



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9702/41

October/November 2020

2 hours

You must answer on the question paper.

No additional materials are needed.

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Blank pages are indicated.

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	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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	$g = 9.81 \text{ m s}^{-2}$

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	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

- 1 (a) (i) State what is meant by a *field of force*.

.....

 [2]

- (ii) Define *gravitational field strength*.

.....
 [1]

- (b) An isolated planet may be assumed to be a uniform sphere of radius $3.39 \times 10^6 \text{ m}$ with its mass of $6.42 \times 10^{23} \text{ kg}$ concentrated at its centre.

Calculate the gravitational field strength at the surface of the planet.

field strength = ... N kg^{-1} [3]

- (c) Calculate the height above the surface of the planet in (b) at which the gravitational field strength is 1.0% less than its value at the surface of the planet.

height = ... m [3]

[Total: 9]

- 2 (a) The first law of thermodynamics may be expressed as

$$\Delta U = (+q) + (+w)$$

where ΔU is the increase in internal energy of the system.

State the meaning of:

$+q$

.....

$+w$

.....

[2]

- (b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

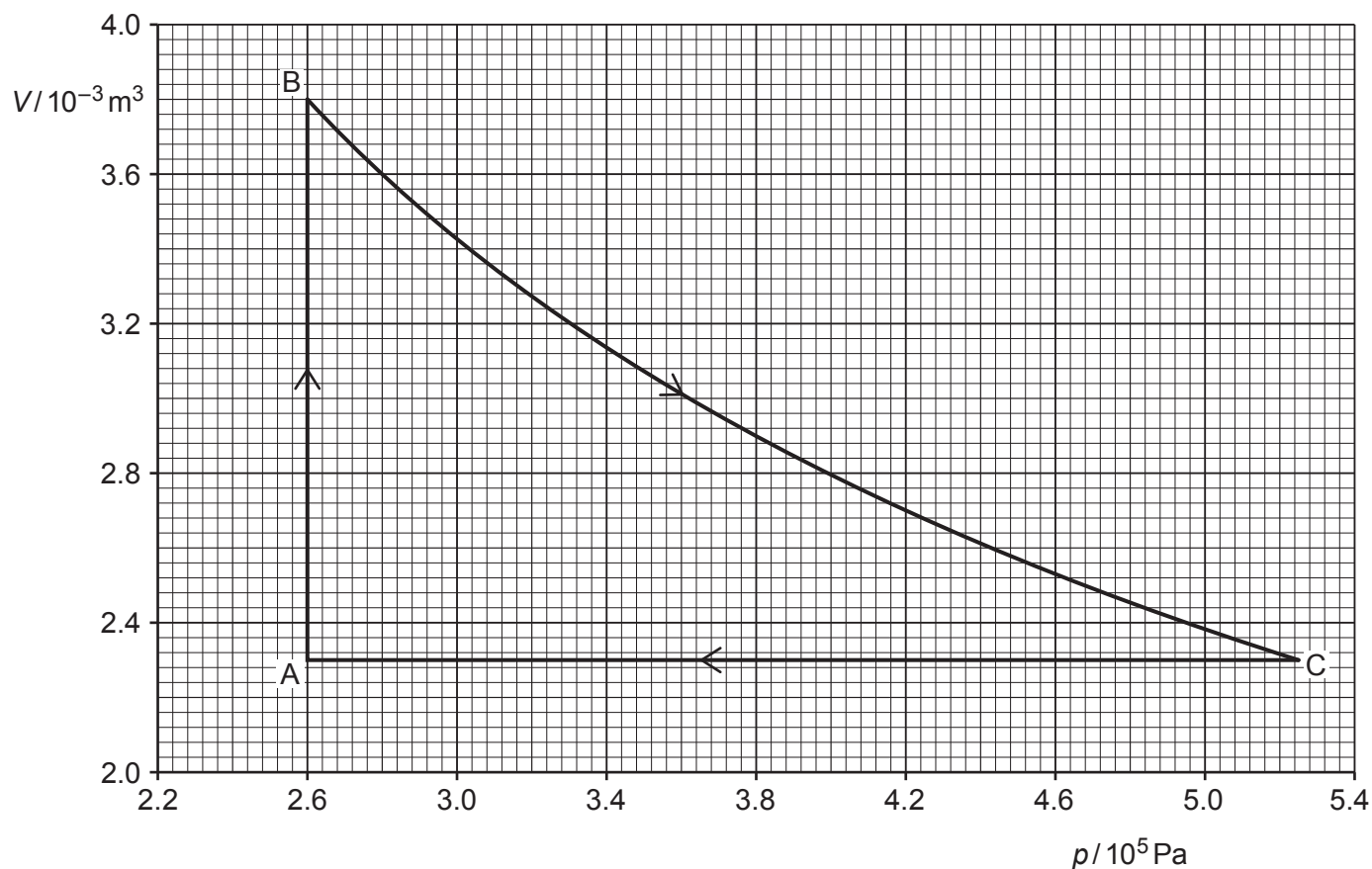


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.

- (i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

- (ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

.....

..... [2]

- (c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]

- 3 A pendulum consists of a metal sphere P suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

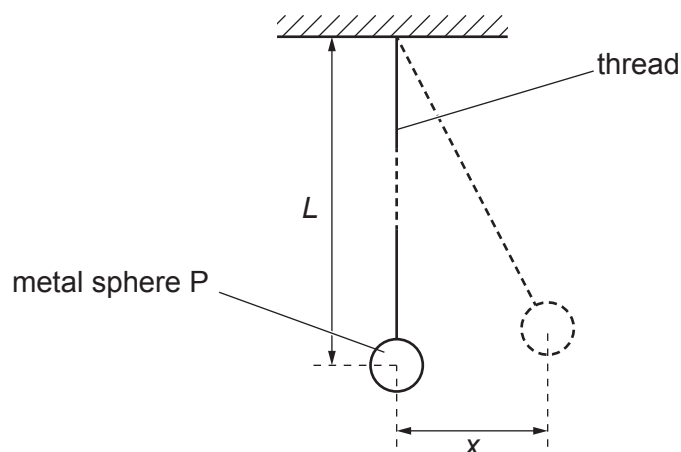


Fig. 3.1

The centre of gravity of sphere P is a distance L from the fixed point.

The sphere is pulled to one side and then released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

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

.....

.....

..... [2]

- (b) The variation of the velocity v of sphere P with the displacement x from its mean position is shown in Fig. 3.2.

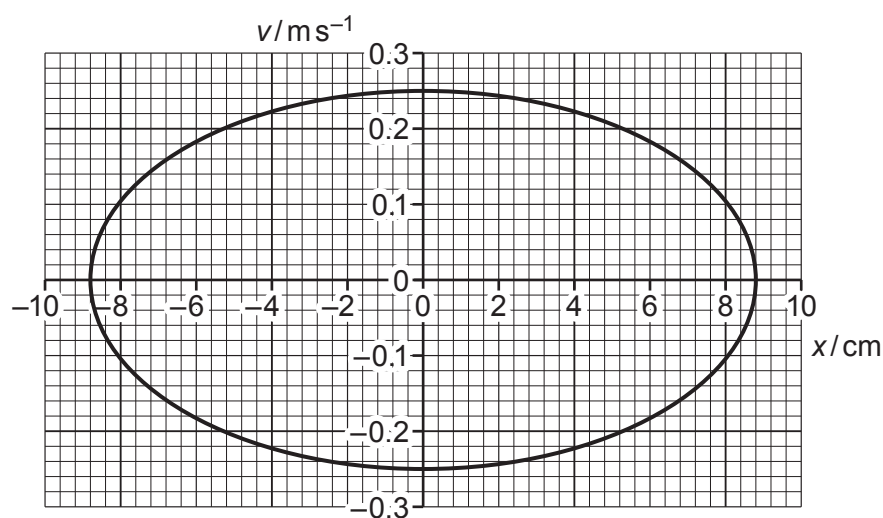


Fig. 3.2

Use Fig. 3.2 to determine the frequency f of the oscillations of sphere P.

$$f = \dots\dots\dots \text{ Hz [3]}$$

- (c) The period T of the oscillations of sphere P is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall.

Use your answer in (b) to determine the length L .

$$L = \dots\dots\dots \text{ m [2]}$$

- (d) Another pendulum consists of a sphere Q suspended by a thread. Spheres P and Q are identical. The thread attached to sphere Q is longer than the thread attached to sphere P.

Sphere Q is displaced and then released. The oscillations of sphere Q have the same amplitude as the oscillations of sphere P.

On Fig. 3.2, sketch the variation of the velocity v with displacement x for sphere Q. [2]

[Total: 9]

- 4 (a) Explain the principles of the **generation** of ultrasound waves for use in medical diagnosis.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) The linear attenuation (absorption) coefficient for a parallel beam of ultrasound waves in air is 1.2cm^{-1} .

The parallel beam passes through a layer of air of thickness 3.5 cm.

Calculate the ratio, in dB,

$$\frac{\text{intensity of beam after passing through the layer of air}}{\text{intensity of beam entering the layer of air}}.$$

ratio = ... dB [4]

[Total: 8]

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

.....

.....

..... [2]

- (b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

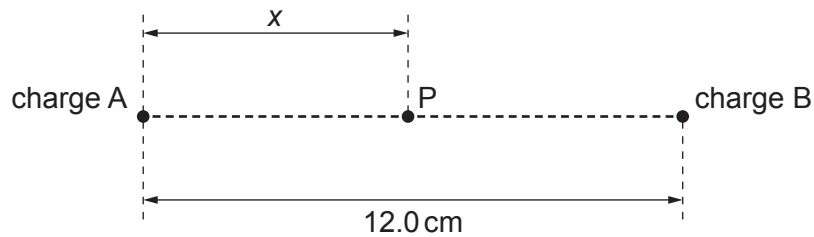


Fig. 5.1

The charge of A is $+2.0 \times 10^{-9} \text{ C}$.

A point P lies on the line joining charges A and B. Its distance from charge A is x .

The variation with distance x of the electric potential V at point P is shown in Fig. 5.2.

