Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME

CENTRE NUMBER | CANDIDATE NUMBER

8896709223

PHYSICS **9702/43**

Paper 4 A2 Structured Questions **October/November 2014**

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.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
Total	

This document consists of **27** printed pages and **1** blank page.

DC (NF/CGW) 77823/2

CAMBRIDGE International Examinations

[Turn over

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,	$p = \rho g h$
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 light spring is suspended from a fixed point. A bar magnet is attached to the end of the spring, as shown in Fig. 1.1.

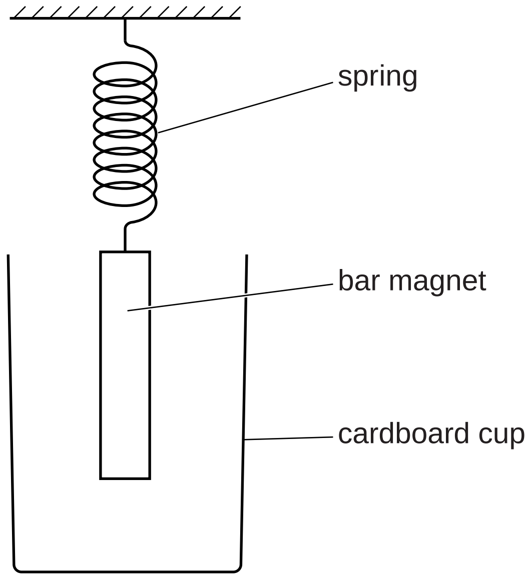

Fig. 1.1

In order to shield the magnet from draughts, a cardboard cup is placed around the magnet but does not touch it.
The magnet is displaced vertically and then released. The variation with time t of the vertical displacement y of the magnet is shown in Fig. 1.2.

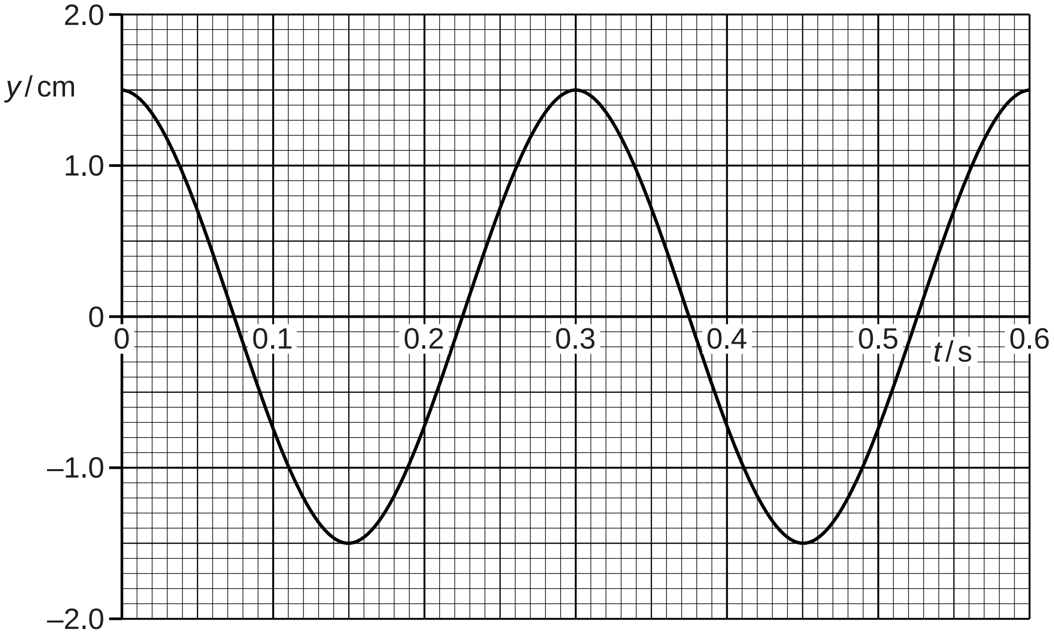

Fig. 1.2

The mass of the magnet is 130 g.

