| Centre Number | Candidate Number | Name |
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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

**PHYSICS** **9702/04**

Paper 4

May/June 2006

**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.
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.
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 | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| Total | |

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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** The Earth may be considered to be a uniform sphere with its mass $M$ concentrated at its centre.

A satellite of mass $m$ orbits the Earth such that the radius of the circular orbit is $r$.

**(a)** Show that the linear speed $v$ of the satellite is given by the expression

$$v = \sqrt{\left(\frac{GM}{r}\right)}.$$

[2]

**(b)** For this satellite, write down expressions, in terms of $G$, $M$, $m$ and $r$, for

**(i)** its kinetic energy,

kinetic energy = ..... [1]

**(ii)** its gravitational potential energy,

potential energy = ..... [1]

**(iii)** its total energy.

total energy = ..... [2]

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**(c)** The total energy of the satellite gradually decreases.

State and explain the effect of this decrease on

**(i)** the radius *r* of the orbit,

.....

.....

..... [2]

**(ii)** the linear speed *v* of the satellite.

.....

.....

..... [2]

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**[Turn over**

**2** **(a)** The equation

$$pV = constant \times T$$

relates the pressure $p$ and volume $V$ of a gas to its kelvin (thermodynamic) temperature $T$.

State two conditions for the equation to be valid.

1. .....

.....

2. .....

..... [2]

**(b)** A gas cylinder contains $4.00 \times 10^4\,cm^3$ of hydrogen at a pressure of $2.50 \times 10^7\,Pa$ and a temperature of 290 K.

The cylinder is to be used to fill balloons. Each balloon, when filled, contains $7.24 \times 10^3\,cm^3$ of hydrogen at a pressure of $1.85 \times 10^5\,Pa$ and a temperature of 290 K.

Calculate, assuming that the hydrogen obeys the equation in **(a)**,

**(i)** the total amount of hydrogen in the cylinder,

amount = …….. mol [3]

**(ii)** the number of balloons that can be filled from the cylinder.

number = …….. [3]

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**3** The electrical resistance of a thermistor is to be used to measure temperatures in the range 12 °C to 24 °C. Fig. 3.1 shows the variation with temperature, measured in degrees Celsius, of the resistance of the thermistor.

