UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

7303645500

PHYSICS **9702/41**

Paper 4 A2 Structured Questions **May/June 2010**

1 hour 45 minutes

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.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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Total	

This document consists of **21** printed pages and **3** 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,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
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,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\dfrac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^{\,2} - x^2)}$
electric potential,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
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,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

Section A

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

For Examiner's Use

1 **(a)** Define the *radian*.

....

....

....[2]

(b) A stone of weight 3.0 N is fixed, using glue, to one end P of a rigid rod CP, as shown in Fig. 1.1.

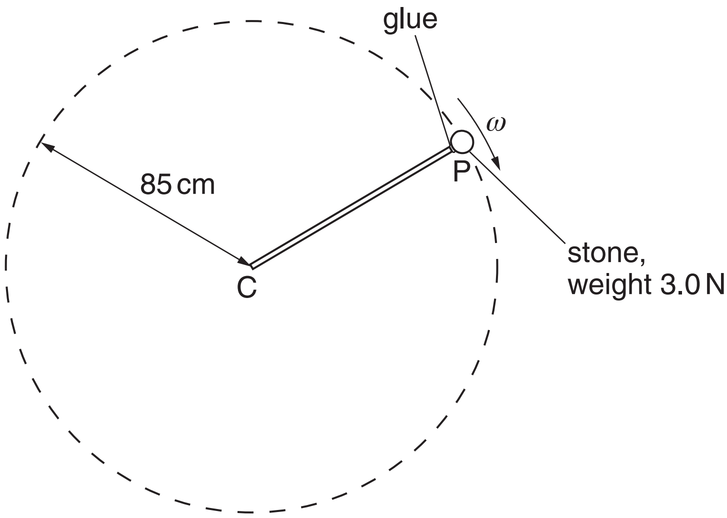

Fig. 1.1

The rod is rotated about end C so that the stone moves in a vertical circle of radius 85 cm.
The angular speed ω of the rod and stone is gradually increased from zero until the glue snaps. The glue fixing the stone snaps when the tension in it is 18 N.

For the position of the stone at which the glue snaps,

(i) on the dotted circle of Fig. 1.1, mark with the letter S the position of the stone, [1]

(ii) calculate the angular speed ω of the stone.

angular speed = ... rad s^{-1} [4]

For Examiner's Use

2 **(a)** Some gas, initially at a temperature of 27.2 °C, is heated so that its temperature rises to 38.8 °C.
Calculate, in kelvin, to an appropriate number of decimal places,

(i) the initial temperature of the gas,

initial temperature = ... K [2]

(ii) the rise in temperature.

rise in temperature = ... K [1]

(b) The pressure p of an ideal gas is given by the expression

$$p = \tfrac{1}{3}\rho\langle c^2\rangle$$

where ρ is the density of the gas.

(i) State the meaning of the symbol $\langle c^2\rangle$.

....

....[1]

(ii) Use the expression to show that the mean kinetic energy $\langle E_K\rangle$ of the atoms of an ideal gas is given by the expression

$$\langle E_K\rangle = \tfrac{3}{2}kT.$$

Explain any symbols that you use.

....

....

....

....

.... [4]

(c) Helium-4 may be assumed to behave as an ideal gas.
A cylinder has a constant volume of $7.8 \times 10^3\,\text{cm}^3$ and contains helium-4 gas at a pressure of $2.1 \times 10^7\,\text{Pa}$ and at a temperature of 290 K.

For Examiner's Use

Calculate, for the helium gas,

(i) the amount of gas,

amount = ... mol [2]

(ii) the mean kinetic energy of the atoms,

mean kinetic energy = ... J [2]

(iii) the total internal energy.

internal energy = ... J [3]

3 **(a)** State what is meant by

(i) *oscillations*,

....

.... [1]

(ii) *free* oscillations,

....

.... [1]

(iii) *simple harmonic motion*.

....

....

.... [2]

(b) Two inclined planes RA and LA each have the same constant gradient. They meet at their lower edges, as shown in Fig. 3.1.