(a) For the oscillations of the magnet, use Fig. 1.2 to

(i) determine the angular frequency ω,

ω = ... rad s^{-1} [2]

(ii) show that the maximum kinetic energy of the oscillating magnet is 6.4 mJ.

[2]

(b) The cardboard cup is now replaced with a cup made of aluminium foil.
During 10 complete oscillations of the magnet, the amplitude of vibration is seen to decrease to 0.75 cm from that shown in Fig. 1.2. The change in angular frequency is negligible.

(i) Use Faraday's law of electromagnetic induction to explain why the amplitude of the oscillations decreases.

....

....

....

....

.... [3]

(ii) Show that the loss in energy of the oscillating magnet is 4.8 mJ.

[2]

(c) The mass of the aluminium cup in **(b)** is 6.2 g. The specific heat capacity of aluminium is 910 J kg^{-1} K^{-1}.
The energy in **(b)(ii)** is transferred to the cup as thermal energy.
Calculate the mean rise in temperature of the cup.

temperature rise = ... K [2]

Please turn over for Question 2.

2 **(a)** On the axes of Fig. 2.1, sketch the variation with distance from a point mass of the gravitational field strength due to the mass.

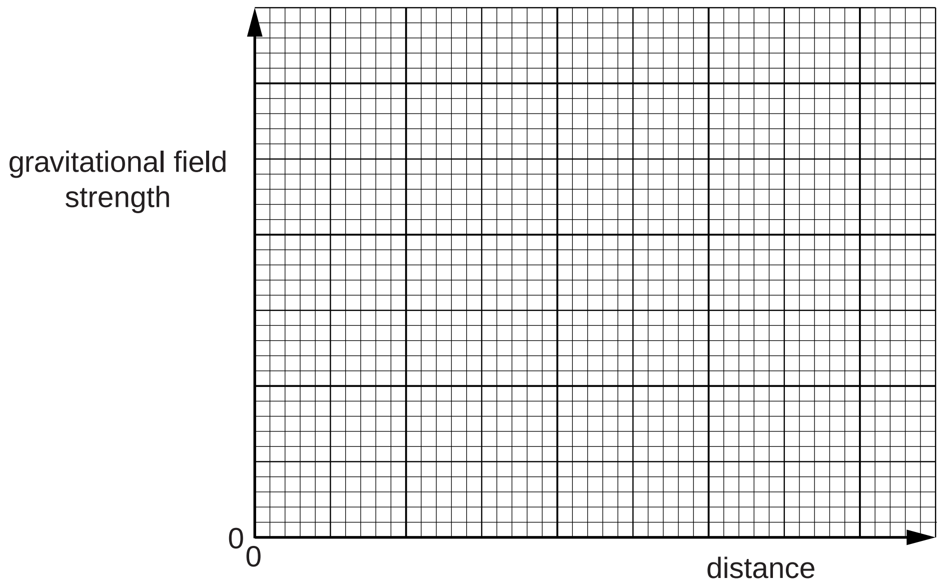

Fig. 2.1

[2]

(b) On the axes of Fig. 2.2, sketch the variation with speed of the magnitude of the force on a charged particle moving at right-angles to a uniform magnetic field.

