Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME: Solved Papers

CENTRE NUMBER

CANDIDATE NUMBER

PHYSICS **9702/41**

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

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	$\phi = -\frac{Gm}{r}$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$V_H = \frac{BI}{ntq}$
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)** State Newton's law of gravitation.

The gravitational force between two point masses is proportional to product of their masses & inversly proportional to the square of their seperation. $F = \frac{GMm}{r^2}$ [2]

(b) A geostationary satellite orbits the Earth. The orbit of the satellite is circular and the period of the orbit is 24 hours.

(i) State **two** other features of this orbit.

1. Above the equator

2. from west to east

[2]

(ii) The radius of the orbit of the satellite is 4.23×10^4 km.

Determine a value for the mass of the Earth. Explain your working.

$F_G = F_c$

$\frac{GMm}{r^2} = \omega^2 r$

$\frac{GMm}{r^3} = \omega^2$

$\frac{GMm}{r^3} = \left(\frac{2\pi}{T}\right)^2$

$\frac{GMm}{r^3} = \frac{4\pi^2}{T^2}$

Remember (m) mass of object (sattalite) doesn't affect force.

$\therefore \frac{GM}{r^3} = \frac{4\pi^2}{T^2}$

$M = \frac{4\pi^2 \times (4.23 \times 10^7)^3}{(24 \times 3600)^2 \times 6.67 \times 10^{-11}}$

$\approx 6.0 \times 10^{24}$

mass = 6.0×10^{24} kg [4]

[Total: 8]

2 (a) The kinetic theory of gases is based on a number of assumptions about the molecules of a gas.

State the assumption that is related to the volume of the molecules of the gas.

Compared to the volume occupied by the gas, the volume of molecules is negligible.

.... [2]

(b) An ideal gas occupies a volume of $2.40 \times 10^{-2}\,m^3$ at a pressure of $4.60 \times 10^5\,Pa$ and a temperature of 23 °C.

$N_A = 6.02 \times 10^{23}\,mol^{-1}$

(i) Calculate the number of molecules in the gas.

$pV = nRT$

$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (23 + 273)$

$n = 4.488 \approx 4.49\ mol$

$\therefore \frac{N}{N_A} = n$

$\frac{\text{Number of molecules}}{\text{Avagandos constant}} = \text{Number of moles}$

$N = 4.49 \times 6.02 \times 10^{23}$

$= 2.701 \times 10^{24}$

$\approx 2.7 \times 10^{24}$

number = 2.7×10^{24} [3]

(ii) Each molecule has a diameter of approximately $3 \times 10^{-10}\,m$.

Estimate the total volume of the gas molecules.

$2.7 \times 10^{24} \times \frac{4}{3} \pi \times \left(\frac{3 \times 10^{-10}}{2}\right)^3$

No of molecules — Volume of a sphere (one molecule)

$= 3.817 \times 10^{-5}$

$\approx 4 \times 10^{-5}$

(ans to least sf in qn)

volume = 4×10^{-5} m^3 [3]

(c) By reference to your answer in **(b)(ii)**, suggest why the assumption in **(a)** is justified.

As $4 \times 10^{-5}\,m^3$ (volume of molecules) is much lower than $2.4 \times 10^{-2}\,m^3$ (volume of gas) [1]

[Total: 9]

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3 **(a)** State what is meant by *specific latent heat*.

Amount of thermal energy required per unit mass to change the state at a constant temprature.

.... [2]

(b) A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.

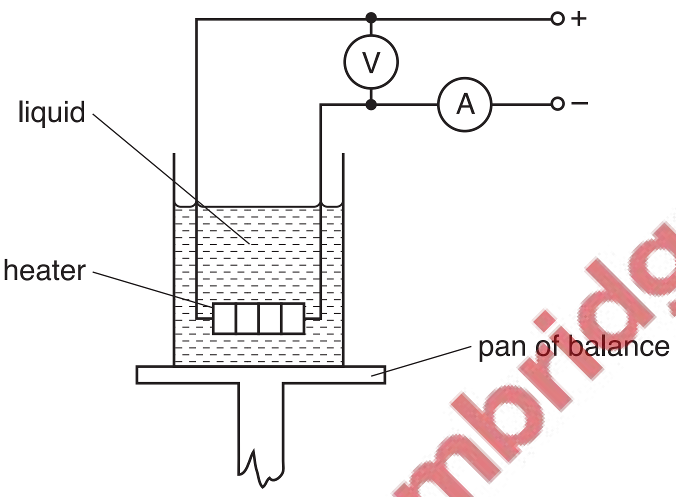


Fig. 3.1

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.

The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

	ammeter reading / A	voltmeter reading / V
from time 0 to time 10 minutes	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

The variation with time of the balance reading is shown in Fig. 3.3.

