76-78

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

7314708539

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **October/November 2016**

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.

DC (RW/JG) 116303/4

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass 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	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

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

1 **(a)** Define *gravitational field strength*.

force per unit mass acting on a small test mass placed in the field [1]

(b) The nearest star to the Sun is Proxima Centauri.
This star has a mass of 2.5×10^{29} kg and is a distance of 4.0×10^{13} km from the Sun.
The Sun has a mass of 2.0×10^{30} kg.

(i) State why Proxima Centauri may be assumed to be a point mass when viewed from the Sun.

The distance between them is really large

[1]

(ii) Calculate

1. the gravitational field strength due to Proxima Centauri at a distance of 4.0×10^{13} km,

$$g = \frac{GM}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times 2.5 \times 10^{29}}{(4 \times 10^{16})^2}$$

$$= 1.0421875 \times 10^{-14}$$

field strength = 1.0×10^{-14} N kg^{-1} [2]

2. the gravitational force of attraction between the Sun and Proxima Centauri.

$$F_g = \frac{GMm}{r^2} = \frac{6.67 \times 10^{-11} \times 2.5 \times 10^{29} \times 2.0 \times 10^{30}}{(4 \times 10^{16})^2}$$

$$= 2.04375 \times 10^{16}$$

force = 2.0×10^{16} N [2]

(c) Suggest quantitatively why it may be assumed that the Sun is isolated in space from other stars.

Because the distance between the stars and sun is very large

order ??

[2]

[Total: 8]

5

2 **(a)** The equation of state for an ideal gas of volume V at pressure p is

$$pV = nRT$$

where R is the molar gas constant.

State what is meant by

(i) the symbol n,

number of moles of gas / Amount of gas

[1] 1

(ii) the symbol T.

Thermodynamic temp of gas (in Kelvins)

[1] 1

(b) An ideal gas is held in a container of volume $2.4 \times 10^3 \, cm^3$ at pressure $4.9 \times 10^5 \, Pa$. The temperature of the gas is 100 °C.

Show that the number of molecules of the gas in the container is 2.3×10^{23}.

$n \times N_a = N$

$$N = \frac{PVN_a}{RT} = \frac{4.9 \times 10^5 \times (2.4 \times 10^3) \times 100^{-3} \times 6.02 \times 10^{23}}{8.31 \times 373.15}$$

$= 2.283 \times 10^{23}$

$\approx 2.3 \times 10^{23}$

[3] 3

(c) Use data from **(b)** to estimate the mean distance between molecules in the gas.

$2.4 \times 10^3 = 2.288 \times 10^{23}$ molecules

$x = 1$

$x = 8.3 \times 10^{-21}$

2

mean distance = 8.3×10^{-21} cm [3]

[Total: 8]

7

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

sum of KE and PE of molecules in random motion

.....[2] 2

(b) Explain, by reference to work done and heating, whether the internal energy of the following increases, decreases or remains constant:

(i) the gas in a toy balloon when the balloon bursts suddenly,

As the gas expands, work is done on the the atmosphere by the ~~system so~~ work done is -ve, no change in ~~thermal energy~~ as it happens suddenly ∴ IE decreases.

.....[3] 3

(ii) ice melting at constant temperature and at atmospheric pressure to form water that is more dense than the ice.

\#

As it turns into water, its volume decreases slightly ∴ work is done by the atmosphere on the system so work done is +ve ∴ IE increases because thermal energy remains constant.

\#

.....[3] 2

heating?

[Total: 8]

7

4 A mass hangs vertically from a fixed point by means of a spring, as shown in Fig. 4.1.

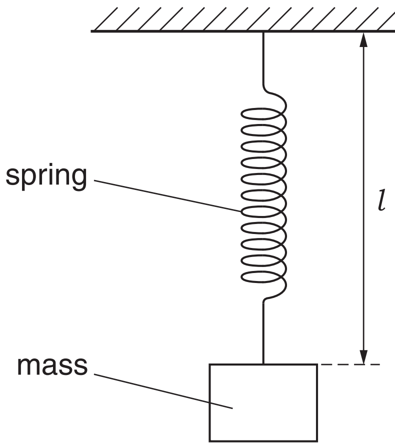

Fig. 4.1

The mass is displaced vertically and then released. The subsequent oscillations of the mass are simple harmonic.

The variation with time t of the length l of the spring is shown in Fig. 4.2.

