Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6110056757

PHYSICS **9702/43**

Paper 4 A2 Structured Questions **October/November 2015**

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 an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, 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.

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This document consists of **23** printed pages and **1** blank page.

DC (NF/CGW) 97089/2

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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,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
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)** State Newton's law of gravitation.

....

....

.... [2]

(b) Some of the planets in the Solar System have several moons (satellites) that have circular orbits about the planet.
The planet and each of its moons may be considered to be point masses.

Show that the radius *x* of a moon's orbit is related to the period *T* of the orbit by the expression

$$GM = \frac{4\pi^2 x^3}{T^2}$$

where *G* is the gravitational constant and *M* is the mass of the planet. Explain your working.

[3]

(c) The planet Neptune has eight moons, each in a circular orbit of radius x and period T. The variation with T^2 of x^3 for some of the moons is shown in Fig. 1.1.

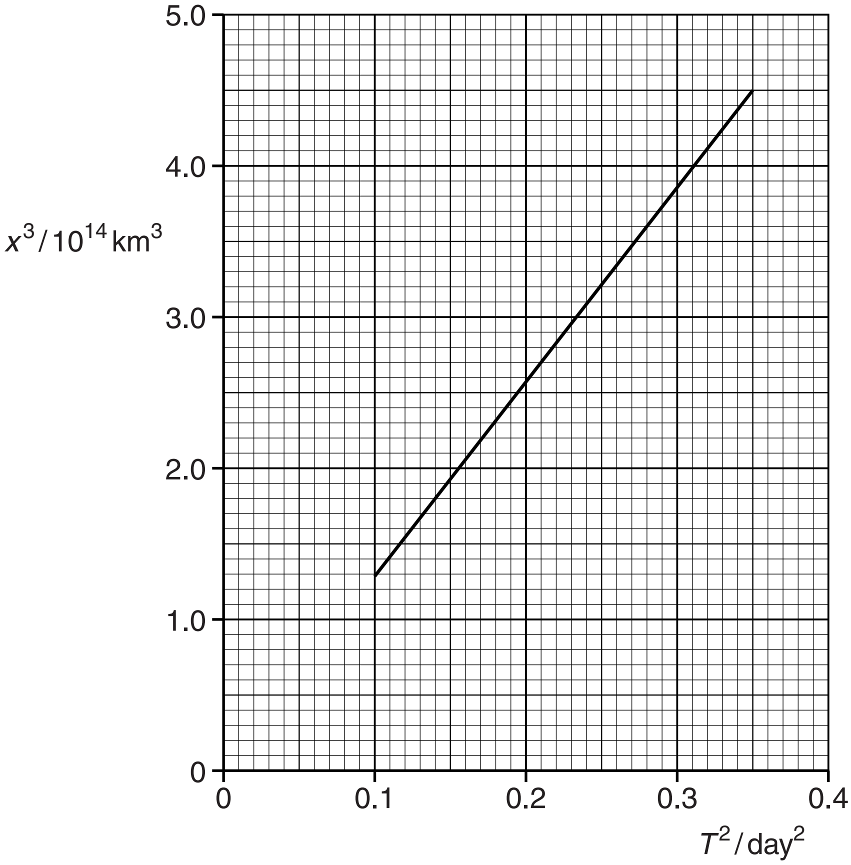

Fig. 1.1

Use Fig. 1.1 and the expression in **(b)** to determine the mass of Neptune.

mass = ... kg [4]

2 **(a)** An ideal gas is said to consist of molecules that are hard elastic identical spheres.

State two further assumptions of the kinetic theory of gases.

1. ....

....

2. ....

.... [2]

(b) The number of molecules per unit volume in an ideal gas is n.

If it is assumed that all the molecules are moving with speed v, the pressure p exerted by the gas on the walls of the vessel is given by

$$p = \frac{1}{3}nmv^2$$

where m is the mass of one molecule.