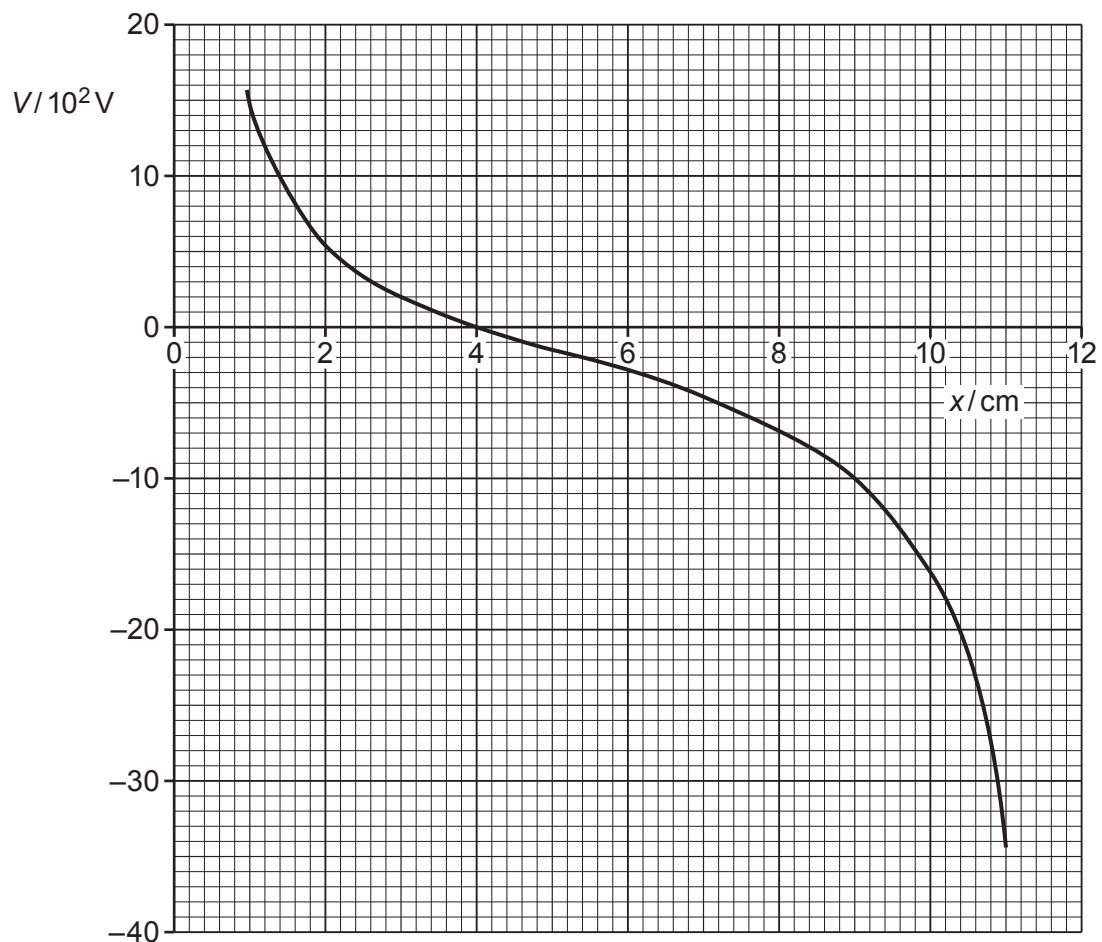


Fig. 5.2

Use Fig. 5.2 to determine:

- (i) the charge of B

charge = ... C [3]

- (ii) the change in electric potential when point P moves from the position where $x = 9.0$ cm to the position where $x = 3.0$ cm.

change = ... V [1]

- (c) An α -particle moves along the line joining point charges A and B in Fig. 5.1.

The α -particle moves from the position where $x = 9.0$ cm and just reaches the position where $x = 3.0$ cm.

Use your answer in (b)(ii) to calculate the speed v of the α -particle at the position where $x = 9.0$ cm.

$v =$ ms^{-1} [3]

[Total: 9]

- 6 (a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

 [2]

- (ii) State **three** functions of capacitors in electrical circuits.

1.
 2.
 3. [3]

- (b) A student has available four capacitors, each of capacitance $24\ \mu\text{F}$.

The capacitors are connected as shown in Fig. 6.1.

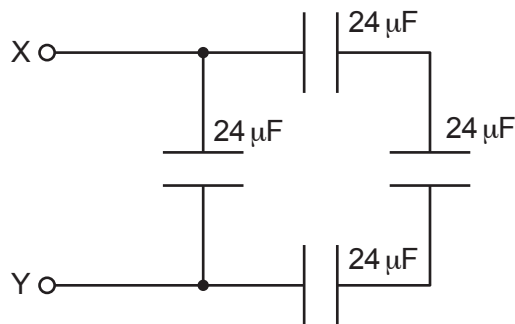


Fig. 6.1

Calculate the combined capacitance between the terminals X and Y.

capacitance = ... μF [2]

[Total: 7]

- 7 An ideal operational amplifier (op-amp) is to be used in a comparator circuit. Part of the comparator circuit is shown in Fig. 7.1.

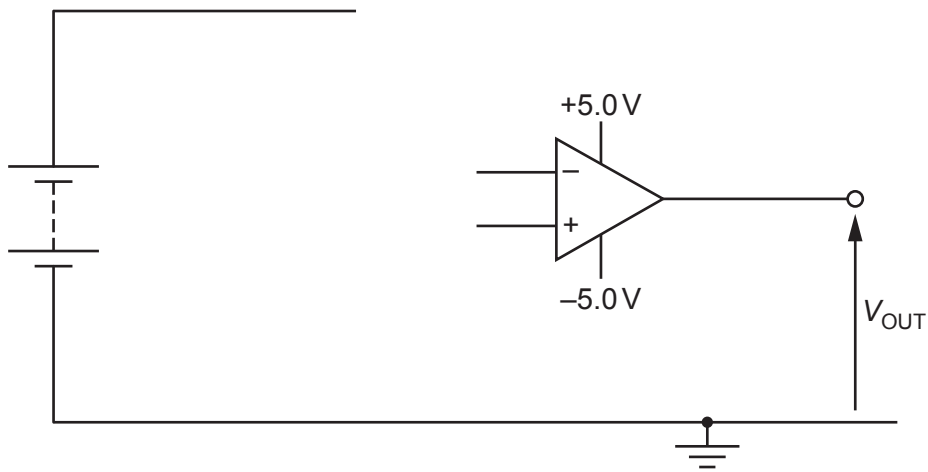


Fig. 7.1

Three resistors, each of resistance 1000Ω , and a negative temperature coefficient thermistor are available to complete the circuit.

The circuit is to be designed so that, at low temperatures, the output V_{OUT} is $-5.0V$ and at higher temperatures, the output V_{OUT} is to be $+5.0V$.

- (a) On Fig. 7.1, draw the input circuit to the inverting and non-inverting inputs of the op-amp. [4]

- (b) State a suitable value for the thermistor resistance when the thermistor is at:

- (i) low temperature where V_{OUT} is $-5.0V$

..... [1]

- (ii) a higher temperature where V_{OUT} is $+5.0V$.

..... [1]

[Total: 6]

- 8 A slice of a conducting material has its face QRLK normal to a uniform magnetic field of flux density B , as illustrated in Fig. 8.1.

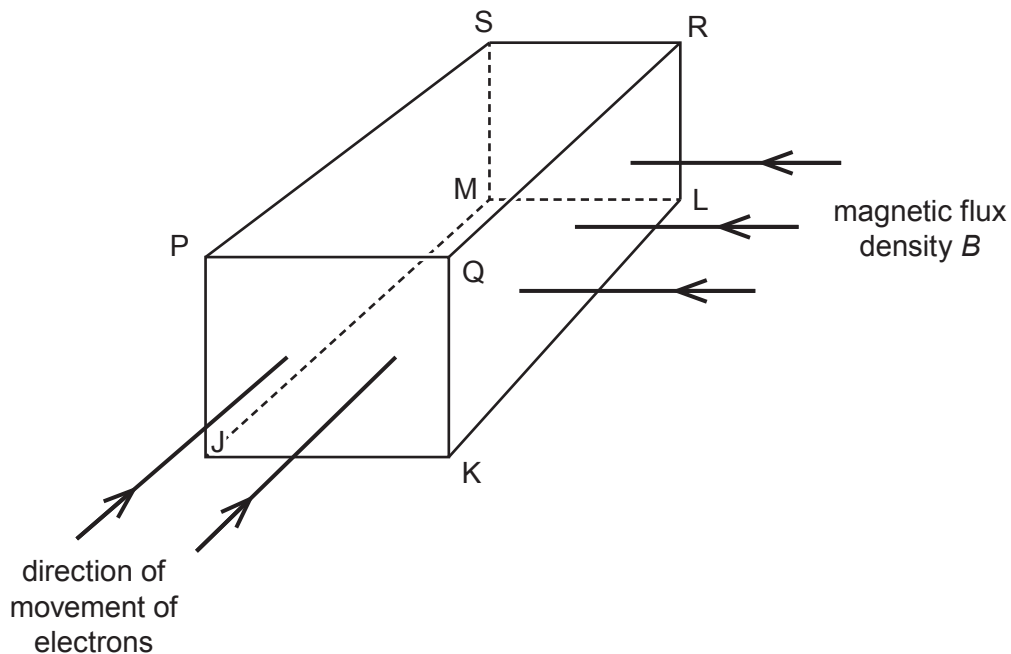


Fig. 8.1

Electrons enter the slice travelling perpendicular to face PQKJ.

(a) For the free electrons moving in the slice:

- (i) state the direction of the force on an electron due to movement of the electron in the magnetic field

.....
 [1]

- (ii) identify the faces, using the letters on Fig. 8.1, between which a potential difference is developed.

face and face [1]

(b) Explain why the potential difference in (a)(ii) reaches a maximum value.

.....

 [2]

- (c) The number of free electrons per unit volume in the slice of material is $1.3 \times 10^{29} \text{ m}^{-3}$.
 The thickness PQ of the slice is 0.10 mm.
 The magnetic flux density B is $4.6 \times 10^{-3} \text{ T}$.

Calculate the potential difference across the slice for a current of $6.3 \times 10^{-4} \text{ A}$.

potential difference = ... V [2]

- (d) The slice in (c) is a metal.

By reference to your answer in (c), suggest why Hall probes are usually made using semiconductors rather than metals.

.....

 [2]

[Total: 8]

- 9 (a) Define *magnetic flux*.

.....

.....

..... [2]

- (b) A simple transformer consists of two coils of wire wound on a soft-iron core, as illustrated in Fig. 9.1.

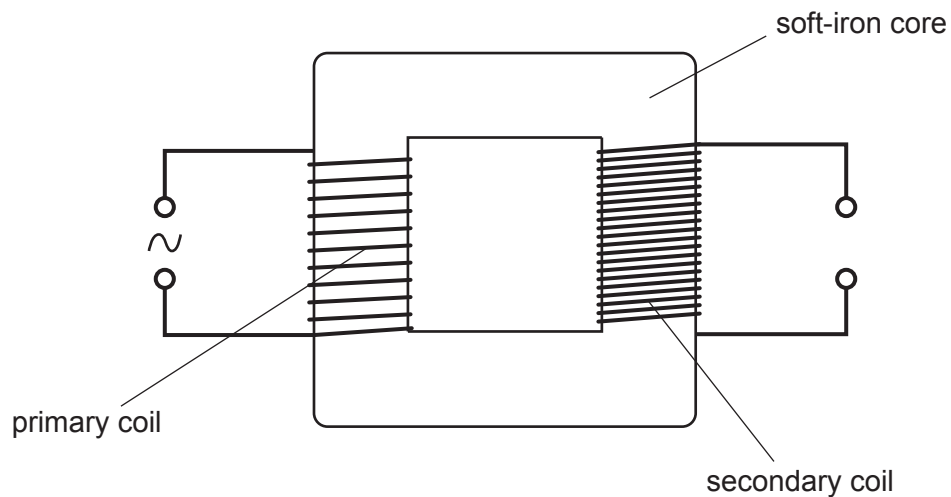


Fig. 9.1

There is a sinusoidal current in the primary coil.

Explain:

- (i) how this current gives rise to an induced electromotive force (e.m.f.) in the secondary coil

.....

.....

.....

.....

..... [3]

- (ii) why the e.m.f. induced in the secondary coil is not constant.

.....

.....

.....

..... [2]

(c) Explain why the soft-iron core in (b) is laminated.

.....

.....

..... [2]

[Total: 9]

10 (a) Outline briefly the principles of computed tomography (CT scanning).

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

- (b) One section of a model designed to illustrate CT scanning is divided into four voxels. The pixel numbers K, L, M and N of the voxels are shown in Fig. 10.1.

