H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**
CLASS	
TUTOR'S NAME	

PHYSICS

9749/02

Paper 2 Structured Questions

Sept 2021

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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.

For Examiner's Use	
1	/ 7
2	/ 8
3	/ 8
4	/ 9
5	/ 9
6	/ 6
7	/ 10
8	/ 15
Total	/ 80

This document consists of **21** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ 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	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / {}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** A body has an initial velocity *u* and an acceleration *a*. After a time *t*, the body has moved a displacement *s* and has a final velocity *v*. One of the equations of motion of this body is

$$s = ut + \frac{1}{2}at^2$$

State the conditions that must be satisfied for the above equation to be valid.

Conditions for equations to be valid:
- Constant acceleration [B1]
- Motion in a straight line [B1]

[2]

(b) A hot air balloon was moving at a velocity of 11.7 m s^{-1}, at an angle of 59.0° from the horizontal, as shown in Fig. 1.1 below.

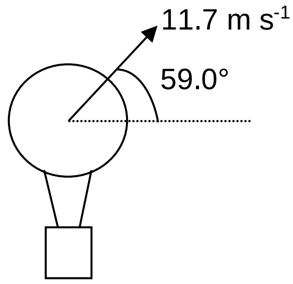


Fig. 1.1

(i) Determine the vertical component of the velocity of the balloon.

$$\sin\theta = \frac{v_y}{v}$$

$$v_y = v\sin\theta = 11.7\sin(59.0) = 10.0 \text{ m s}^{-1}$$

vertical component of the velocity = ... m s^{-1} [1]

(ii) A slotted mass is released from the balloon. Fig. 1.2 shows the subsequent path of the slotted mass. The dotted figure shows the position of the hot air balloon at the instant when the slotted mass is released.

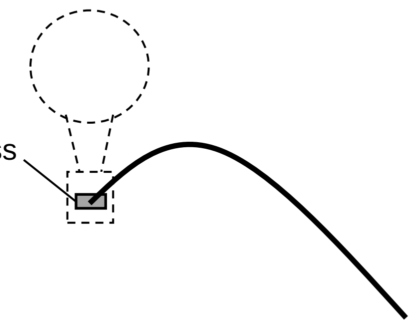


Fig. 1.2

1. Throughout the motion, the slotted mass is observed to be directly below the hot air balloon. Explain why this is so.

Both the mass and balloon have the same horizontal velocity [B1], hence their horizontal displacements are the same.

[1]

2. Determine how far below the balloon would the slotted mass be after 3.0 s. You may assume that the slotted mass has not yet landed on the ground and that air resistance on the slotted mass is negligible.

$s_{mass} = 10.0\ (3.0) + \frac{1}{2}(-9.81)(3.0)^2$

$= -14.1$ m [B1]

$s_{balloon} = 10.0\ (3.0) = 30.0$m [M1]

Distance = 30.0 – (-14.1) = 44.1 ≈ 44 m [A1]

distance = ... m [3]

3. Describe qualitatively the changes, if any, to the answer in **(b)(ii)2** if a 100 kg cargo was dropped from the balloon instead of the slotted mass. Assume air resistance on the cargo is negligible too.

The distance between cargo and balloon will be greater.

....[1]

[Total: 8]

2 **(a)** State the conditions required for a body to be in equilibrium.

When a body is in equilibrium, the following two conditions must both be satisfied:

1. The resultant force on it must be zero. [B1]
2. The resultant torque on it must be zero. [B1]

....[2]

(b) Fig. 2.1 shows a lamp weighing 5.00 N that is hung from the end of a beam 4.50 m long and weighing 1.00 N, making an angle of 25.0° below the horizontal.