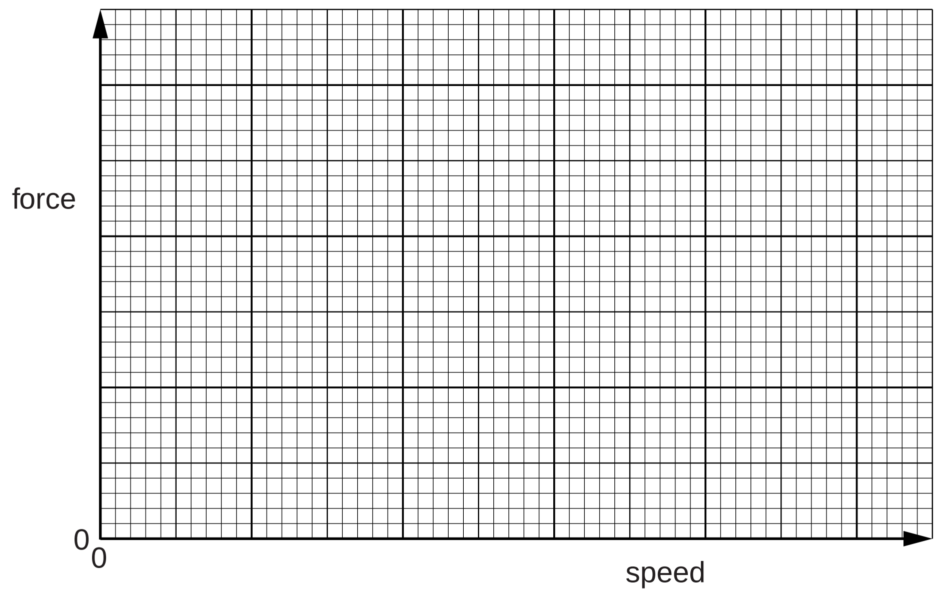

Fig. 2.2

[2]

(c) On the axes of Fig. 2.3, sketch the variation with time of the power dissipated in a resistor by a sinusoidal alternating current during two cycles of the current.

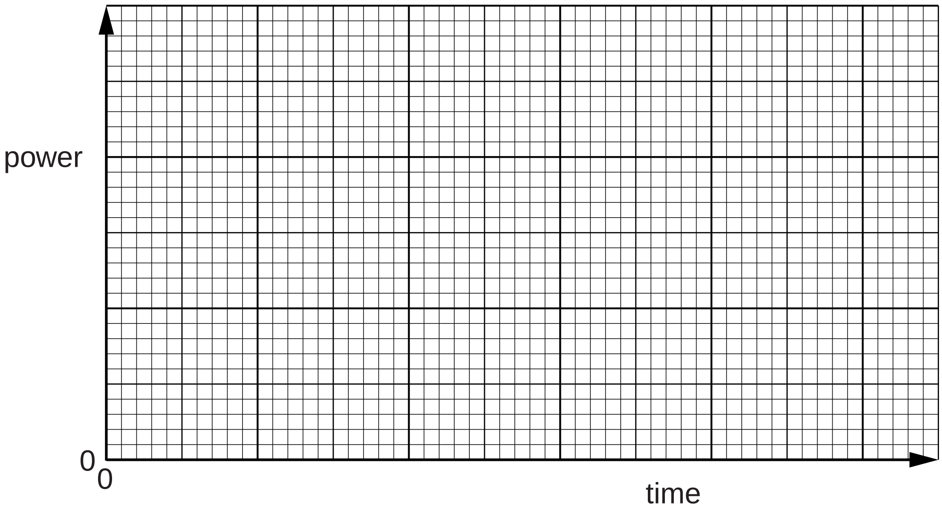

Fig. 2.3

[3]

3 A fixed mass of gas has an initial volume of $5.00 \times 10^{-4}\,m^3$ at a pressure of $2.40 \times 10^5\,Pa$ and a temperature of 288 K. It is heated at constant pressure so that, in its final state, the volume is $14.5 \times 10^{-4}\,m^3$ at a temperature of 835 K, as illustrated in Fig. 3.1.

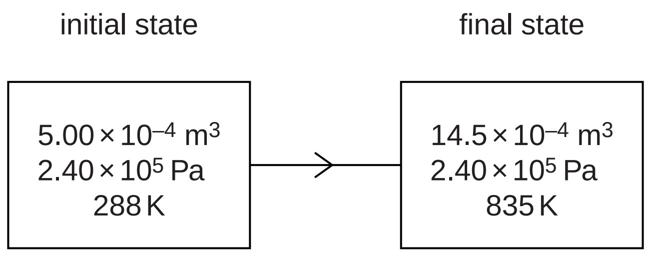

Fig. 3.1

(a) Show that these two states provide evidence that the gas behaves as an ideal gas.

[3]

(b) The total thermal energy supplied to the gas for this change is 569 J.

Determine

(i) the external work done,

work done = ... J [2]

(ii) the change in internal energy of the gas. State whether the change is an increase or a decrease in internal energy.

change in internal energy = ... J

.... [2]

4 **(a)** State what is meant by *simple harmonic motion*.

....