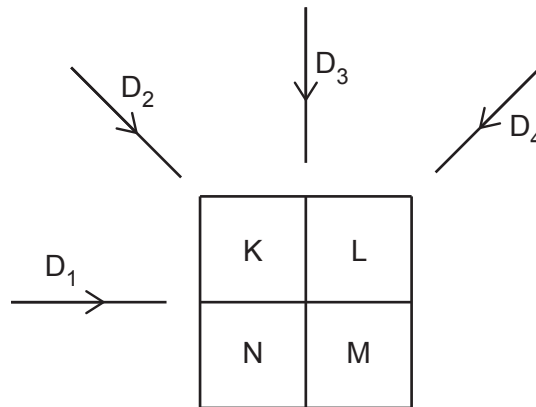


Fig. 10.1

The section is viewed, in turn, from four different directions D₁, D₂, D₃ and D₄, as shown in Fig. 10.1.

The detector readings for each direction are noted and these are summed to give the values shown in Fig. 10.2.

42	45
51	30

Fig. 10.2

The background reading is 24.

Determine the pixel numbers K, L, M and N shown in Fig. 10.1.

K = ...

L = ...

M = ...

N = ...

[3]

[Total: 8]

- 11 A photon of wavelength 540 nm collides with an isolated stationary electron, as illustrated in Fig. 11.1.

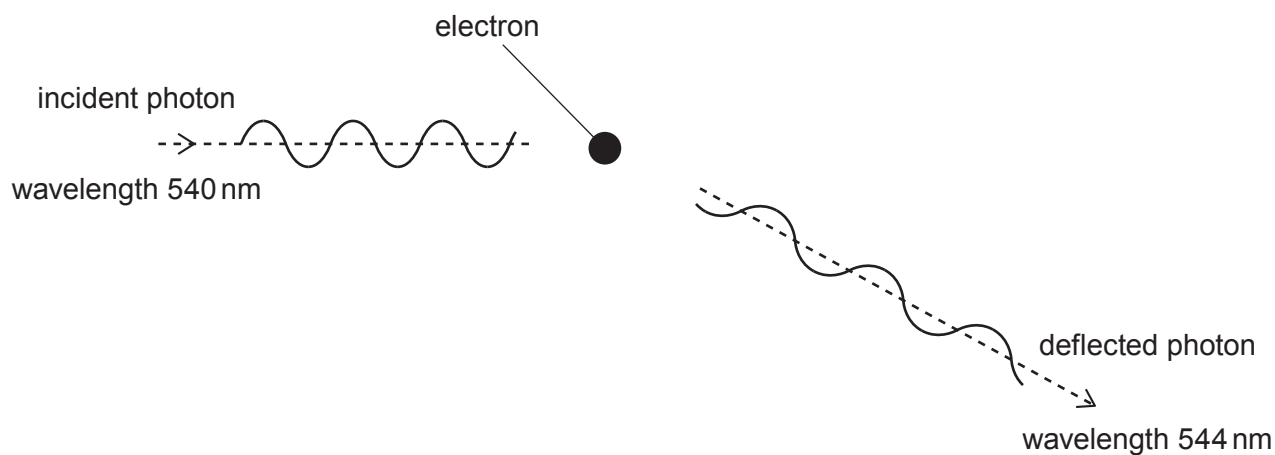


Fig. 11.1

The photon is deflected elastically by the electron.
The wavelength of the deflected photon is 544 nm.

- (a) (i) State what is meant by a *photon*.

.....

.....

..... [2]

- (ii) On Fig. 11.1, draw an arrow to indicate the approximate direction of motion of the deflected electron. [1]

(b) Calculate:

(i) the momentum of the deflected photon

momentum = ... N s [2]

(ii) the energy transferred to the deflected electron.

energy = ... J [2]

(c) Another photon of wavelength 540 nm collides with an isolated stationary electron.

Explain why it is not possible for the deflected photon to have a wavelength less than 540 nm.

.....
.....
..... [2]

[Total: 9]

12 Iodine-131 ($^{131}_{53}\text{I}$) is a radioactive isotope with a decay constant of $9.9 \times 10^{-7} \text{ s}^{-1}$.

(a) State what is meant by:

(i) *radioactive*

.....

 [2]

(ii) *decay constant*.

.....

 [2]

(b) Some water becomes contaminated with iodine-131.
 The activity of the iodine-131 in 1.0 kg of water is 560 Bq.

Determine the number of iodine-131 atoms in 1.0 kg of water.

number = ... [2]

(c) Regulations require that the activity of iodine-131 in 1.0 kg of water is to be less than 170 Bq.

Calculate the time, in days, for the activity of the contaminated water in (b) to be reduced to 170 Bq.

time = ... days [3]

[Total: 9]



CANDIDATE
NAME

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9702/42

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Data

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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	$g = 9.81 \text{ m s}^{-2}$

Formulae

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pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
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electric current	$I = Anvq$
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Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

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

.....

.....

..... [2]

- (b) The Earth may be considered to be a uniform sphere of radius $6.4 \times 10^6 \text{ m}$ with its mass of $6.0 \times 10^{24} \text{ kg}$ concentrated at its centre.

A satellite of mass $2.4 \times 10^3 \text{ kg}$ is launched from the Equator. It is placed in an equatorial orbit at a height of $5.6 \times 10^6 \text{ m}$ above the Earth's surface.

- (i) Calculate the change ΔE_p in gravitational potential energy of the satellite for its movement from the surface of the Earth to its position in the equatorial orbit.

$$\Delta E_p = \dots\dots\dots \text{ J [3]}$$

- (ii) Determine the speed of the satellite when in orbit.

$$\text{speed} = \dots\dots\dots \text{ ms}^{-1} [3]$$

- (c) Before the satellite in (b) is launched, its speed at the Equator due to the Earth's rotation is 470 m s^{-1} .

Suggest why the energy required to launch the satellite depends on whether the satellite, in its orbit, is travelling from west to east or from east to west.

.....
..... [1]

[Total: 9]

- 2 (a) State what is meant by the *internal energy* of a system.

.....

 [2]

- (b) The atoms of an ideal gas occupy a container of volume $2.30 \times 10^{-3} \text{ m}^3$ at pressure $2.60 \times 10^5 \text{ Pa}$ and temperature 180 K , as illustrated in Fig. 2.1.

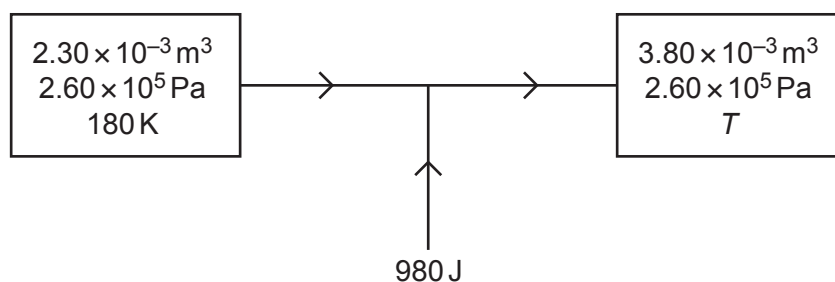


Fig. 2.1

The gas is heated at constant pressure so that its volume becomes $3.80 \times 10^{-3} \text{ m}^3$ at a temperature T .

For the fixed mass of gas, calculate:

- (i) the amount of substance, in mol

amount = ... mol [2]

- (ii) the temperature T , in K.

$T = \dots\dots\dots \text{ K}$ [2]

(c) During the change in (b), the thermal energy supplied to the gas is 980 J.

(i) Determine the work done on the gas during this change. Explain your working.

work done = ... J [3]

(ii) Determine the change ΔU in internal energy of the gas.

$\Delta U =$ J [1]

[Total: 10]

- 3 A simple pendulum consists of a metal sphere suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

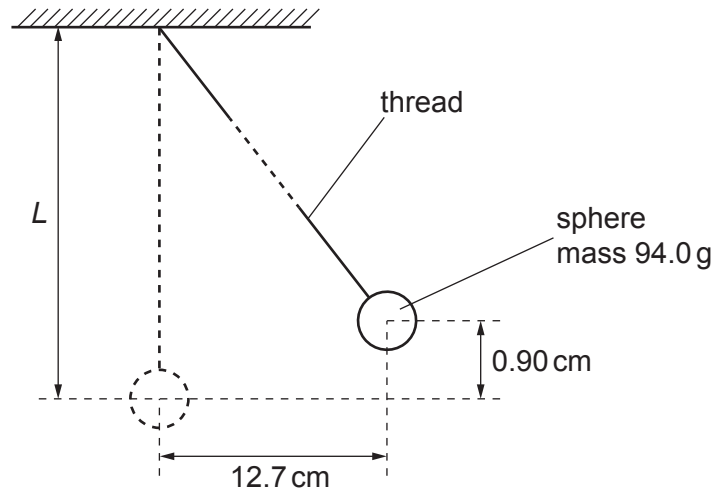


Fig. 3.1 (not to scale)

The sphere of mass 94.0 g is displaced to one side through a horizontal distance of 12.7 cm. The centre of gravity of the sphere rises vertically by 0.90 cm.

The sphere is released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

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

.....

 [2]

- (b) (i) State the kinetic energy of the sphere when the sphere returns to the displaced position shown in Fig. 3.1.

kinetic energy = ... J [1]

- (ii) Calculate the total energy E_T of the oscillations.

E_T = ... J [2]

- (iii) Use your answer in (ii) to show that the angular frequency ω of the oscillations of the pendulum is 3.3 rad s^{-1} .

[2]

- (c) The period T of oscillation of the pendulum is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall and L is the length of the pendulum.

Use data from (b) to determine L .

$L = \dots\dots\dots \text{m}$ [3]

[Total: 10]

- 4 (a) State **two** advantages of the transmission of data in digital, rather than analogue, form.

1.
-
2.
-

[2]

- (b) An analogue signal is to be transmitted in digital form.

The transmission system may be represented in block form as in Fig. 4.1.

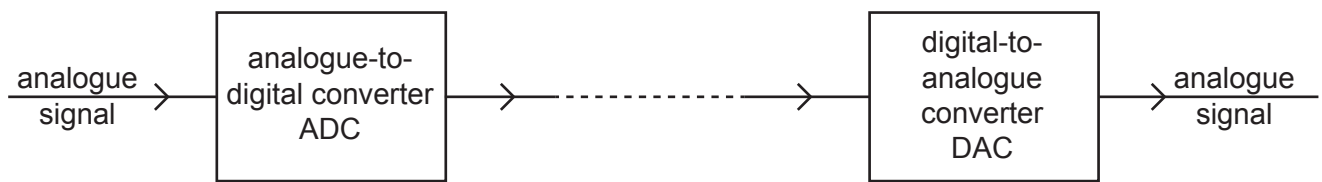


Fig. 4.1

The variation with time t of part of the input analogue signal is shown in Fig. 4.2.

