UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

0004834121

PHYSICS **9702/42**

Paper 4 A2 Structured Questions **October/November 2013**

2 hours

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 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.

Electronic calculators may be used.
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 **22** printed pages and **2** blank pages.

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UNIVERSITY *of* CAMBRIDGE International Examinations

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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,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
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.

1 **(a)** Define *gravitational potential* at a point.

....

....

.... [2]

(b) The Moon may be considered to be an isolated sphere of radius 1.74×10^3 km with its mass of 7.35×10^{22} kg concentrated at its centre.

(i) A rock of mass 4.50 kg is situated on the surface of the Moon. Show that the change in gravitational potential energy of the rock in moving it from the Moon's surface to infinity is 1.27×10^7 J.

[1]

(ii) The escape speed of the rock is the minimum speed that the rock must be given when it is on the Moon's surface so that it can escape to infinity.
Use the answer in **(i)** to determine the escape speed. Explain your working.

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

(c) The Moon in **(b)** is assumed to be isolated in space. The Moon does, in fact, orbit the Earth.
State and explain whether the minimum speed for the rock to reach the Earth from the surface of the Moon is different from the escape speed calculated in **(b)**.

....

....

.... [2]

For Examiner's Use

2 The product of the pressure p and the volume V of an ideal gas is given by the expression

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where m is the mass of one molecule of the gas.

(a) State the meaning of the symbol

(i) N,

.... [1]

(ii) $\langle c^2\rangle$.

.... [1]

(b) The product pV is also given by the expression

$$pV = NkT.$$

Deduce an expression, in terms of the Boltzmann constant k and the thermodynamic temperature T, for the mean kinetic energy of a molecule of the ideal gas.

[2]

(c) A cylinder contains 1.0 mol of an ideal gas.

(i) The volume of the cylinder is constant.
Calculate the energy required to raise the temperature of the gas by 1.0 kelvin.

energy = ... J [2]

(ii) The volume of the cylinder is now allowed to increase so that the gas remains at constant pressure when it is heated.
Explain whether the energy required to raise the temperature of the gas by 1.0 kelvin is now different from your answer in **(i)**.

....

....

.... [2]

For Examiner's Use

3 A metal ball is suspended from a fixed point by means of a string, as illustrated in Fig. 3.1.

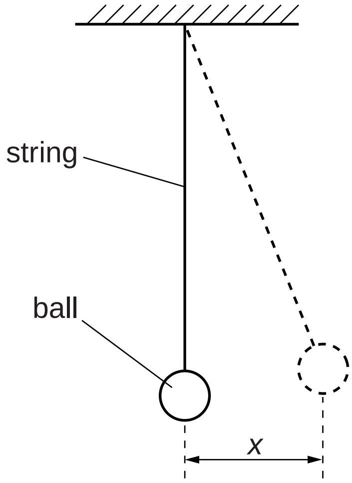

Fig. 3.1

The ball is given a small displacement and then released. The variation with time *t* of the displacement *x* of the ball is shown in Fig. 3.2.