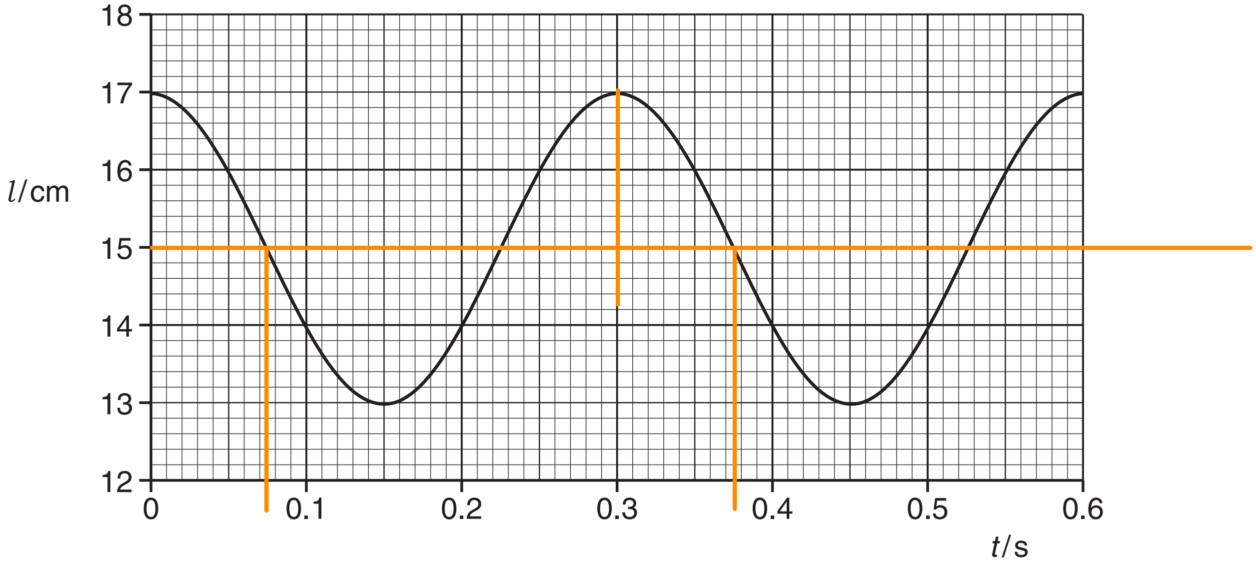

Fig. 4.2

(a) Use Fig. 4.2 to

(i) state two values of t at which the mass is moving downwards with maximum speed,

#

t = ...0.075...... s and t = ...0.375...... s [1]

(ii) determine, for these oscillations, the angular frequency ω,

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.3} = 20.94395$$

ω = ...21.......... rad s^{-1} [2]

2

(iii) show that the maximum speed of the mass is 0.42 m s^{-1}.

$$V_{max} = \omega x_0$$
$$= 21 \times \frac{2}{100}$$
$$= 0.42$$

[2]

2

(b) Use data from Fig. 4.2 and **(a)(iii)** to sketch, on the axes of Fig. 4.3, the variation with displacement x from the equilibrium position of the velocity v of the mass.