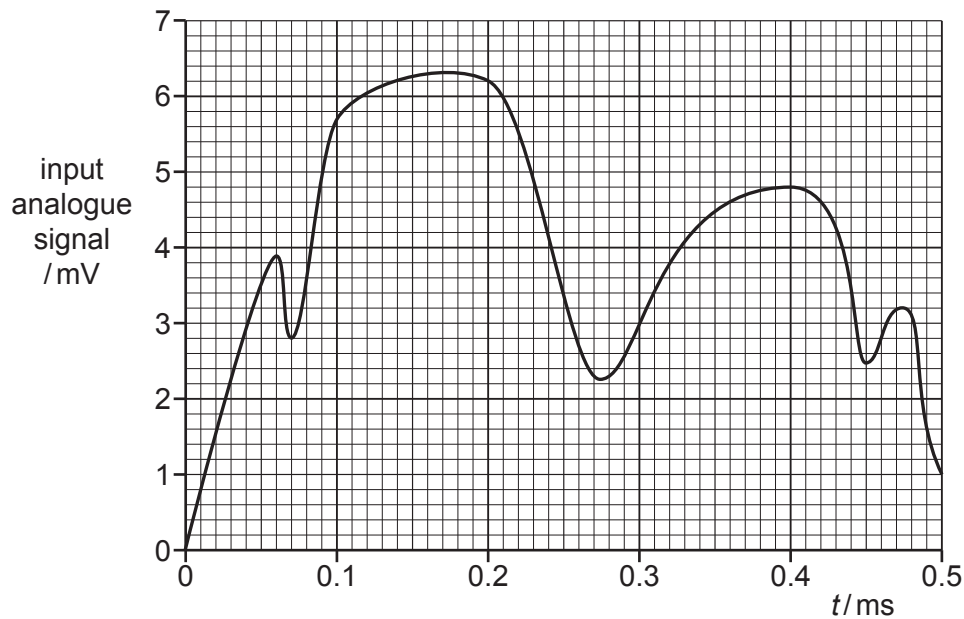


Fig. 4.2

The analogue signal is sampled at time intervals of 0.10 ms. The first sample is taken at time $t = 0$.

Some values of the sampled analogue signal and the corresponding digital signals are shown in Table 4.1.

Each digitised number contains four bits.

Table 4.1

time t /ms	0	0.10	0.20	0.30	0.40	0.50
analogue signal /mV	0	5.7	6.2			
digital signal	0000	0101	0110			

- (i) In Table 4.1, underline the least significant bit (LSB) in the digital signal for the time of 0.20 ms. [1]
- (ii) Complete Table 4.1. [3]
- (c) A single bit from the output of the digital-to-analogue converter corresponds to an output analogue signal of 1.0 mV.

Assume that the conversion and transmission do not introduce a time delay.

On the axes of Fig. 4.3, show the variation with time t of the output from the digital-to-analogue converter.

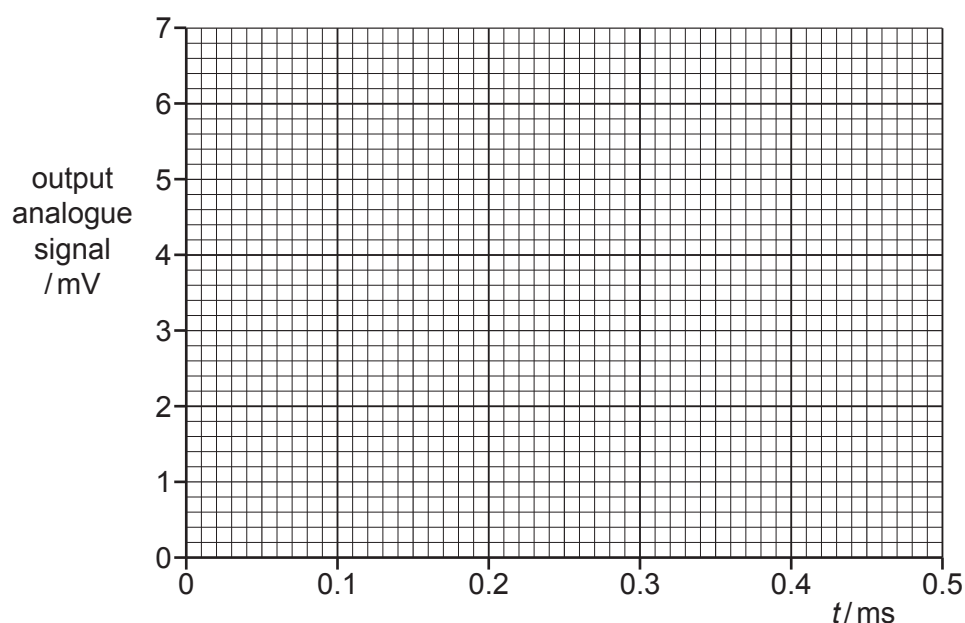


Fig. 4.3

[3]

[Total: 9]

- 5 (a) (i) State what is meant by a *field of force*.

.....

 [2]

- (ii) State **one** similarity and **one** difference between the electric field due to a point charge and the gravitational field due to a point mass.

similarity:

 difference:

 [2]

- (b) An isolated solid metal sphere of radius 0.15 m is situated in a vacuum, as illustrated in Fig. 5.1.

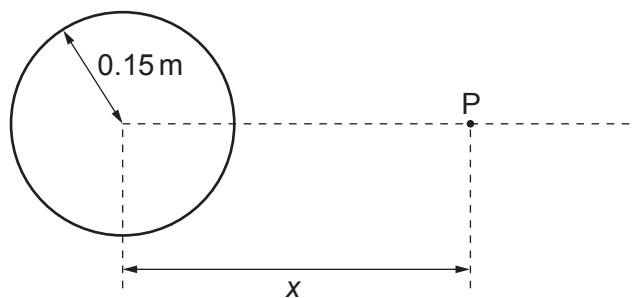


Fig. 5.1

The electric field strength at the surface of the sphere is 84 V m^{-1} .

Determine:

- (i) the charge Q on the sphere

$Q = \dots\dots\dots \text{ C}$ [2]

- (ii) the electric field strength at point P, a distance $x = 0.45\text{ m}$ from the centre of the sphere.

electric field strength = ... V m^{-1} [2]

- (c) Use information from (b) to show, on the axes of Fig. 5.2, the variation of the electric field strength E with distance x from the centre of the sphere for values of x from $x = 0$ to $x = 0.45\text{ m}$.

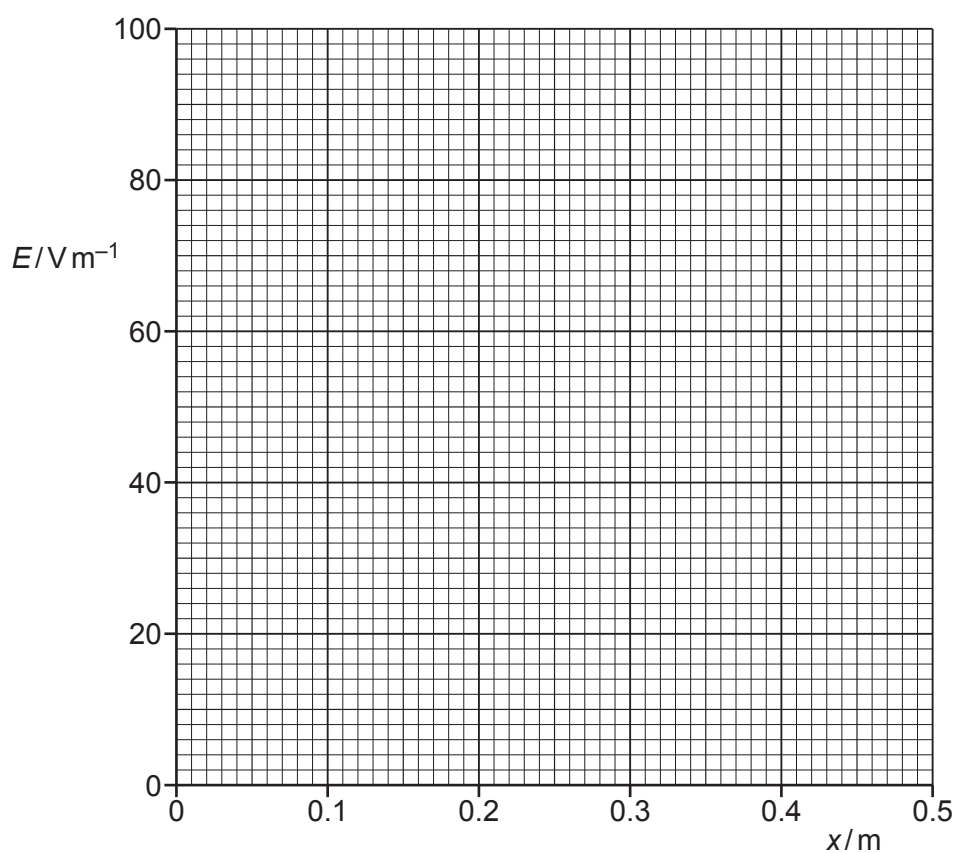


Fig. 5.2

[3]

[Total: 11]

- 6 (a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

.....

..... [2]

- (ii) State **three** functions of capacitors in electrical circuits.

1.

2.

3. [3]

- (b) A student has available **three** capacitors, each of capacitance $12\ \mu\text{F}$.

Draw diagrams, one in each case, to show how the student connects the capacitors to give a combined capacitance between the terminals of:

- (i) $18\ \mu\text{F}$



[1]

- (ii) $8\ \mu\text{F}$.



[1]

[Total: 7]

- 7 Electrons in a beam are travelling at high speed in a vacuum. The electrons are incident on a metal target, causing X-ray radiation to be emitted.

The variation with wavelength λ of the intensity I of the emitted X-ray radiation is shown in Fig. 7.1.

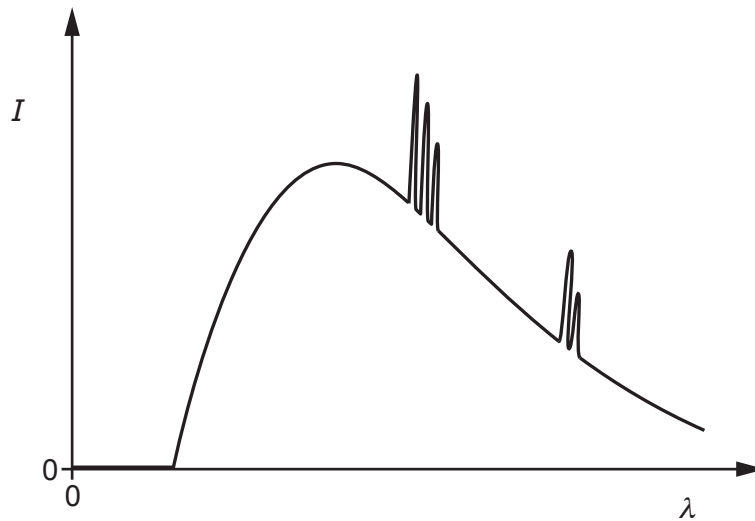


Fig. 7.1

Explain why:

- (a) there is a continuous distribution of wavelengths

.....

 [3]

- (b) at certain wavelengths, there are narrow peaks of increased intensity.

.....

 [3]

[Total: 6]

- 8 (a) An ideal operational amplifier (op-amp) is said to have infinite bandwidth and infinite slew rate.

State what is meant by:

- (i) *infinite bandwidth*

.....
 [1]

- (ii) *infinite slew rate.*

.....
 [1]

- (b) An amplifier circuit incorporating an op-amp is shown in Fig. 8.1.

