e = \frac{\rho v r}{\eta}$

drag force in turbulent flow, $F = Br^2\rho v^2$

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[Turn over

Answer **all** the questions in the spaces provided.

1 **(a)** State the significance of the Millikan experiment.

.....

..... [1]

(b) In the Millikan experiment, oil droplets were found to have the following charges.

1.56×10^{-19} C
4.88×10^{-19} C
1.64×10^{-19} C
3.14×10^{-19} C
4.76×10^{-19} C

Use these data to determine a value for the elementary charge. Explain your working.

.....

.....

elementary charge = ... C [2]

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2 The pressure p of an ideal gas is given by the expression

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

(a) Explain the meaning of the symbol $\langle c^2 \rangle$.

.....

..... [2]

(b) The ideal gas has a density of $2.4\,\text{kg m}^{-3}$ at a pressure of 2.0×10^5 Pa and a temperature of 300 K.

(i) Determine the root-mean-square (r.m.s.) speed of the gas atoms at 300 K.

r.m.s. speed = ... m s^{-1} [3]

(ii) Calculate the temperature of the gas for the atoms to have an r.m.s. speed that is twice that calculated in **(i)**.

temperature = ... K [3]

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[Turn over

3 A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 3.1.

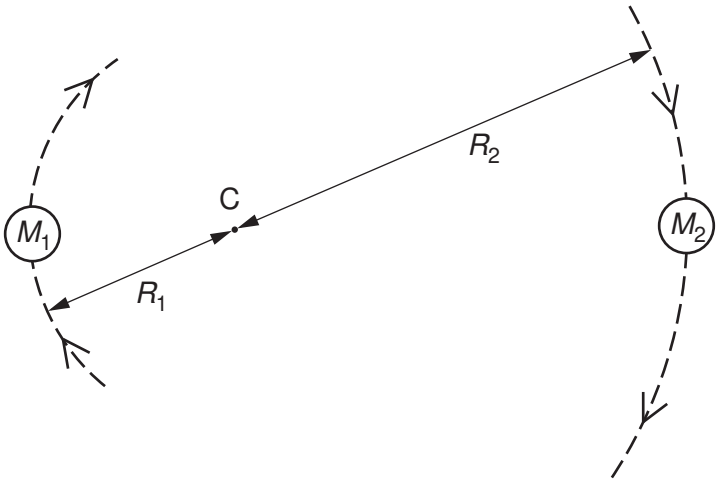

Fig. 3.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω, about C.

(a) State the formula, in terms of G, M_1, M_2, R_1, R_2 and ω for

(i) the gravitational force between the two stars,

.....

(ii) the centripetal force on the star of mass M_1.

.....

[2]

(b) The stars orbit each other in a time of 1.26×10^8 s (4.0 years). Calculate the angular speed ω for each star.

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

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(c) (i) Show that the ratio of the masses of the stars is given by the expression

$$\frac{M_1}{M_2} = \frac{R_2}{R_1}.$$

[2]

(ii) The ratio $\frac{M_1}{M_2}$ is equal to 3.0 and the separation of the stars is 3.2×10^{11} m.

Calculate the radii R_1 and R_2.

R_1 = ... m

R_2 = ... m

[2]

(d) (i) By equating the expressions you have given in **(a)** and using the data calculated in **(b)** and **(c)**, determine the mass of one of the stars.

mass of star = ... kg

(ii) State whether the answer in **(i)** is for the more massive or for the less massive star.

.....

[4]

4 A vertical spring supports a mass, as shown in Fig. 4.1.

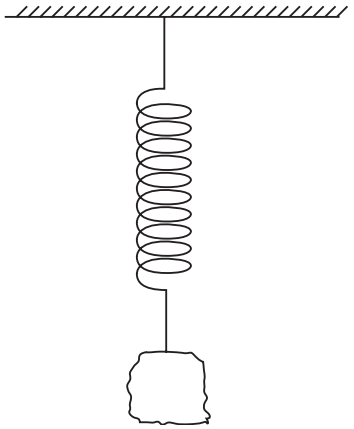

Fig. 4.1

The mass is displaced vertically then released. The variation with time t of the displacement y from its mean position is shown in Fig. 4.2.