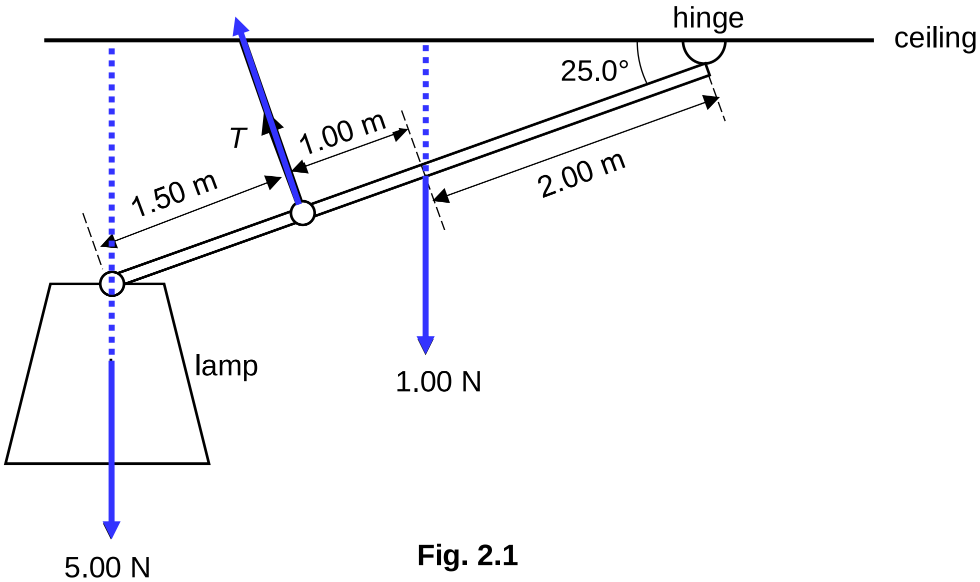


Fig. 2.1

The beam is held in position by a hinge at its upper end and by a cable 3.00 m lower down the beam and perpendicular to it. The centre of gravity of the beam is 2.00 m down the beam from the hinge.

(i) The position of the centre of gravity of the beam is not at its midpoint. Suggest what this implies about the distribution of the mass in the beam.

The distribution of mass in the beam would be non-uniform. [B1]

.... [1]

(ii) Show that the tension T in the cable is 7.40 N. [2]

taking moments about the pivot

1.00 (2.00 cos 25.0) + 5.00 (4.5 cos 25.0) -T(3.00) = 0 [B1]

T = 7.40 N [A1]

(iii) Determine the magnitude and the direction of the force acting on the beam at the hinge.

taking moments about the pivot

1.00 (2.00 cos 25.0) + 5.00 (4.5 cos 25.0) -T(3.00) = 0

where the forces are all in kN

T = 7.40 kN

(the minus sign meens that this force is actually acting downwards)

Assume the horizontal component of the force at the hinge is F_x to the right

$F_x + 7.40 \sin 25.0° = 0$

$F_x = 3.13$ N [B1 for finding F_X and F_Y]

$F = \sqrt{F_x^{\ 2} + F_Y^{\ 2}}$

$= \sqrt{3.13^2 + 0.707^2}$

$= 3.21$ N [B1 for finding F]

Let θ be the angle of F <u>below the horizontal</u>

$\tan \theta = \dfrac{0.707}{3.10}$

$\theta = 12.8°$ [B1 for finding θ and describing direction]

magnitude = ...

direction = ... [3]

[Total: 8]

3 The Earth may be assumed to be a uniform sphere of radius R and mass M. At its surface, the gravitational field strength is g. A satellite orbits the Earth at a height $0.30R$ above its surface.

(a) Show that the gravitational field strength at this height is $0.59g$.

$$g = \frac{GM}{r^2} \Rightarrow g \propto \frac{1}{r^2}$$

$$\frac{g'}{g} = \frac{r^2}{(r')^2} \quad \text{[B1]}$$

$$g' = \frac{R^2}{(1.3R)^2} g \quad \text{[B1]}$$

$$g' = 0.59g \quad \text{(shown)}$$

[2]

(b) Determine the angular speed of the satellite about the Earth. The radius R of the Earth is 6.4×10^6 m.