Explain the reasoning by which this expression is modified to give the formula

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

....

.... [1]

(c) The density of an ideal gas is $1.2\,\text{kg}\,\text{m}^{-3}$ at a pressure of $1.0 \times 10^5\,\text{Pa}$ and a temperature of 27 °C.

(i) Calculate the root-mean-square (r.m.s.) speed of the molecules of the gas at 27 °C.

r.m.s. speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(ii) Calculate the mean-square speed of the molecules at 207 °C.

mean-square speed = ... $m^2 s^{-2}$ [2]

3 **(a)** Two bodies are in thermal equilibrium.

State what is meant by *thermal equilibrium*.

....

....

.... [2]

(b) The temperature of a body is found to increase from 15.9 °C to 57.2 °C.

Determine, in kelvin and to an appropriate number of decimal places,

(i) the rise in temperature of the body,

temperature rise = ... K [1]

(ii) the final temperature.

temperature = ... K [1]

(c) An ideal gas at a constant pressure of 1.2×10^5 Pa is heated from a temperature of 290 K to a final temperature of 350 K. The change in volume of the gas is 950 cm^3.

The total change in kinetic energy ΔE_K, measured in joules, of the gas molecules is given by the expression

$$\Delta E_K = \frac{3}{2} \times 1.9 \times \Delta T$$

where ΔT is the change in temperature in kelvin.

Determine the thermal energy required to produce the change in temperature from 290 K to 350 K.

energy = ... J [4]

4 **(a)** Define *simple harmonic motion*.

....

....

.... [2]

(b) A tube, sealed at one end, has a circular cross-sectional area A of $4.9 \times 10^{-4}\,\text{m}^2$. Some sand is put in the tube so that the total mass M of the tube and its contents is 70 g. The tube floats upright in a liquid, as shown in Fig. 4.1.

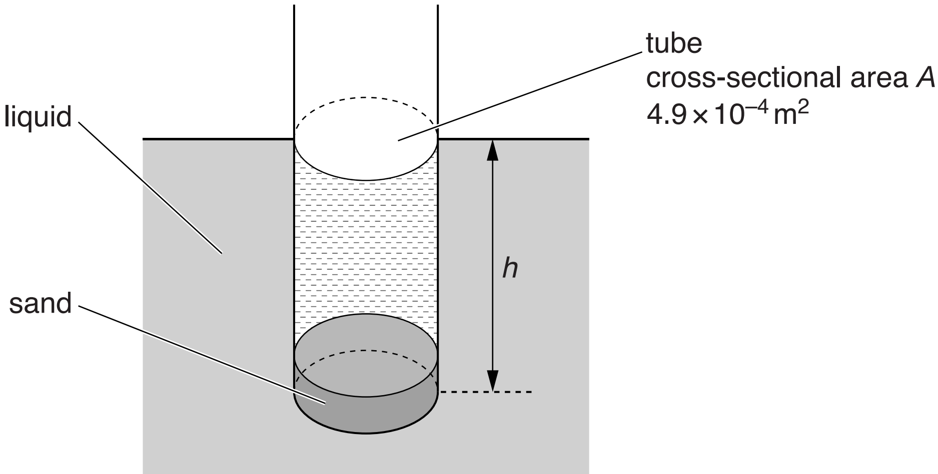

Fig. 4.1

The liquid has a density ρ of $0.79\,\text{g}\,\text{cm}^{-3}$.

By reference to the liquid pressure exerted on the base of the tube, show that the distance h of the base of the tube below the liquid surface is 18 cm. Explain your working.

[2]

(c) The tube in **(b)** is displaced vertically and then released. The variation with time t of the distance h is shown in Fig. 4.2.