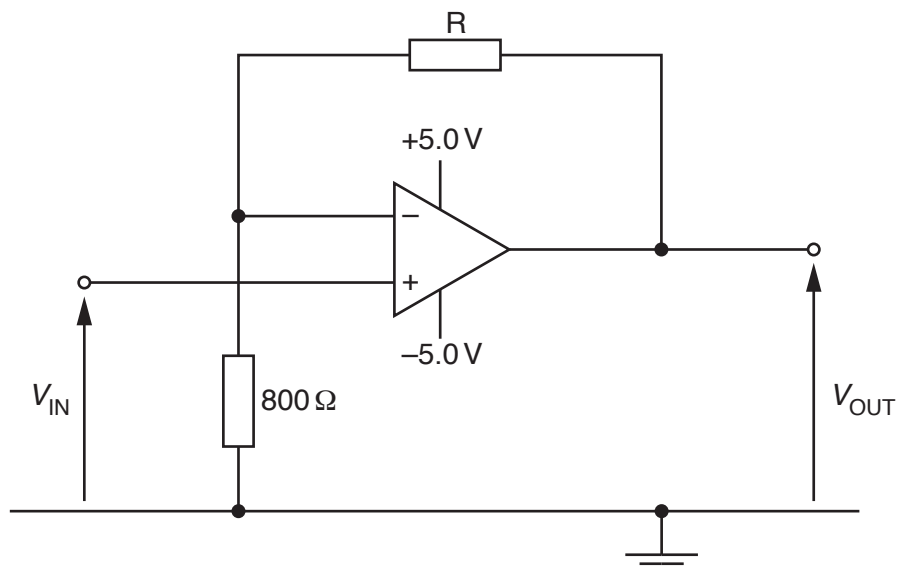


Fig. 8.1

The resistance of resistor R is to be fixed so that, for an input potential difference V_{IN} of 0.40V, the amplifier is on the point of saturation.

Determine:

- (i) the gain of the amplifier circuit

gain = ... [2]

(ii) the resistance of resistor R.

resistance = ... Ω [2]

[Total: 6]

- 9 (a) A small coil is placed close to one end of a solenoid connected to a power supply. The plane of the small coil is normal to the axis of the solenoid, as illustrated in Fig. 9.1.

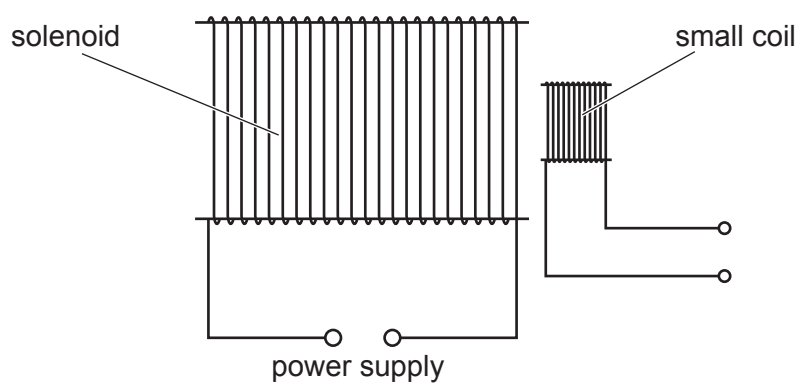


Fig. 9.1

The power supply causes the current I in the solenoid to vary with time t as shown in Fig. 9.2.

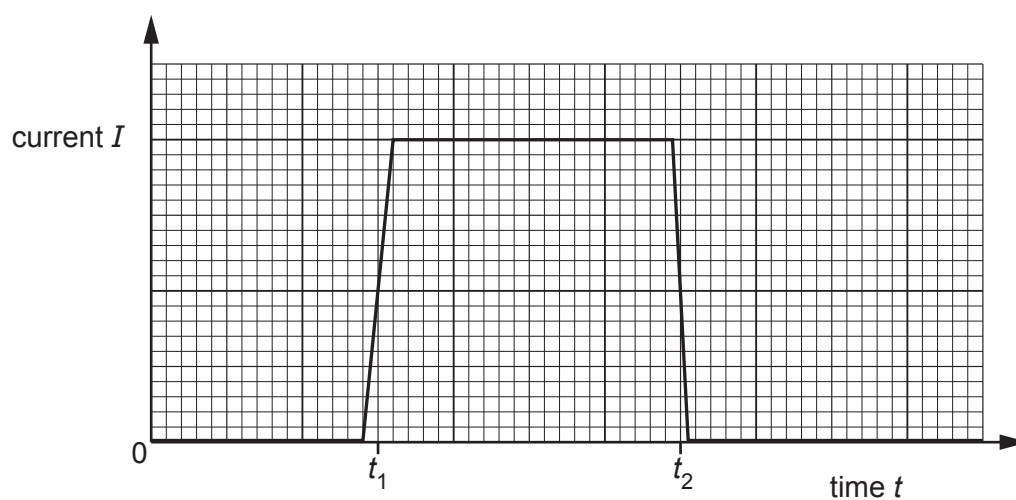


Fig. 9.2

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

.....

 [2]

- (ii) On the axes of Fig. 9.3, sketch a graph to show the variation with time t of the electromotive force (e.m.f.) induced in the small coil.

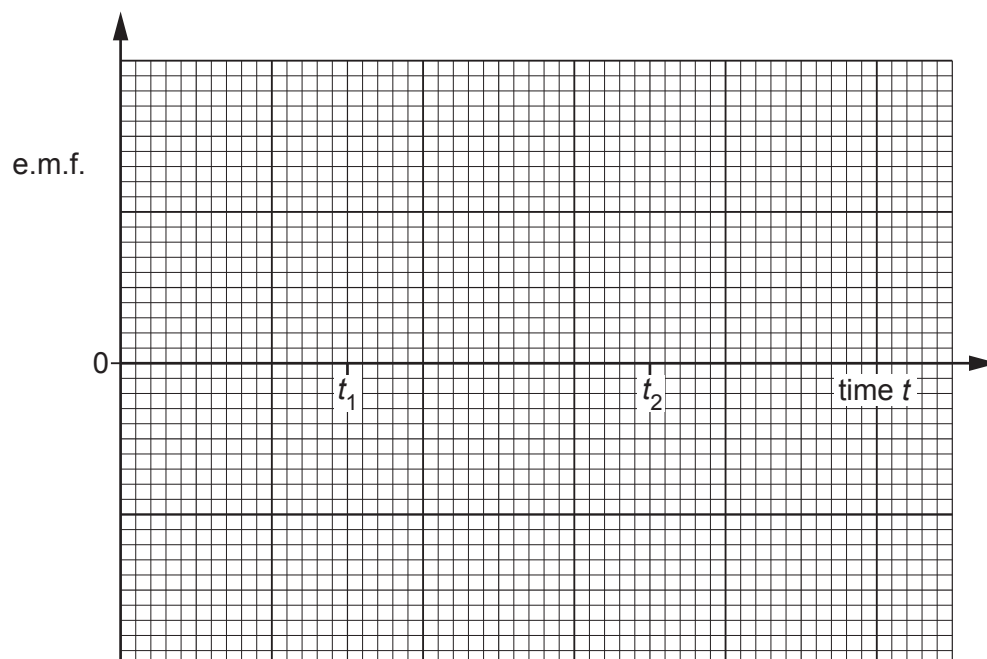


Fig. 9.3

[4]

(b) The small coil in (a) is now replaced by a Hall probe.

The Hall probe is positioned so that the reading for the probe is a maximum.

The current I in the solenoid varies again as shown in Fig. 9.2.

On the axes of Fig. 9.4, sketch a graph to show the variation with time t of the reading V_H of the probe.

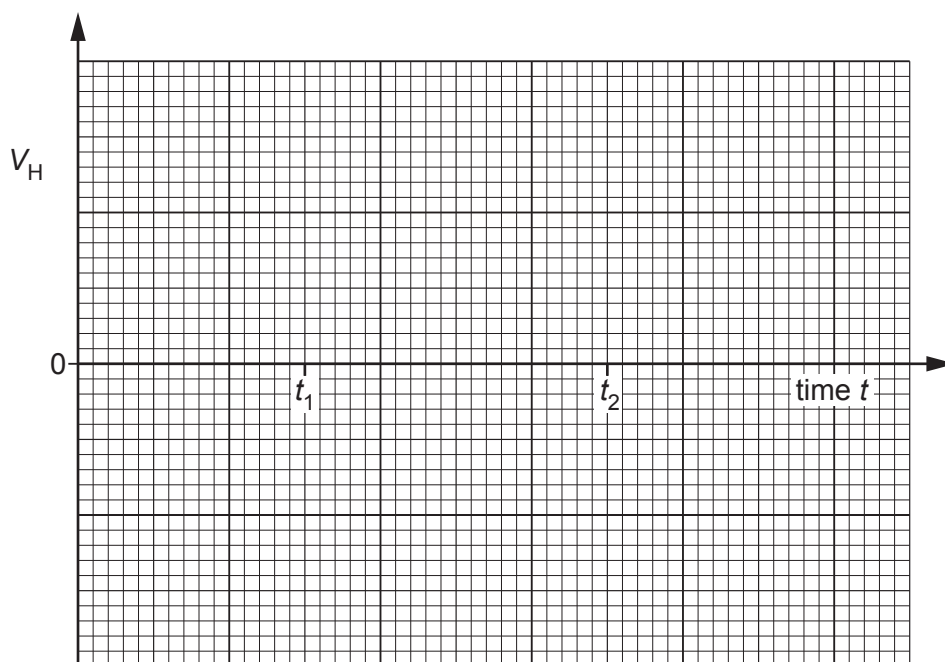


Fig. 9.4

[2]

[Total: 8]

- 10 (a) A long straight vertical wire A carries a current in an upward direction. The wire passes through the centre of a horizontal card, as illustrated in Fig. 10.1.

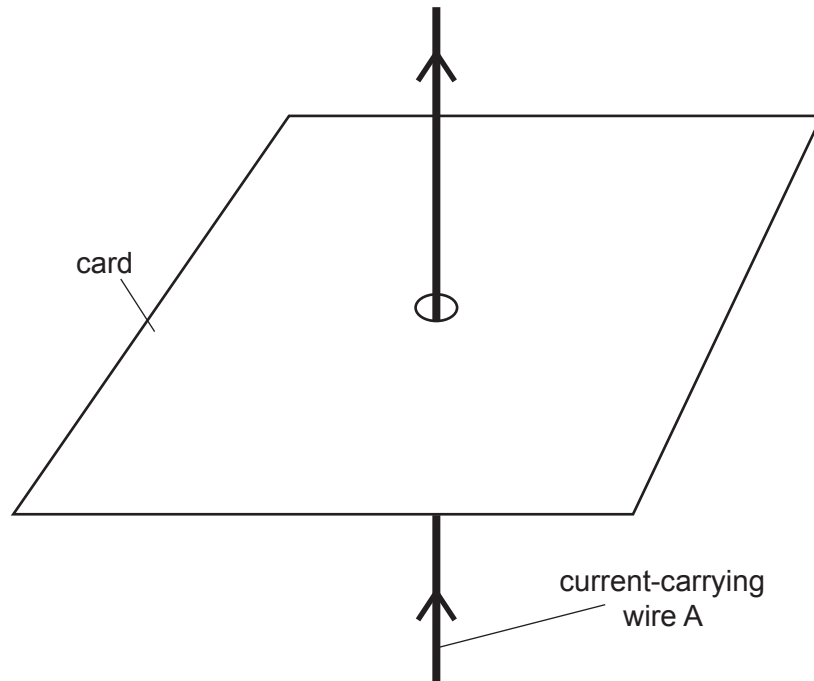


Fig. 10.1

The card is viewed from above. The card is shown from above in Fig. 10.2.

