Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

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CENTRE NUMBER

CANDIDATE NUMBER

4651206235

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2019**

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.

This document consists of **22** printed pages and **2** blank pages.

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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) (i) Define *gravitational potential* at a point.

It is the work done per unit mass in moving a small test mass from infinity to a point in a gravitational field [2]

2

(ii) Use your answer in (i) to explain why the gravitational potential near an isolated mass is always negative.

#

potential at infinity = 0

because gravitational force is attractive and so when it pulls a mass, the work done in doing so, with respect to the mass is negative, hence gravitational potential is negative

[3]

1

(b) A spherical planet has mass 6.00×10^{24} kg and radius 6.40×10^{6} m.
The planet may be assumed to be isolated in space with its mass concentrated at its centre.

A satellite of mass 340 kg is in a circular orbit about the planet at a height 9.00×10^{5} m above its surface.

For the satellite:

(i) show that its orbital speed is $7.4 \times 10^{3}\,\text{m}\,\text{s}^{-1}$

$$\frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$$

$$v = \sqrt{\frac{GM}{r}}$$

$$= \sqrt{\frac{G(6\times10^{24})}{6.4\times10^{6}+9\times10^{5}}} = 7.404\times10^{3} \approx 7.4\times10^{3}\,\text{ms}^{-1}$$

[2]

2

(ii) calculate its gravitational potential energy.

$$-\frac{GMm}{r} = \frac{G \times 6 \times 10^{24} \times 340}{(6.4 \times 10^{6}) + (9 \times 10^{5})}$$

$$= 1.8639 \times 10^{10}$$

energy = 1.9×10^{10} J [3]

2

(c) Rockets on the satellite are fired for a short time. The satellite's orbit is now closer to the surface of the planet.

State and explain the change, if any, in the kinetic energy of the satellite.

decreased, because P.E increases as $PE \propto \frac{1}{r}$, and $KE = TE - PE$, so if PE increase, KE decrease

[2]

1

$T.E - P.E = K.E$

[Total: 12]

3

$\frac{2}{1}$, $\frac{2}{0.5}$

2 4

2 The pressure p of an ideal gas having density ρ is given by the expression

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

(a) State what is meant by:

(i) an ideal gas

A gas that obeys $pV = nRT$ at all temperatures and pressures , V = volume , T is temp

.... [2]

(ii) the symbol $\langle c^2\rangle$.

mean speed of the molecules squared.

.... [1]

(b) A cylinder contains a fixed mass of a gas at a temperature of 120 °C. The gas has a volume of $6.8 \times 10^{-3}\,\text{m}^3$ at a pressure 2.4×10^5 Pa.

(i) Assuming the gas acts like an ideal gas, show that the number of atoms of gas in the cylinder is 3.0×10^{23}.

$$n = \frac{PV}{Rt} = \frac{2.4\times10^5 \times 6.8\times10^{-3}}{8.31 \times (120 + 273)}$$

$$= 0.49972 \text{ mol.}$$

$$\# \text{No} = 0.49972 \times 6.02 \times 10^{23}$$
$$\approx 3\times10^{23} \text{ molecules}$$

[3]

(ii) Each atom of the gas, assumed to be a sphere, has a radius of 3.2×10^{-11} m.

Use the answer in **(i)** to estimate the actual volume occupied by the gas atoms.

$$\text{Vol of 1 atom} = \frac{4\pi}{3}r^3 = \frac{4\pi}{3}(3.2\times10^{-11})^3$$
$$= 1.3726\times10^{-31}$$

$$\text{Total vol} = 3\times10^{23} \times (1.3726\times10^{-31})$$
$$= 4.1177\times10^{-8}$$

volume = 4.1×10^{-8} m^3 [2]

(iii) One of the assumptions of the kinetic theory of gases is related to the volume of the atoms.
State this assumption. Explain whether your answer in **(ii)** is consistent with this assumption.

Vol of the molecules of gas is neglegible compared to the vol. of the container. Yes the answer is consistent with it as the vol of molecules is 10^{-8} compared to the container which is 10^{-3}.