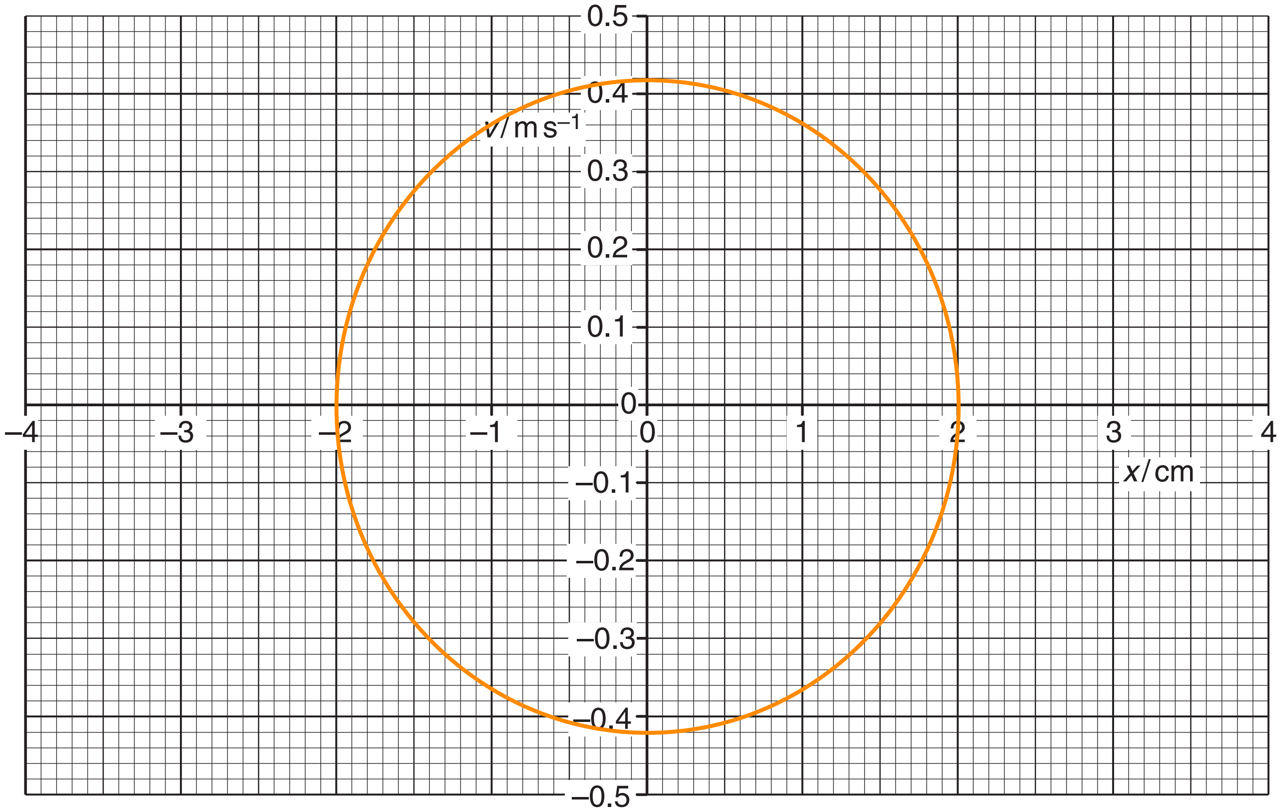

Fig. 4.3

[3]

3

[Total: 8]

7

5 Ultrasound may be used to obtain information about internal body structures.

(a) Suggest why the ultrasound from the transducer is pulsed.

so that reflected pulse can be distinguished from emmited pulses and the transducer can only emit or detect at once so its able to measure depth at intervals and determine nature of body [2]

(b) **(i)** State what is meant by *specific acoustic impedance*.

Product of density and speed of sound in that medium :) [2]

(ii) A parallel beam of ultrasound of intensity I_0 is incident normally on the boundary between two media, as shown in Fig. 5.1.

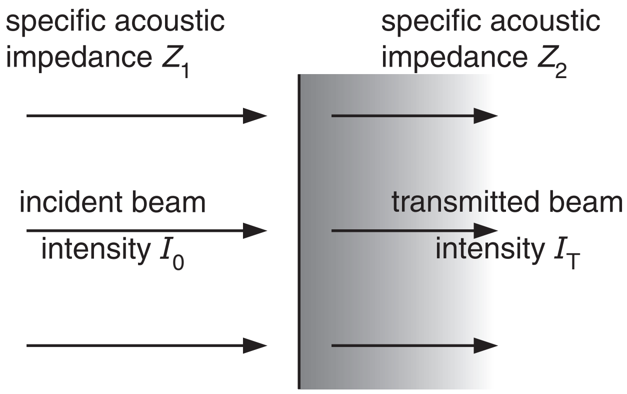

Fig. 5.1

The media have specific acoustic impedances Z_1 and Z_2.
The intensity of the ultrasound beam transmitted across the boundary is I_T.

Explain the significance of the magnitudes of Z_1 and of Z_2 on the ratio I_T/I_0.

If Z_1 and Z_2 are close together then the ration is almost 1 and if Z_1 and Z_2 are very different then the rations is almost zero. [2]

[Total: 6]

6

6 Two solid metal spheres A and B, each of radius 1.5 cm, are situated in a vacuum. Their centres are separated by a distance of 20.0 cm, as shown in Fig. 6.1.