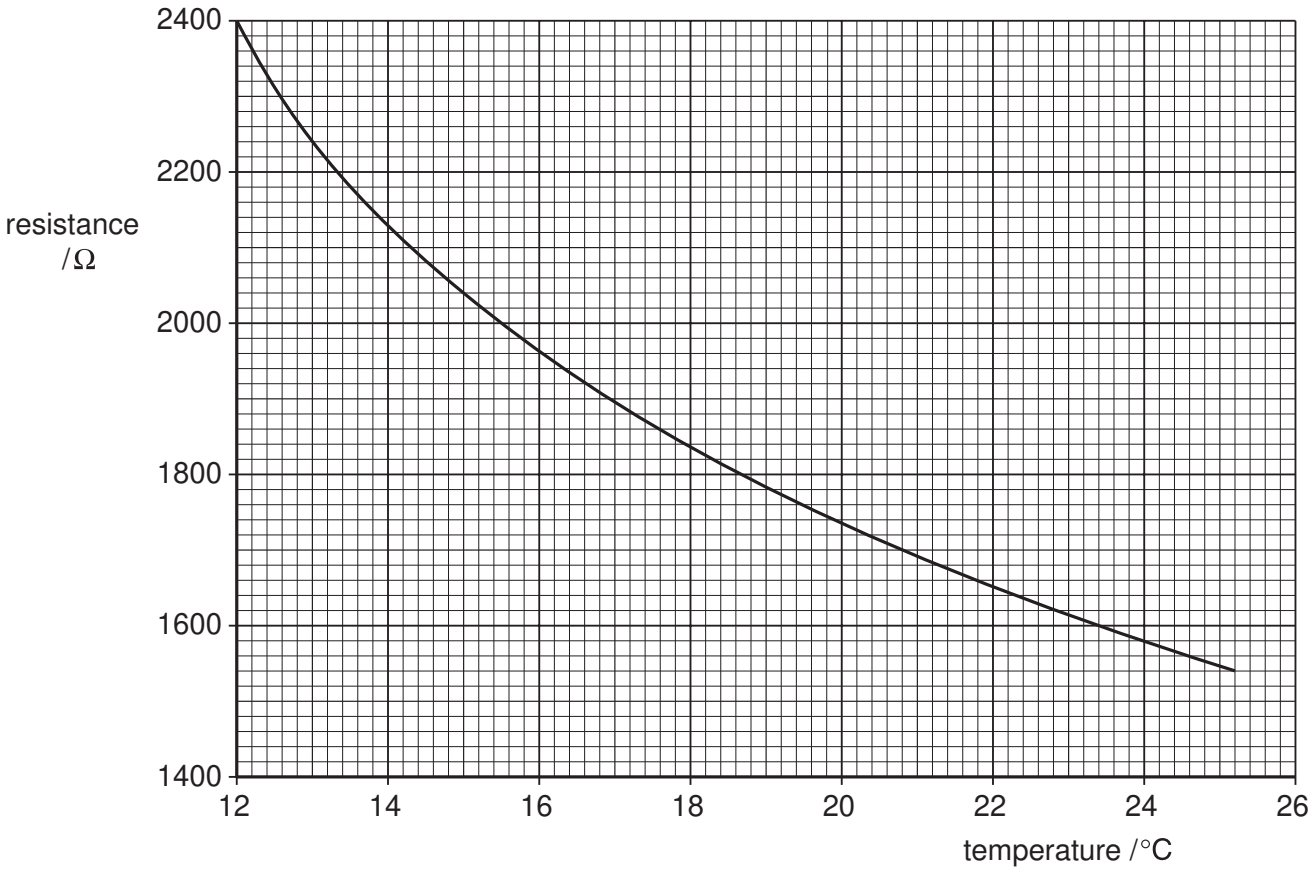


**Fig. 3.1**

**(a)** State and explain the feature of Fig. 3.1 which shows that the thermometer has a sensitivity that varies with temperature.

.....

.....

..... [2]

**(b)** At one particular temperature, the resistance of the thermistor is 2040 ± 20 Ω.

Determine this temperature, in kelvin, to an appropriate number of decimal places.

temperature = ..... K [3]

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**[Turn over**

**4** A piston moves vertically up and down in a cylinder, as illustrated in Fig. 4.1.

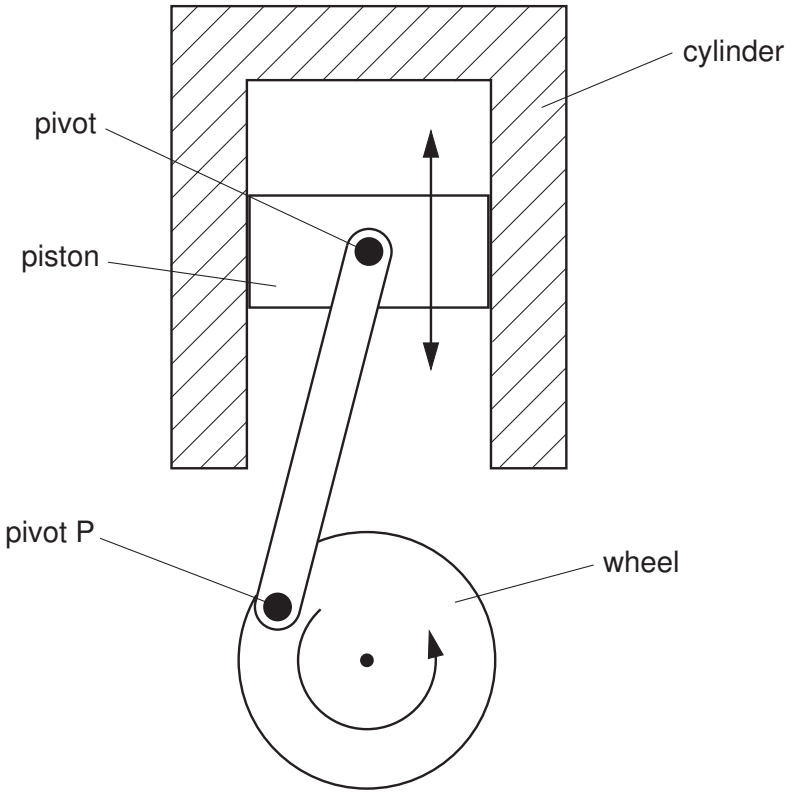


**Fig. 4.1**

The piston is connected to a wheel by means of a rod that is pivoted at the piston and at the wheel. As the piston moves up and down, the wheel is made to rotate.