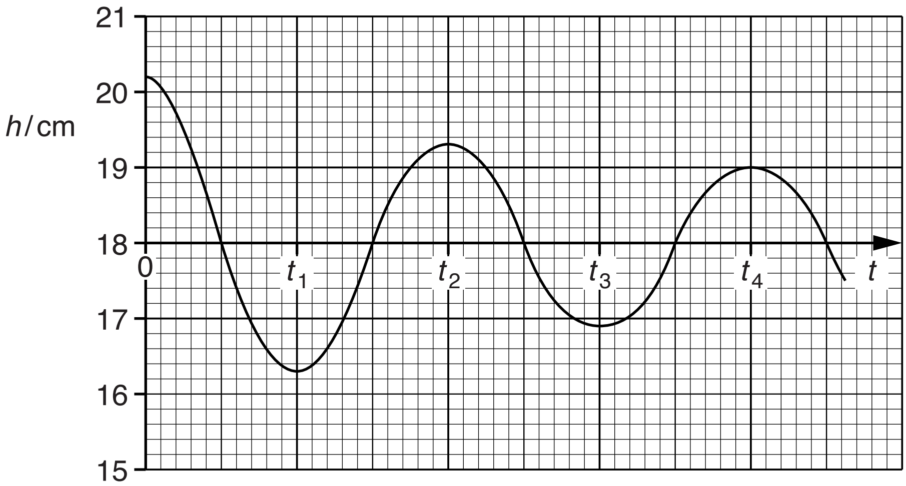

Fig. 4.2

The system oscillates with simple harmonic motion of angular frequency ω given by the expression

$$\omega^2 = \frac{\rho A g}{M}$$

where g is the acceleration of free fall.

(i) Use data from **(b)** to determine

1. the time t_1,

t_1 = ... s [3]

2. the time t_3.

t_3 = ... s [1]

(ii) Determine the loss in total energy of the oscillating system between time $t = 0$ and time $t = t_4$.

loss in energy = ... J [3]

5 A positively charged solid metal sphere is isolated in space. The electric field strength E is measured for different distances x from the centre of the sphere. The variation with x of the field strength E is shown in Fig. 5.1.