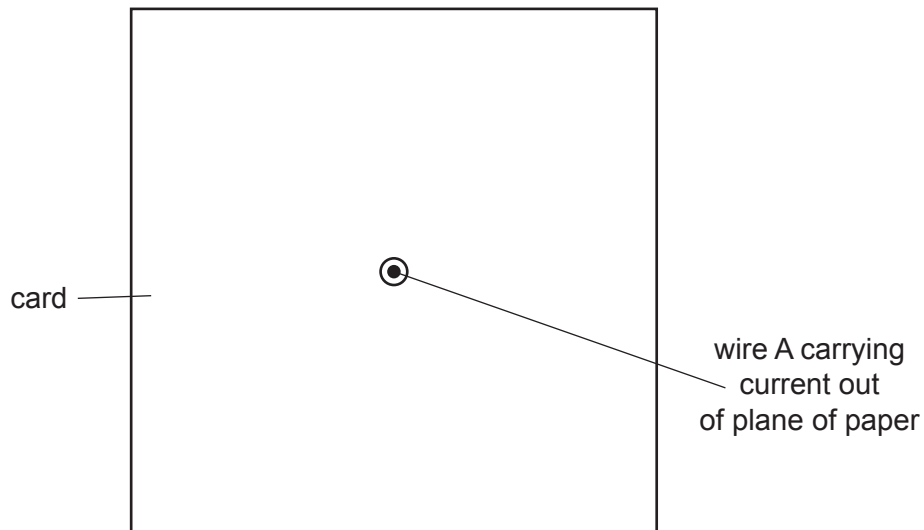


Fig. 10.2

On Fig. 10.2, draw four lines to represent the magnetic field produced by the current-carrying wire. [3]

- (b) Two wires A and B are now placed through a card. The two wires are parallel and carrying currents in the same direction, as illustrated in Fig. 10.3.

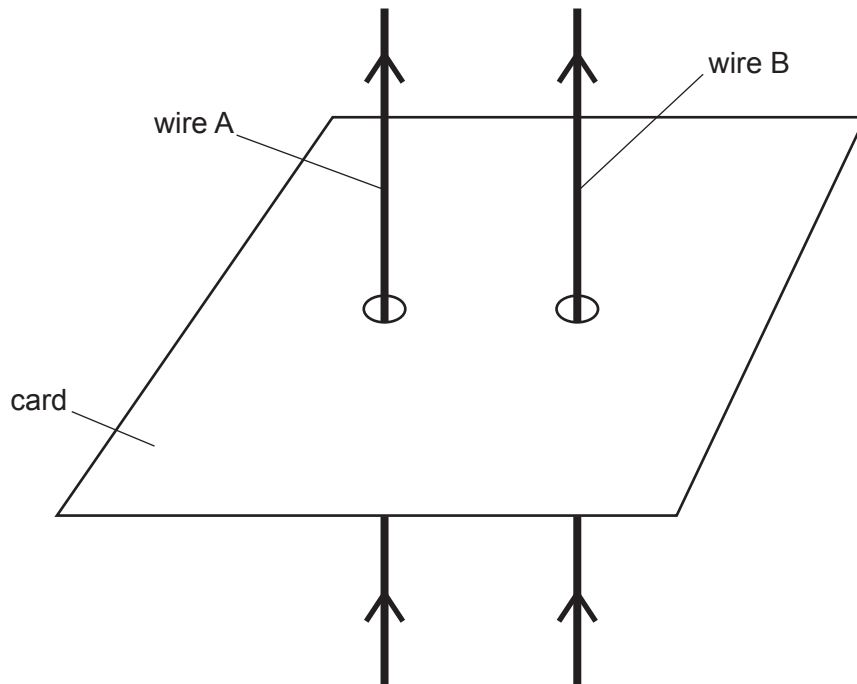


Fig. 10.3

- (i) Explain why a magnetic force is exerted on each wire.

.....

 [2]

- (ii) State the directions of the forces.

.....
 [1]

- (c) The currents in the two wires are not equal.

Explain whether the magnetic forces on the two wires are equal in magnitude.

.....

 [1]

[Total: 7]

- 11 (a) Electromagnetic radiation is incident on a metal surface.

It is observed that there is a minimum frequency of electromagnetic radiation below which emission of electrons does not occur.

This observation provides evidence for a particulate nature of electromagnetic radiation.

State **two** other observations associated with photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1.

.....

2.

.....

[2]

- (b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 11.1.

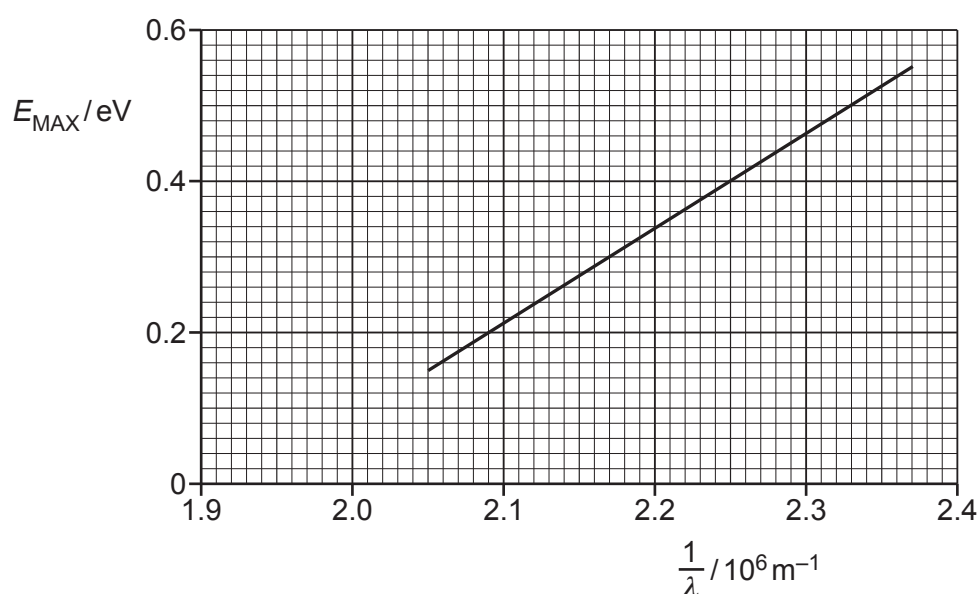


Fig. 11.1

- (i) Use Fig. 11.1 to determine the threshold frequency f_0 .

$$f_0 = \dots\dots\dots \text{ Hz [2]}$$

- (ii) Use the gradient of the line on Fig. 11.1 to determine a value for the Planck constant h .
Explain your working.

$$h = \dots\dots\dots \text{ Js [4]}$$

- (c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in (b).

On Fig. 11.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX} . [2]

[Total: 10]

12 (a) (i) Define nuclear *binding energy*.

.....

.....

..... [2]

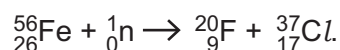
(ii) Explain what is meant by a *nuclear fission* reaction.

.....

.....

..... [2]

(b) A student suggests that one possible nuclear reaction is



The binding energy per nucleon of a nucleus varies with the nucleon number.
Use this variation to explain why the reaction would **not** result in an overall release of energy.

.....

.....

.....

.....

..... [3]

[Total: 7]

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PHYSICS

9702/43

Paper 4 A Level Structured Questions

October/November 2020

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Blank pages are indicated.



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	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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	$g = 9.81 \text{ m s}^{-2}$

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	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

- 1 (a) (i) State what is meant by a *field of force*.

.....

 [2]

- (ii) Define *gravitational field strength*.

.....
 [1]

- (b) An isolated planet may be assumed to be a uniform sphere of radius $3.39 \times 10^6 \text{ m}$ with its mass of $6.42 \times 10^{23} \text{ kg}$ concentrated at its centre.

Calculate the gravitational field strength at the surface of the planet.

field strength = ... N kg^{-1} [3]

- (c) Calculate the height above the surface of the planet in (b) at which the gravitational field strength is 1.0% less than its value at the surface of the planet.

height = ... m [3]

[Total: 9]

- 2 (a) The first law of thermodynamics may be expressed as

$$\Delta U = (+q) + (+w)$$

where ΔU is the increase in internal energy of the system.

State the meaning of:

$+q$

.....

$+w$

.....

[2]

- (b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

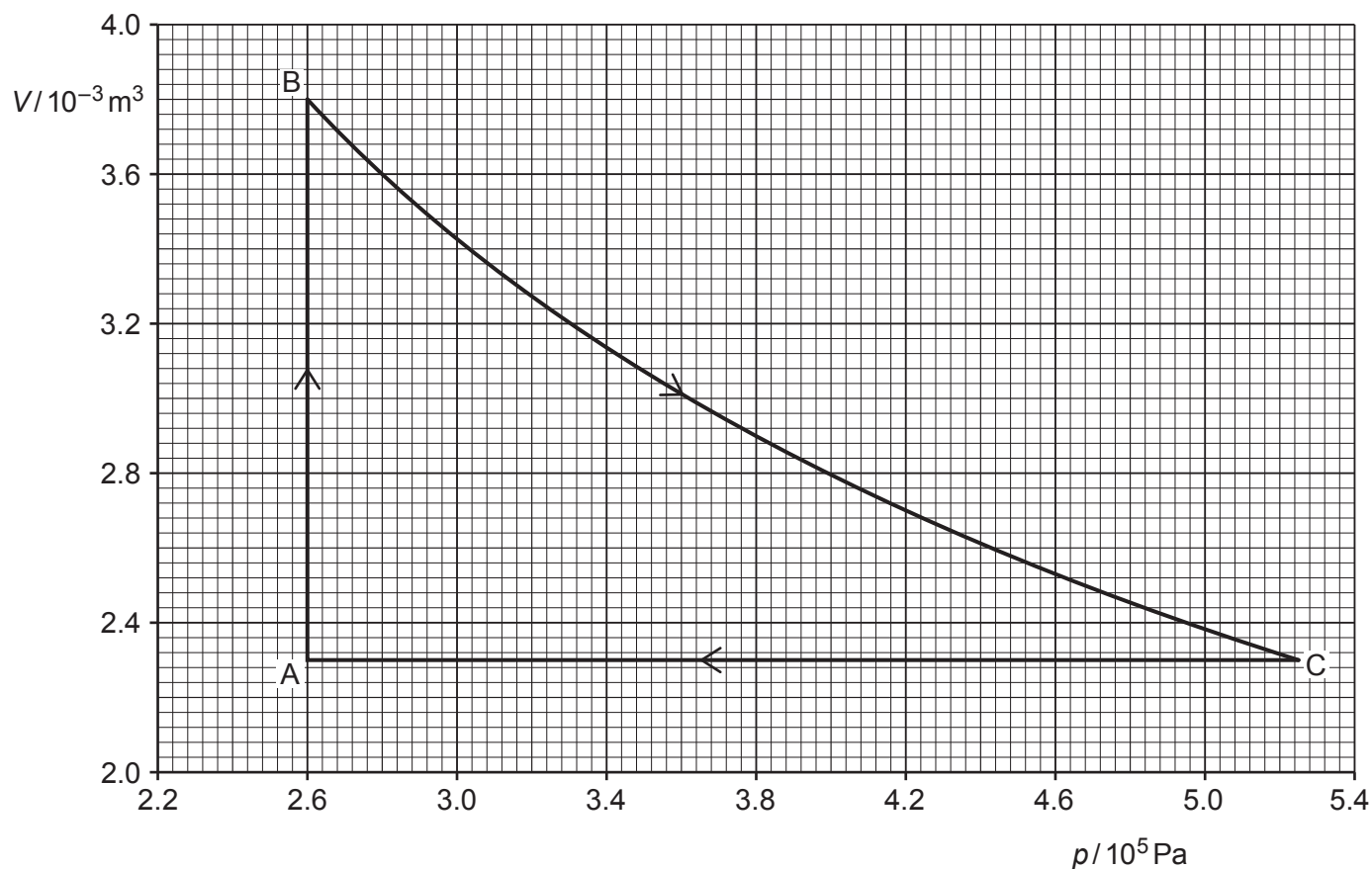


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.