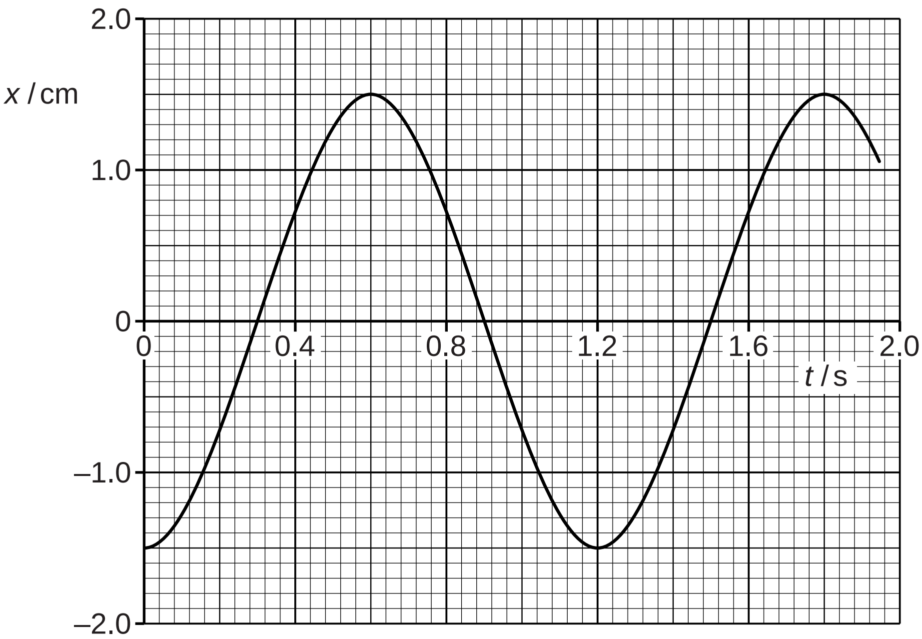

Fig. 3.2

(a) (i) State two times at which the speed of the ball is a maximum.

time = ... s and time = ... s [1]

(ii) Show that the maximum speed of the ball is approximately 0.08 m s^{-1}.

[2]

(b) The variation with displacement *x* of the potential energy E_P of the oscillations of the ball is shown in Fig. 3.3.

For Examiner's Use

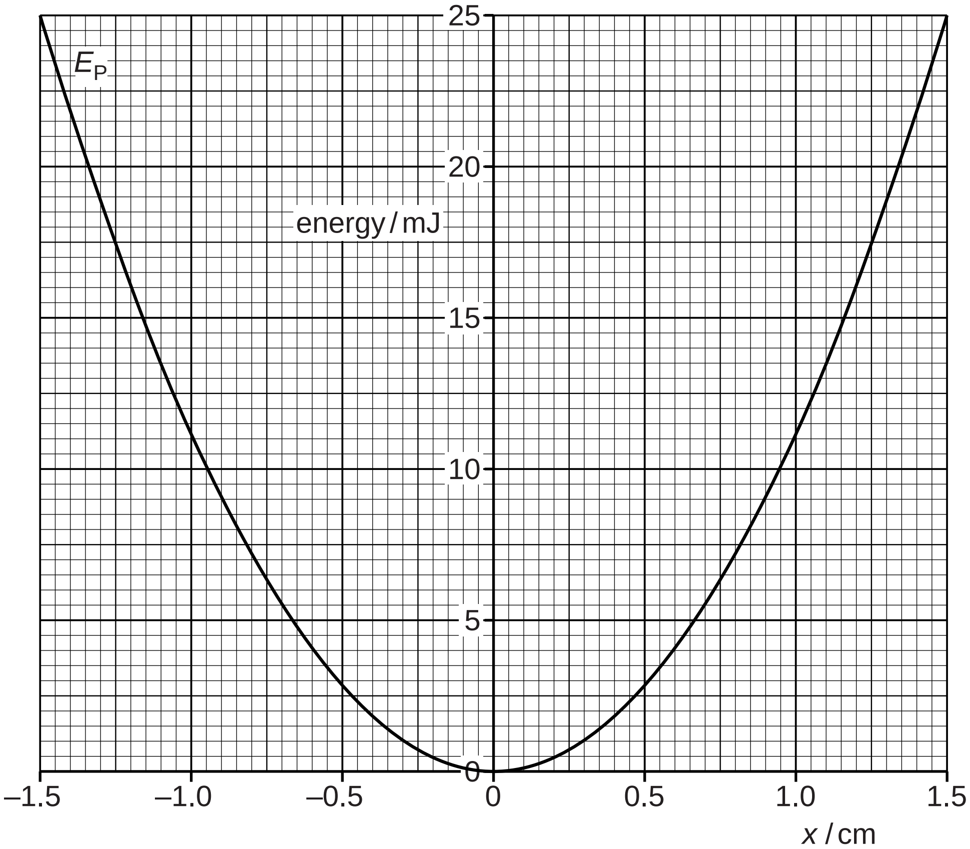

Fig. 3.3

(i) On the axes of Fig. 3.3, sketch a graph to show the variation with displacement *x* of the kinetic energy of the ball. [2]

(ii) The amplitude of the oscillations reduces over a long period of time.
After many oscillations, the amplitude of the oscillations is 0.60 cm.