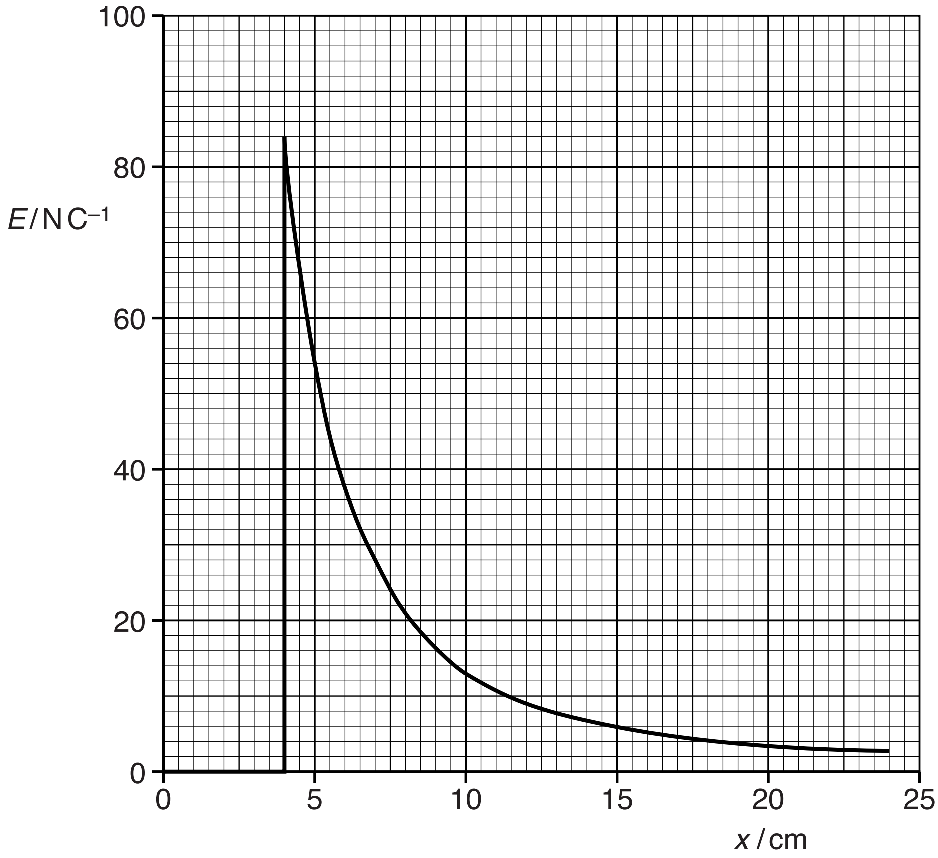

Fig. 5.1

(a) Suggest why, for values of x less than 4.0 cm, the electric field strength is zero.

....

....

.... [2]

(b) A point charge of $+8.5 \times 10^{-9}$ C moves from a point where $x = 7.0$ cm to a point where $x = 5.0$ cm.
Use Fig. 5.1 to estimate the change in electric potential energy of this point charge.

energy = ... J [3]

6 Suggest an explanation for each of the following observations.

(a) Two wires are laid side-by-side and carry equal currents I in opposite directions, as shown in Fig. 6.1.

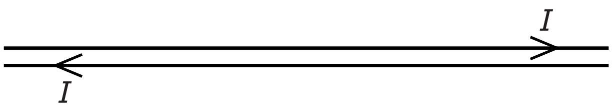

Fig. 6.1

The total magnetic flux density due to the current in the wires is negligible.

....

....

....

....

.... [3]

(b) An air-cored solenoid is connected in series with a battery, as shown in Fig. 6.2.

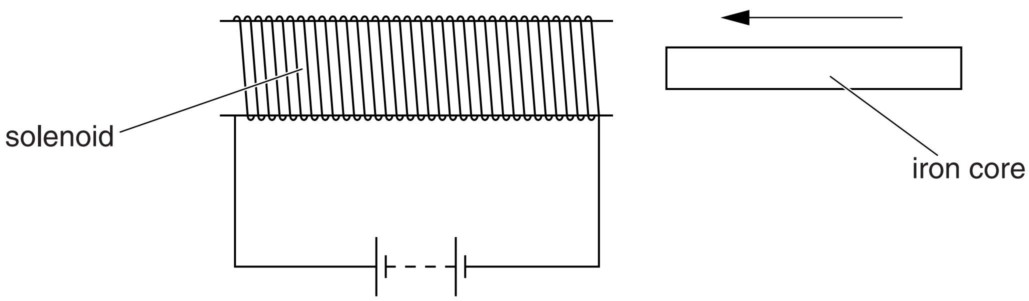

Fig. 6.2

As an iron core is inserted into the solenoid, an e.m.f. that opposes the e.m.f. of the battery is induced in the solenoid.

....

....

....

....

.... [4]

7 A student is using a power supply that produces a sinusoidal output. The meters on the supply show that the output voltage V has a root-mean-square (r.m.s.) value of 14 V with a frequency of 750 Hz.

The variation with time t of the output voltage V may be represented by the expression

$$V = V_0 \sin \omega t.$$

(a) Determine the value of

(i) V_0,

V_0 = ... V [1]

(ii) ω.

ω = ... rad s^{-1} [1]

(b) A capacitor with a large capacitance is connected across the terminals of the supply.

Suggest and explain why this may lead to a large current from the supply.

....

....

.... [3]

8 Light of wavelength λ is incident on a metal surface having a work function energy Φ.

Photoelectrons of maximum kinetic energy E_{MAX} are emitted from the surface.

(a) State an equation relating Φ, E_{MAX} and λ. Explain any other symbols you use.

....

....

.... [2]

(b) The variation with $1/\lambda$ of E_{MAX} is shown in Fig. 8.1.

