Cambridge Assessment International Education

80/100

Cambridge International AS & A Level

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PHYSICS **9702/41**

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.

DC (KN) 206161

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 unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
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.	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^{\,2} - x^2)}$
Doppler effect	$f_o = \dfrac{f_s v}{v \pm v_s}$
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	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \dfrac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

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

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

region of space in which a mass or charge experiences a force

[2] 2

(ii) Define *gravitational field strength*.

force per unit mass

[1] 1

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

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

$$g = \frac{GM}{r^2} = \frac{G \times 6.42 \times 10^{23}}{(3.39 \times 10^6)^2} = 3.72855$$

field strength = 3.73 N kg^{-1} [3] 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.

$$3.729 - (3.729 \times 0.01) = 3.6917$$

$$h = \sqrt{\frac{G \times (6.42 \times 10^{23})}{3.6917}} - 3.39 \times 10^6$$

$$= 16877.549$$

height = 16900 m [3] 1

20000

[Total: 9]

$\frac{9}{9}$

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:

$+q$ Increase in thermal energy of the system

$+w$. Work done on the system by the atmosphere.

[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.

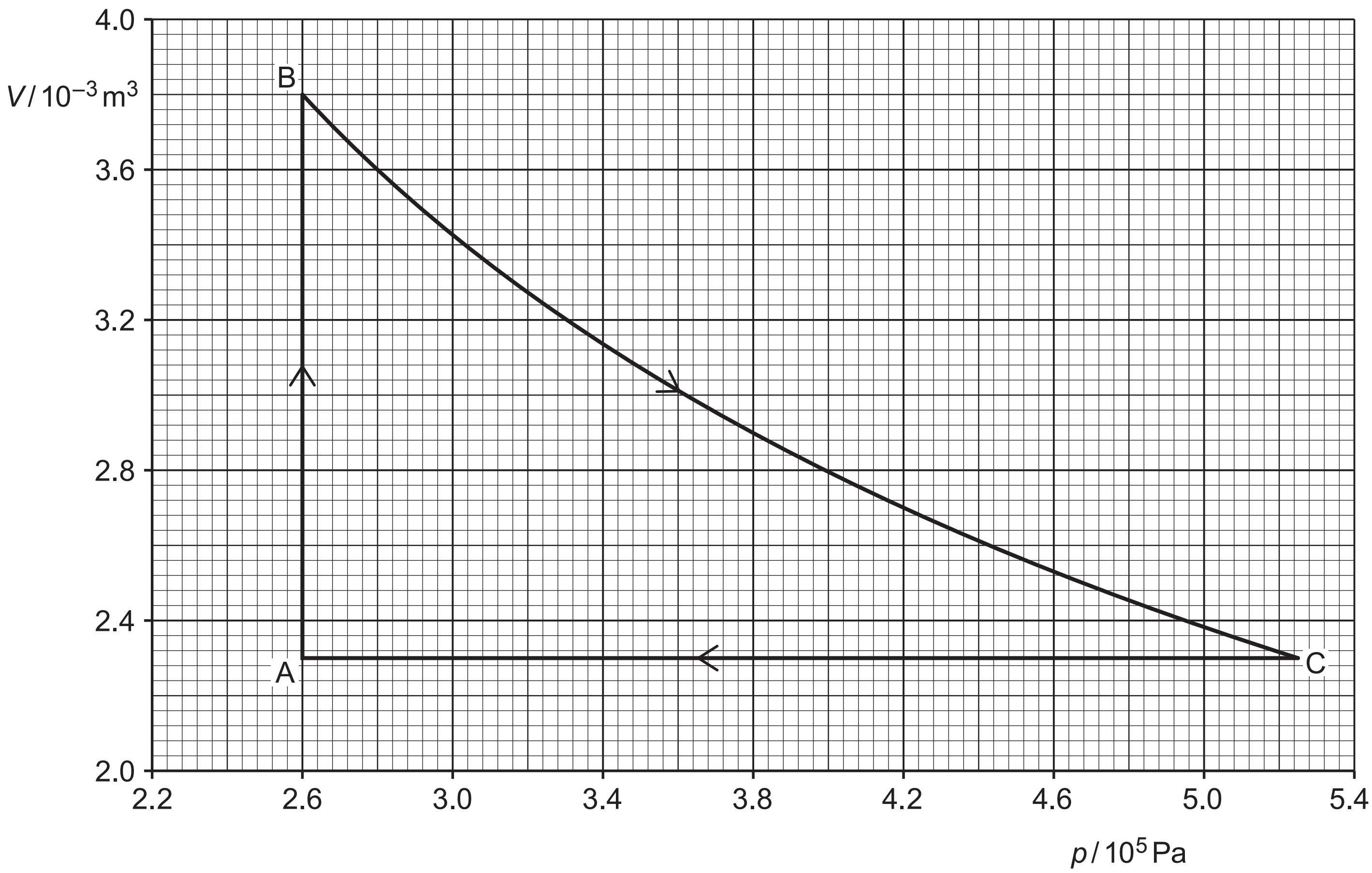

Fig. 2.1

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 $2.3 \times 10^{-3}\,m^3$ to $3.8 \times 10^{-3}\,m^3$.

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

$W = p\Delta V$

$= 2.6\times10^{5}\times\left[(3.8-2.3)\times10^{-3}\right]$

$= 390$

1

[1]

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

Zero, because initial and final, p and V is the same. returns to org temp

1

[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	ΔU / J
A to B	+1370	−390	980
B to C	0	+550	550
C to A	−1530	0	−1530

2

[4]

$980 + 550 + x = 0$

$x = -1530$

[Total: 9]

8/9

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.

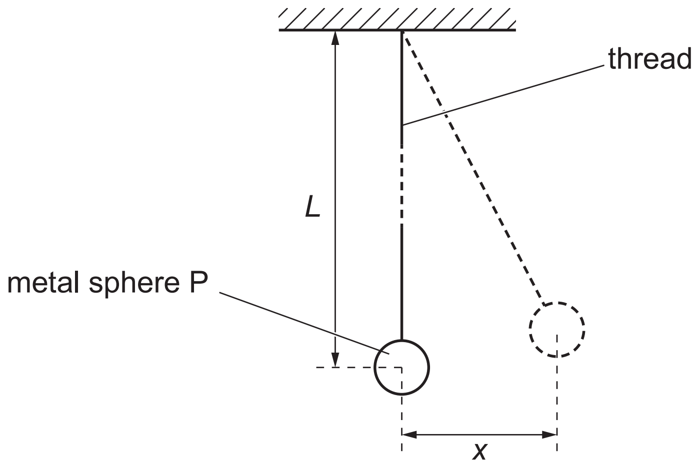

Fig. 3.1

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*.

To and fro motion of a body about a point, where the acceleration is always towards that point.

is ∝ to displacement

[2] 1

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

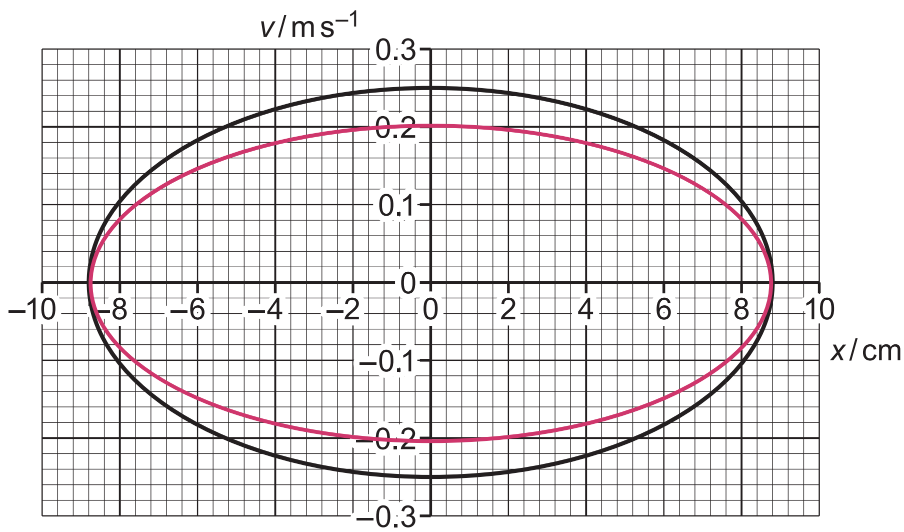

Fig. 3.2

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

$v = \omega x_0$

$v = 2\pi f x_0$

$f = \dfrac{v}{2\pi x_0} = \dfrac{0.25}{2\pi(8.8\times10^{-2})} = 0.452$

f = ...0.45...................................... Hz [3]

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*.