....

.... [2]

(b) A trolley is attached to two extended springs, as shown in Fig. 4.1.

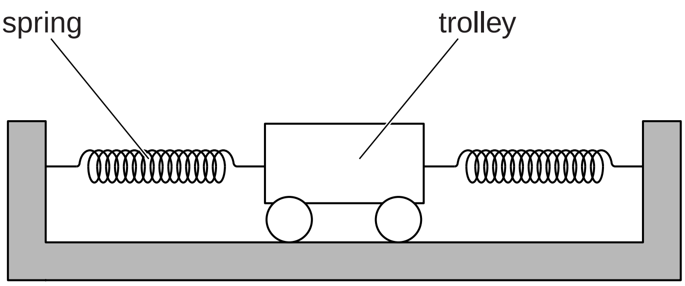

Fig. 4.1

The trolley is displaced along the line joining the two springs and is then released. At one point in the motion, a stopwatch is started. The variation with time t of the velocity v of the trolley is shown in Fig. 4.2.

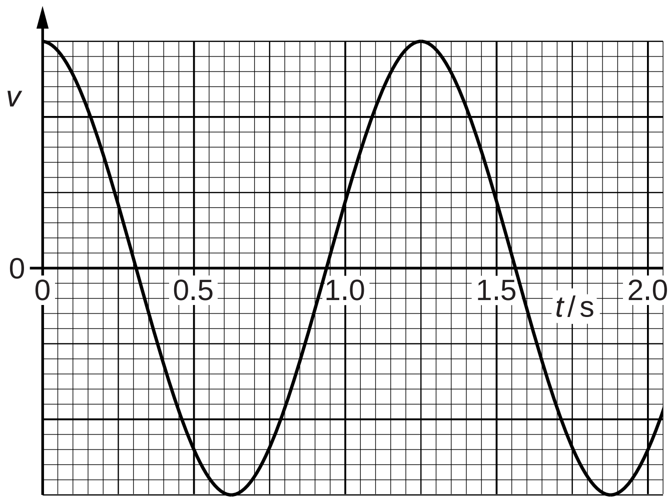

Fig. 4.2

The motion of the trolley is simple harmonic.

(i) State one time at which the trolley is moving through the equilibrium position and also state the next time that it moves through this position.

....s and ....s [1]

(ii) The amplitude of vibration of the trolley is 3.2 cm.

Determine

1. the maximum speed v_0 of the trolley,

v_0 = ... $cm\,s^{-1}$ [3]

2. the displacement of the trolley for a speed of $\frac{1}{2}v_0$.

displacement = ... cm [2]

(c) Use your answers in **(b)** to sketch, on the axes of Fig. 4.3, a graph to show the variation with displacement x of the velocity v of the trolley.

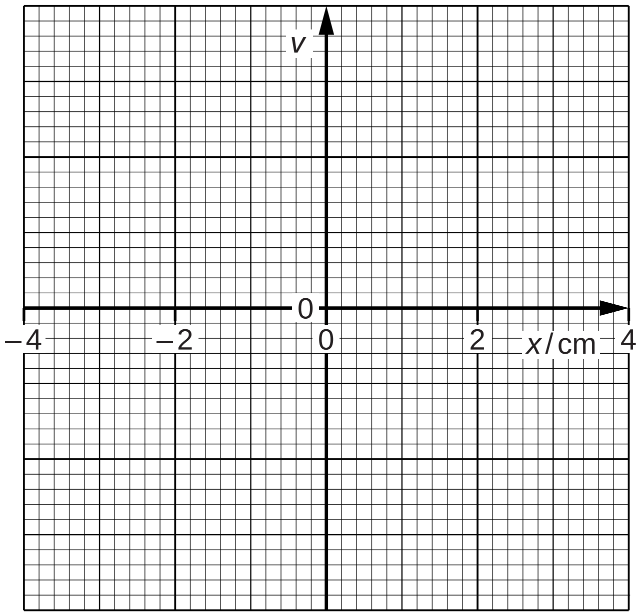

Fig. 4.3

[2]

5 **(a)** Define *electric potential* at a point.

....

....