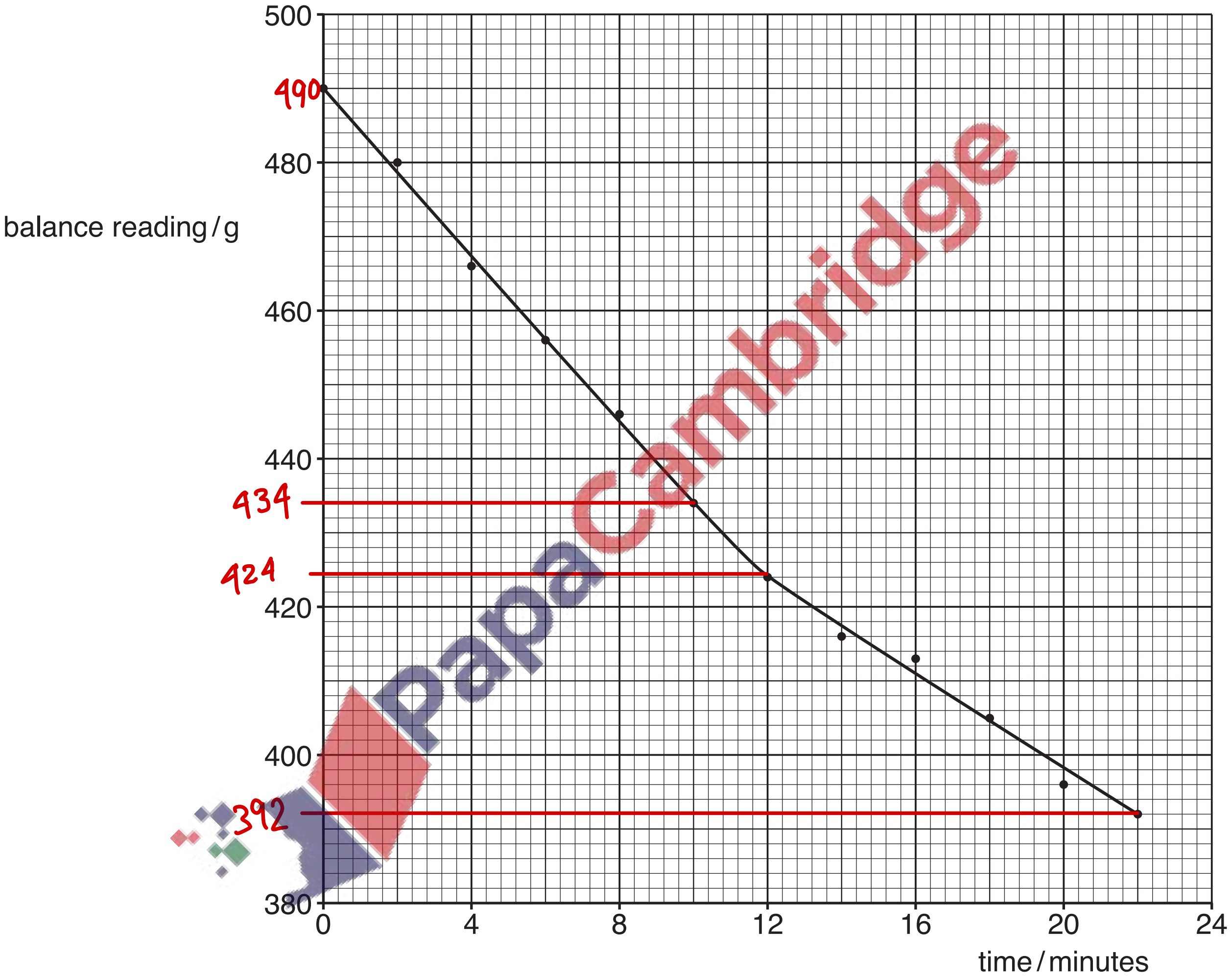


Fig. 3.3

NOTE

for latent heat of vapourisation H is "−" liquid → gas

for latent heat of fusion H is "+" solid → liquid

490 − 434 =

(i) From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

424 − 392 = 32

mass = ...32.......... g [1]

(ii) Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

temprature diffrence between apparatus & surrounding doesn't change. [1]

(iii) Determine a value for the specific latent heat of vaporisation L of the liquid.

−H + E = mL

(−H: thermal energy lost to surrounding; E: Energy from heater)

−H + VIt = mL

no conversion required as final ans in grams

from 0 to 10 min: −H + 230 × 1.2 × 10 × 60 = 56 × L

= 165600 = 56L + H → ①

from 12 to 22 min: −H + 190 × 1 × 10 × 60 = 32 × L

114 000 = 32L + H → ②

Solving ① & ② simultaneously:

H = 45 200 J

&

L = 2150 Jg⁻¹ ≈ 2200 (2sf)

L = ...2200.......... Jg^{-1} [4]

(iv) Calculate the rate at which thermal energy is transferred to the surroundings.