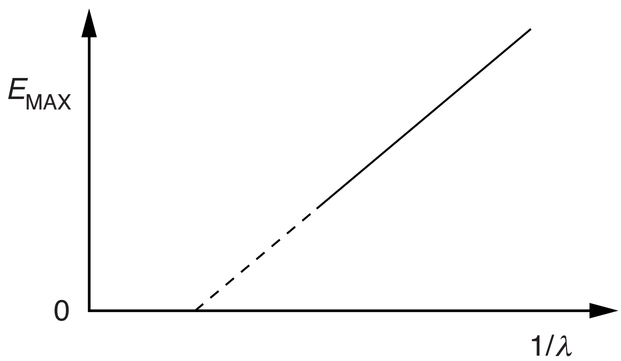

Fig. 8.1

(i) By reference to your answer in **(a)**, explain why the gradient of the line does not depend on the metal surface.

....

....

.... [2]

(ii) The work function energy of sodium is 2.28 eV.

Determine the minimum wavelength λ_0 at which E_{MAX} is zero.

λ_0 = ... m [3]

9 **(a)** State what is meant by the *binding energy* of a nucleus.

....

....

.... [2]

(b) Data for two isotopes of uranium are given in Fig. 9.1.

isotope	binding energy per nucleon / MeV	binding energy / MeV
uranium-235	7.59	....
uranium-238	....	1802

Fig. 9.1

(i) State what is meant by *isotopes*.

....

....

.... [2]

(ii) Complete Fig. 9.1. [2]

(c) Uranium-235 has a half-life of 7.1×10^{8} years.

(i) Show that the decay constant λ of uranium-235 is $3.1 \times 10^{-17}\,s^{-1}$.

[1]

(ii) A sample of uranium-235 has an activity of 5.0×10^{3} Bq.

Calculate the mass of the sample.

mass = ... g [3]

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Section B

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

10 The output potential V_{OUT} from an operational amplifier is to be monitored using an output device. The output V_{OUT} can be either +5V or –5V.

(a) On Fig. 10.1, draw a circuit for the output device that consists of two light-emitting diodes B and G.
Diode B alone is to emit light when V_{OUT} is +5V. Diode G alone is to emit light when V_{OUT} is –5V.

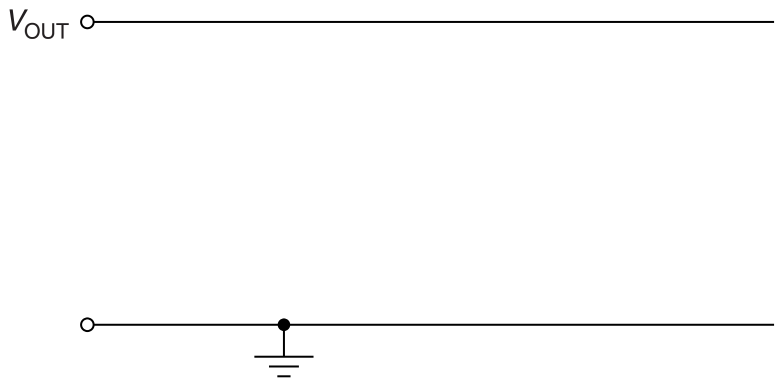

Fig. 10.1

[3]

(b) On Fig. 10.2, draw a circuit of the output device that consists of a relay and a diode such that a high-power lamp is switched on only when V_{OUT} is –5V.