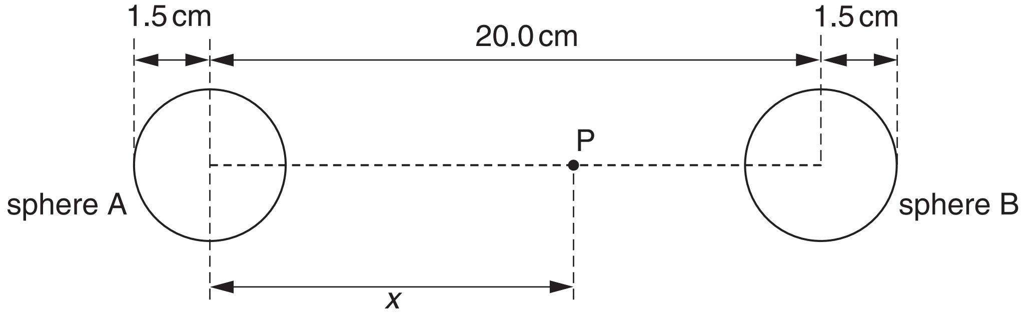

Fig. 6.1 (not to scale)

Both spheres are positively charged.

Point P lies on the line joining the centres of the two spheres, at a distance x from the centre of sphere A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

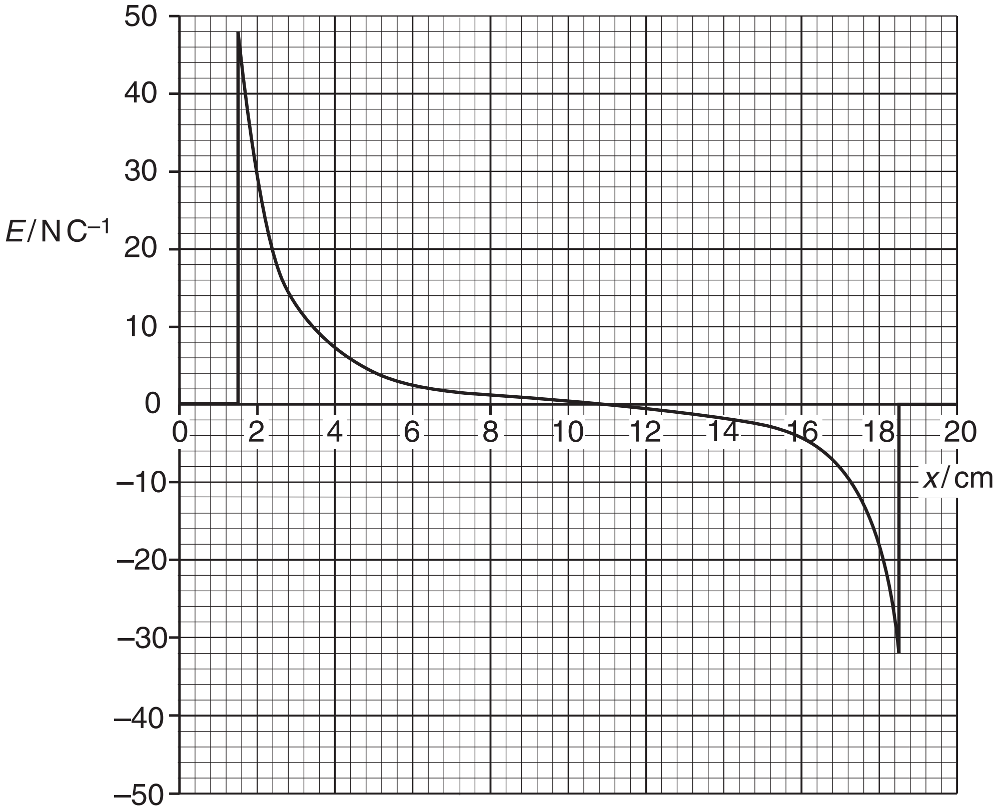

Fig. 6.2

(a) Use Fig. 6.2 to determine the ratio

$$\frac{\text{magnitude of charge on sphere A}}{\text{magnitude of charge on sphere B}}.$$

Explain your working.

$$\frac{E_A}{E_B} = \frac{\frac{\cancel{k}Q_A}{\cancel{r^2}}}{\frac{\cancel{k}Q_B}{\cancel{r^2}}} = \frac{48}{32}$$

ratio = ...1 : 5...... [3]

(b) The variation with distance x of the electric potential V at point P is shown in Fig. 6.3.