1 [2]

[Total: 10]

9

3 A cylindrical tube, sealed at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

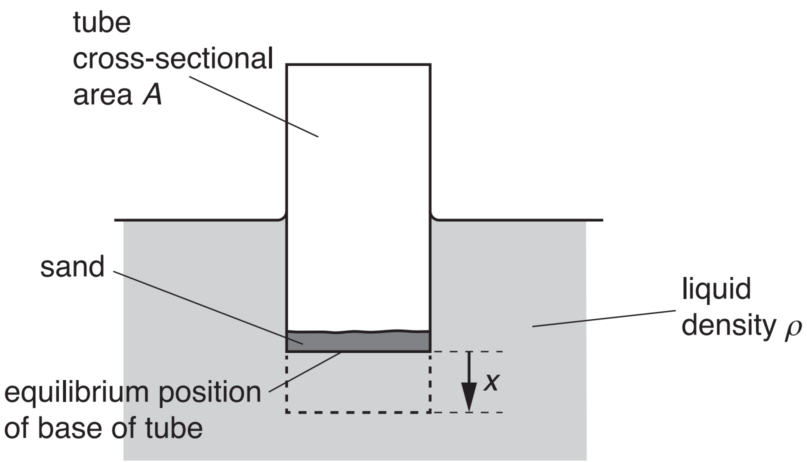


Fig. 3.1

The tube is pushed a short distance into the liquid and then released.

(a) **(i)** State the two forces that act on the tube immediately after its release.

gravitational force (wgt) and upward force due to the liquid / boyance force .... [1]

(ii) State and explain the direction of the resultant force acting on the tube immediately after its release.

Towards the top of the page as the force due to the displacement of water is more than the gravitational force due to weight .... [2]

(b) The acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where x is the vertical displacement of the tube from its equilibrium position.

Use the expression to explain why the tube undergoes simple harmonic oscillations in the liquid.

for an object to undergo SHM, $a \propto -x$ and in the expression $a \propto -x$ so it follows SHM. $\frac{A\rho g}{M}$ is constant .... [2] 1

(c) For a tube having cross-sectional area A of 4.5 cm^2 and a total mass M of 0.17 kg, the period of oscillation of the tube is 1.3 s.

(i) Determine the angular frequency ω of the oscillations.

$\omega = \frac{2\pi}{T} = \frac{2\pi}{1.3} = 4.8332...$

ω = ...4.83.... rad s^{-1} [2] 2

(ii) Use your answer in **(i)** and the expression in **(b)** to determine the density ρ of the liquid in which the tube is floating.

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

$\rho = \frac{M\omega^2}{Ag}$ $\rho = \frac{0.17 \times 4.833^2}{\frac{4.5}{100^2} \times 9.81} = 8.99499 \times 10^{3}$

ρ = ...9.0×10^{3}.... kg m^{-3} [3] 2

[Total: 10]

8

4 **(a)** State **three** features of the orbit of a geostationary satellite.

1. movement is west to east

2. it is on an equitorial plane.

3. Time period = 24 hours

[3]

(b) A signal is transmitted from Earth to a geostationary satellite. Initially, the signal has power 3.2 kW. The signal is attenuated by 194 dB.

Calculate the signal power received by the satellite.

$$-194 = 10 \log \frac{P}{3200}$$

$$\log\left(\frac{P}{3200}\right) = -19.4$$

$$\frac{P}{3200} = 10^{-19.4}$$

$$P = 3200 \times 10^{-19.4}$$

$$= 1.2739 \times 10^{-16}$$

power = 1.27×10^{-16} W [2]

(c) Suggest one advantage and one disadvantage of the use of geostationary satellites compared with polar-orbiting satellites for communication between points on the Earth's surface.

advantage: Can be used for a TV no tracking required

disadvantage: More expensive as need to be put into orbit higher up.

[2]

Can be used only on a certain part of world

[Total: 7]

It can only cover a small reg

6

5 **(a)** State what is meant by an *electric field*.

Region of space in which a charged particle experience a force

[1]

(b) An isolated solid metal sphere has radius R. The charge on the sphere is $+Q$ and the electric field strength at its surface is E.

On Fig. 5.1, draw a line to show the variation of the electric field strength with distance x from the centre of the solid sphere for values of x from $x = 0$ to $x = 3R$.