Use Fig. 3.3 to determine the total energy of the oscillations of the ball for oscillations of amplitude 0.60 cm. Explain your working.

energy = ... J [2]

4 An α-particle and a proton are at rest a distance 20 μm apart in a vacuum, as illustrated in Fig. 4.1.

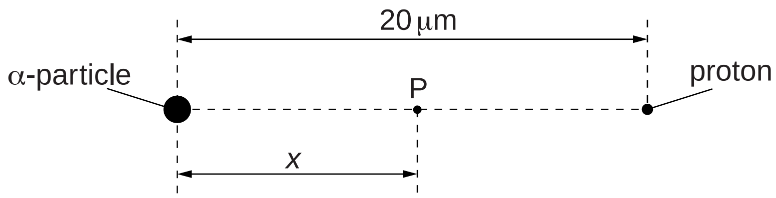

Fig. 4.1

(a) **(i)** State Coulomb's law.

....

....

.... [2]

(ii) The α-particle and the proton may be considered to be point charges.
Calculate the electric force between the α-particle and the proton.

force = ... N [2]

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

....

....

.... [2]

For Examiner's Use

(ii) A point P is distance x from the α-particle along the line joining the α-particle to the proton (see Fig. 4.1). The variation with distance x of the electric field strength E_α due to the α-particle alone is shown in Fig. 4.2.