$T = \dfrac{1}{f} = 2.21168$

$L = \dfrac{T^2 g}{4\pi^2} = \dfrac{(2.21168)^2 \times 9.81}{4\pi^2} = 1.21549$

L = ...1.22...................................... ~~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]

$T \propto \sqrt{\dfrac{L}{g}}$

$\therefore L\uparrow \rightarrow T\uparrow$

if $T\uparrow \rightarrow f\downarrow$

$v_{max} \propto f$

$\therefore$ if $f\downarrow$, $v\downarrow$

$\dfrac{3}{9}$

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

x

....

....

....

....

....

....

....

.... [4] 0

* **(b)** The linear attenuation (absorption) coefficient for a parallel beam of ultrasound waves in air is $1.2\,\text{cm}^{-1}$.
μ 2.

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

Calculate the ratio, in dB,

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

$$\frac{I}{I_0} = e^{-\mu x} = e^{-1.2 \times 3.5}$$
$$= 0.01499558$$
$$10 \log[0.01499558]$$
$$= -18.24$$

ratio = ...-18...................................... dB [4] 0

[Total: 8]

$\frac{8}{8}$

ε-

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

It is the work done in bringing a small test +ve charge from infinity to a point in an electric field.

[2] 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.

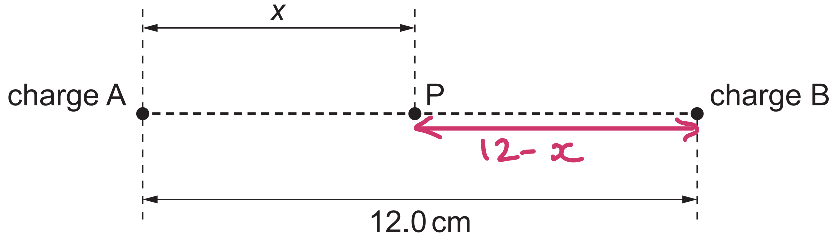


Fig. 5.1