.... [2]

(b) An isolated metal sphere is charged to a potential V. The charge on the sphere is q.
The charge on the sphere may be considered to act as a point charge at the centre of the sphere.

The variation with potential V of the charge q on the sphere is shown in Fig. 5.1.

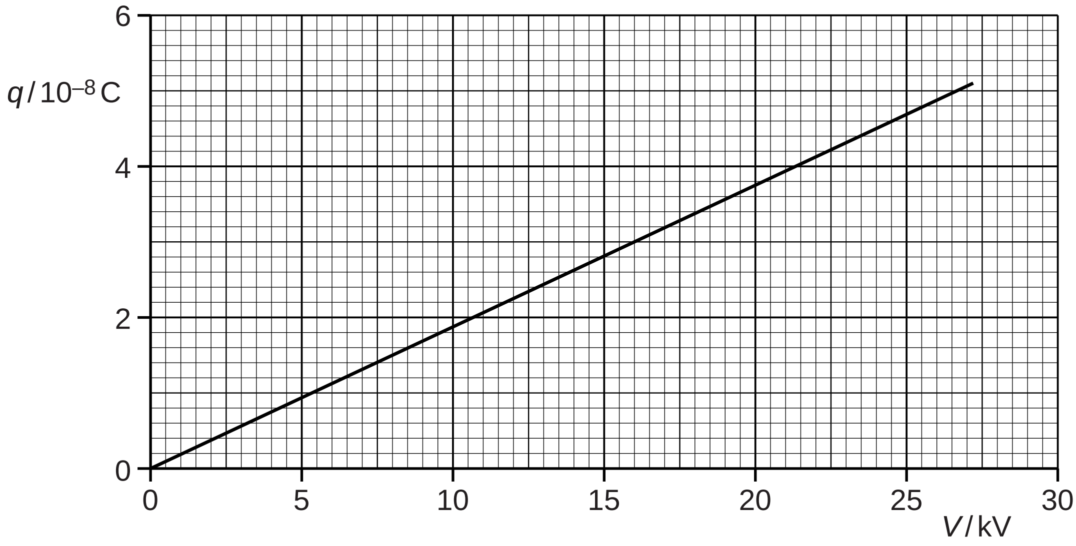

Fig. 5.1

Use Fig. 5.1 to determine

(i) the radius of the sphere,

radius = ... m [2]

(ii) the energy required to increase the potential of the sphere from zero to 24 kV.

energy = ... J [3]

(c) The sphere in **(b)** discharges by causing sparks when the electric field strength at the surface of the sphere is greater than $2.0 \times 10^{6}\,\text{V m}^{-1}$.

Use your answer in **(b)(i)** to calculate the maximum potential to which the sphere can be charged.

potential = ... V [3]

6 Three capacitors, each of capacitance 48 μF, are connected as shown in Fig. 6.1.

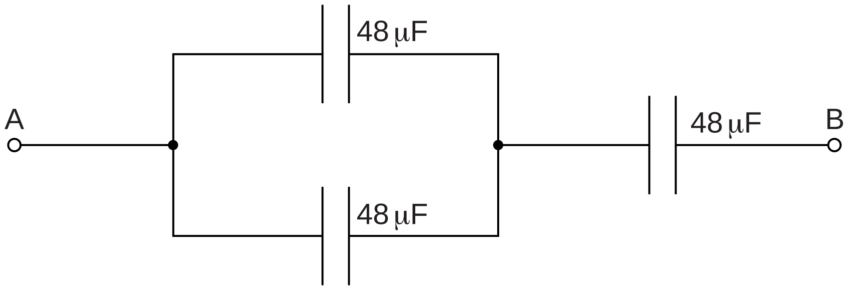

Fig. 6.1

(a) Calculate the total capacitance between points A and B.

capacitance = ... μF [2]

(b) The maximum safe potential difference that can be applied across any one capacitor is 6 V.

Determine the maximum safe potential difference that can be applied between points A and B.

potential difference = ... V [2]

7 **(a)** State what is meant by *quantisation* of charge.

....

.... [1]

(b) Charged parallel plates, as shown in Fig. 7.1, produce a uniform electric field between the plates.