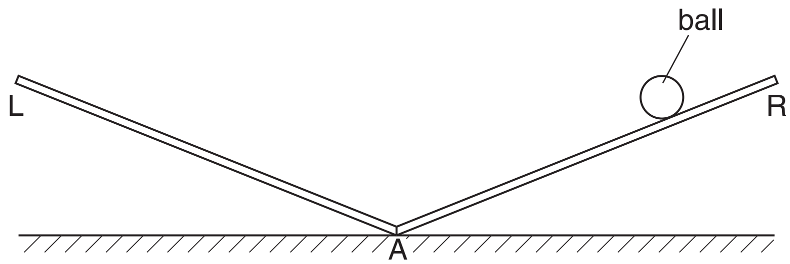

Fig. 3.1

A small ball moves from rest down plane RA and then rises up plane LA. It then moves down plane LA and rises up plane RA to its original height. The motion repeats itself.

State and explain whether the motion of the ball is simple harmonic.

....

....

.... [2]

4 **(a)** Explain what is meant by the *potential energy* of a body.

....

....

.... [2]

(b) Two deuterium (^2_1H) nuclei each have initial kinetic energy E_K and are initially separated by a large distance.
The nuclei may be considered to be spheres of diameter 3.8×10^{-15} m with their masses and charges concentrated at their centres.
The nuclei move from their initial positions to their final position of just touching, as illustrated in Fig. 4.1.

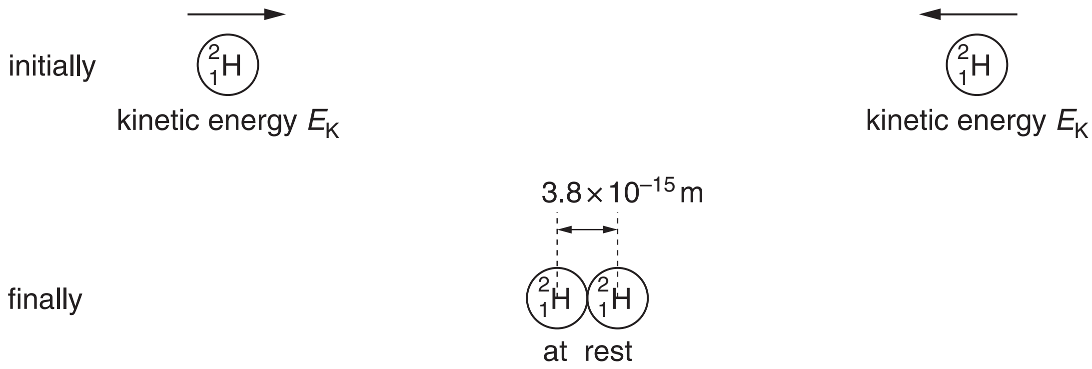

Fig. 4.1

(i) For the two nuclei approaching each other, calculate the total change in

1. gravitational potential energy,

energy = ... J [3]

2. electric potential energy.

energy = ... J [3]

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(ii) Use your answers in **(i)** to show that the initial kinetic energy E_K of each nucleus is 0.19 MeV.

[2]

(iii) The two nuclei may rebound from each other. Suggest one other effect that could happen to the two nuclei if the initial kinetic energy of each nucleus is greater than that calculated in **(ii)**.

....

....[1]

For Examiner's Use

5 **(a)** A constant current is maintained in a long straight vertical wire. A Hall probe is positioned a distance r from the centre of the wire, as shown in Fig. 5.1.