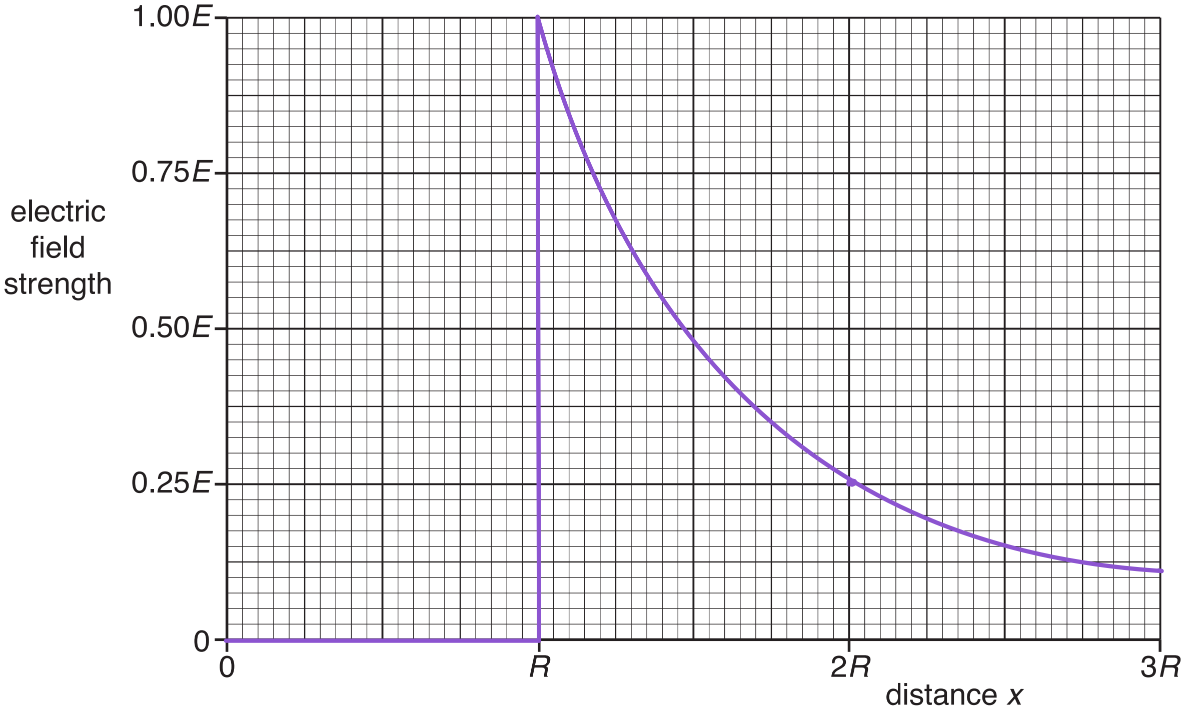


Fig. 5.1

[4]

(c) The sphere in **(b)** has radius $R = 0.26\,\text{m}$.

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^6\,\text{V}\,\text{m}^{-1}$.

Determine the maximum charge that can be stored on the sphere before electrical breakdown occurs.

$$E = \frac{kQ}{R^2}$$

$$Q = \frac{ER^2}{k} = \frac{2 \times 10^6 \times 0.26^2}{9 \times 10^9}$$

$$= 1.50222 \times 10^{-5}$$

charge = 1.5×10^{-5} C [3]

[Total: 8]

8

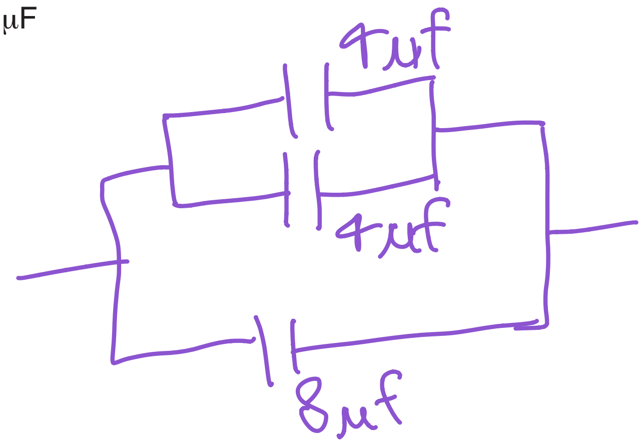
6 (a) Define the *capacitance* of a parallel-plate capacitor.