VIt = mL + H

10 × 60 × 190 × 1 = 32 × 2150 + H

H = 45200 J (same as calculated above)

Rate (Power) = E / Δt = 45200 / 600 = 75.3 ≈ 75 W

rate = ...75.......... W [2]

[Total: 10]

4 A mass is suspended vertically from a fixed point by means of a spring, as illustrated in Fig. 4.1.

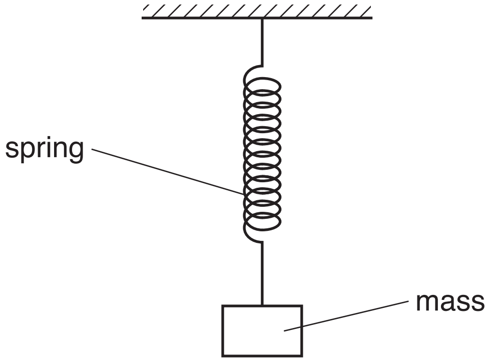


Fig. 4.1

The mass is oscillating vertically. The variation with displacement *x* of the acceleration *a* of the mass is shown in Fig. 4.2.

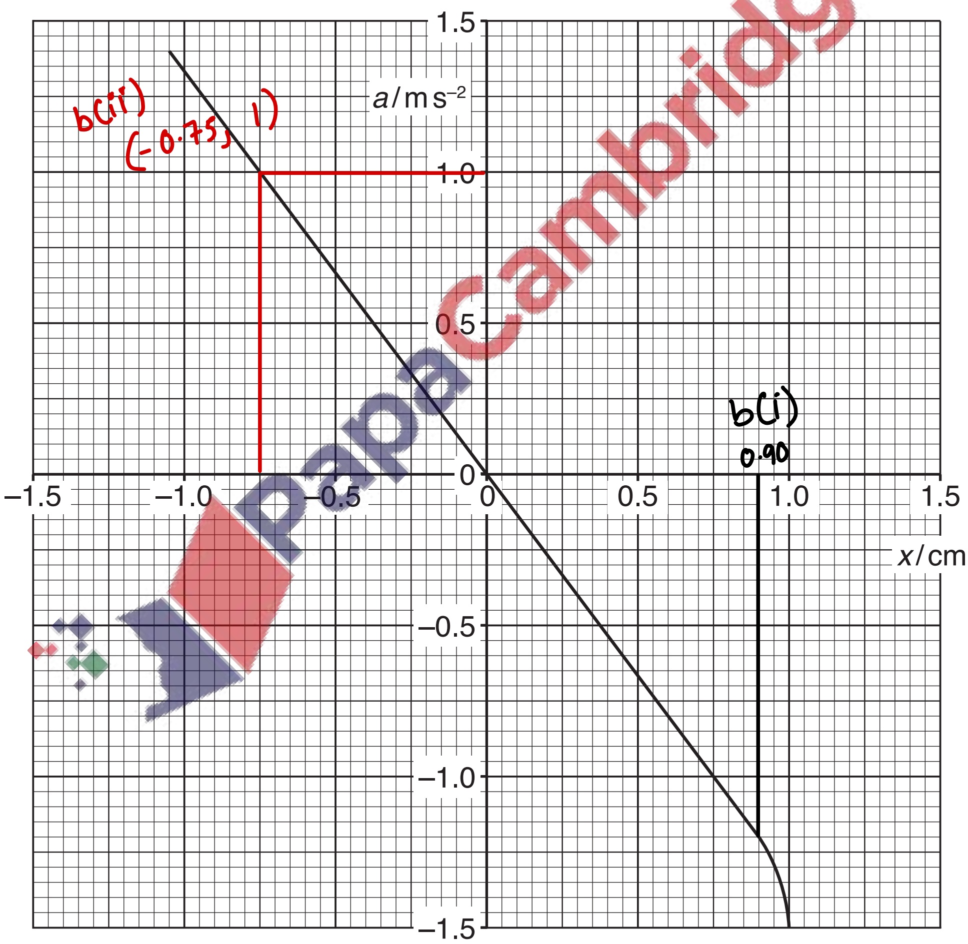


Fig. 4.2

(a) **(i)** State what is meant by the *displacement* of the mass on the spring.

Distance from a point in a given direction.

.... [1]

(ii) Suggest how Fig. 4.2 shows that the mass is not performing simple harmonic motion.

line is not straight

.... [1]

(b) (i) The amplitude of oscillation of the mass may be changed.

State the maximum amplitude x_0 for which the oscillations are simple harmonic.

x_0 = 0.90 cm [1]

(ii) For the simple harmonic oscillations of the mass, use Fig. 4.2 to determine the frequency of the oscillations.