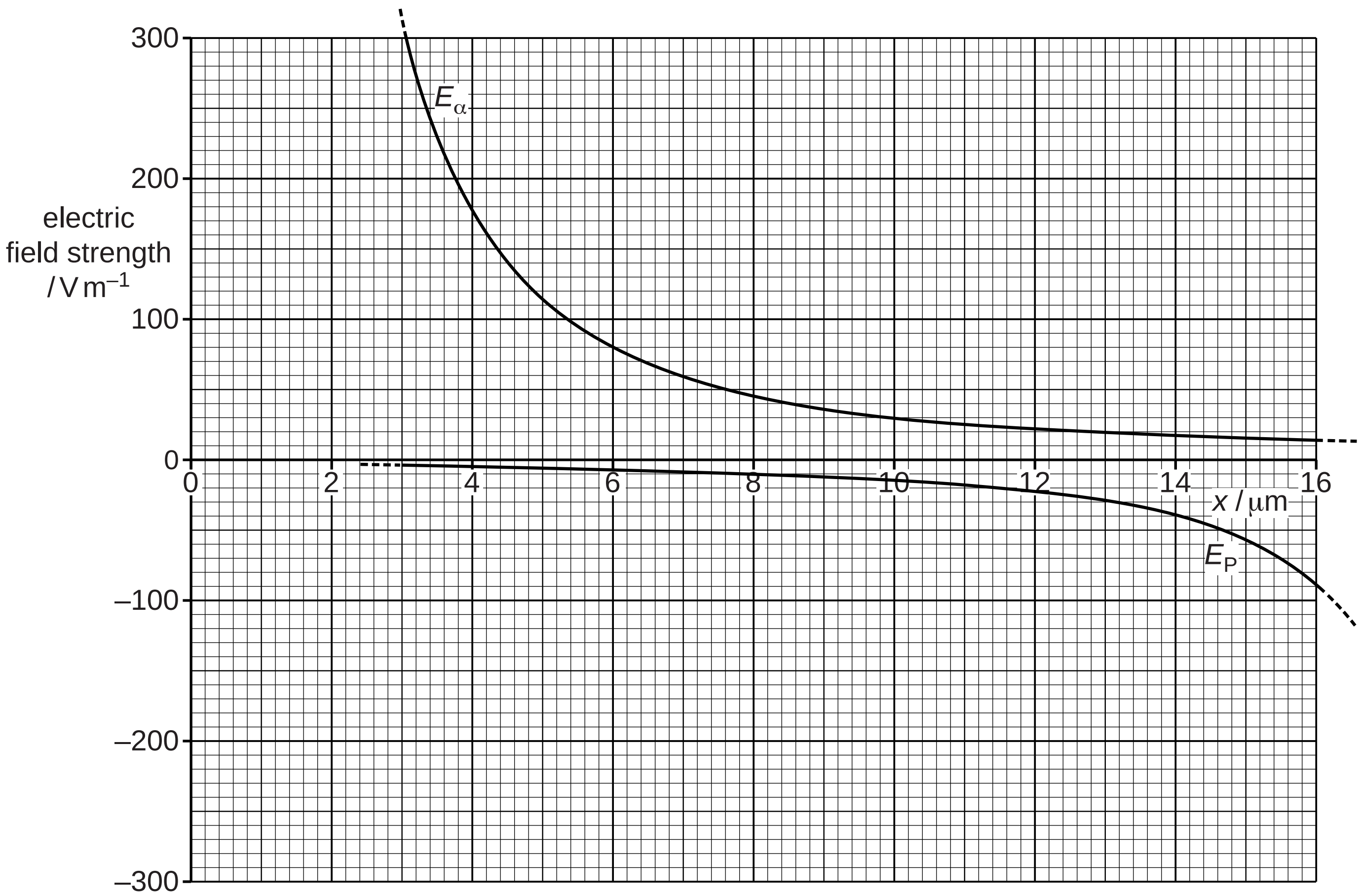

Fig. 4.2

The variation with distance x of the electric field strength E_P due to the proton alone is also shown in Fig. 4.2.

1. Explain why the two separate electric fields have opposite signs.

....

....

.... [2]

2. On Fig. 4.2, sketch the variation with x of the combined electric field due to the α-particle and the proton for values of x from 4 μm to 16 μm. [3]

For Examiner's Use

5 **(a)** An incomplete diagram for the magnetic flux pattern due to a current-carrying solenoid is illustrated in Fig. 5.1.

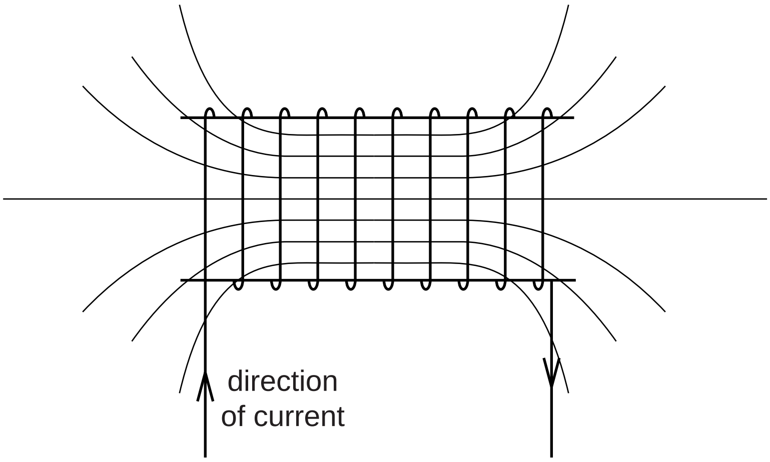

Fig. 5.1

(i) On Fig. 5.1, draw arrows on the field lines to show the direction of the magnetic field. [1]

(ii) State the feature of Fig. 5.1 that indicates that the magnetic field strength at each end of the solenoid is less than that at the centre.

.... [1]

(b) A Hall probe is placed near one end of the solenoid in **(a)**, as shown in Fig. 5.2.