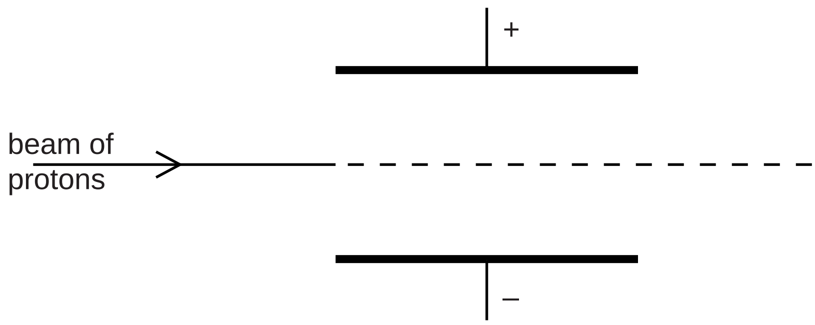

Fig. 7.1

The electric field outside the region between the plates is zero.
A uniform magnetic field is applied in the region between the plates so that a beam of protons passes undeviated between the plates.

(i) State and explain the direction of the magnetic field between the plates.

....

....

.... [2]

(ii) The magnetic flux density between the plates is now increased.

On Fig. 7.1, sketch the path of the protons between the plates. [2]

8 **(a)** State what is meant by a *photon*.

....

....

.... [2]

(b) A beam of light is incident normally on a metal surface, as illustrated in Fig. 8.1.

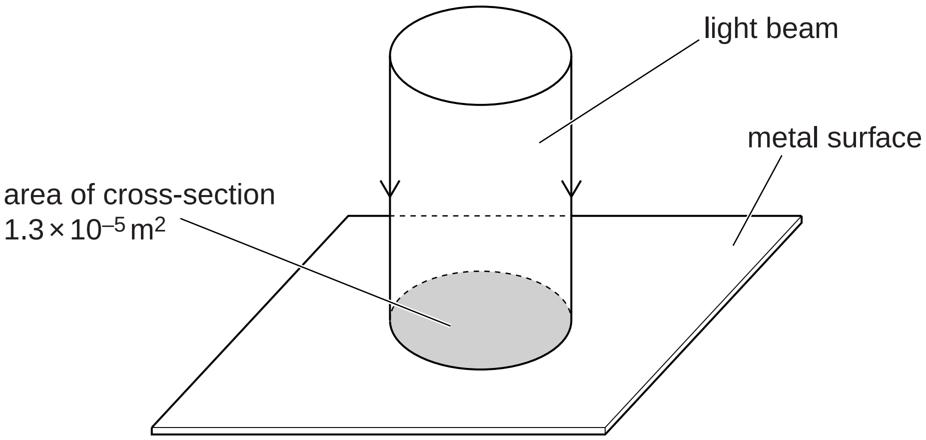

Fig. 8.1

The beam of light has cross-sectional area $1.3 \times 10^{-5}\,m^2$ and power $2.7 \times 10^{-3}\,W$.
The light has wavelength 570 nm.

The light energy is absorbed by the metal and no light is reflected.

(i) Show that a photon of this light has an energy of $3.5 \times 10^{-19}\,J$.

[1]

(ii) Calculate, for a time of 1.0 s,

1. the number of photons incident on the surface,

number = ... [2]

2. the change in momentum of the photons.

change in momentum = ... $kg\,m\,s^{-1}$ [3]

(c) Use your answer in **(b)(ii)** to calculate the pressure that the light exerts on the metal surface.

pressure = ... Pa [2]

9 During the de-commissioning of a nuclear reactor, a mass of 2.5×10^6 kg of steel is found to be contaminated with radioactive nickel-63 ($^{63}_{28}Ni$).
The total activity of the steel due to the nickel-63 contamination is 1.7×10^{14} Bq.

(a) Calculate the activity per unit mass of the steel.

activity per unit mass = ... $Bq\,kg^{-1}$ [1]

(b) Special storage precautions need to be taken when the activity per unit mass due to contamination exceeds 400 $Bq\,kg^{-1}$.
Nickel-63 is a β-emitter with a half-life of 92 years.
The maximum energy of an emitted β-particle is 0.067 MeV.