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

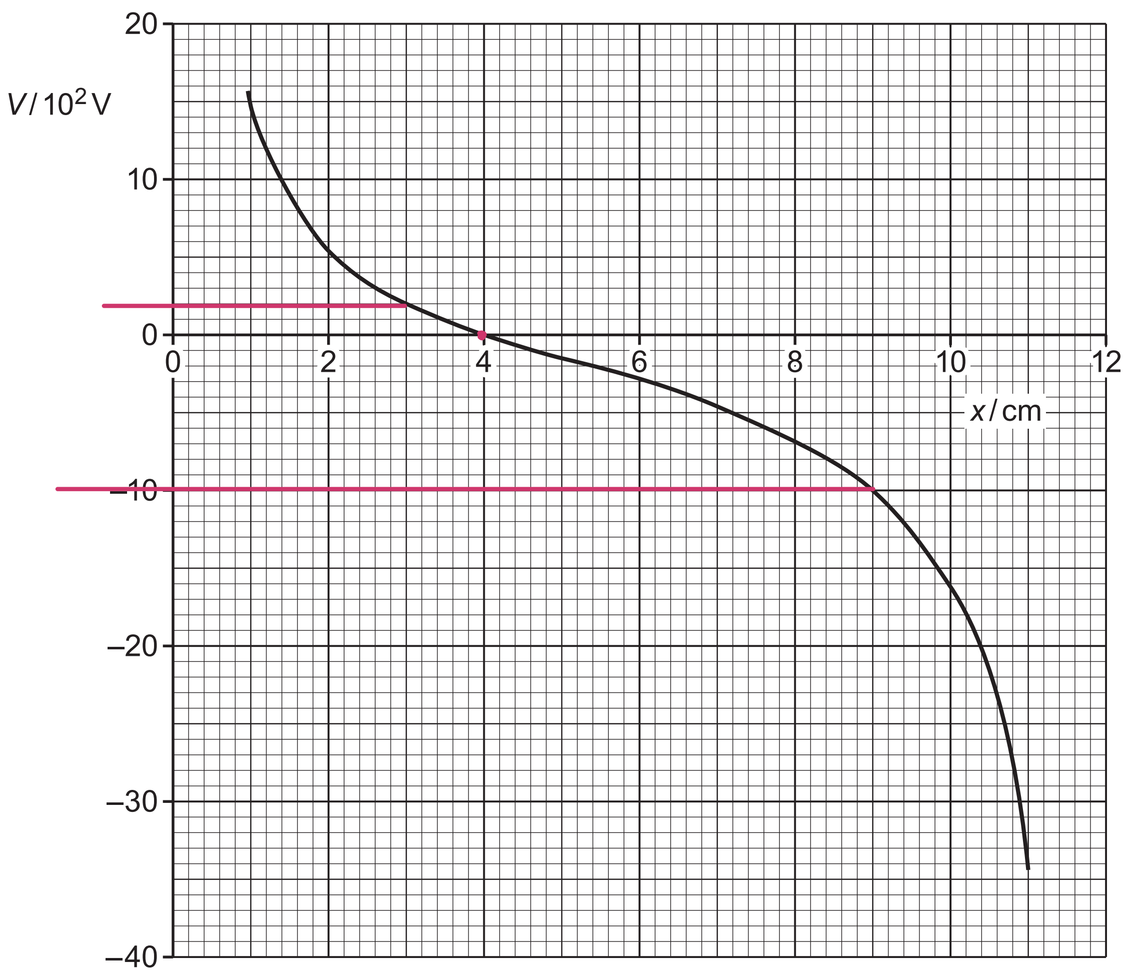


Fig. 5.2

Use Fig. 5.2 to determine:

(i) the charge of B

$$\frac{\cancel{k}(2\times10^{-9})}{4} = \frac{\cancel{k}\,Q}{8}$$

$$4Q = 8(2\times10^{-9})$$

$$Q = 2(2\times10^{-9})$$

$$= 4\times10^{-9}$$

charge = ...4×10^{-9}.... 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 = ...1.2×10^{3}.... 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.

$$1.2\times10^{3}\times2\times1.6\times10^{-19} = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{4\times1.2\times10^{3}\times1.6\times10^{-19}}{4\times1.66\times10^{-27}}}$$

$$v = 3.4\times10^{5}$$

v = ...3.4×10^{5}.... m s^{-1} [3]

[Total: 9]

$\frac{8}{9}$

$q = CV$

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

it is the ratio of charge to potential, where the charge is the magnitude of charge on one plate and potential is the p.d between the two plate. [2] 1

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

1. smoothing
2. store of charge × energy oscillator
3. tuning

[3] 2

(b) A student has available four capacitors, each of capacitance 24 μF.

The capacitors are connected as shown in Fig. 6.1.

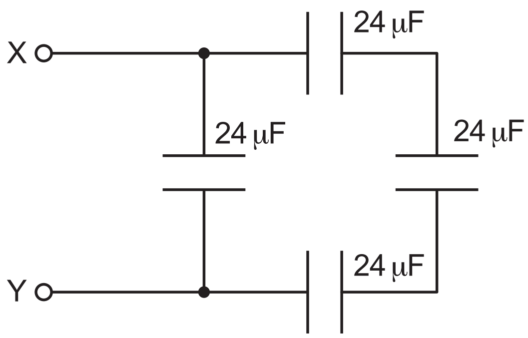


Fig. 6.1

Calculate the combined capacitance between the terminals X and Y.