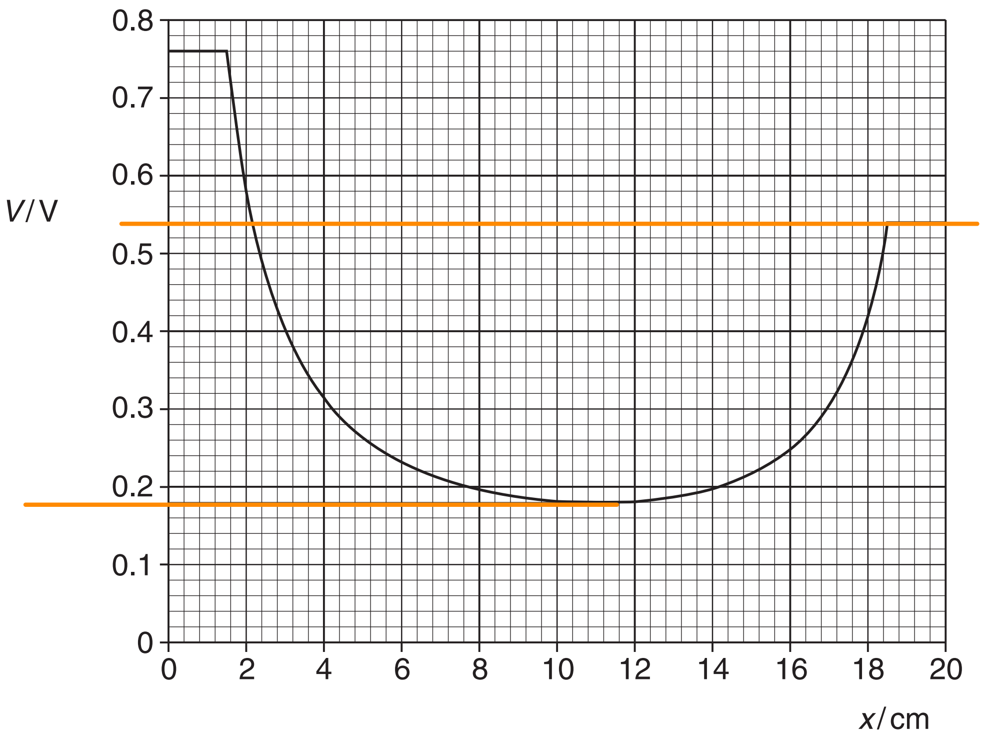

Fig. 6.3

An α-particle is initially at rest on the surface of sphere A.
The α-particle moves along the line joining the centres of the two spheres.

Determine, for the α-particle as it moves between the two spheres,

(i) its maximum speed,

$$\Delta V q = \frac{1}{2} m v^2$$

$$V = \sqrt{\frac{2 \Delta V q}{m}} = \sqrt{\frac{2(0.76-0.18) \times 2 \times 1.6 \times 10^{-19}}{4 \times 1.66 \times 10^{-23}}}$$

$$= 74.7687$$

maximum speed = ...75...... $m\,s^{-1}$ [3]

(ii) its speed on reaching the surface of sphere B.

$$V = \sqrt{\frac{2 \times (0.76 - 0.54) \times 2 \times 1.6 \times 10^{-19}}{4 \times 1.66 \times 10^{-24}}}$$

$$= 46.04869$$

speed = ...46...... $m\,s^{-1}$ [2]

[Total: 8]

6

7 **(a)** **(i)** Define *capacitance*.

Ratio of Charge to potential

[1]

(ii) Use the expression for the electric potential due to a point charge to show that an isolated metal sphere of diameter 25 cm has a capacitance of 1.4×10^{-11} F.

$E = \frac{kQq}{r}$

$q = \frac{Er}{kQ}$

$C = \frac{q}{V} = \frac{q}{Vqd}$

#

anlei

[2]

(b) Three capacitors of capacitances 2.0 μF, 3.0 μF and 4.0 μF are connected as shown in Fig. 7.1 to a battery of e.m.f. 9.0 V.