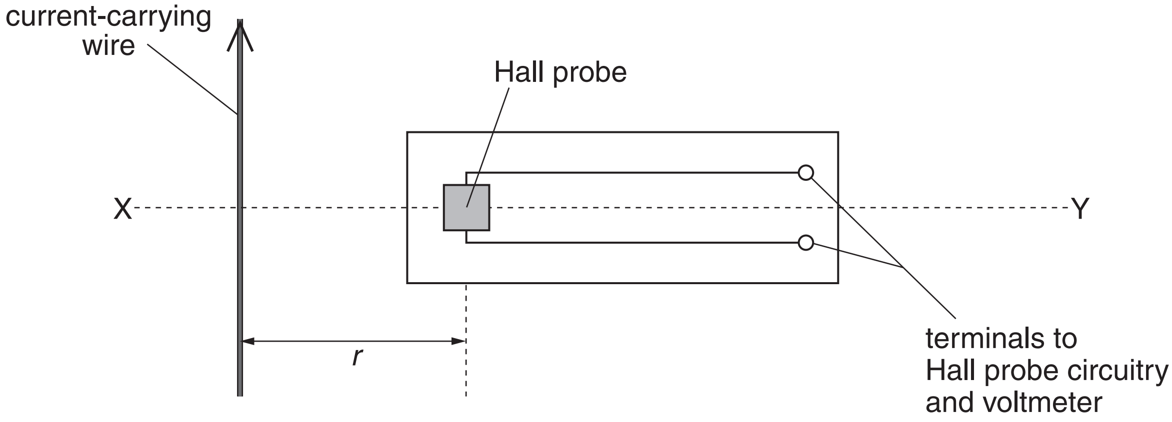

Fig. 5.1

(i) Explain why, when the Hall probe is rotated about the horizontal axis XY, the Hall voltage varies between a maximum positive value and a maximum negative value.

....

....

.... [2]

(ii) The maximum Hall voltage V_H is measured at different distances r.
Data for V_H and the corresponding values of r are shown in Fig. 5.2.

V_H / V	r / cm
0.290	1.0
0.190	1.5
0.140	2.0
0.097	3.0
0.073	4.0
0.060	5.0

Fig. 5.2

It is thought that V_H and r are related by an expression of the form

$$V_H = \frac{k}{r}$$

where k is a constant.

1. Without drawing a graph, use data from Fig. 5.2 to suggest whether the expression is valid.

[2]

2. A graph showing the variation with $\frac{1}{r}$ of V_H is plotted.

State the features of the graph that suggest that the expression is valid.

....

....[1]

(b) The Hall probe in **(a)** is now replaced with a small coil of wire connected to a sensitive voltmeter. The coil is arranged so that its plane is normal to the magnetic field of the wire.

(i) State Faraday's law of electromagnetic induction and hence explain why the voltmeter indicates a zero reading.

....

....

....

....[3]

(ii) State three different ways in which an e.m.f. may be induced in the coil.

1. ....

....

2. ....

....

3. ....

....

[3]

6 A student is asked to design a circuit by which a direct voltage of peak value 9.0 V is obtained from a 240 V alternating supply.
The student uses a transformer that may be considered to be ideal and a bridge rectifier incorporating four ideal diodes.
The partially completed circuit diagram is shown in Fig. 6.1.

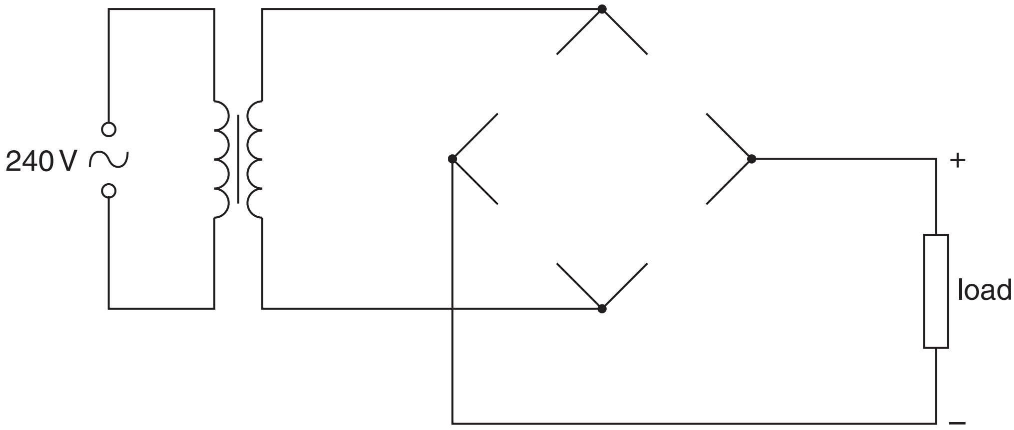

Fig. 6.1

(a) On Fig. 6.1, draw symbols for the four diodes so as to produce the polarity across the load as shown on the diagram. [2]

(b) Calculate the ratio

$$\frac{\text{number of turns on the secondary coil}}{\text{number of turns on the primary coil}}.$$

ratio = ... [3]

7 Negatively-charged particles are moving through a vacuum in a parallel beam. The particles have speed *v*.
The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 7.1.