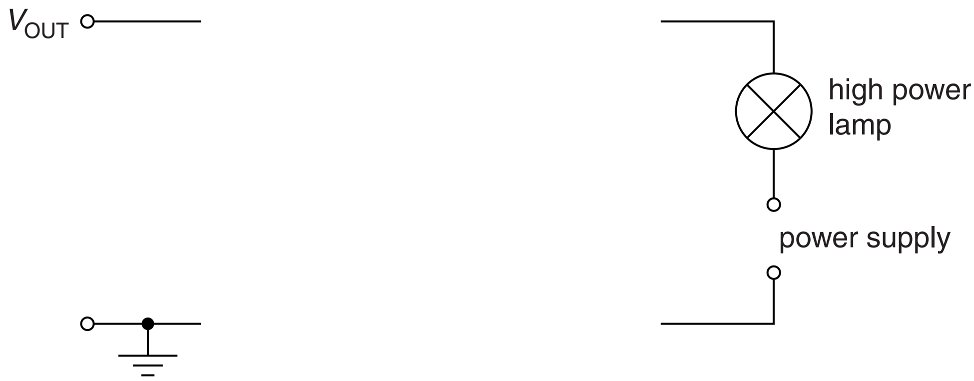

Fig. 10.2

[4]

11 **(a)** An X-ray source is placed on one side of a metal plate, as shown in Fig. 11.1.

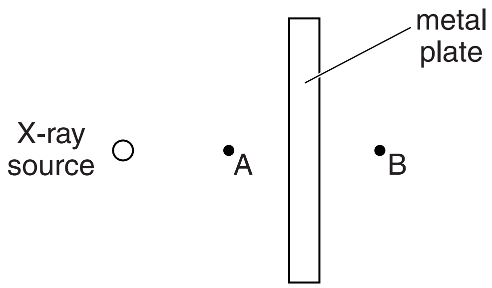

Fig. 11.1

The intensity of the X-ray beam is measured at points A and B.

State two reasons, other than absorption of X-ray photons in the metal, for the intensity at point A to be different to that at point B.

1. ....

....

2. ....

....
[2]

(b) A specimen of muscle and bone undergoes X-ray examination. Parallel beams of X-rays are incident on the specimen, as shown in Fig. 11.2.

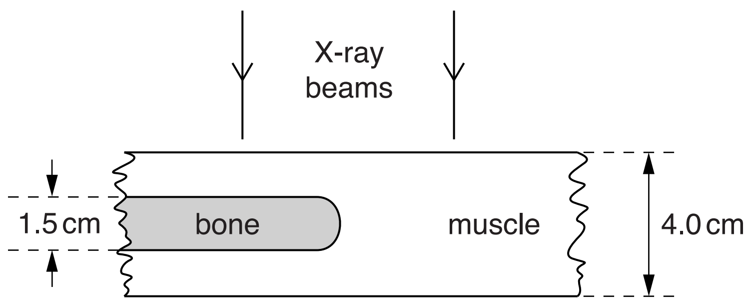

Fig. 11.2

The specimen has a total thickness of 4.0 cm. One section contains a bone of thickness 1.5 cm.

Data for the linear absorption (attenuation) coefficient μ for the bone and for the muscle in the specimen are given in Fig. 11.3.

	μ / cm^{-1}
bone muscle	3.0 0.27

Fig. 11.3

(i) Calculate the ratio

$$\frac{\text{intensity of X-ray beam incident on the specimen}}{\text{intensity of X-ray beam emerging from the specimen}}$$

for the beam passing through

1. the 4.0 cm thickness of muscle alone,

ratio = ... [2]

2. the bone and the muscle.

ratio = ... [2]

(ii) Using your answers in **(i)**, suggest and explain whether an X-ray image of this specimen is likely to have good contrast.

....

....

.... [2]

12 A transmission system for speech may be represented by the block diagram of Fig. 12.1.

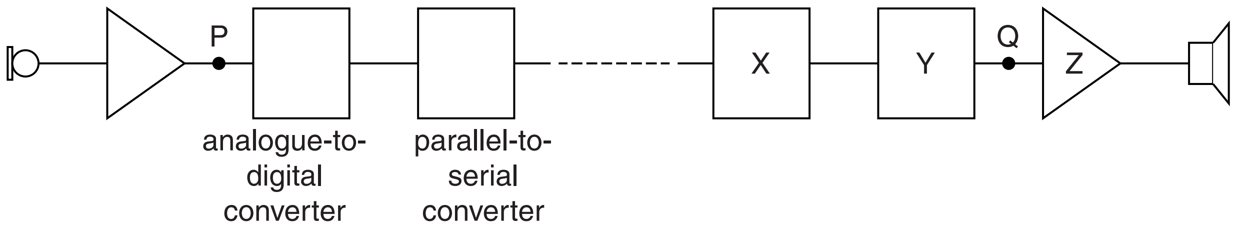

Fig. 12.1

(a) Name the component labelled

(i) block X,

.... [1]

(ii) block Y,

.... [1]

(iii) Z.