The gravitational force by Earth provides the centripetal force on the mass.

$$mg = ma_c$$

$$0.59g = 1.3(6.4 \times 10^6)\omega^2 \quad \text{[B1]}$$

$$\omega = 8.3 \times 10^{-4} \text{ rad s}^{-1} \quad \text{[B1]}$$

angular speed = ... rad s^{-1} [2]

(c) Calculate the time, in hours, for one complete orbit of the satellite.

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

$$8.34 \times 10^{-4} = \frac{2\pi}{T}$$

$$T = 7.5 \times 10^3 \text{ s} \quad \text{[B1]}$$

$$T = 2.1 \text{ h} \quad \text{[B1]}$$

time = ... h [2]

(d) Explain why the satellite does not fall towards the Earth even though the gravitational force is directed toward the centre of the Earth.

The satellite is rotating about the Earth. The force exerted by Earth on the satellite is perpendicular to the linear velocity of the satellite [B1], and the magnitude of this force provides the centripetal acceleration required for the satellite to revolve around the Earth [B1] at a constant distance and a constant speed. $F = \frac{mv^2}{r}$ [2]

[Total: 8]

4 The piston in the cylinder of a car engine is made to move in the cylinder with simple harmonic motion.

Fig. 4.1 shows the highest and lowest positions of the piston.

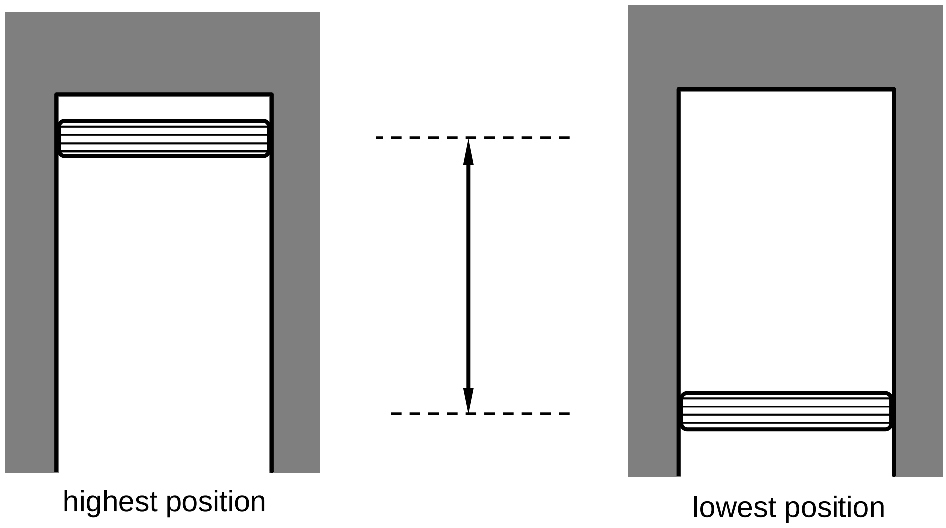


Fig. 4.1

The variation of the acceleration a of the piston with its displacement x from position O is as shown in Fig. 4.2.