(i) Use your answer in **(a)** to calculate the energy, in J, released per second in a mass of 1.0 kg of steel due to the radioactive decay of the nickel.

energy = ... J [1]

(ii) Use your answer in **(i)** to suggest, with a reason, whether the steel will be at a high temperature.

....

....

.... [1]

(iii) Use your answer in **(a)** to determine the time interval before special storage precautions for the steel are not required.

time = ... years [3]

Section B

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

10 An electronic sensor may be represented by the block diagram of Fig. 10.1.

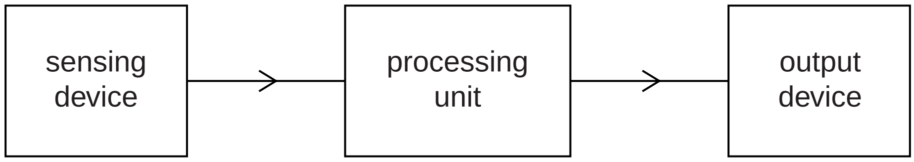

Fig. 10.1

(a) State suitable sensing devices, one in each case, for the detection of

(i) change of temperature,

.... [1]

(ii) pressure changes in a sound wave.

.... [1]

(b) The ideal operational amplifier (op-amp) shown in Fig. 10.2 is to be used as a processing unit.

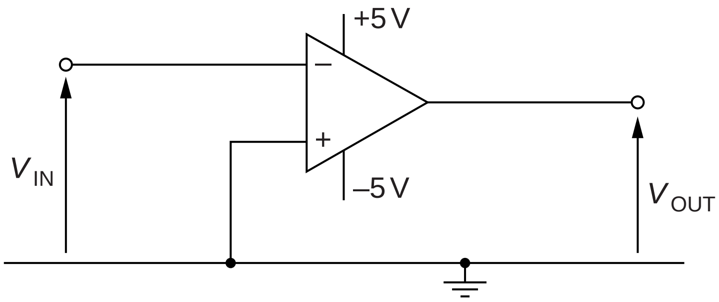

Fig. 10.2

(i) State the value of the output potential V_{OUT} for an input potential V_{IN} of +0.5 V. Explain your answer.

....

....

....

.... [3]

(ii) A sensing device produces a variable potential V_{IN}.
The variation with time t of V_{IN} is shown in Fig. 10.3.