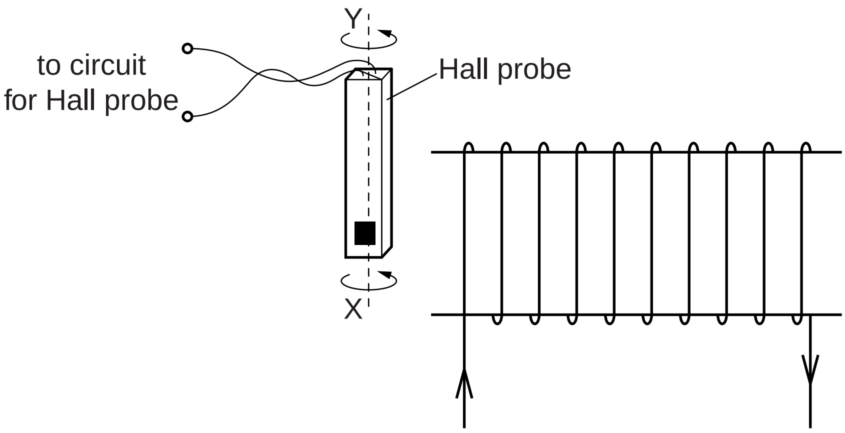

Fig. 5.2

The Hall probe is rotated about the axis XY. State and explain why the magnitude of the Hall voltage varies.

....

....

.... [2]

For Examiner's Use

(c) (i) State Faraday's law of electromagnetic induction.

....

....

.... [2]

(ii) The Hall probe in **(b)** is replaced by a small coil of wire connected to a sensitive voltmeter.
State three different ways in which an e.m.f. may be induced in the coil.

1. ....

....

2. ....

....

3. ....

....
[3]

For Examiner's Use

6 A charged particle of mass m and charge $-q$ is travelling through a vacuum at constant speed v.
It enters a uniform magnetic field of flux density B. The initial angle between the direction of motion of the particle and the direction of the magnetic field is 90°.

(a) Explain why the path of the particle in the magnetic field is the arc of a circle.

....

....

....

.... [3]

(b) The radius of the arc in **(a)** is r.

Show that the ratio $\frac{q}{m}$ for the particle is given by the expression

$$\frac{q}{m} = \frac{v}{Br}.$$

[1]

(c) The initial speed v of the particle is $2.0 \times 10^{7}\,\mathrm{m\,s^{-1}}$. The magnetic flux density B is $2.5 \times 10^{-3}\,\mathrm{T}$.
The radius r of the arc in the magnetic field is 4.5 cm.

(i) Use these data to calculate the ratio $\frac{q}{m}$.

ratio = ... $\mathrm{C\,kg^{-1}}$ [2]

For Examiner's Use

(ii) The path of the negatively-charged particle before it enters the magnetic field is shown in Fig. 6.1.

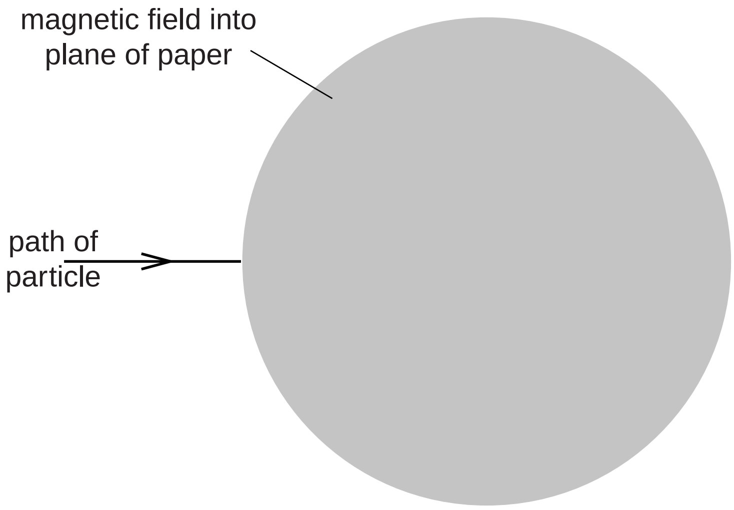

Fig. 6.1

The direction of the magnetic field is into the plane of the paper.