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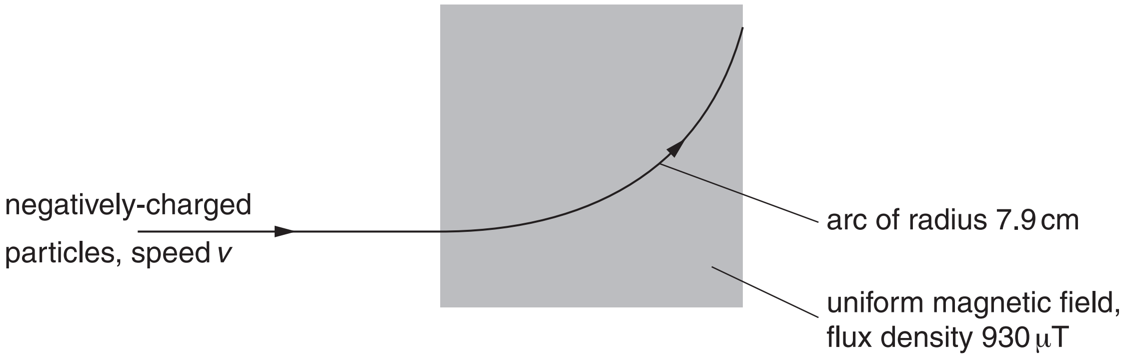

Fig. 7.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 $kV\,m^{-1}$, the particles are undeviated as they pass through the region of the fields.

(a) On Fig. 7.1, mark with an arrow the direction of the electric field. [1]

(b) Calculate, for the negatively-charged particles,

(i) the speed *v*,

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

(ii) the ratio $\frac{\text{charge}}{\text{mass}}$.

ratio = ... $C\,kg^{-1}$ [3]

For Examiner's Use

8 A π^0 meson is a sub-atomic particle.
A stationary π^0 meson, which has mass 2.4×10^{-28} kg, decays to form two γ-ray photons.
The nuclear equation for this decay is

$$\pi^0 \rightarrow \gamma + \gamma.$$

(a) Explain why the two γ-ray photons have the same energy.

....

....

.... [2]

(b) Determine, for each γ-ray photon,

(i) the energy, in joule,

energy = ... J [2]

(ii) the wavelength,

wavelength = ... m [2]

(iii) the momentum.

For Examiner's Use

momentum = ... N s [2]

Section B

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

For Examiner's Use

9 The circuit diagram of Fig. 9.1 is an amplifier circuit incorporating an operational amplifier (op-amp).

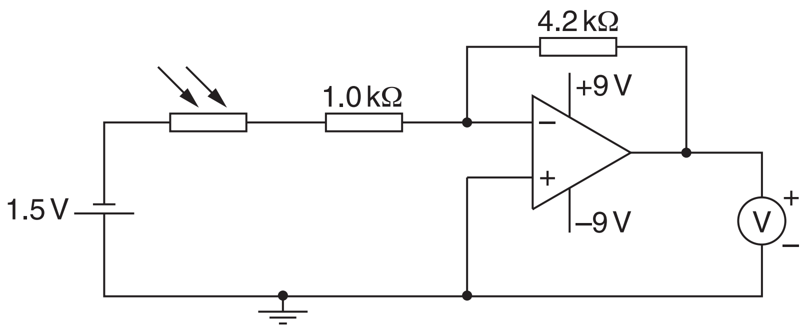

Fig. 9.1

(a) (i) On Fig. 9.1, mark, with the letter X, the virtual earth. [1]

(ii) Explain what is meant by a *virtual earth*.

....

....

....

....[3]

(b) In bright sunlight, the light-dependent resistor (LDR) has resistance 200 Ω.

(i) Calculate, for the LDR in bright sunlight, the voltmeter reading.

reading = ... V [3]

(ii) The sunlight incident on the LDR becomes less bright.
State and explain the effect on the voltmeter reading of this decrease in brightness.

....

....

....

....[3]

For Examiner's Use

For Examiner's Use

10 **(a)** Briefly explain the principles of CT scanning.

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.... [6]

For Examiner's Use

(b) A simple section through a body consists of four voxels, as illustrated in Fig. 10.1.