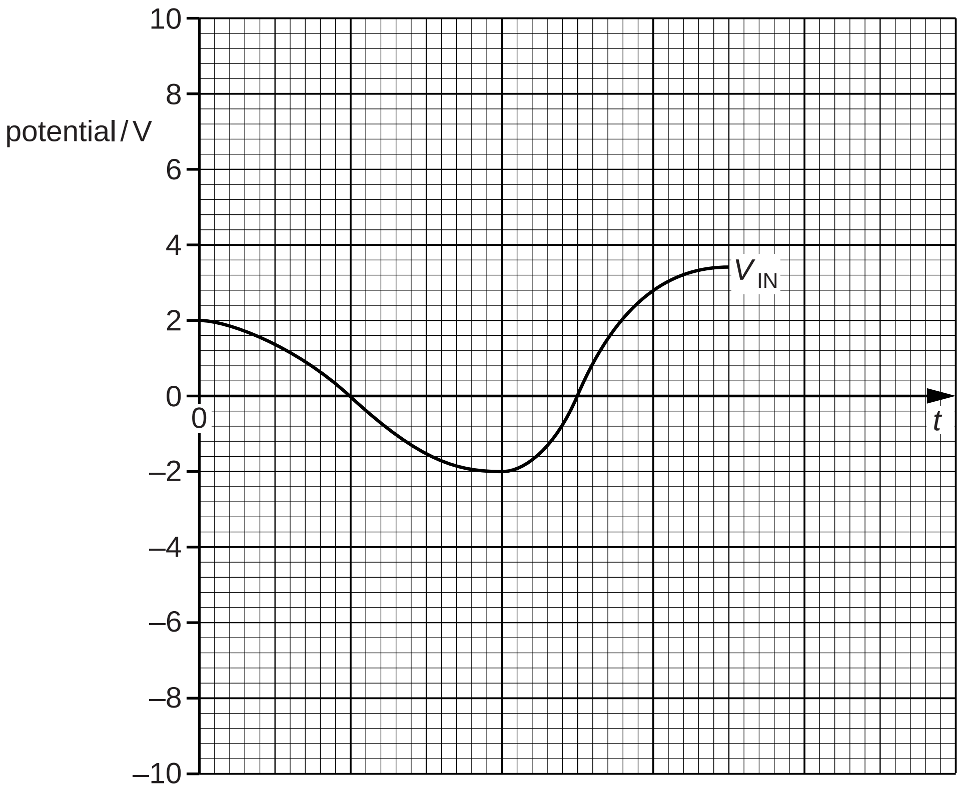

Fig. 10.3

On the axes of Fig. 10.3, sketch the variation with time t of the output potential V_{OUT}. [3]

11 **(a)** By reference to ultrasound waves, state what is meant by the *specific acoustic impedance* of a medium.

....

....

.... [2]

(b) A parallel beam of ultrasound of intensity I is incident normally on a muscle of thickness 3.4 cm, as shown in Fig. 11.1.

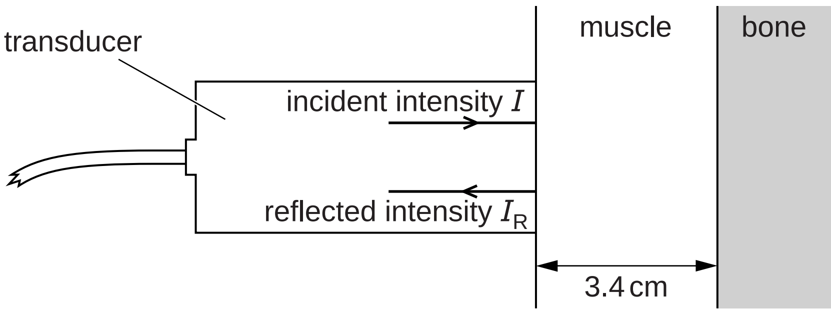

Fig. 11.1

The ultrasound wave is reflected at a muscle-bone boundary. The intensity of the ultrasound received back at the transducer is I_R.

Some data for bone and muscle are given in Fig. 11.2.

	specific acoustic impedance / $kg\,m^{-2}\,s^{-1}$	linear absorption coefficient / m^{-1}
bone	6.4×10^6	130
muscle	1.7×10^6	23

Fig. 11.2

(i) The intensity reflection coefficient α for two media having specific acoustic impedances Z_1 and Z_2 is given by

$$\alpha = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}.$$

Calculate the fraction of the ultrasound intensity that is reflected at the muscle-bone boundary.

fraction = ... [2]

(ii) Calculate the fraction of the ultrasound intensity that is transmitted through a thickness of 3.4 cm of muscle.

fraction = ... [3]

(iii) Use your answers in **(i)** and **(ii)** to determine the ratio $\frac{I_R}{I}$.

ratio = ... [2]

12 **(a)** Distinguish between an *analogue* signal and a *digital* signal.

analogue signal: ....

....

digital signal: ....

....
[2]

(b) An analogue-to-digital converter (ADC) converts whole decimal numbers between 0 and 23 into digital numbers.

State

(i) the minimum number of bits in each digital number,

number of bits = ... [1]

(ii) the digital number representing decimal 13.

.... [1]

(c) An analogue signal is digitised before transmission. It is then converted back to an analogue signal after reception.

State and explain the effect on the reproduction of the signal when the number of bits in the analogue-to-digital converter (ADC) and the digital-to-analogue converter (DAC) is increased.

....

....

....

.... [3]

13 In a mobile phone system, the country is divided into a number of cells, each with its own base station.

State and explain

(a) why the country is divided into cells,

....

....

.... [2]

(b) two reasons why the base stations operate on UHF frequencies.

1. ....

....

....

2. ....

....

....
[4]

BLANK PAGE