$a = -\omega^2 x$

from Graph $a = 1\,ms^{-1}$ when $x = -0.75 \times 10^{-2}$

$\therefore\ 1 = -(2\pi f)^2 \times (-0.75 \times 10^{-2})$

$1 = 4\pi^2 f^2 \times 0.75 \times 10^{-2}$

$f = \sqrt{\frac{1}{0.75 \times 10^{-2} \times 4\pi^2}}$

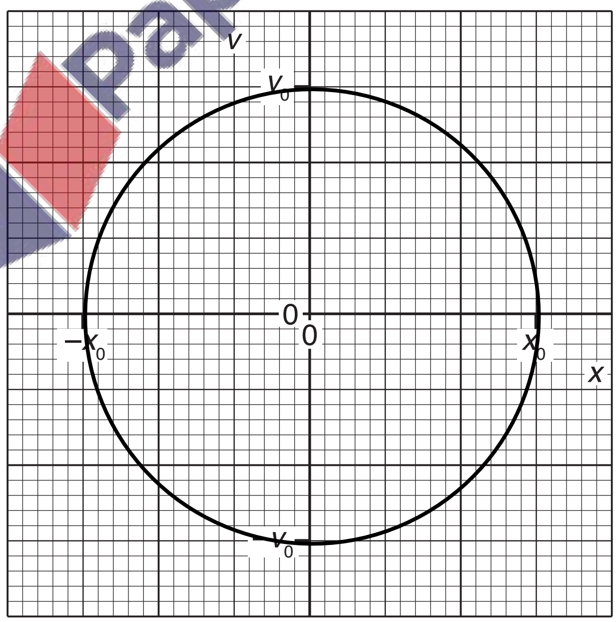
$= 1.837$ Hz

≈ 1.8 Hz

frequency = 1.8 Hz Hz [3]

(c) The maximum speed of the mass when oscillating with simple harmonic motion of amplitude x_0 is v_0.

On Fig. 4.3, show the variation with displacement x of the velocity v of the mass for displacements from $+x_0$ to $-x_0$.



In SHM, max KE is at amplitude(x) = 0.

0 KE at max Amplitude

Fig. 4.3

[2]

[Total: 8]

5 **(a)** A section of a coaxial cable is shown in Fig. 5.1.

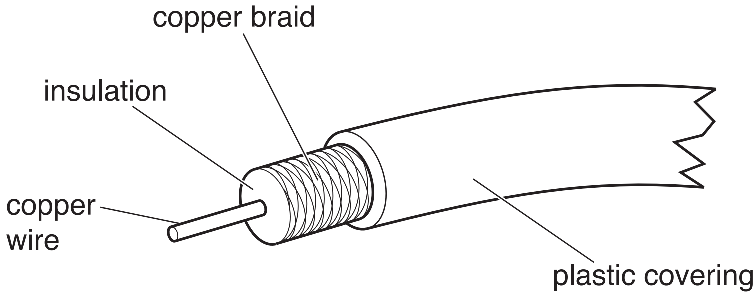


Fig. 5.1

(i) Suggest **two** functions of the copper braid.

1. Provides Return for the signal

2. shields signal from noise.

[2]

(ii) Suggest **one** application of a coaxial cable for the transmission of electrical signals.

provides connection between aerial & TV set.

[1]

(b) **(i)** The constant noise power in a transmission cable is 7.6 μW. The minimum acceptable signal-to-noise ratio is 32 dB.

Calculate the minimum acceptable signal power P_{MIN} in the cable.

$$\text{gain} = 10 \lg \left(\frac{P_{MIN}}{P_2}\right)$$

$$32 = 10 \lg \left(\frac{P_{MIN}}{7.6 \times 10^{-6}}\right)$$

$$P_{MIN} = 10^{3.2} \times 7.6 \times 10^{-6}$$

$$= 0.012 \text{ W}$$

P_{MIN} = 0.012 W [2]

(ii) The input power of the signal to the transmission cable is 2.6 W. The attenuation per unit length of the cable is 6.3 dB km^{-1}.

Use your answer in **(i)** to determine the maximum uninterrupted length L of cable along which the signal may be transmitted.

Attenuation per unit length = $\frac{\text{Attenuation}}{\text{Length}}$

Attenuation = $10 \log \left(\frac{P_{INP}}{P_{OUT}}\right)$

$= 10 \log \left(\frac{2.6}{0.012}\right)$

$\therefore 6.3 = \frac{10 \log \left(\frac{2.6}{0.012}\right)}{L}$

$\therefore L = \frac{10 \log \left(\frac{2.6}{0.012}\right)}{6.3}$

$= 3.707 \approx 3.7$ (2sf)

L = 3.7 km [2]

[Total: 7]

6 **(a)** State an expression for the electric field strength E at a distance r from a point charge Q in a vacuum.
State the name of any other symbol used.

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ where ε_0 is the permittivity of free space

....

.... [2]

(b) Two point charges A and B are situated a distance 10.0 cm apart in a vacuum, as illustrated in Fig. 6.1.