It is the ratio of charg to potential, where the change is the magnitude of charge on one of the plates. and pd between the 2 plates [2]

(b) A student has three capacitors. Two of the capacitors have a capacitance of 4.0 μF and one has a capacitance of 8.0 μF.

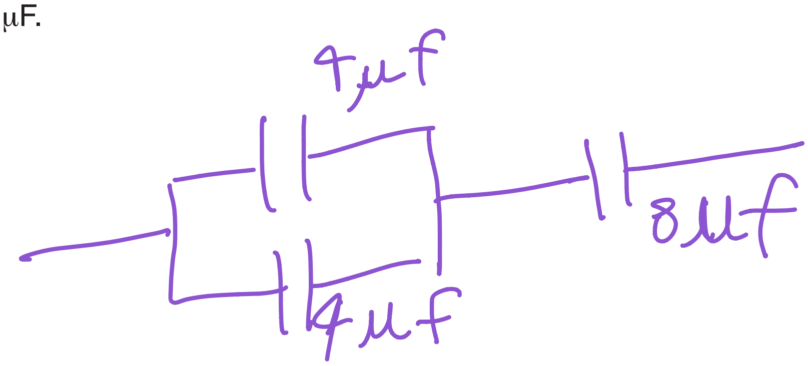
Draw labelled circuit diagrams, one in each case, to show how the three capacitors may be connected to give a total capacitance of:

(i) 1.6 μF



~~[1]~~

(ii) 10 μF.



~~[1]~~

Revise capacitance Energy

(c) A capacitor C of capacitance 47 μF is connected across the output terminals of a bridge rectifier, as shown in Fig. 6.1.

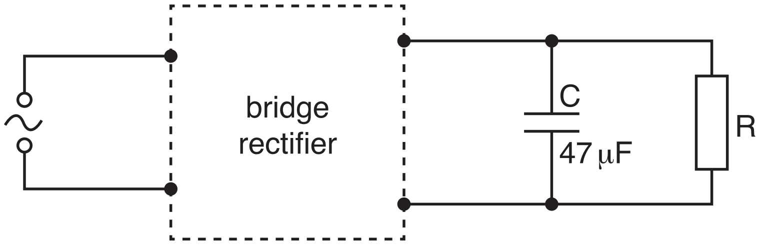


Fig. 6.1

The variation with time t of the potential difference V across the resistor R is shown in Fig. 6.2.