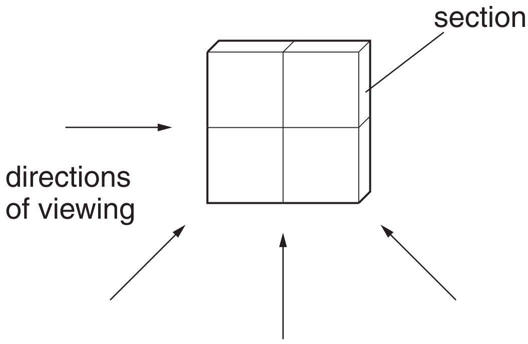

Fig. 10.1

An X-ray image of the section is obtained by viewing along each of the directions shown in Fig. 10.1.
The detector readings for each direction of viewing are summed to give the pattern of readings shown in Fig. 10.2.

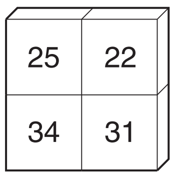

Fig. 10.2

For any one direction, the total of the detector readings is 16.

(i) For the pattern of readings of Fig. 10.2, state the magnitude of the background reading.

background reading = ... [1]

(ii) On Fig. 10.1, mark the pattern of pixels for the four-voxel section. [2]

For Examiner's Use

11 Many radio stations now broadcast on FM rather than on AM. In general, FM is broadcast at much higher frequencies than AM.

(a) Explain what is meant by *FM* (*frequency modulation*).

....

....

....

.... [2]

(b) State two advantages and two disadvantages of FM transmissions when compared with AM transmissions.

advantages of FM transmissions

1. ....

....

2. ....

....

disadvantages of FM transmissions

1. ....

....

2. ....

....

[4]

12 A ground station on Earth transmits a signal of frequency 14 GHz and power 18 kW towards a communications satellite orbiting the Earth, as illustrated in Fig. 12.1.

For Examiner's Use

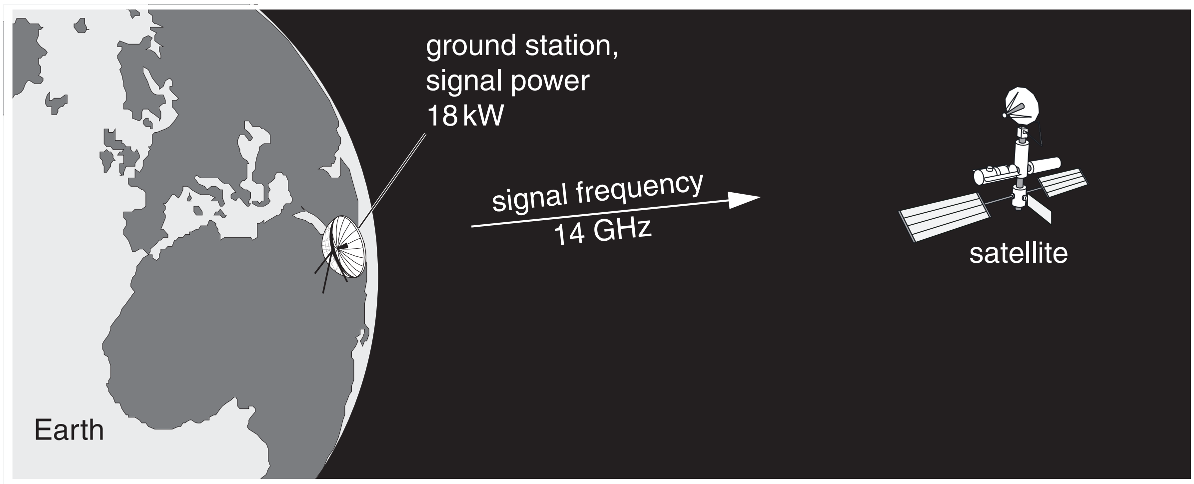

Fig. 12.1

The loss in signal power between the ground station and the satellite is 190 dB.

(a) Calculate the power of the signal received by the satellite.

power = ... W [3]

(b) The signal received by the satellite is amplified and transmitted back to Earth.

(i) Suggest a frequency for the signal that is sent back to Earth.

frequency = ... GHz [1]

(ii) Give a reason for your answer in **(i)**.

....

....[1]

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