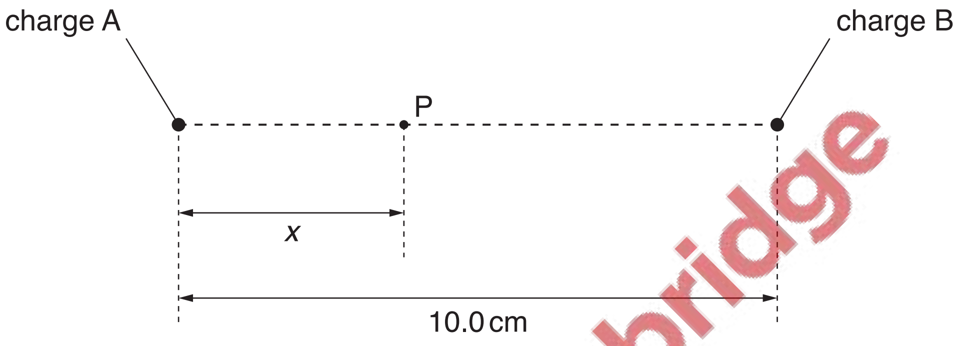


Fig. 6.1

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

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

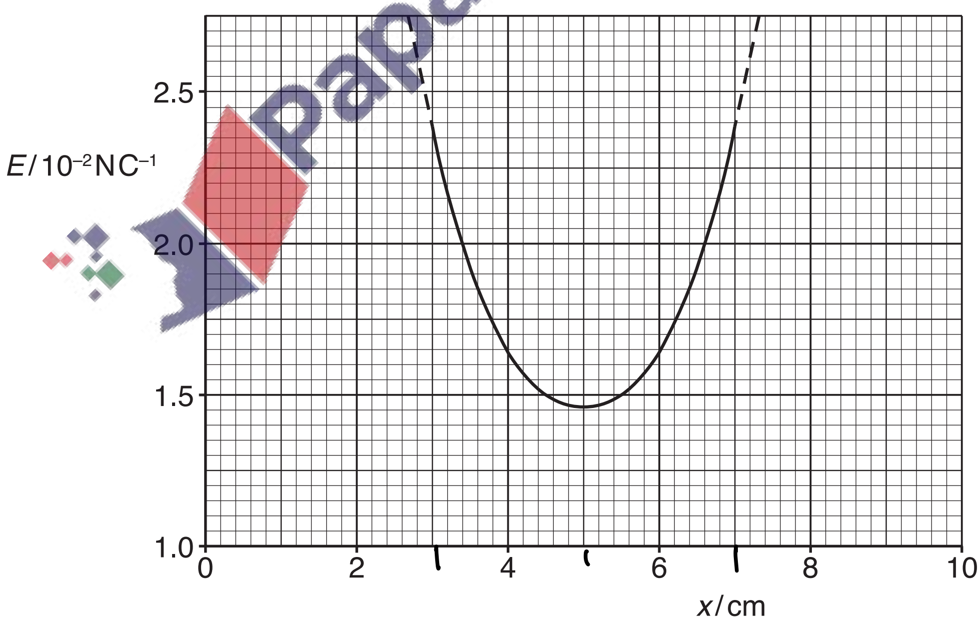


Fig. 6.2

State and explain whether the charges A and B:

(i) have the same, or opposite, signs

As the field does not become zero, they are opposite signs

.... [2]

(ii) have the same, or different, magnitudes.

Same magnitudes as the minimum value is at the midpoint

.... [2]

(c) An electron is situated at point P.

Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where $x = 3\,\text{cm}$ to the position where $x = 7\,\text{cm}$.

Acceleration is proportional to field strength so initaly the electron will decelerate from $x = 3\text{cm}$ to $x = 5\text{cm}$ at point $x = 5\text{cm}$ it will the minimum acceleration. from $x = 5\text{cm}$ to $x = 7\text{cm}$ the electron will start accelerating.

NOTE : $E \propto a$, negative gradient = deceleration, positive gradient = acceleration. [4]

[Total: 10]

7 **(a)** An ideal operational amplifier (op-amp) has infinite bandwidth and zero output impedance.

State what is meant by:

(i) *infinite bandwidth*

All frequencies are amplified equally ....

.... [1]

(ii) *zero output impedance*.

No drop in output voltage ....

.... [1]

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

gain for non inverting op amp $= 1 + \frac{R_F}{R_{IN}}$

Gain for inverting op amp $= \frac{R_F}{R_{IN}}$

gain $= \frac{V_{OUT}}{V_{IN}}$

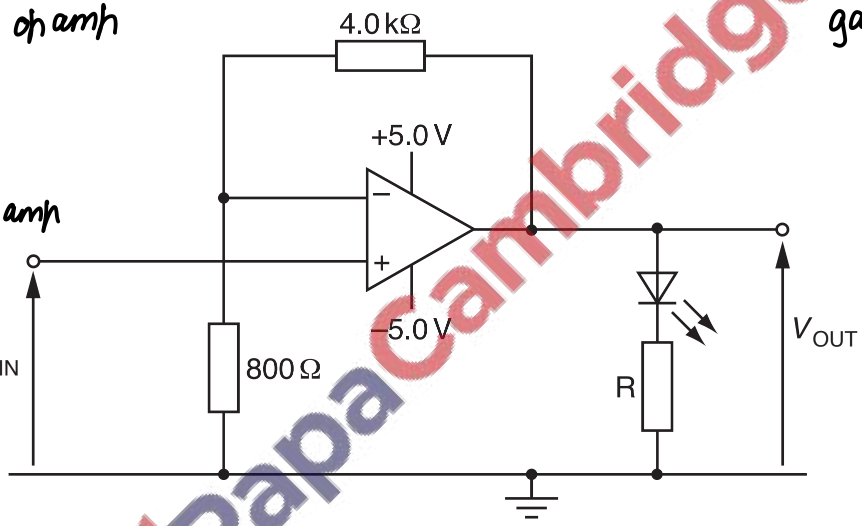


Fig. 7.1

The light-emitting diode (LED) emits light when the potential difference across it is at least 2.0 V.
The current in the LED must not be greater than 20 mA.