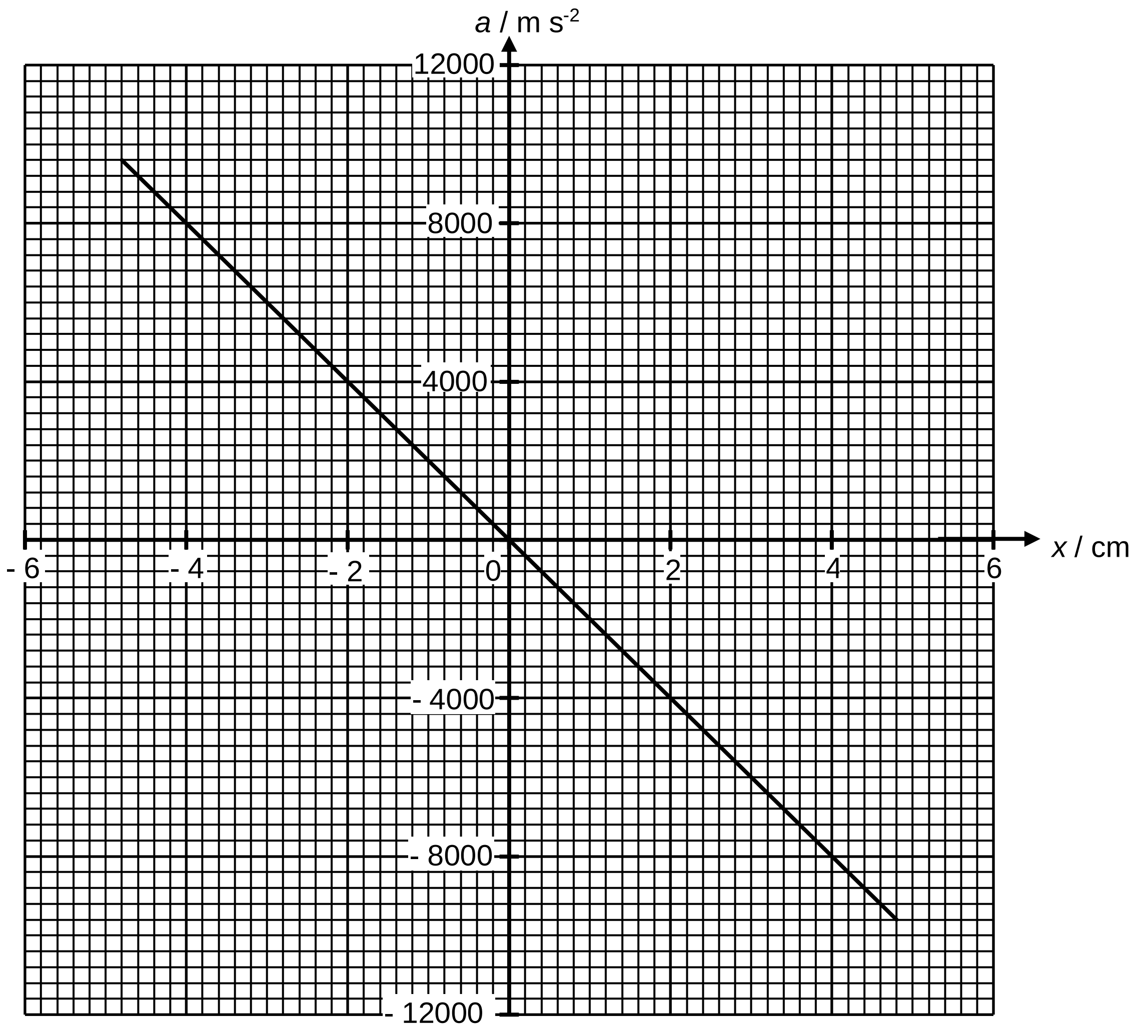


Fig. 4.2

(a) State and explain the features of Fig. 4.2 that indicate that the motion of the piston is simple harmonic.

The graph is a straight line passing through origin implying the acceleration is proportional to the displacement from a fixed point. [B1]

The negative gradient indicate that the direction of acceleration is always opposite to the displacement. [B1]

[2]

(b) Determine the maximum speed of the piston.

$gradient = -\omega^2$

$\frac{9600 - 0}{4.8 \times 10^{-2}} = -\omega^2$ [B1]

$v_o = \omega x_o = 447(4.8 \times 10^{-2}) = 21\ m\ s^{-1}$ [B1]

maximum speed = ... m s^{-1}[2]

(c) With reference to Fig. 4.2,

(i) explain why the time taken for the piston to move from x = 3.3 cm to x = 0 cm is the same as that from x = 0 cm to x = -3.3 cm.

The magnitude of the acceleration is symmetical about origin. [B1] This results in the speed to be the same value at the distance from origin as the velocity at the origin is the maximum. Hence the time taken for the piston to move from x = 3.3 cm to origin and from oriign to x = -3.3 cm is the same as the distance travelled is the same. [B1]

[2]

(ii) The area under the graph in Fig. 4.2 from $x = 0$ to $x = 4.8$ cm is given by Z.

A student calculates K, the maximum kinetic energy of the piston, using the relationship

$$K = Z \times M$$

where M is the mass of the piston.