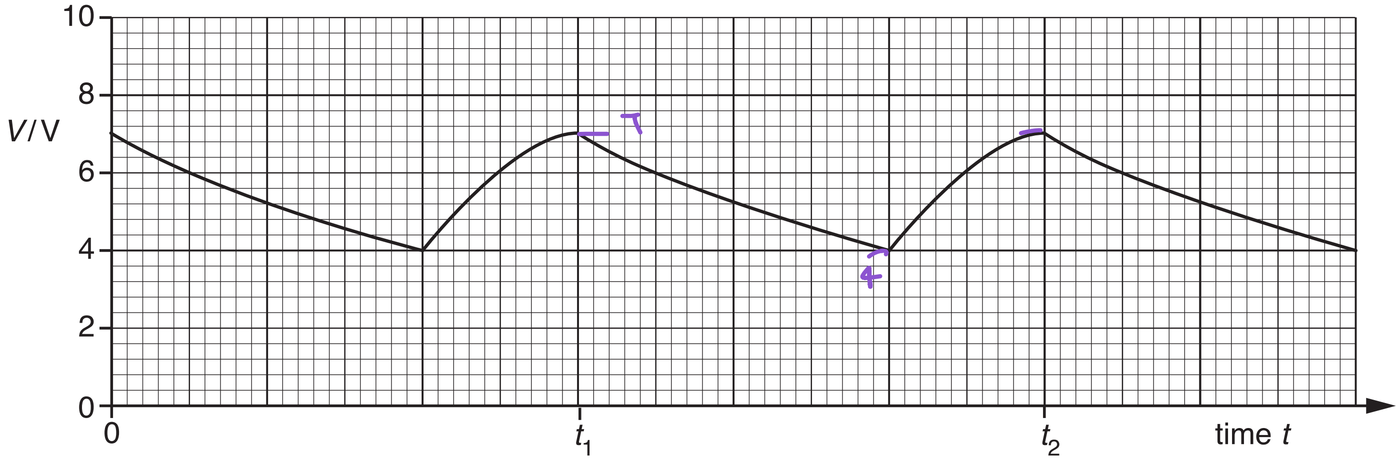


Fig. 6.2

Use data from Fig. 6.2 to determine the energy transfer from the capacitor C to the resistor R between time t_1 and time t_2.

Q is charge.

$Q_1 = CV$
$= 47 \times 10^{-6} \times 7$
$= 3.29 \times 10^{-4}$ J

$Q_2 = 47 \times 10^{-6} \times 4$
$= 1.88 \times 10^{-4}$

$Q_3 = 3.29 \times 10^{-4}$

$(3.29 - 1.88) \times 10^{-4}$
$Q_m = 1.41 \times 10^{-4}$

$Q_3 - Q_m = (3.29 + 1.41) \times 10^{-4}$
$= 1.88$

energy = ... 4.7×10^{-4} .... J [3]

[Total: 7]

2

7 **(a)** Two properties that an ideal operational amplifier (op-amp) would have are constant voltage gain and infinite slew rate.

State what is meant by:

(i) *gain* of an amplifier

range of frequencies that are amplified by an op-amp

V_{out}/V_{in} [1]

(ii) *infinite slew rate*.

There is no time delay between the change of input and output, output of an op-amp changes instantaneously with a change in input [2]

(b) The partially completed circuit of a non-inverting amplifier, incorporating an ideal op-amp, is shown in Fig. 7.1.

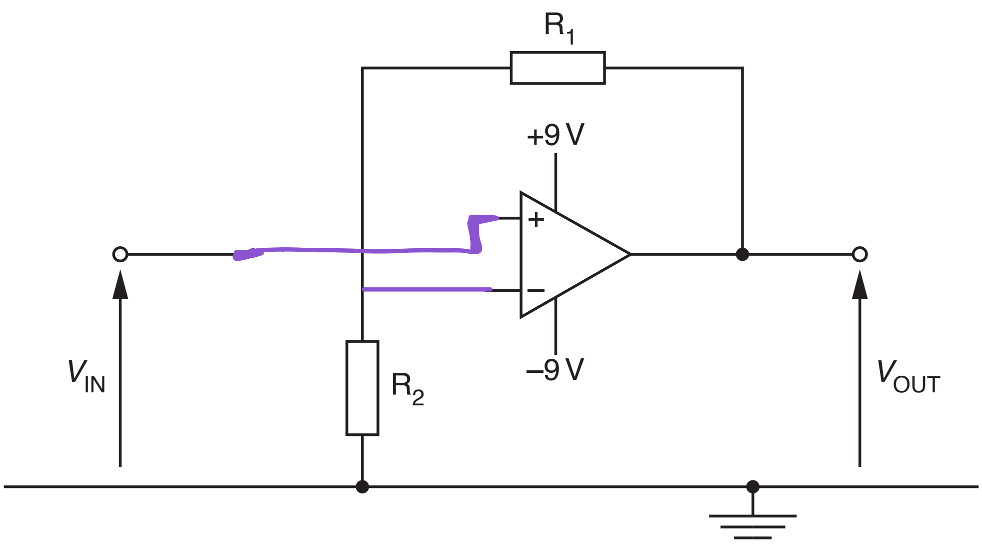


Fig. 7.1

(i) On Fig. 7.1, complete the circuit for the non-inverting amplifier. [2]

(ii) For the completed circuit of Fig. 7.1, the gain of the amplifier is 25. The resistance of resistor R_1 is 12 kΩ.