- (i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

- (ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

.....

..... [2]

- (c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]

- 3 A pendulum consists of a metal sphere P suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

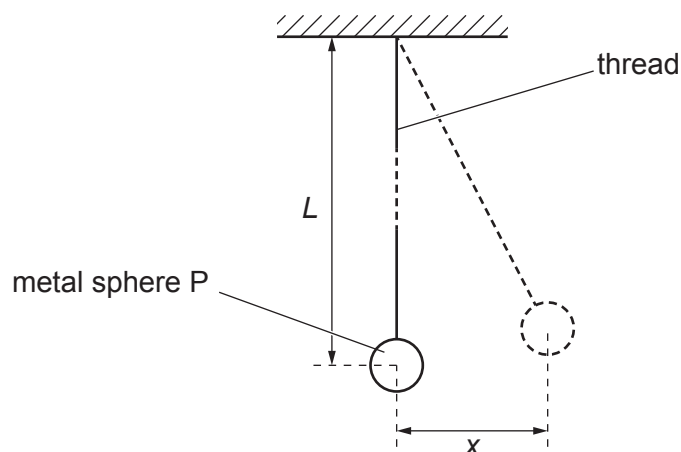


Fig. 3.1

The centre of gravity of sphere P is a distance L from the fixed point.

The sphere is pulled to one side and then released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

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

.....

.....

..... [2]

- (b) The variation of the velocity v of sphere P with the displacement x from its mean position is shown in Fig. 3.2.

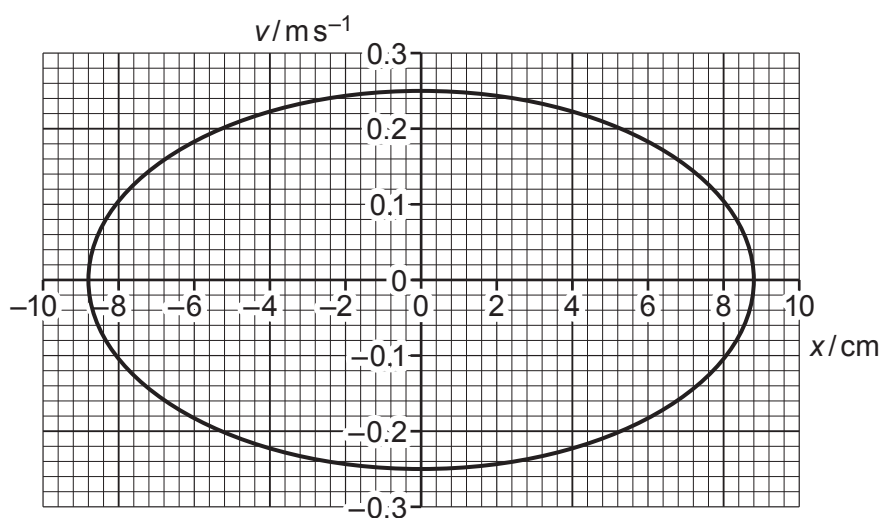


Fig. 3.2

Use Fig. 3.2 to determine the frequency f of the oscillations of sphere P.

$$f = \dots\dots\dots \text{ Hz [3]}$$

- (c) The period T of the oscillations of sphere P is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall.

Use your answer in (b) to determine the length L .

$$L = \dots\dots\dots \text{ m [2]}$$

- (d) Another pendulum consists of a sphere Q suspended by a thread. Spheres P and Q are identical. The thread attached to sphere Q is longer than the thread attached to sphere P.

Sphere Q is displaced and then released. The oscillations of sphere Q have the same amplitude as the oscillations of sphere P.

On Fig. 3.2, sketch the variation of the velocity v with displacement x for sphere Q. [2]

[Total: 9]

- 4 (a) Explain the principles of the **generation** of ultrasound waves for use in medical diagnosis.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) The linear attenuation (absorption) coefficient for a parallel beam of ultrasound waves in air is 1.2cm^{-1} .

The parallel beam passes through a layer of air of thickness 3.5 cm.

Calculate the ratio, in dB,

$$\frac{\text{intensity of beam after passing through the layer of air}}{\text{intensity of beam entering the layer of air}}.$$

ratio = ... dB [4]

[Total: 8]

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

.....

.....

..... [2]

- (b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

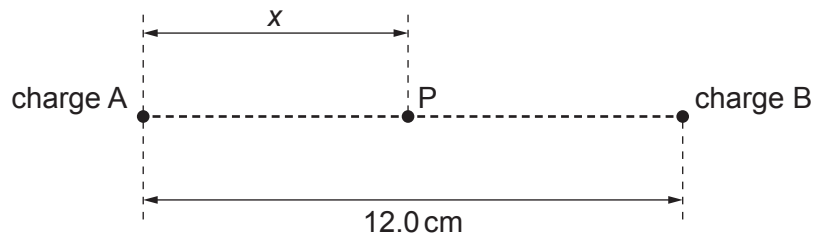


Fig. 5.1

The charge of A is $+2.0 \times 10^{-9} \text{ C}$.

A point P lies on the line joining charges A and B. Its distance from charge A is x .

The variation with distance x of the electric potential V at point P is shown in Fig. 5.2.

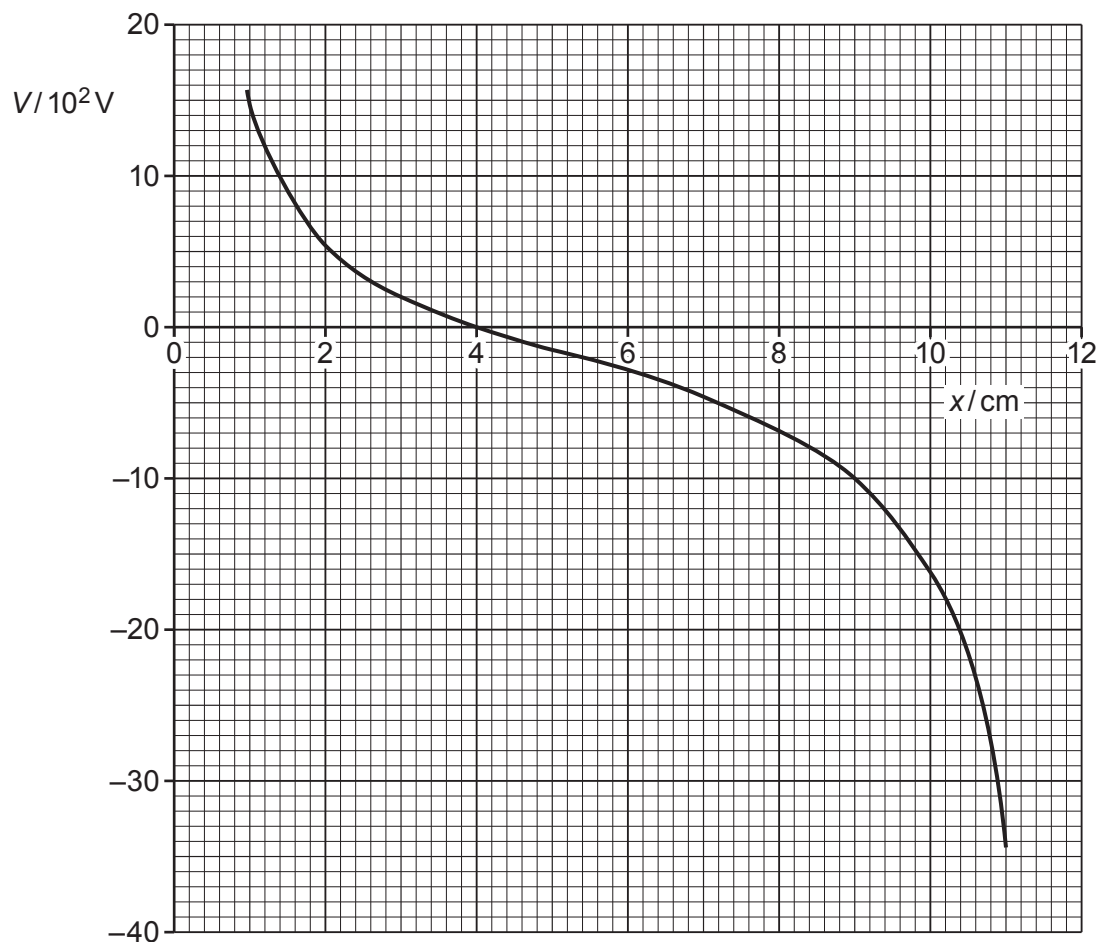


Fig. 5.2

Use Fig. 5.2 to determine:

- (i) the charge of B

charge = ... C [3]

- (ii) the change in electric potential when point P moves from the position where $x = 9.0$ cm to the position where $x = 3.0$ cm.

change = ... V [1]

- (c) An α -particle moves along the line joining point charges A and B in Fig. 5.1.

The α -particle moves from the position where $x = 9.0$ cm and just reaches the position where $x = 3.0$ cm.

Use your answer in (b)(ii) to calculate the speed v of the α -particle at the position where $x = 9.0$ cm.

$v =$ ms^{-1} [3]

[Total: 9]

- 6 (a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

 [2]

- (ii) State **three** functions of capacitors in electrical circuits.

1.
 2.
 3. [3]

- (b) A student has available four capacitors, each of capacitance $24\ \mu\text{F}$.

The capacitors are connected as shown in Fig. 6.1.

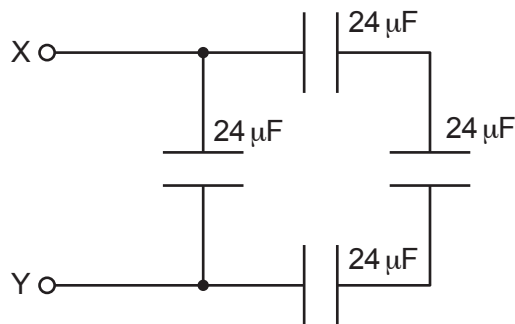


Fig. 6.1

Calculate the combined capacitance between the terminals X and Y.

capacitance = ... μF [2]

[Total: 7]

- 7 An ideal operational amplifier (op-amp) is to be used in a comparator circuit. Part of the comparator circuit is shown in Fig. 7.1.

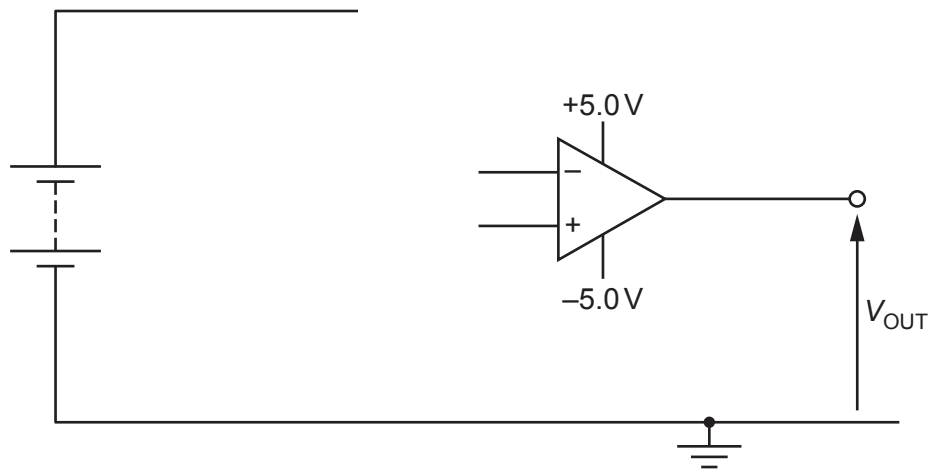


Fig. 7.1

Three resistors, each of resistance 1000Ω , and a negative temperature coefficient thermistor are available to complete the circuit.