Explain why this relationship is valid.

By N2L, the product of mass of piston and the acceleration of piston represent the net force acting on the piston. [B1]
The area under the graph for the variation of net force with displacement represent the work done on the system to start the oscillation. Since the work done on the system results in the piston gaining a maximum kinetic energy when it is at the origin,
the area under the graph x mass = maximum kinetic energy piston. [B1]

....[2]

(d) The piston is made to move by connecting a rod to a rotating crankshaft as shown in Fig. 4.3. As the pivot P on the crankshaft rotates, the piston will move up and down.

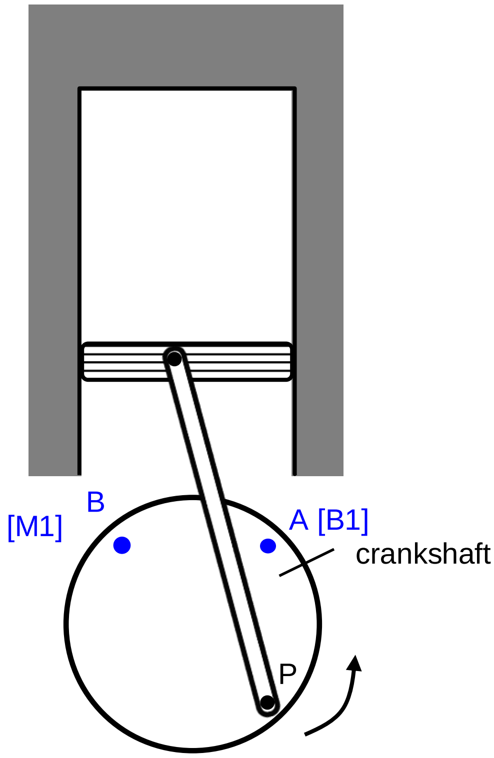


Fig. 4.3

When pivot P is at the position shown in Fig. 4.3, the piston is moving upward with a position of $x = -3.3$ cm.

Indicate on Fig. 4.3 the position of pivot P when the piston is at the following positions,

(i) $x = 3.3$ cm moving upwards. (Indicate this position with A)

(ii) $x = 3.3$ cm moving downwards. (indicate this position with B) [2]

[Total: 10]

5 An isolated spherical conductor has charge q, as shown in Fig 5.1.

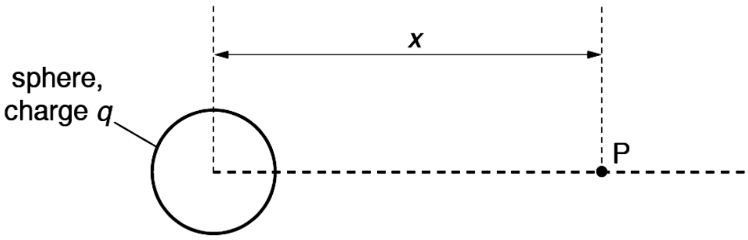


Fig. 5.1

Point P is a movable point with a distance of x from the centre of the sphere. The variation with distance x of the electric potential V at a point P due to the charges on the sphere is shown in Fig. 5.2.