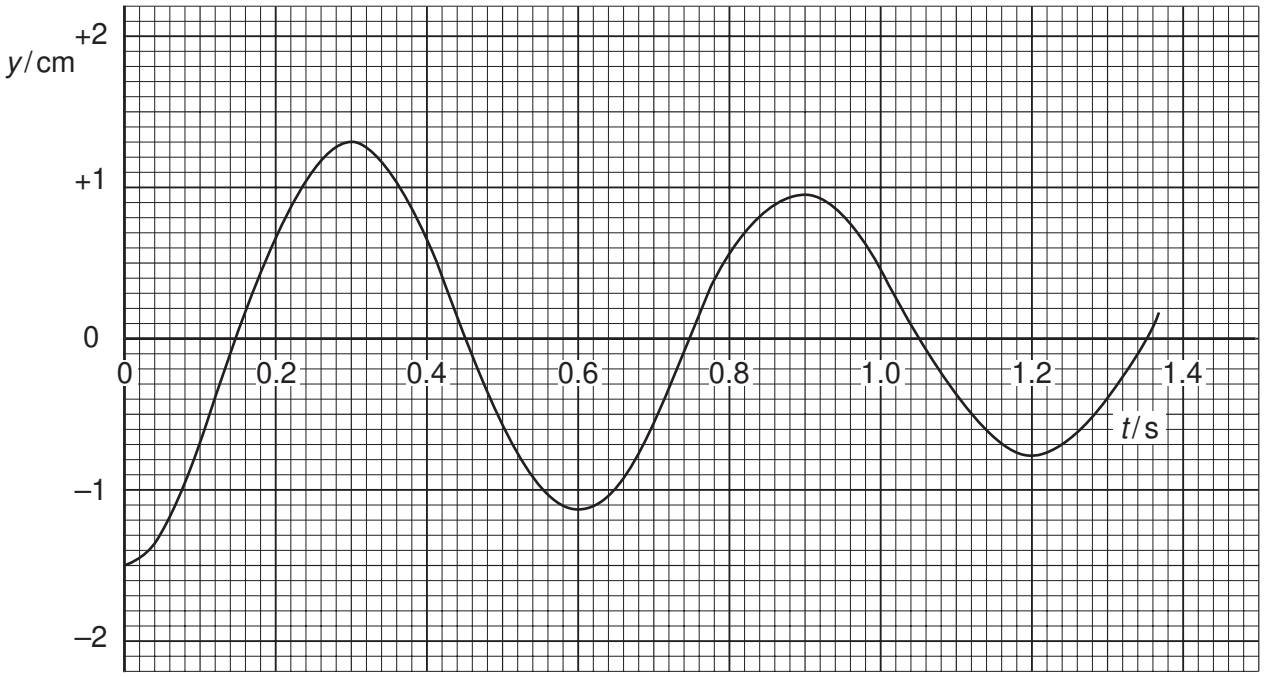

Fig. 4.2

A student claims that the motion of the mass may be represented by the equation

$$y = y_0 \sin \omega t.$$

(a) Give two reasons why the use of this equation is inappropriate.

1. .....

.....

2. .....

..... [2]

(b) Determine the angular frequency ω of the oscillations.

angular frequency = ... rad s^{-1} [2]

(c) The mass is a lump of plasticine. The plasticine is now flattened so that its surface area is increased. The mass of the lump remains constant and the large surface area is horizontal.
The plasticine is displaced downwards by 1.5 cm and then released.
On Fig. 4.2, sketch a graph to show the subsequent oscillations of the plasticine. [3]

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5 **(a)** Explain, in terms of heating effect, what is meant by the *root-mean-square (r.m.s.) value* of an alternating current.

.....

.....

..... [2]

(b) State the relation between the peak current I_0 and the r.m.s. current I_{rms} of a sinusoidally-varying current.

..... [1]

(c) The value of a direct current and the peak value of a sinusoidal alternating current are equal.

(i) Determine the ratio

$$\frac{\text{power dissipation in a resistor of resistance } R \text{ by the direct current}}{\text{power dissipation in the resistor of resistance } R \text{ by the alternating current}}.$$

ratio = ... [2]

(ii) State one advantage and one disadvantage of the use of alternating rather than direct current in the home.

advantage .....

.....

disadvantage .....

..... [2]

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(d) A current I varies with time t as shown in Fig. 5.1.