**(a) (i)** State the number of oscillations made by the piston during one complete rotation of the wheel.

number = ..... [1]

**(ii)** The wheel makes 2400 revolutions per minute. Determine the frequency of oscillation of the piston.

frequency = ..... Hz [1]

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**(b)** The amplitude of the oscillations of the piston is 42 mm.

Assuming that these oscillations are simple harmonic, calculate the maximum values for the piston of

**(i)** the linear speed,

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

**(ii)** the acceleration.

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

**(c)** On Fig. 4.1, mark a position of the pivot P for the piston to have

**(i)** maximum speed (mark this position S), [1]

**(ii)** maximum acceleration (mark this position A). [1]

**5** An isolated conducting sphere of radius $r$ is placed in air. It is given a charge $+Q$. This charge may be assumed to act as a point charge situated at the centre of the sphere.

**(a) (i)** Define *electric field strength*.

.....

..... [1]

**(ii)** State a formula for the electric field strength $E$ at the surface of the sphere. Also, state the meaning of any other symbols used.

.....

.....

..... [2]

**(b)** The maximum field strength at the surface of the sphere before electrical breakdown (sparking) occurs is $2.0 \times 10^6$ V m$^{-1}$. The sphere has a radius $r$ of 0.35 m.

Calculate the maximum values of

**(i)** the charge that can be stored on the sphere,

charge = ……..…… C [2]

**(ii)** the potential at the surface of the sphere.

potential = ……..…… V [2]

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**(c)** Suggest the effect of the electric field on a single atom near the sphere's surface as electrical breakdown of the air occurs.

.....

.....

..... [2]

**6** Two long, straight, current-carrying conductors, PQ and XY, are held a constant distance apart, as shown in Fig. 6.1.

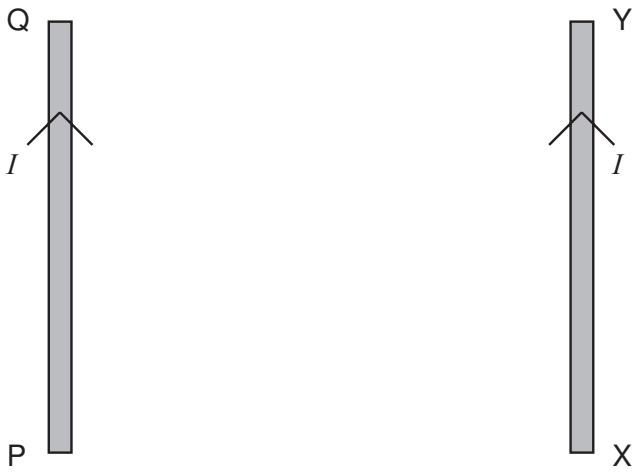


**Fig. 6.1**

The conductors each carry the same magnitude current in the same direction.

A plan view from above the conductors is shown in Fig. 6.2.




**Fig. 6.2**

**(a)** On Fig. 6.2 draw arrows, one in each case, to show the direction of

**(i)** the magnetic field at Q due to the current in wire XY (label this arrow B), [1]

**(ii)** the force at Q as a result of the magnetic field due to the current in wire XY (label this arrow F). [1]

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**(b) (i)** State Newton's third law of motion.

.....

.....

..... [1]

**(ii)** Use this law and your answer in **(a)(ii)** to state the direction of the force on wire XY.

.....

..... [1]

**(c)** The magnetic flux density $B$ at a distance $d$ from a long straight wire carrying a current $I$ is given by

$$B = 2.0 \times 10^{-7} \times \frac{I}{d} .$$

Use this expression to explain why, under normal circumstances, wires carrying alternating current are not seen to vibrate. Make reasonable estimates of the magnitudes of the quantities involved.

.....

.....

.....

.....

..... [4]

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**[Turn over**

**7** A parallel beam of electrons, all travelling at the same speed, is incident normally on a carbon film. The scattering of the electrons by the film is observed on a fluorescent screen, as illustrated in Fig. 7.1.