$$\left(\frac{1}{24}+\frac{1}{24}+\frac{1}{24}\right)^{-1} + 24$$

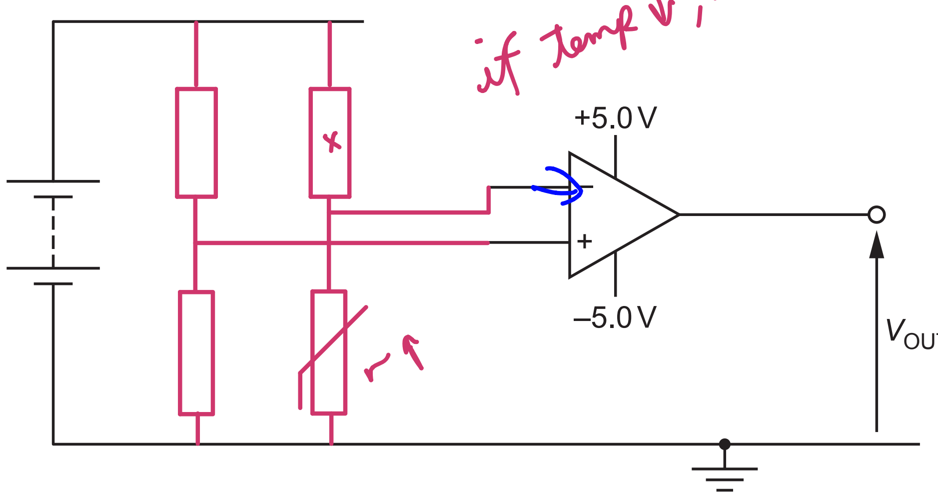
capacitance = 32 ~~.0~~ μF [2] 1

[Total: 7]

5/7

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.

if temp ↓ , – ↑



$V_{out} = \alpha \times (V_+ - V_-)$

Fig. 7.1

Three resistors, each of resistance 1000 Ω, 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 –5.0 V and at higher temperatures, the output V_{OUT} is to be +5.0 V.

(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 –5.0 V

100 kΩ .... [1]

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

10 Ω .... [1]

[Total: 6]

6/6

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.

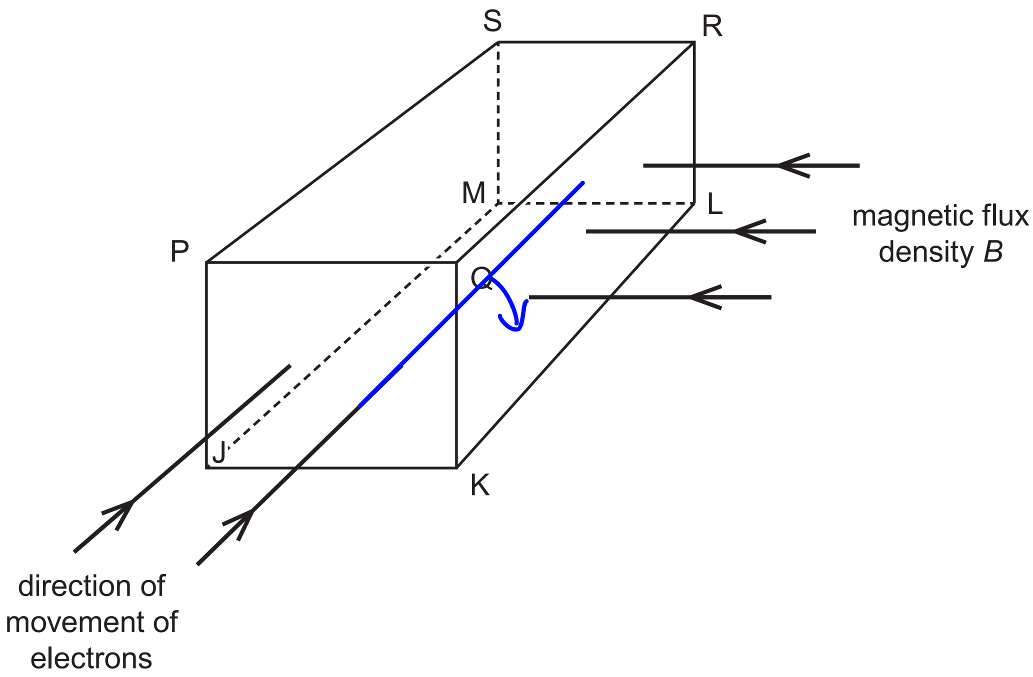


Fig. 8.1

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

downwards, towards the JKLM face

.... [1]