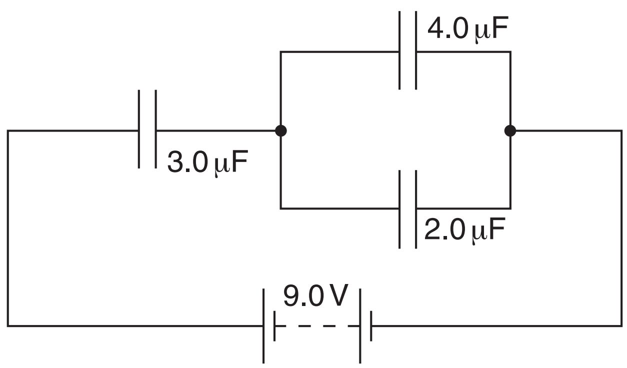

Fig. 7.1

Determine

(i) the combined capacitance of the three capacitors,

$\left(\frac{1}{3} + \frac{1}{6}\right)^{-1} = 2$

capacitance = ...2........ μF [1]

(ii) the potential difference across the capacitor of capacitance 3.0 μF, #

$q = CV$
$= 2\times10^{-6} \times 9$
$= 1.8\times10^{-5}$

$V = \frac{q}{C} = \frac{1.8\times10^{-5}}{3\times10^{-6}} = 6$

potential difference = ...6.......... V [2] 2

(iii) the positive charge stored on the capacitor of capacitance 2.0 μF.

$q = CV$
$= 2\times10^{-6} \times 3$
$= 6\times10^{-6}$

charge = ...6.......... μC [2] 2

[Total: 8]

6

8 A circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 8.1.

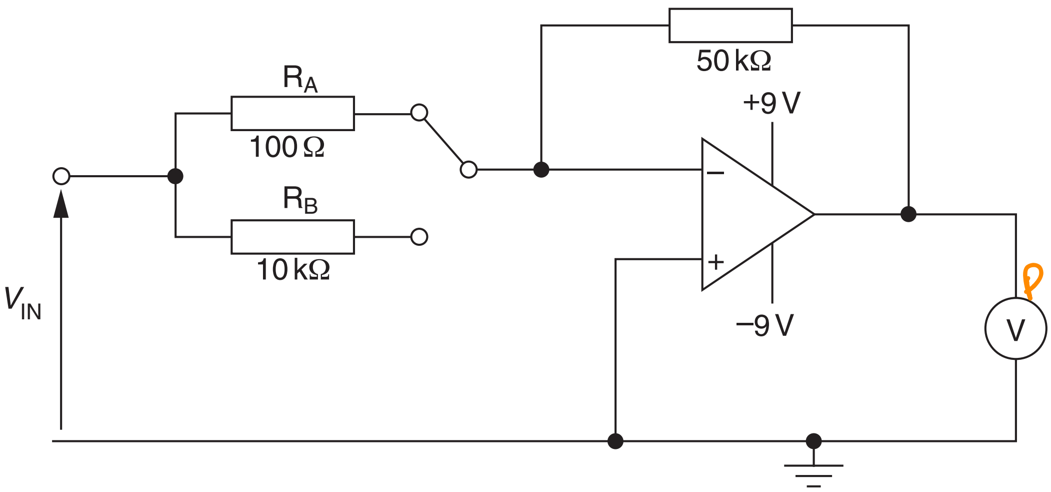

Fig. 8.1

The supply to the op-amp is +9 V / –9 V.
The output of the amplifier is measured using a voltmeter having a range 0 – 5.0 V.

A switch enables the inverting input to the op-amp to be connected to either resistor R_A or resistor R_B.

(a) A positive potential $+V_{IN}$ is applied to the input to the circuit.

On Fig. 8.1, mark with the letter P the positive connection of the voltmeter such that the voltmeter shows a positive reading. [1]

(b) Calculate the potential V_{IN} such that the voltmeter has a full-scale deflection when the inverting input to the op-amp is connected to

(i) resistor R_A of resistance 100 Ω,

$$\text{gain} = 1 + \frac{50}{0.1} = 501$$

$$V_{out} = g(V^+ - V^-)$$

$$5 = 501(0 - V_{in})$$

$$5 = -501\, V_{in}$$

$$V_{in} = -0.01$$

V_{IN} = ... −0.01 .... V [2]

(ii) resistor R_B of resistance $10\,k\Omega$.

$1 + \frac{50}{10} = 6$

$5 = 6(0 - V_{in})$

$5 = -6V_{in}$

$V_{in} = -0.83$

V_{IN} = ...-0.83........ V [1]

(c) Suggest a use for this type of circuit.

........To compare resistances........