On Fig. 6.1, sketch the path of the particle in the magnetic field and as it emerges from the field. [2]

For Examiner's Use

7 Electrons, travelling at speed *v* in a vacuum, are incident on a very thin carbon film, as illustrated in Fig. 7.1.

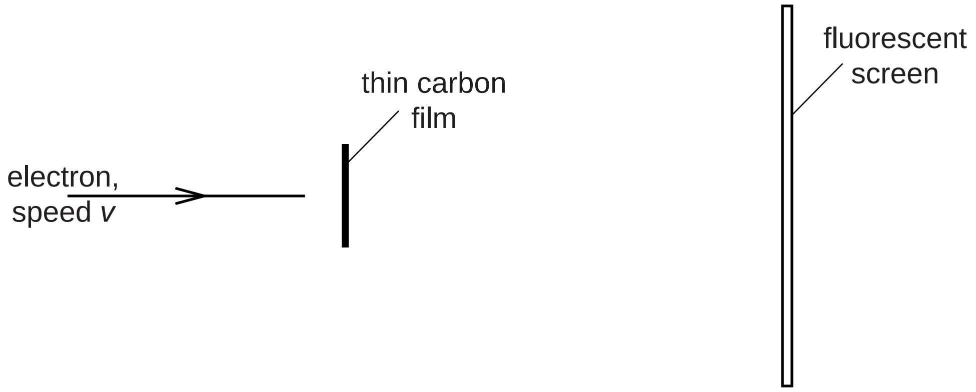

Fig. 7.1

The emergent electrons are incident on a fluorescent screen.
A series of concentric rings is observed on the screen.

(a) Suggest why the observed rings provide evidence for the wave nature of particles.

....

....

....

.... [2]

(b) The initial speed of the electrons is increased. State and explain the effect, if any, on the radii of the rings observed on the screen.

....

....

....

.... [3]

For Examiner's Use

(c) A proton and an electron are each accelerated from rest through the same potential difference.
Determine the ratio

$$\frac{\text{de Broglie wavelength of the proton}}{\text{de Broglie wavelength of the electron}}.$$

ratio = ... [4]

8 **(a)** State what is meant by *nuclear binding energy*.

....

....

....[2]

(b) The variation with nucleon number A of the binding energy per nucleon B_E is shown in Fig. 8.1.

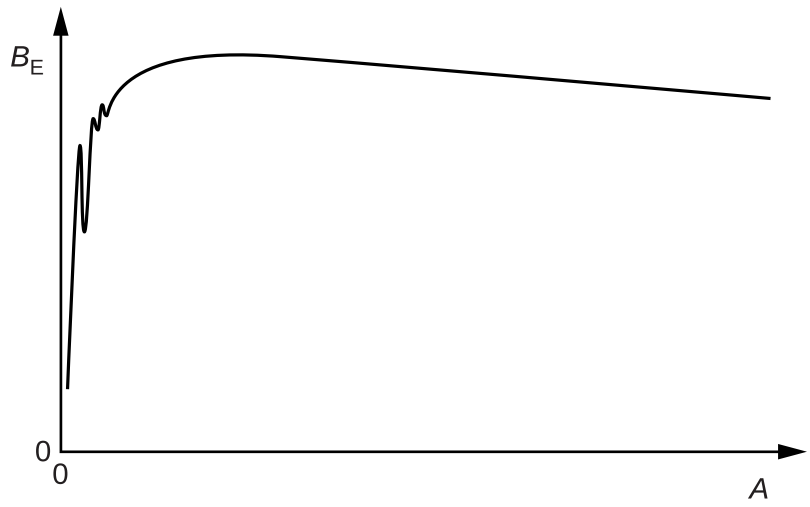

Fig. 8.1

When uranium-235 ($^{235}_{92}U$) absorbs a slow-moving neutron, one possible nuclear reaction is

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{95}_{42}Mo + {}^{139}_{57}La + 2{}^{1}_{0}n + 7{}^{0}_{-1}\beta + \text{energy.}$$

(i) State the name of this type of nuclear reaction.