.... [1]

(b) The variation with time of part of the signal at the input P to the analogue-to-digital converter (ADC) is shown in Fig. 12.2.

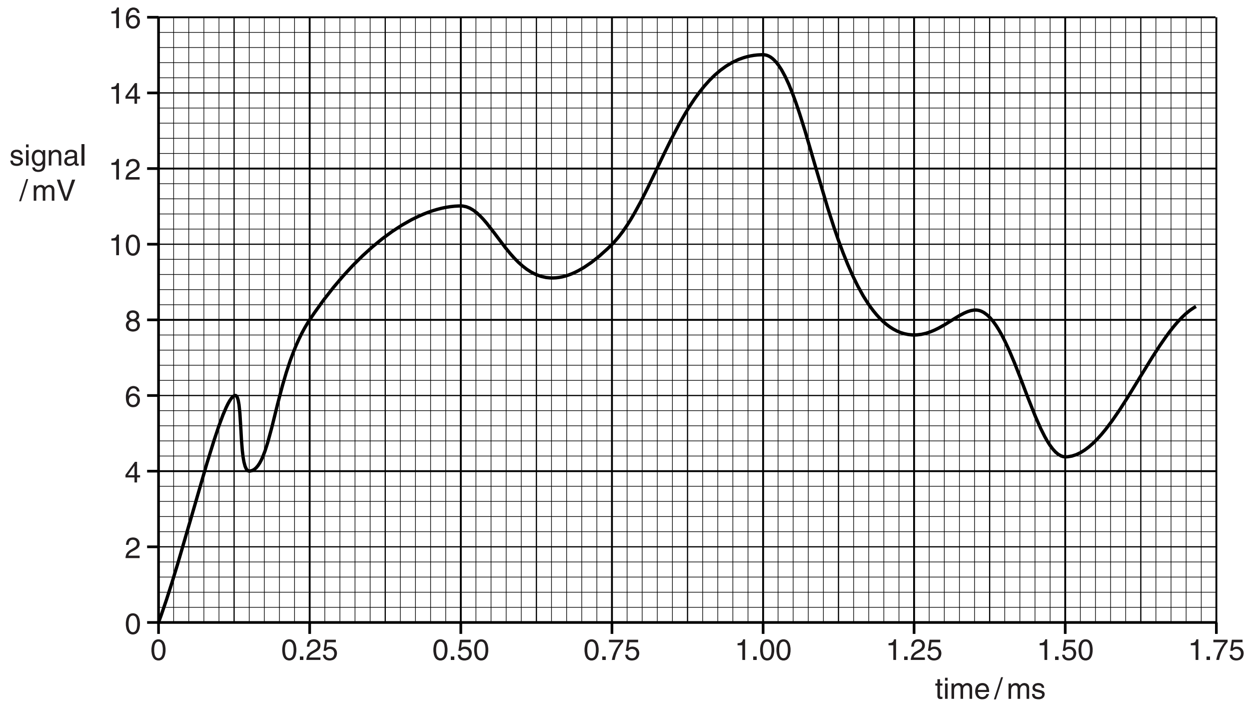

Fig. 12.2

Each number of the output from the ADC is a digital number where the smallest bit represents 1 mV.