Calculate the resistance of resistor R_2.

$$1 + \frac{R_1}{R_2} = 25$$

$$\frac{12000}{R_2} = 24$$

$$R_2 = \frac{12000}{24}$$

$$500$$

resistance = 500 Ω [2]

(iii) Calculate, for the amplifier gain of 25, the range of values of V_{IN} for which the amplifier does not saturate.

$V_{out} = 25(x - 0)$

$9 = 25x$

$x = \frac{9}{25} = 0.36$

range from ......-0.36...... V to ......0.36...... V [2]

[Total: 9]

8 A horseshoe magnet is placed on a top pan balance. A rigid copper wire is fixed between the poles of the magnet, as illustrated in Fig. 8.1.

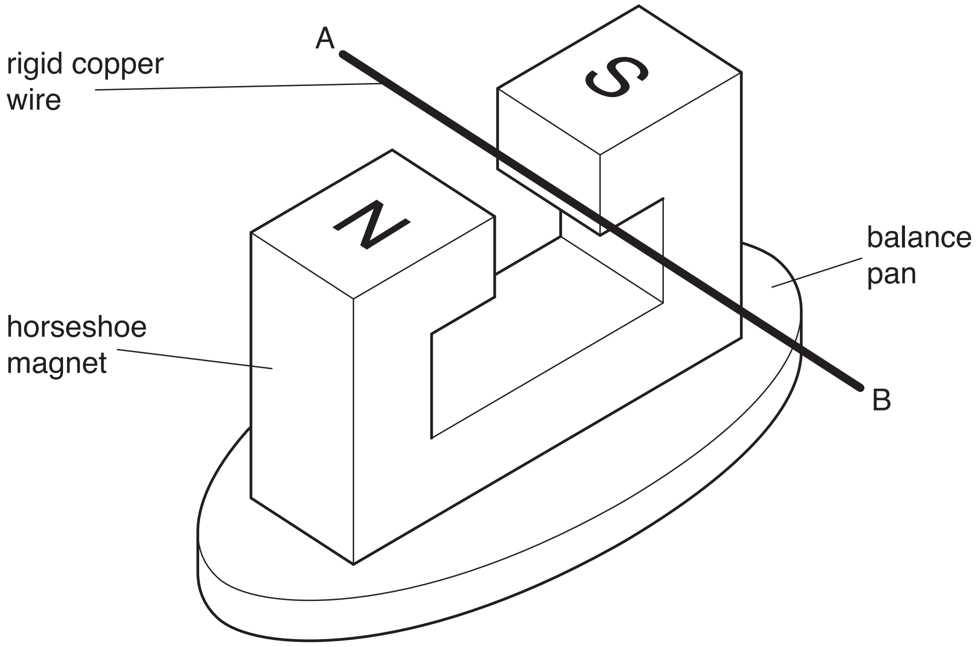


Fig. 8.1

The wire is clamped at ends A and B.

(a) When a direct current is switched on in the wire, the reading on the balance is seen to **decrease**.

State and explain the direction of:

(i) the force acting on the wire

downwards, because for the reading to decrease there needs to be an upward force on the magnet and according to newtons third law the force on wire will be equal but opposite, so it is downwards. [3]

(ii) the current in the wire.

B to A, as according to the left hand rule when the force on the wire is downwards, and field lines left to right, current has to be B to A. [2]

(b) A direct current of 4.6A in the wire causes the reading on the balance to change by 4.5×10^{-3} N.

The direct current is now replaced by an alternating current of frequency 40 Hz and root-mean-square (r.m.s.) value 4.6 A.

On the axes of Fig. 8.2, sketch a graph to show the change in balance reading over a time of 50 ms.