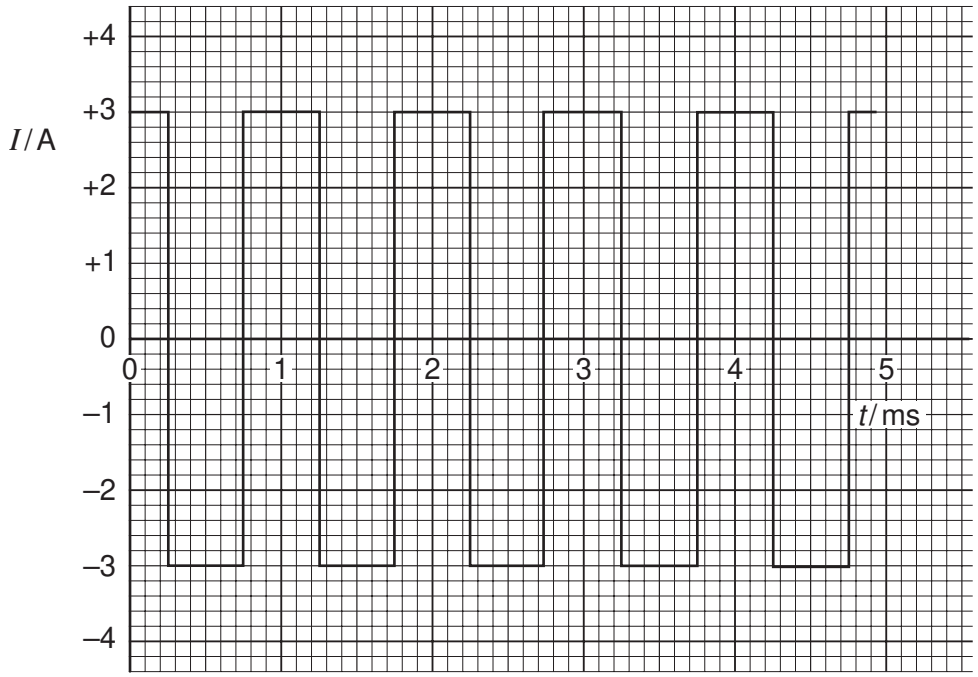

Fig. 5.1

For this varying current, state

(i) the peak value,

peak value = ... A [1]

(ii) the r.m.s. value.

r.m.s. value = ... A [1]

6 The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w,$$

where U is the internal energy of the system,
ΔU is the increase in internal energy,
q is the thermal energy supplied to the system,
w is the work done on the system.

Complete Fig. 6.1 for each of the processes shown. Write down the symbol '+' for an increase, the symbol '–' to indicate a decrease and the symbol '0' for no change, as appropriate.

	U	q	w
the compression of an ideal gas at constant temperature			
the heating of a solid with no expansion			
the melting of ice at 0 °C to give water at 0 °C (Note: ice is less dense than water)			

[6]

Fig. 6.1

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7 **(a)** State the de Broglie relation, explaining any symbols you use.

.....

.....

..... [2]

(b) An electron of mass m has kinetic energy E. Show that the de Broglie wavelength λ of this electron is given by

$$\lambda = \frac{h}{\sqrt{2mE}}.$$

[2]

(c) Calculate the potential difference through which an electron, initially at rest, must be accelerated so that its de Broglie wavelength is equal to 0.40 nm (the diameter of an atom).

potential difference = ... V [3]

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[Turn over

8 Fig. 8.1 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

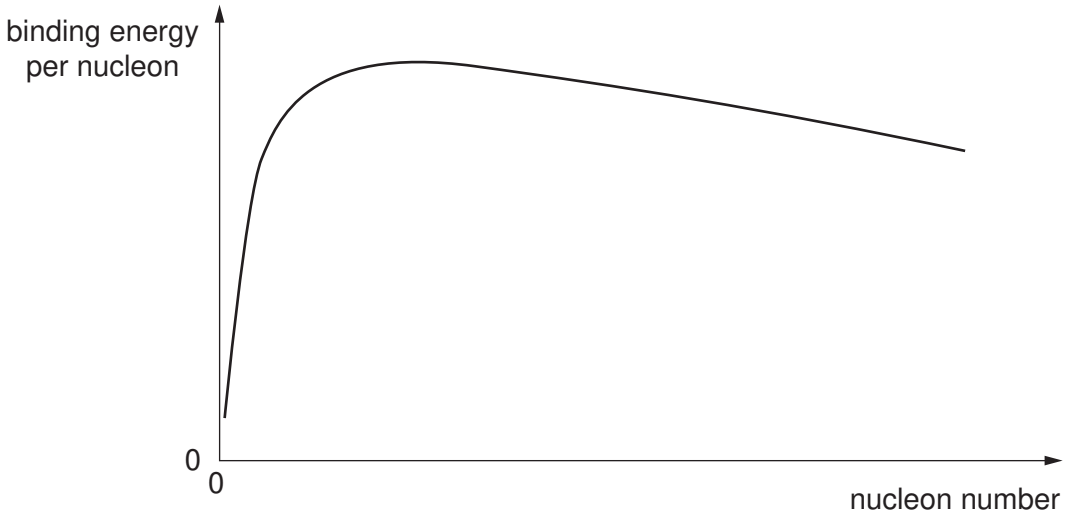

Fig. 8.1

(a) On Fig. 8.1, mark with the letter S the position of the nucleus with the greatest stability. [1]

(b) One possible fission reaction is

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2{}^{1}_{0}\text{n}.$$

(i) On Fig. 8.1, mark possible positions for

1. the Uranium-235 ($^{235}_{92}$U) nucleus (label this position U),

2. the Krypton-90 ($^{90}_{36}$Kr) nucleus (label this position Kr). [1]

(ii) The binding energy per nucleon of each nucleus is as follows.

$^{235}_{92}$U: 1.2191×10^{-12} J
$^{144}_{56}$Ba: 1.3341×10^{-12} J
$^{90}_{36}$Kr: 1.3864×10^{-12} J

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Use these data to calculate

1. the energy release in this fission reaction (give your answer to three significant figures),

energy = ... J [3]

2. the mass equivalent of this energy.

mass = ... kg [2]

(iii) Suggest why the neutrons were not included in your calculation in **(ii)**.

.....

..... [1]

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