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

face JKLM and face PQRS [1]

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

After some time an electric field is generated due to which F_E ↑

and soon when it is equal and opposite to

the magnetic force, Vmax is generated which V_H [2] 0

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

Calculate the potential difference across the slice for a current of 6.3×10^{-4} A.

$$V_H = \frac{BI}{Net} = \frac{4.6\times10^{-3} \times 6.3\times10^{-4}}{1.3\times10^{29} \times 1.6\times10^{-19} \times \left[\left(\frac{0.1}{10}\right)\times10^{-2}\right]}$$

$$= 1.3932 \times 10^{-12}$$

potential difference = 1.4×10^{-12} 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.

because the value of N is much lower, ∴ larger Hall voltage.

[2]

[Total: 8]

$\frac{6}{8}$

9 **(a)** Define *magnetic flux*.

magnetic flux = B A sin θ where B is the magnetic field strength perpendicular to the area, A.

.... [2] 2

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

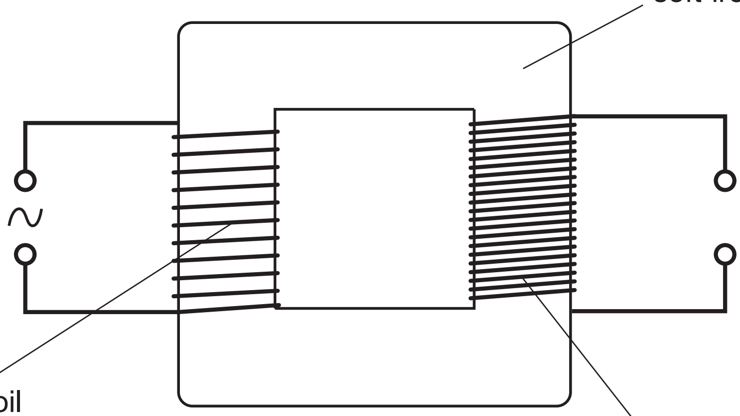


Fig. 9.1

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

The current in the primary coil gives rise to a constantly varying magnetic field around the coil, this creates a magnetic flux linkage which is constantly changing, this causes emf to be induced in the secondary coil, as emf ∝ rate of change of magnetic flux linkage. [3] 3

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

As the magnetic flux linkage because of primary coil constantly varies, this creates a constantly varying emf which varies, following a cosinusoidal curve. [2] 2

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

to prevent heat losses caused by eddy currents in order to improve efficiency

2

[2]

[Total: 9]

9

9

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

*

X rays are used, the section is scanned, scans are taken at many angles the images are combined to give 3D image of whole structure

[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.

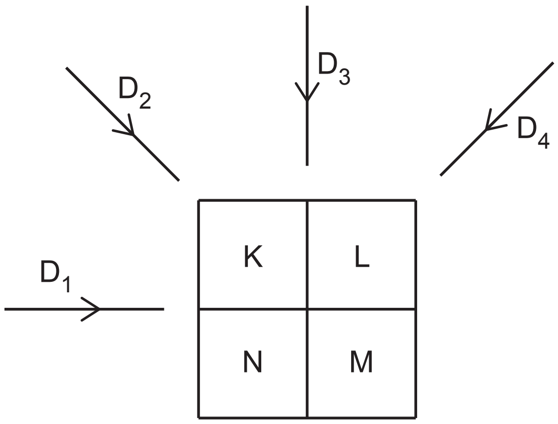


Fig. 10.1

The section is viewed, in turn, from four different directions D_1, D_2, D_3 and D_4, 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. $K + L + M + N = 24$

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

$$\frac{45 - 24}{3} =$$

K = 6

L = 7

M = 2

N = 9

[3]

[Total: 8]