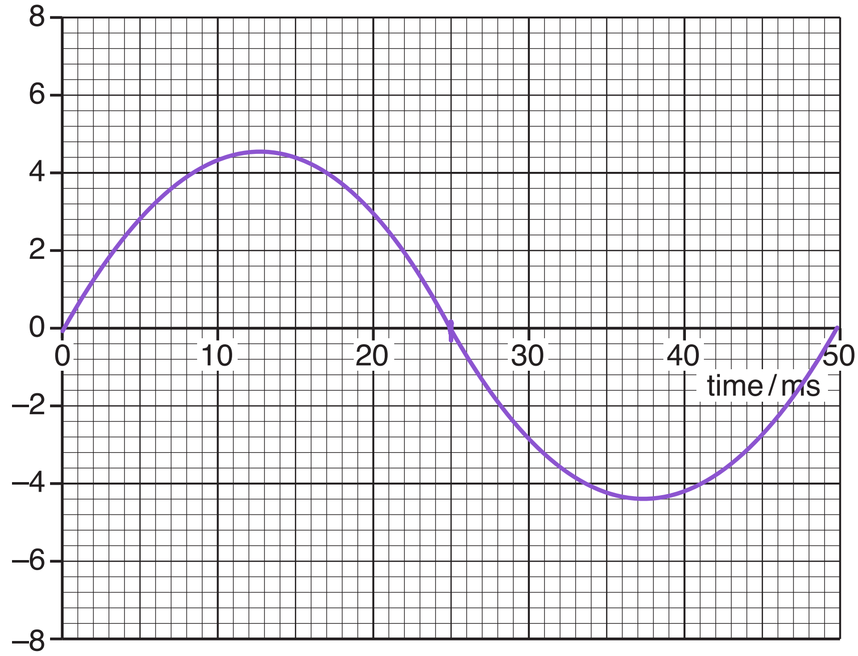


Fig. 8.2

2

[3]

$T = \frac{1}{f} = \frac{1}{40} = 25$ ms

[Total: 8]

~~$F = BIL$~~

~~$B = \frac{F}{IL} = \frac{4.5 \times 10^{-3}}{4.6 \times L}$~~

7

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

X-ray is used to scan one section of the body. Image of one slice is captured from many different angles in the same plane. All these images are combined using a computer to produce a 2D image of the section. This is repeated for many sections and all the 2D images are combined using computers to produce a 3D image of the whole body. This can then be viewed from many different angles.

[5]

5

[Total: 5]

Watch field lines in a solenoid video.

10 **(a)** A cross-section through a current-carrying solenoid is shown in Fig. 10.1.

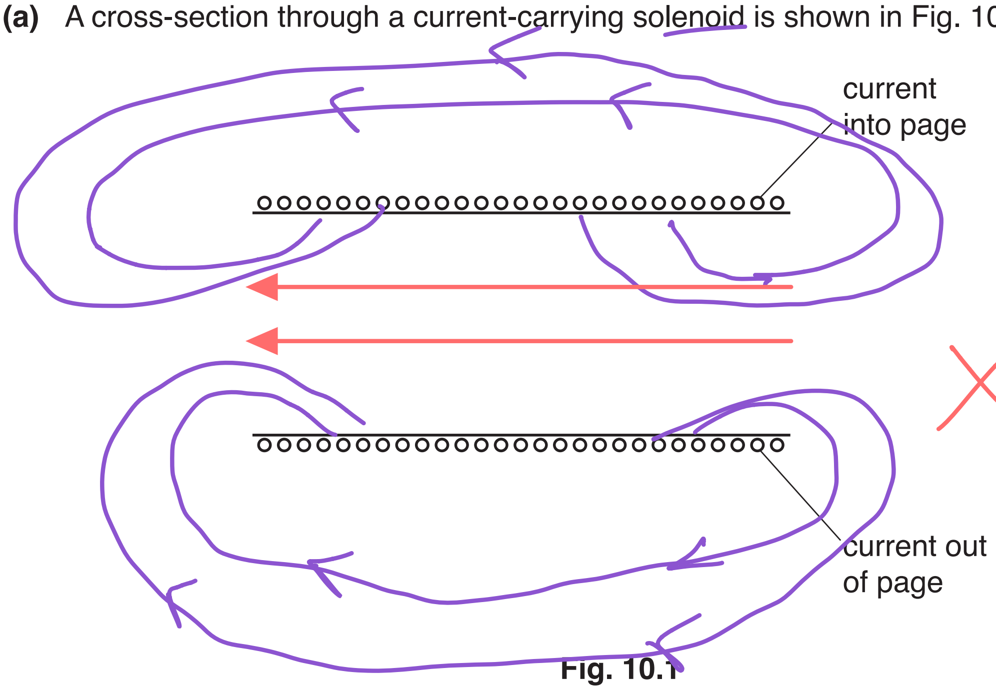

Fig. 10.1

On Fig. 10.1, draw field lines to represent the magnetic field inside the solenoid. [3]

1

(b) State Faraday's law of electromagnetic induction.