....[1]

[Total: 5]

0

9 A stiff wire is held horizontally between the poles of a magnet, as illustrated in Fig. 9.1.

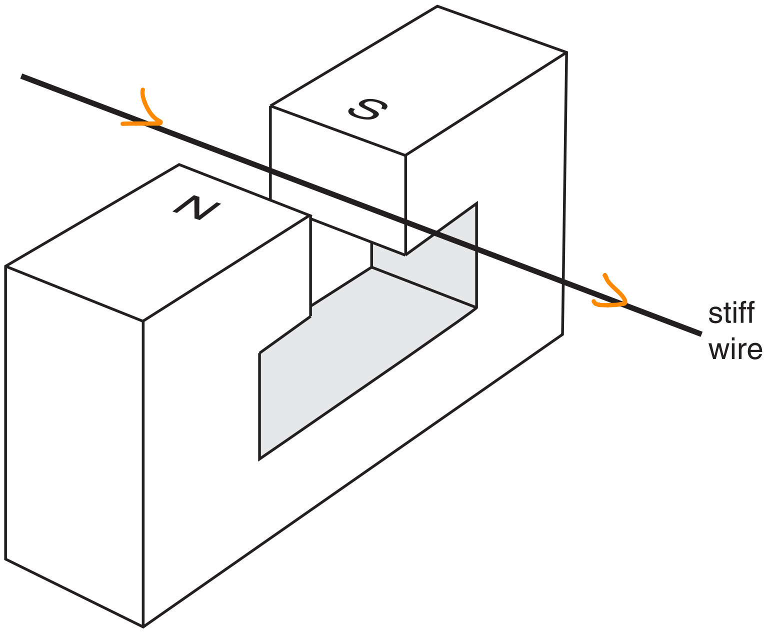

Fig. 9.1

When a constant current of 6.0A is passed through the wire, there is an additional downwards force on the magnet of 0.080N. ∴ ↑ on wire

(a) On Fig. 9.1, draw an arrow on the wire to show the direction of the current in the wire. Explain your answer.

force on wire is upwards as force on magnet is downwards so according to flemings left hand rule, current should be let to right

.... [3]

(b) The constant current of 6.0A is now replaced by a low-frequency sinusoidal current. The root-mean-square (r.m.s.) value of this current is 2.5A.

Calculate the difference between the maximum and the minimum forces now acting on the magnet.

$I_0 = \sqrt{2} \times 2.5 = 3.5355$

$F = BLI$

$\frac{0.08}{6} = BL$

$BL = \frac{1}{75}$

max

min ??

min ??

$F = \frac{1}{75} \times 3.5355$

$= 0.047114 \text{ N} = f_{max}$

difference = 0.047 N [4]

[Total: 7]

A

10 Explain the function of the non-uniform magnetic field that is superimposed on a large uniform magnetic field in diagnosis using nuclear magnetic resonance imaging (NMRI).

strong uniform magnetic field is applied along the body which causes nuclei to rotate about field direction. Radio-frequency pulse applied at lormour freq which causes resonance of hydrogen nuclei. On deexcitation nuclei emit pulse of RF which is detected processed and displayed. Non uniform magnetic field allows for position of nuclei to be determined and location of detection to be changed. [4]

[Total: 4]

4

11 **(a)** State Faraday's law of electromagnetic induction.

Induced emf is proportional to rate of change of magnetic flux linkage.

[2]

(b) An alternating current is passed through an air-cored solenoid.
An iron core is inserted into the solenoid and then held stationary within the solenoid. The current in the solenoid is now smaller.

Explain why the root-mean-square (r.m.s.) value of the current in the solenoid is reduced as a result of inserting the core.

constantly changing current causes a constantly varying magnetic flux linkage in the the core which induces emf and hence eddy currents in the core. Induced emf and current oppose the change causing them and hence the peak value of current fall and so the rmf value too [3]

2

(c) Practical transformers are very efficient. However, there are some power losses.

State two sources of power loss within a transformer.

1. Heat loss due to eddy currents in the core

2. Heat loss " " resistance in coil wire.

[2]

[Total: 7]

6

12 **(a)** State an effect, one in each case, that provides evidence for

(i) the wave nature of a particle,

concentric circles on screen .... [1]

(ii) the particulate nature of electromagnetic radiation.

photoelectric effect .... [1]

(b) Four electron energy levels in an isolated atom are shown in Fig. 12.1.