....[1]

(ii) On Fig. 8.1, mark the position of

1. the uranium-235 nucleus (label this position U), [1]

2. the molybdenum-95 ($^{95}_{42}Mo$) nucleus (label this position Mo), [1]

3. the lanthanum-139 ($^{139}_{57}La$) nucleus (label this position La). [1]

For Examiner's Use

(iii) The masses of some particles and nuclei are given in Fig. 8.2.

	mass / u
β-particle	5.5×10^{-4}
neutron	1.009
proton	1.007
uranium-235	235.123
molybdenum-95	94.945
lanthanum-139	138.955

Fig. 8.2

Calculate, for this reaction,

1. the change, in u, of the rest mass,

change in mass = ... u [2]

2. the energy released, in MeV, to three significant figures.

energy = ... MeV [3]

Section B

For Examiner's Use

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

9 An electronic sensor may be represented by the block diagram of Fig. 9.1.

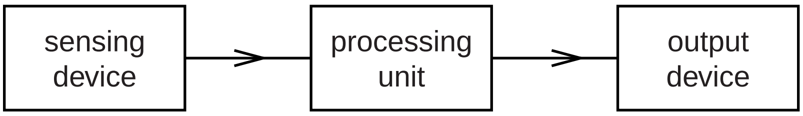

Fig. 9.1

(a) State the function of the processing unit.

....

....

.... [2]

(b) A student designs a sensing unit for temperature change. A 4V supply, a fixed resistor of resistance 2.5kΩ and a thermistor are available. The thermistor has resistance 3.0kΩ at 6°C and resistance 1.8kΩ at 20°C.

Complete the circuit diagram of Fig. 9.2 to show how the resistor and the thermistor are connected to provide an output that is greater than 2V at 6°C and less than 2V at 20°C. Mark clearly the output V_{OUT}.

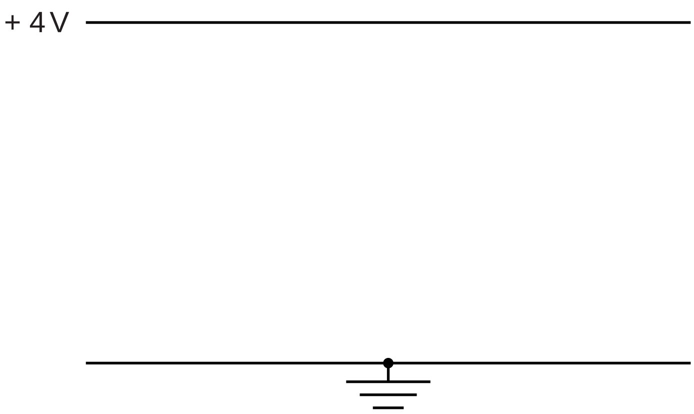

Fig. 9.2

[3]

(c) Suggest two uses of a relay as part of an output device.

1. ....

....

2. ....

....

[2]

For Examiner's Use

10 **(a)** Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

....

....

....

....

....

....

....

....

....

....

.... [6]

(b) State and explain one advantage of the use of high frequency ultrasound as compared with low frequency ultrasound for medical diagnosis.

....

....

.... [2]

(c) The absorption (attenuation) coefficient for ultrasound in muscle is 23 m^{-1}.
A parallel beam of ultrasound is passed through a muscle of thickness 6.4 cm.

(i) Calculate the ratio

$$\frac{\text{intensity of transmitted beam}}{\text{intensity of incident beam}}.$$

ratio = ... [3]

(ii) An ultrasound transmitter emits a pulse.
Suggest why, when the signal from the pulse is processed, any signal received later at the detector is usually amplified more than that received at an earlier time.