State

(i) the minimum number of bits in each digital number so that the signal in Fig. 12.2 can be sampled fully,

number = ... [1]

(ii) the digital number produced by the ADC at time 0.50 ms.

number = ... [1]

(c) The ADC samples the signal in Fig. 12.2 at a frequency of 4.0 kHz. The first sample is taken at time zero.

Using data from Fig. 12.2, draw, on the axes of Fig. 12.3, the variation with time of the output at point Q for time zero to time 1.5 ms.

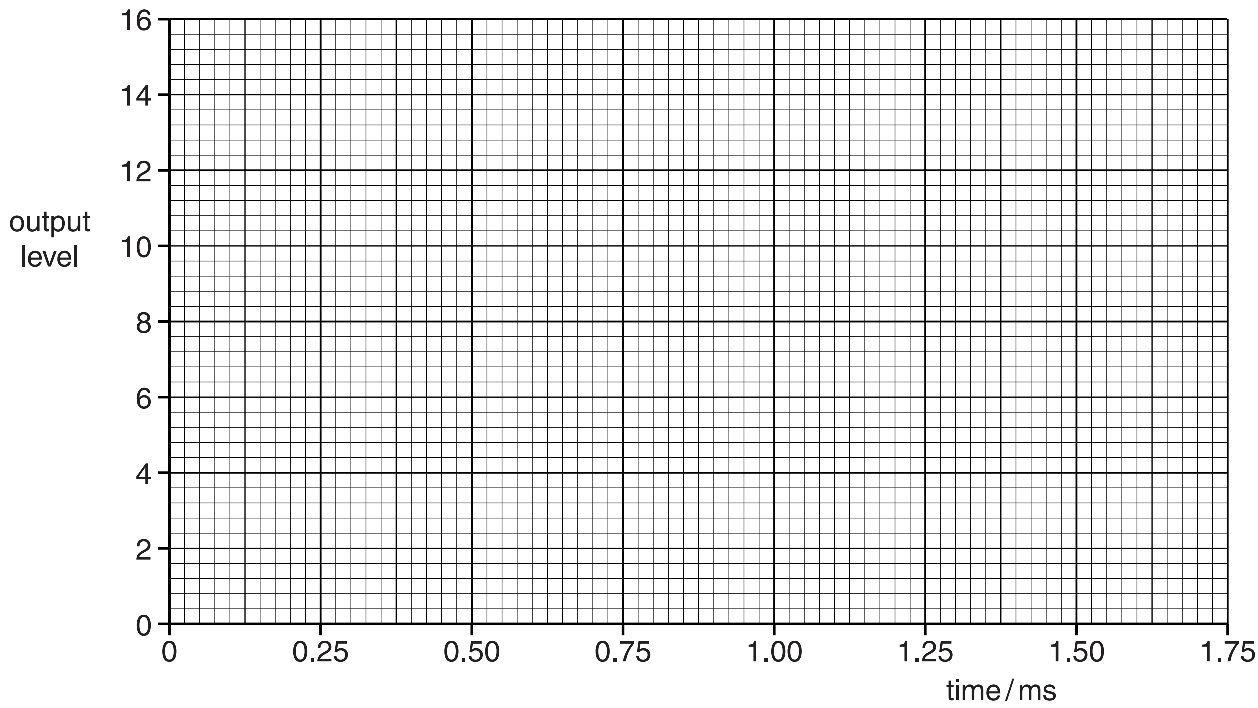

Fig. 12.3

[4]

Please turn over for Question 13.

13 Polar orbiting satellites have orbits over the poles of the Earth. Geostationary satellites are in equatorial orbits. Both are used as part of communication channels.

(a) State one advantage and one disadvantage of the use of a polar orbiting satellite as compared with a geostationary satellite.

advantage: ....

....

disadvantage: ....

....
[2]

(b) A geostationary satellite is known to operate on the 6/4 GHz band.

Explain

(i) what is meant by the 6/4 GHz band,

....

....

.... [2]

(ii) why two different frequencies are necessary.

....

....

....

.... [2]