(i) Calculate the gain of the amplifier circuit.

$1 + \frac{4000}{800} = 6.0$

gain = ...6.0...................................... [2]

(ii) Determine the value of V_{IN} for which the value of V_{OUT} is +2.0 V.

gain = $\frac{V_{OUT}}{V_{IN}}$ ∴ $6 = \frac{2}{V_{IN}}$

∴ $V_{IN} = 1/3 \approx 0.33$ V

V_{IN} = ...0.33.. V [1]

(iii) State the maximum value of the output potential V_{OUT}.

maximum potential = ...5 V.. V [1]

(iv) When the op-amp is saturated, the potential difference across the LED is 2.2 V.

Calculate the minimum resistance of resistor R so that the current in the LED is limited to 20 mA.

$V = 5 - 2.2 = 2.8$

$V = IR$

$2.8 = 20 \times 10^{-3} \times R$

$R = \frac{2.8}{20 \times 10^{-3}} = 140\,\Omega$

resistance = ...140.. Ω [2]

[Total: 8]

8 **(a)** A long straight vertical wire carries a current I. The wire passes through a horizontal card EFGH, as shown in Fig. 8.1 and Fig. 8.2.

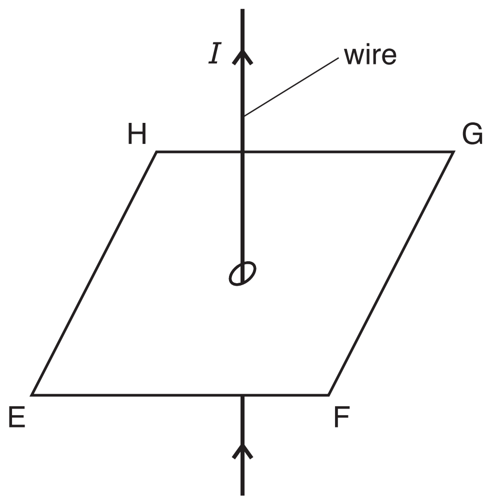


Fig. 8.1

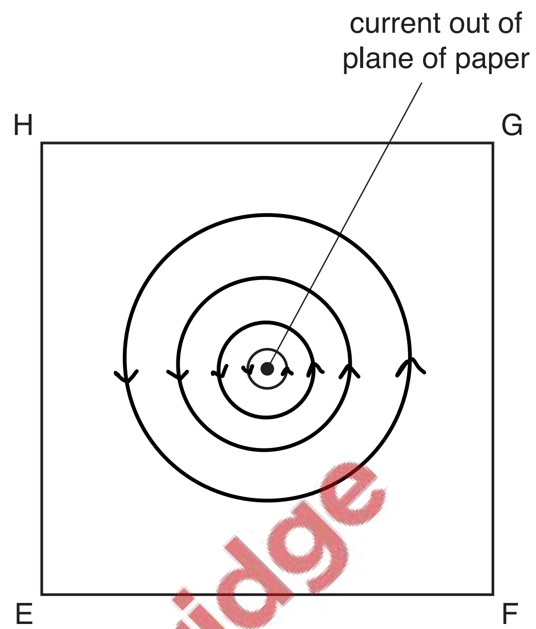


Fig. 8.2 (view from above)

On Fig. 8.2, draw the pattern of the magnetic field produced by the current-carrying wire on the plane EFGH. [3]

(b) Two long straight parallel wires P and Q are situated a distance 3.1 cm apart, as illustrated in Fig. 8.3.

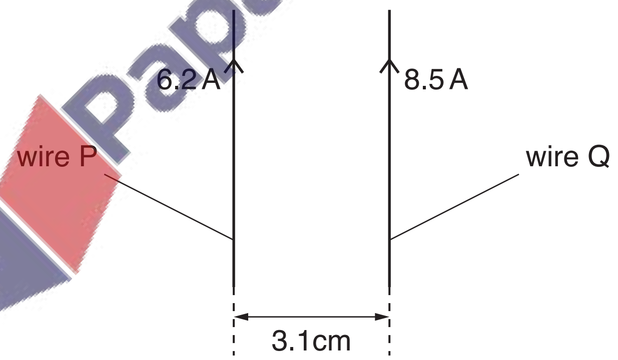


Fig. 8.3

The current in wire P is 6.2 A. The current in wire Q is 8.5 A.