The circuit is to be designed so that, at low temperatures, the output V_{OUT} is $-5.0V$ and at higher temperatures, the output V_{OUT} is to be $+5.0V$.

- (a) On Fig. 7.1, draw the input circuit to the inverting and non-inverting inputs of the op-amp. [4]

- (b) State a suitable value for the thermistor resistance when the thermistor is at:

- (i) low temperature where V_{OUT} is $-5.0V$

..... [1]

- (ii) a higher temperature where V_{OUT} is $+5.0V$.

..... [1]

[Total: 6]

- 8 A slice of a conducting material has its face QRLK normal to a uniform magnetic field of flux density B , as illustrated in Fig. 8.1.

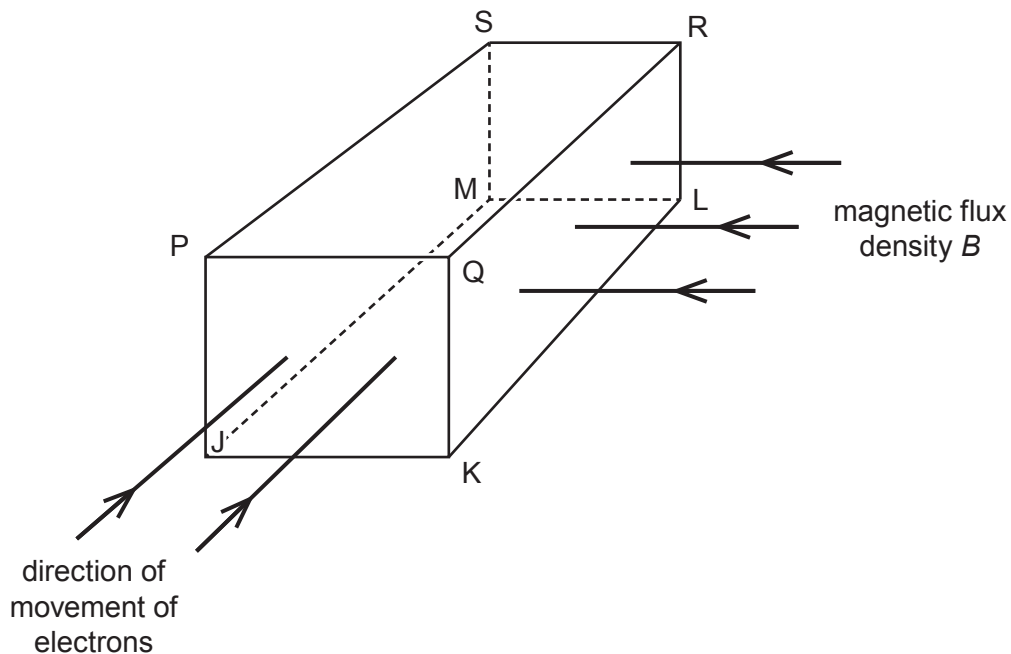


Fig. 8.1

Electrons enter the slice travelling perpendicular to face PQKJ.

(a) For the free electrons moving in the slice:

- (i) state the direction of the force on an electron due to movement of the electron in the magnetic field

.....
 [1]

- (ii) identify the faces, using the letters on Fig. 8.1, between which a potential difference is developed.

face and face [1]

(b) Explain why the potential difference in (a)(ii) reaches a maximum value.

.....

 [2]

- (c) The number of free electrons per unit volume in the slice of material is $1.3 \times 10^{29} \text{ m}^{-3}$.
 The thickness PQ of the slice is 0.10 mm.
 The magnetic flux density B is $4.6 \times 10^{-3} \text{ T}$.

Calculate the potential difference across the slice for a current of $6.3 \times 10^{-4} \text{ A}$.

potential difference = ... V [2]

- (d) The slice in (c) is a metal.

By reference to your answer in (c), suggest why Hall probes are usually made using semiconductors rather than metals.

.....

 [2]

[Total: 8]

- 9 (a) Define *magnetic flux*.

.....

.....

..... [2]

- (b) A simple transformer consists of two coils of wire wound on a soft-iron core, as illustrated in Fig. 9.1.

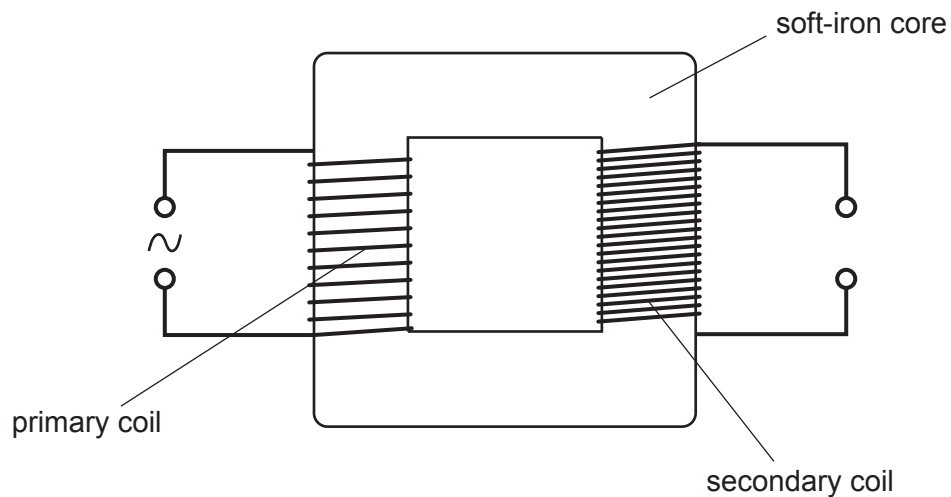


Fig. 9.1

There is a sinusoidal current in the primary coil.

Explain:

- (i) how this current gives rise to an induced electromotive force (e.m.f.) in the secondary coil

.....

.....

.....

..... [3]

- (ii) why the e.m.f. induced in the secondary coil is not constant.

.....

.....

.....

..... [2]

(c) Explain why the soft-iron core in (b) is laminated.

.....

.....

..... [2]

[Total: 9]

10 (a) Outline briefly the principles of computed tomography (CT scanning).

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

- (b) One section of a model designed to illustrate CT scanning is divided into four voxels. The pixel numbers K, L, M and N of the voxels are shown in Fig. 10.1.

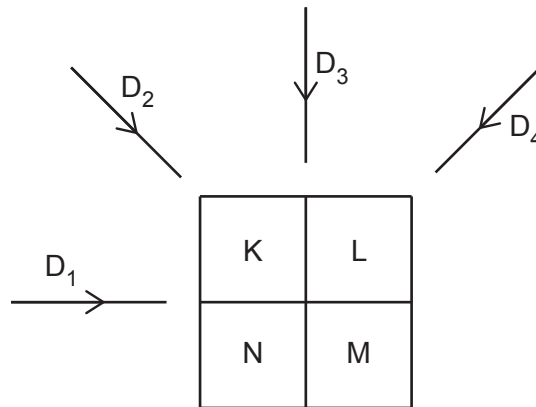


Fig. 10.1

The section is viewed, in turn, from four different directions D₁, D₂, D₃ and D₄, as shown in Fig. 10.1.

The detector readings for each direction are noted and these are summed to give the values shown in Fig. 10.2.

42	45
51	30

Fig. 10.2

The background reading is 24.

Determine the pixel numbers K, L, M and N shown in Fig. 10.1.

K = ...

L = ...

M = ...

N = ...

[3]

[Total: 8]

- 11 A photon of wavelength 540 nm collides with an isolated stationary electron, as illustrated in Fig. 11.1.

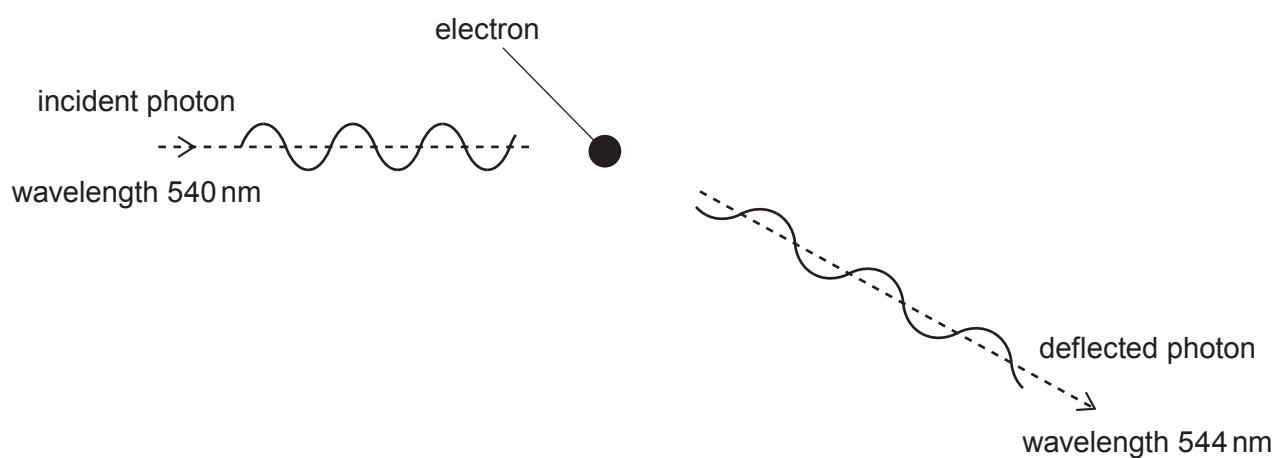


Fig. 11.1

The photon is deflected elastically by the electron.
The wavelength of the deflected photon is 544 nm.

- (a) (i) State what is meant by a *photon*.

.....

.....

..... [2]

- (ii) On Fig. 11.1, draw an arrow to indicate the approximate direction of motion of the deflected electron. [1]

(b) Calculate:

(i) the momentum of the deflected photon

momentum = ... N s [2]

(ii) the energy transferred to the deflected electron.

energy = ... J [2]

(c) Another photon of wavelength 540 nm collides with an isolated stationary electron.

Explain why it is not possible for the deflected photon to have a wavelength less than 540 nm.

.....
.....
..... [2]

[Total: 9]

12 Iodine-131 ($^{131}_{53}\text{I}$) is a radioactive isotope with a decay constant of $9.9 \times 10^{-7} \text{ s}^{-1}$.

(a) State what is meant by:

(i) *radioactive*

.....

 [2]

(ii) *decay constant*.

.....

 [2]

(b) Some water becomes contaminated with iodine-131.
 The activity of the iodine-131 in 1.0 kg of water is 560 Bq.

Determine the number of iodine-131 atoms in 1.0 kg of water.

number = ... [2]

(c) Regulations require that the activity of iodine-131 in 1.0 kg of water is to be less than 170 Bq.

Calculate the time, in days, for the activity of the contaminated water in **(b)** to be reduced to 170 Bq.

time = ... days [3]

[Total: 9]