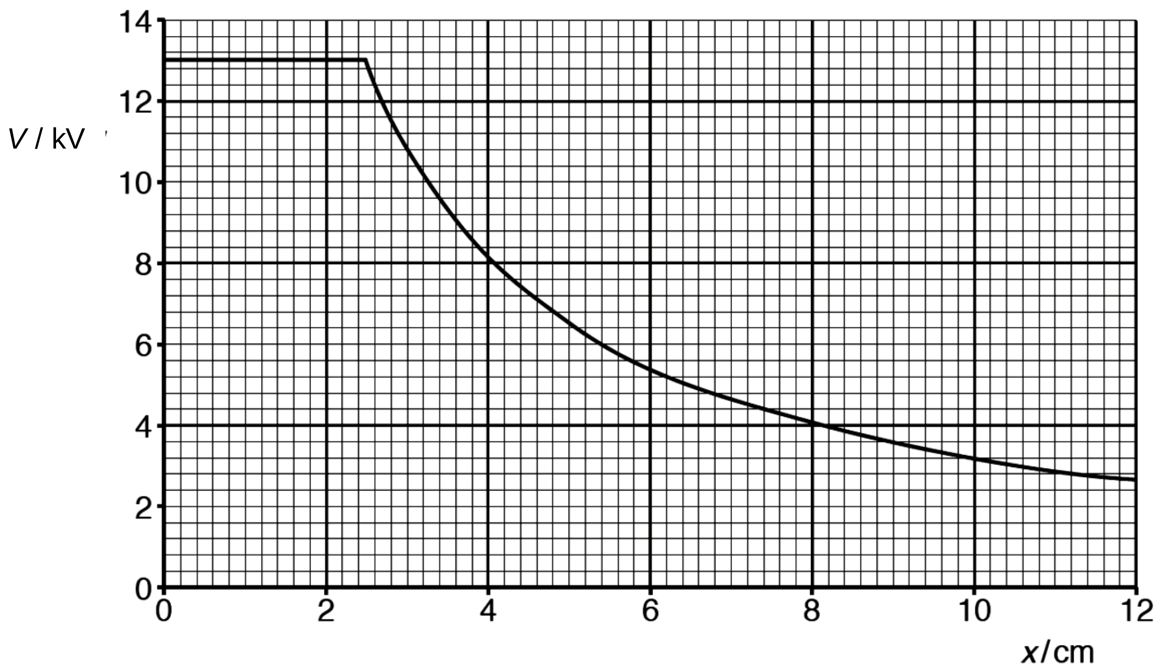


Fig. 5.2

(a) By making reference to the electric field, explain why the potential is constant for x = 0 cm to x = 2.5 cm.

- For x = 0 cm to x = 2.5 cm is the region inside the spherical conductor, so no electric field / electric field strength is zero inside [B1].
- Since electric field strength is equal to the negative of potential gradient (i.e. $E = -\frac{dV}{dx}$), potential gradient is zero, therefore potential must remain constant [B1]. [2]

(b) Use Fig. 5.2 to determine the acceleration of a proton at point P where x = 5.0 cm.

Method 1:

- Tangent drawn at x = 5.0 cm and chosen gradient coordinates must be longer than half the tangent line, to find E. [C1]
- Use of N2L and $a = \frac{qE}{m}$ seen. [C1]
- Correct calculation of final ans. [A1]

Method 2:

- Determine charge, Q, of sphere using formula for isolated point charge $V = \frac{Q}{4\pi\varepsilon_0 r}$. [C1]
- Determine electric force using Coulomb's law $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ and N2L to find a. [C1]
- Correct calculation of final ans. [A1]

acceleration = **1.2 to 1.4 x 10^{13}** m s^{-2} [3]

(c) Describe and explain the variation of the speed of the proton when it moves from x = 5.0 cm to x = 9.0 cm.

Method 1 (COE approach):

- Electric potential decreases, electric potential energy decreases, kinetic energy increases [C1]
- So speed increases [A1]

Method 2 (N2L approach):

....[2]

- Electric field strength decreases, electric force decreases [C1]
- Acceleration decreases, so speed increases at a decreasing rate [A1]

(d) If the proton has a speed of 1.3 × 10^5 m s^{-1} initially at x = 5.0 cm, calculate the speed of the proton when it is at x = 9.0 cm.

$$Ep_i + Ek_i = Ep_f + Ek_f \text{ [C1]}$$

$$(1.6\times10^{-19})(6.4\times10^{3}) + \frac{1}{2}(1.67\times10^{-27})(1.3\times10^{5})^2 = (1.6\times10^{-19})(3.6\times10^{3}) + \frac{1}{2}(1.67\times10^{-27})v_f^{\,2} \text{ [C1]}$$

$$v_f = 7.44\times10^{5} \text{ m s}^{-1} \text{ [A1]}$$

speed = ...m s^{-1} [3]

[Total: 10]

6 **(a)** Two cylindrical resistors M and N of the same material are connected parallel in Fig. 6.1. The mass of M is twice the mass of N and the radius of M is half the radius of N.