The magnetic flux density B at a distance x from a long straight wire carrying current I is given by the expression

$$B = \frac{\mu_0 I}{2\pi x}$$

where μ_0 is the permeability of free space.

permeability of free space $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$

Calculate:

(i) the magnetic flux density at wire Q due to the current in wire P

$$B = \frac{\mu_0 I}{2\pi x} = \frac{4\pi \times 10^{-7} \times 6.2}{2\pi \times 3.1 \times 10^{-2}}$$

$$= 4 \times 10^{-5}\ \mathrm{T}$$

flux density = 4×10^{-5} T [2]

(ii) the force per unit length, in $\mathrm{N\,m^{-1}}$, acting on wire Q due to the current in wire P.

$$F = BIL$$

$$= 4 \times 10^{-5} \times 8.5 \times 1 = 3.4 \times 10^{-4}$$

flux density at Q

current in Q as force in Q is calculated

unit length

force per unit length = 3.4×10^{-4} $\mathrm{N\,m^{-1}}$ [2]

(c) The currents in wires P and Q are different in magnitude.

State and explain whether the forces per unit length on the two wires will be different.

They will be of the same magnitude as Newton's Third law states every action has an equal and opposite reaction, the forces will hence have the same magnitude. [2]

[Total: 9]

Rember, $F = \frac{\mu_0 I_1 I_2 L}{2\pi x}$, so the product of I_1 & I_2 will stay the same for both the wires, and force will be the same, given they are of equal lengths.

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9 Diagnosis using nuclear magnetic resonance imaging (NMRI) requires the use of a non-uniform magnetic field superimposed on a constant magnetic field of large magnitude.

Explain the purpose of:

(a) the large constant magnetic field

The main purpose is nuclei precess (the spinning of the proton around it's axis due to a external force : in this case the magnetic field) A constant magnetic field is used so that the frequency of the precession (Larmor frequency) is in the range of Radio waves.

[2]

(b) the non-uniform magnetic field.

The frequency of the precession depends on the field strength, a non-uniform magnetic field allows for the spinning nuclei to be located

[2]

[Total: 4]

10 A bridge rectifier using four ideal diodes is shown in Fig. 10.1.

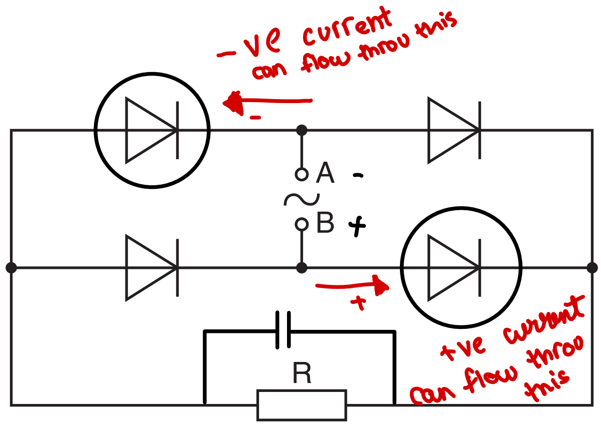

Fig. 10.1

The sinusoidal alternating electromotive force (e.m.f.) applied between points A and B has a root-mean-square (r.m.s.) value of 7.0 V.

(a) **(i)** On Fig. 10.1, circle the diodes that conduct when point B is positive with respect to point A. [1]

(ii) Calculate the maximum potential difference V_{MAX} across resistor R.

$\frac{7}{\sqrt{2}} = 9.9$

V_{MAX} = 9.9 V [1]

(b) A capacitor is connected into the circuit to produce smoothing of the potential difference across resistor R.

The variation with time *t* of the potential difference *V* across resistor R is shown in Fig. 10.2.

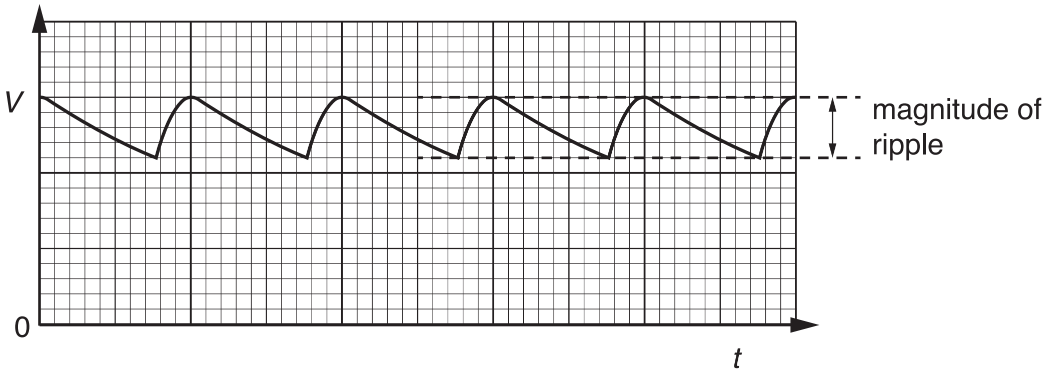

Fig. 10.2

(i) On Fig. 10.1, draw the symbol for a capacitor, connected so as to produce smoothing. [1]

(ii) State the effect, if any, on the magnitude of the ripple on *V* when, separately:

1. a capacitor of larger capacitance is used

decreases ....