....

....

....[2]

For Examiner's Use

11 The variation with time t of the output V produced by a microphone is shown in Fig. 11.1.

For Examiner's Use

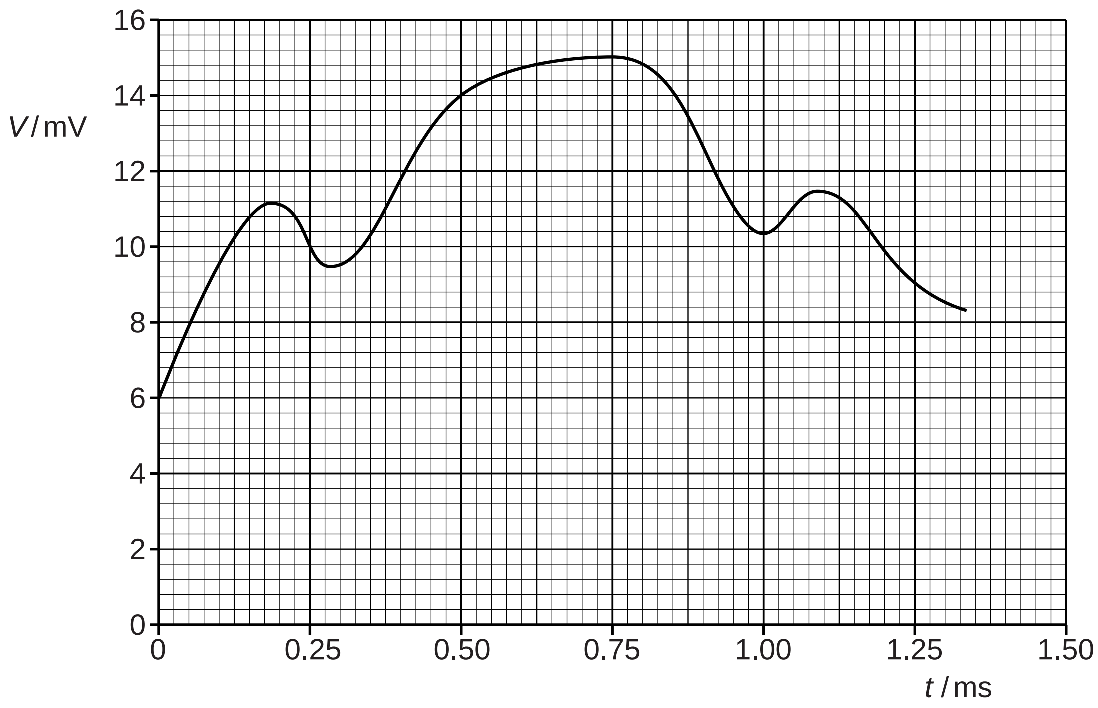

Fig. 11.1

The output is processed by a four-bit analogue-to-digital converter (ADC) that samples the output every 0.25 ms.
The first sample is taken at time t = 0 and is shown in Fig. 11.2.

0110					

Fig. 11.2

(a) On Fig. 11.2, underline the most significant bit (MSB) of the sample shown. [1]

(b) Complete Fig. 11.2 for the next five samples. [2]

(c) Explain whether the sampling frequency is adequate to enable detail of the output V to be reproduced.

....

....

....[2]

For Examiner's Use

12 **(a)** Suggest why attenuation of a signal in channels of communication is usually measured on a logarithmic rather than a linear scale.

....

.... [1]

(b) For a particular channel of communication having low attenuation, the input power is 6.5 mW and the attenuation per unit length is $1.8\,\text{dB}\,\text{km}^{-1}$.

(i) Suggest the name of this channel of communication.

.... [1]

(ii) Calculate the distance over which the power of the signal is reduced to 1.5×10^{-15} W.

distance = ... km [3]

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