8/8

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

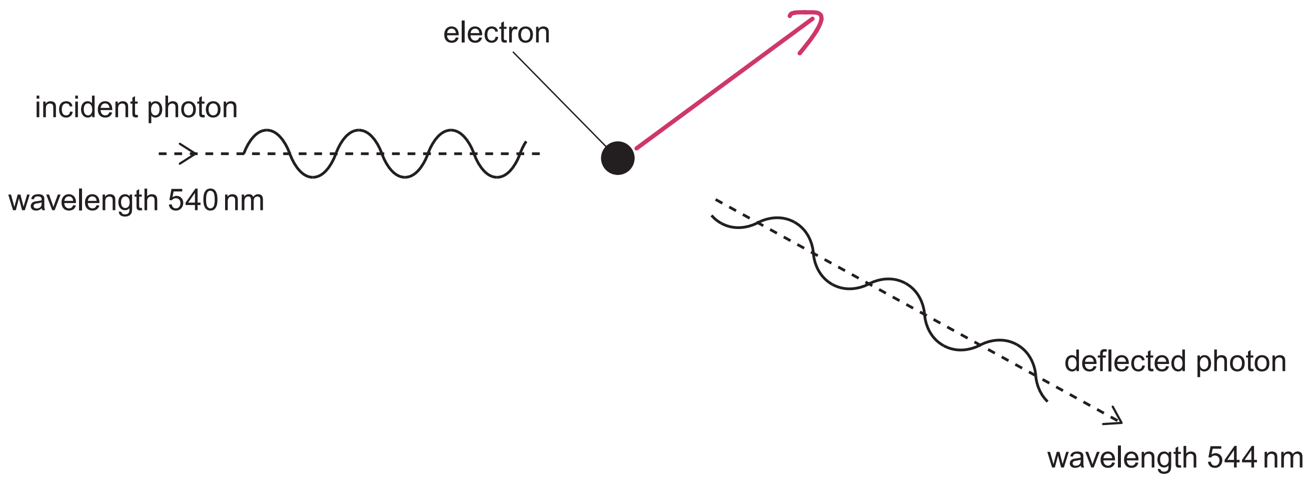


Fig. 11.1

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*.

a descrete packet of energy of electro-magnetic radiation.

[2] 1

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

(b) Calculate:

(i) the momentum of the deflected photon

$\lambda = \frac{h}{p}$

$p = \frac{h}{\lambda} = \frac{h}{544 \times 10^{-9}} = 1.218 \times 10^{-27}$

momentum = ...$1.2\cancel{3}2 \times 10^{-27}$........ N s [2]

(ii) the energy transferred to the deflected electron.

$E_k = \frac{p^2}{2m} = \frac{(1.218 \times 10^{-27})^2}{2 \times 9.31 \times 10^{-31}}$

$E = \frac{hc}{\lambda}$ $= 7.967 \times 10^{-25}$

energy = ...7.97×10^{-25}........ J [2] 0

(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.

~~because there is loss of energy as the collision is inelastic.~~

As λ decreases, more energy will be required. deflected photon will have less energy. so its not possible

[2]

[Total: 9]

4/9

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

(a) State what is meant by:

(i) *radioactive*

an ~~element~~ Nucleus that breaks down into a smaller element by releasing , α, β, γ radiation

1

[2]

(ii) *decay constant.*

? probability of decaying per unit time

[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.

$n = n_0 e^{-\lambda t}$ $A = \lambda n$

$$n = \frac{A}{\lambda} = \frac{560}{9.9 \times 10^{-7}} = 5.66 \times 10^{8}$$

number = 5.7×10^{8} [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.

$$n = \frac{170}{9.9 \times 10^{-7}} = 1.717 \times 10^{8}$$

$$\frac{n}{n_0} = e^{-\lambda t}$$

$$\ln\left(\frac{n}{n_0}\right) = -\lambda t$$

$$t = \ln\left(\frac{n}{n_0}\right) \div -\lambda$$

$$t = \ln\left(\frac{1.717 \times 10^{8}}{5.66 \times 10^{8}}\right) \div -9.9 \times 10^{-7}$$

$$= 1.194 \times 10^{6}\,s = 13.8198 \text{ days}$$

time = 14 days [3]

3

[Total: 9]

8/9