2. the resistor R has a smaller resistance.

Increases ....

[2]

[Total: 5]

11 **(a)** With reference to the photoelectric effect, state what is meant by *work function energy*.

The amount of energy required by a photon to remove a electron from a surface.

.... [2]

(b) The work function energy of a clean metal surface is 5.5×10^{-19} J.

Electromagnetic radiation of wavelength 280 nm is incident on the metal surface. The metal is in a vacuum.

(i) Calculate:

$E = hf \quad v = f\lambda \quad \frac{v}{\lambda} = f$

1. the photon energy

$E = \frac{hc}{\lambda}$

$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{280 \times 10^{-9}}$

$\approx 7.1 \times 10^{-19}$

photon energy = 7.1×10^{-19} J [2]

rest mass of electron $m_e = 9.11 \times 10^{-31}$ kg

2. the maximum speed v_{MAX} of the electrons emitted from the surface.

Work function energy = photon energy − K. energy of ē

$5.5 \times 10^{-19} = 7.1 \times 10^{-19} - KE$

$KE = 7.1 \times 10^{-19} - 5.5 \times 10^{-19}$

$\frac{1}{2} mv^2 = (7.1 \times 10^{-19}) - (5.5 \times 10^{-19})$

$\frac{1}{2}(9.11 \times 10^{-31}) v^2 = (7.1 \times 10^{-19}) - (5.5 \times 10^{-19})$

$v = 5.9 \times 10^{5}$

v_{MAX} = 5.9×10^{5} m s^{-1} [3]

(ii) Explain why most of the emitted electrons will have a speed lower than v_{MAX}.

Energy is required to bring ē to the surface.

.... [1]

(c) The electromagnetic radiation incident on the metal surface may change in intensity or in frequency.

Complete Fig. 11.1 by inserting either '*increases*' or '*decreases*' or '*no change*' to describe the effects of the changes shown on the maximum speed and on the rate of emission of electrons.

Intensity is not dependent of velocity

change	maximum speed of electrons	rate of emission of electrons
reduced intensity at constant frequency	No change	decreases
increased frequency at constant intensity	Increases	decreases

Fig. 11.1

[4]

[Total: 12]

$V = F\lambda$

$\uparrow f \quad \uparrow V$

$I = \frac{P}{A}$

$I = \frac{E/t}{A}$

$I = \frac{hf}{t} \times \frac{1}{A}$

$I = \frac{hf}{tA}$

12 One possible nuclear reaction that takes place is

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

Data for nuclei in this reaction are given in Fig. 12.1.

nucleus	mass/u	total mass of separate nucleons/u	mass defect/u	binding energy per nucleon/MeV
$^{95}_{42}Mo$	94.906	95.765	0.859	8.443
$^{139}_{57}La$	138.906	140.125	1.219	8.189
$^{235}_{92}U$	235.044	236.909	1.865	7.41

Fig. 12.1

unified atomic mass unit 1 u = 1.66 × 10^{-27} kg

(a) Show that the energy equivalent to a mass of 1.00 u is 934 MeV.

Binding Energy of Mo^{95}_{42} = 8.443 × 95
= 802.085

Energy = Binding energy / Mass Defect = 802.085 / 0.859 = 933.74

≈ 934 MeV

[2]

(b) (i) Use data from Fig. 12.1 to calculate the binding energy per nucleon of a nucleus of uranium-235 ($^{235}_{92}U$). Complete Fig. 12.1.

Energy = Binding energy / Mass Defect

934 = Binding E / 1.865

Binding Energy = 1.865 × 934
= 1741.91

Binding Energy per nucleon
= 1741.91 / 235 = 7.412
≈ 7.41 MeV

[2]

(ii) The nucleon number of an isotope of the element rutherfordium is 267.

State whether the binding energy per nucleon of this isotope will be greater than, equal to or less than the binding energy per nucleon of uranium-235.

less than [1]

↗ single nucleons themselves dont have binding energy

(c) Calculate the total energy, in MeV, released in this nuclear reaction.

Total Energy = Energy Products − Energy Reactants

= $(8.443 \times 95) + (139 \times 8.189) - (235 \times 7.41)$

= 199.006

≈ 199

energy = ...199........ MeV [2]

(d) The nuclei in 1.2×10^{-7} mol of uranium-235 all undergo this reaction in a time of 25 ms.

Calculate the average power release during the time of 25 ms.

No of atoms = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$

= 7.22×10^{16}

Total Energy Released = $7.22 \times 10^{16} \times 199.006 \times 1.6 \times 10^{-19} \times 10^{6}$

Power = $\frac{E}{t} = \frac{7.22 \times 10^{16} \times 199.006 \times 1.6 \times 10^{-19} \times 10^{6}}{25 \times 10^{-3}}$

= 91956692.48

≈ 9.2×10^{7} W

power = ...9.2×10^{7}........ W [3]

[Total: 10]