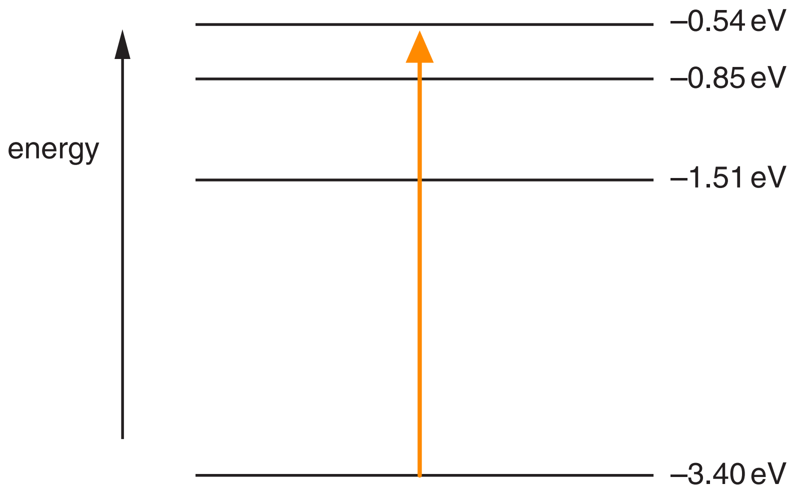

Fig. 12.1

For the emission spectrum associated with these energy levels,

(i) on Fig. 12.1, mark with an arrow the transition that gives rise to the shortest wavelength, [1]

(ii) show that the wavelength of the transition in **(i)** is 4.35×10^{-7} m.

$$\frac{hc}{\Delta E} = \frac{hc}{(3.4 - 0.54) \times 1.6 \times 10^{-19}} = 4.3465 \times 10^{-7}$$

$$\approx 4.35 \times 10^{-7}$$

[2]

(c) **(i)** State what is meant by the *de Broglie wavelength*.

$\lambda = \frac{h}{p}$, where λ is ..., h is plancks constant, p is momentum

....[2]

(ii) Calculate the speed of an electron having a de Broglie wavelength equal to the wavelength in **(b)(ii)**.

$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34}}{4.35 \times 10^{-7} \times 9.11 \times 10^{-31}}$

$= 1.673 \times 10^{3}$

speed = 1.67×10^{3} m s^{-1} [2]

[Total: 9]

13 Outline the principles of computed tomography (CT scanning).

Image of a section is captured using X-rays. Multiple images of the same slice are captured from many different angles in the same plane. Data sent to computer which combines all the images to make a 2 D image of the slice. This is repeated for many successful sections to make up a 3D image of the whole body which can be viewed from any angle

.... [6]

[Total: 6]

6

14 Phosphorus-30 ($^{30}_{15}P$) was the first artificial radioactive nuclide to be produced in a laboratory. This was achieved by bombarding aluminium-27 ($^{27}_{13}Al$) with α-particles.

A partial nuclear equation to represent this reaction is

$$^{27}_{13}Al + ^{4}_{2}\alpha \rightarrow ^{30}_{15}P + ^{1}_{0}\Phi$$

(a) State the full nuclear notation for

(i) the α-particle,

$^{4}_{2}\alpha$ .... [1]

(ii) the particle represented by the symbol Φ.

$^{1}_{0}\Phi$ .... [1]

(b) Data for the rest masses of the particles in the reaction are given in Fig. 14.1.

particle	mass / u
$^{27}_{13}Al$	26.98153
α	4.00260
$^{30}_{15}P$	29.97830
Φ	1.00867

Fig. 14.1

Calculate, for this reaction,

(i) the change in the total rest mass of the particles,

$(29.9783 + 1.00867) - (26.98153 + 4.00260)$

$= 2.84 \times 10^{-3}$

sf

mass change = 2.84×10^{-3} u [2]

2

(ii) the energy, in joule, equivalent to the mass change calculated in **(i)**.

$E = \Delta mc^2$ $\quad 2.84 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3 \times 10^8)^2$

$= 4.24296 \times 10^{-13}$

energy = 4.2×10^{-13} J [2]

2

(c) With reference to your answer in **(b)(i)**, comment on the energy of the α-particle such that the reaction can take place.

The alpha particle must remain stationary otherwise its ~~mass~~ ~~will~~ decrease.

[2]

6

[Total: 8]