Emf is proportional to rate of change of magnetic flux linkage.

[2]

2

(c) A coil of insulated wire is wound on to a soft-iron core.

e.g.

The coil is connected in series with a battery, a switch and an ammeter, as shown in Fig. 10.2.

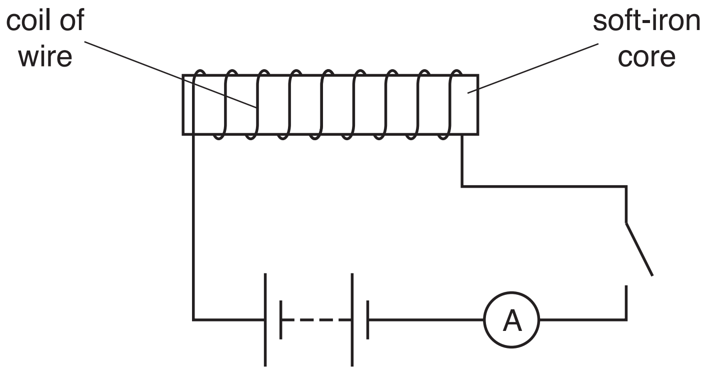

Fig. 10.2

#

Use laws of electromagnetic induction to explain why, when the switch is closed, the current increases **gradually** to its maximum value.

As the switch closes, a magnetic field is formed around the coil, which links with the iron core causing

1

.... [3]

e.g.

[Total: 8]

3

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

A quantum packet of energy of electromagnetic radiation.

.... [2]

(b) Calculate the energy, in eV, of a photon of light of wavelength 540 nm.

$$E = \frac{hc}{\lambda} = \frac{hc}{540 \times 10^{-9}}$$

$$= 3.6786 \times 10^{-19}$$

$$\frac{3.6786 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.299\ \text{eV}$$

energy = ...2.3........ eV [3]

(c) The outermost electron energy bands of a semiconductor material are illustrated in Fig. 11.1.

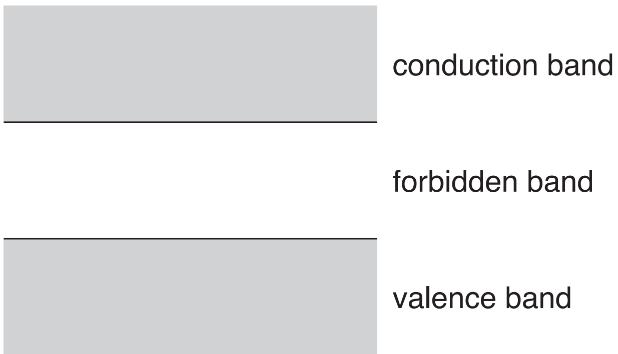

Fig. 11.1

The width of the forbidden band is 1.1 eV.

Explain why, when photons of light, each of energy 2.1 eV, are incident on the semiconductor material, its resistance decreases.

....

....

....

....

....

.... [4]

[Total: 9]

12 The incomplete nuclear equation for one possible reaction that takes place in the core of a nuclear reactor is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{57}La + ^{95}_{42}Mo + 2^{1}_{0}n + \ldots 7^{\,0}_{-1}e \ldots$$

(a) **(i)** State the name given to this type of nuclear reaction.

nuclear fission .... [1]

(ii) Complete the nuclear equation. [2]

(b) The mass defect for the reaction is 0.223 u.

(i) Calculate the energy, in J, equivalent to 0.223 u.

$0.223 \times (1.66 \times 10^{-27})$
$= 3.7018 \times 10^{-28} \times c^2$
$= 3.327 \times 10^{-11}$

energy = ... 3.33×10^{-11} .... J [2]

(ii) Suggest **two** forms of the energy released in this reaction.

1. .... Kinetic energy of product ....

2. .... Heat (thermal energy .... [2]

[Total: 7]

5
7

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