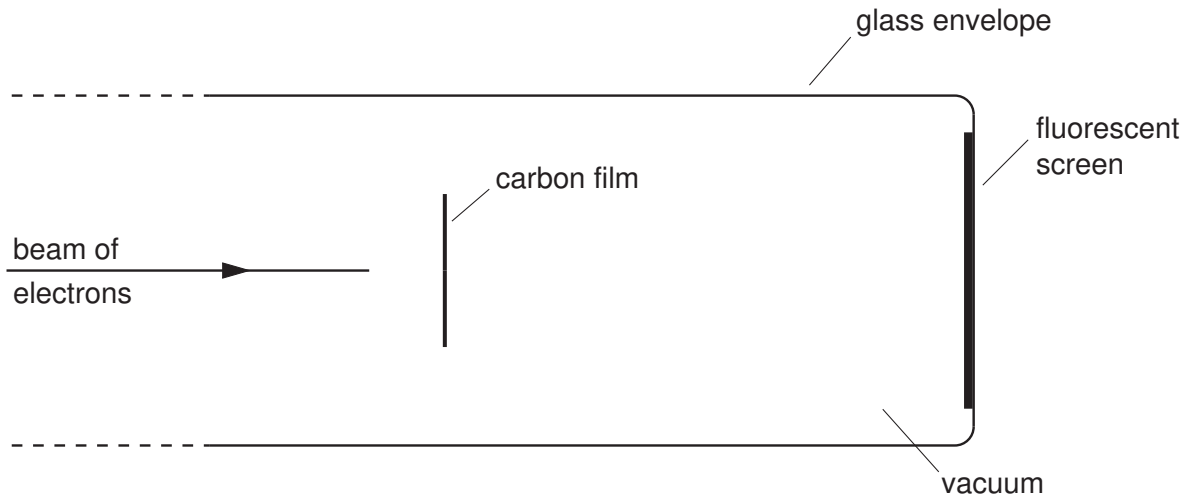


**Fig. 7.1**

**(a)** Assuming that the electrons behave as **particles**, predict what would be seen on the screen.

.....

..... [1]

**(b)** In this experiment, the electrons do **not** behave as particles.

Describe briefly the pattern that is actually observed on the screen. You may draw a sketch if you wish.

.....

..... [1]

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**(c)** The speed of the electrons is gradually increased.

State and explain what change, if any, is observed in the pattern on the screen.

.....

.....

.....

..... [3]

**QUESTION 8 IS ON THE NEXT PAGE**

**8** A proton is moving with constant velocity $v$. It enters a uniform magnetic field that is normal to the initial direction of motion of the proton, as shown in Fig. 8.1.

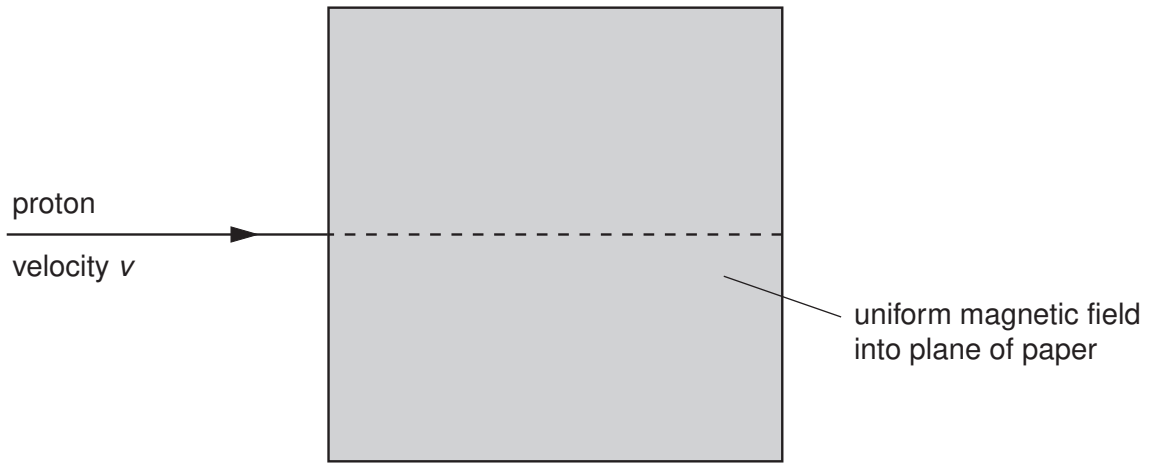


**Fig. 8.1**

A uniform electric field is applied in the same region as the magnetic field so that the proton passes undeviated through the fields.

**(a)** On Fig. 8.1, draw an arrow labelled E to show the direction of the electric field. [1]

**(b)** The proton is replaced by other particles. The electric and magnetic fields remain unchanged.

State and explain the deviation, if any, of the following particles in the region of the fields.

**(i)** an $\alpha$-particle with initial velocity $v$

.....

.....

.....

..... [3]

**(ii)** an electron with initial velocity $2v$

.....

.....

.....

..... [3]

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