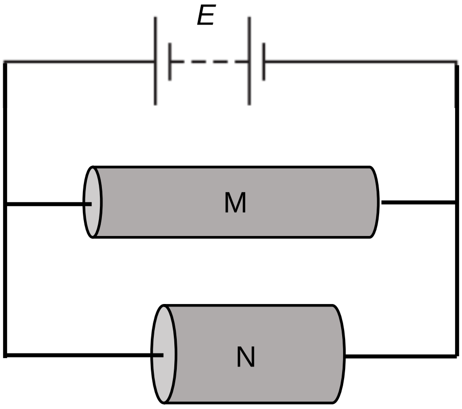


Fig. 6.1 (not to scale)

Determine the ratio

(i) $\dfrac{\text{resistance of M}}{\text{resistance of N}}$,

$$\frac{\text{mass of M}}{\text{mass of N}} = \frac{density_M Volume_M}{density_N Volume_N} = \frac{L_M}{L_N} \times \frac{A_M}{A_N} = \frac{L_M}{L_N} \times \frac{1}{4} = 2, \frac{L_M}{L_N} = 8$$

$$\frac{A_M}{A_N} = \frac{\pi r_M^2}{\pi r_N^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

$$\frac{\text{resistance of M}}{\text{resistance of N}} = \frac{\rho_M L_M}{A_M} \times \frac{A_N}{\rho_N L_N} = \frac{L_M}{L_N} \times \frac{A_N}{A_M} = 8 \times 4 = 32$$

ratio = ... [2]

(ii) $\dfrac{\text{average drift speed of electrons in M}}{\text{average drift speed of electrons in N}}$.

$I = Anvq$, for same charge carriers and same material, $I \propto Av$

for same potential difference, $I \propto \dfrac{1}{R}$, so, $v \propto \dfrac{1}{AR}$

$$\frac{v_M}{v_N} = \frac{A_N R_N}{A_M R_M} = 4 \times \frac{1}{32} = 0.125$$

ratio = ... [2]

(b) A cell of electromotive force (e.m.f.) 1.5 V and internal resistance 1.0 Ω is connected to a resistor X and resistor Y as shown in Fig. 6.2.

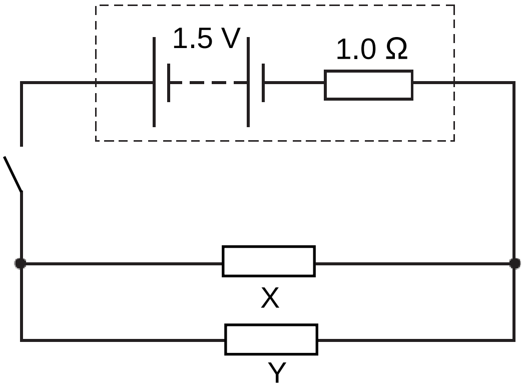


Fig. 6.2

Resistor X has resistance 2.0 Ω while resistor Y has a resistance of 6.0 Ω**.**

(i) Show that the current in the cell is 0.60 A when the switch is closed.

Total resistance, $R_T = 1.0 + \frac{1}{\frac{1}{2.0}+\frac{1}{6.0}} = 2.5\ \Omega$

E = I R_T

I = 1.5 / 2.5 = 0.60 A. (Shown)

[2]

(ii) Determine the energy dissipated in the cell when the switch is closed for 8.0 minutes.

Energy dissipated = I^2 r t = $(0.60)^2$ (1.0)(8.0 × 60) = 172.8 = 170 J

energy dissipated = ... J [1]

(iii) Resistor Y is replaced with a component Z with similar resistance value. When the temperature increases, the resistance of component Z decreases. State and explain the change to the power dissipated in the cell when temperature increases.

When temperature increased and resistance of Z decreases, the total current in the cell will increases. Thus, the power dissipated in the cell increases.

....[1]

(iv) The I-V characteristic of X and Z are given in Fig. 6.3.

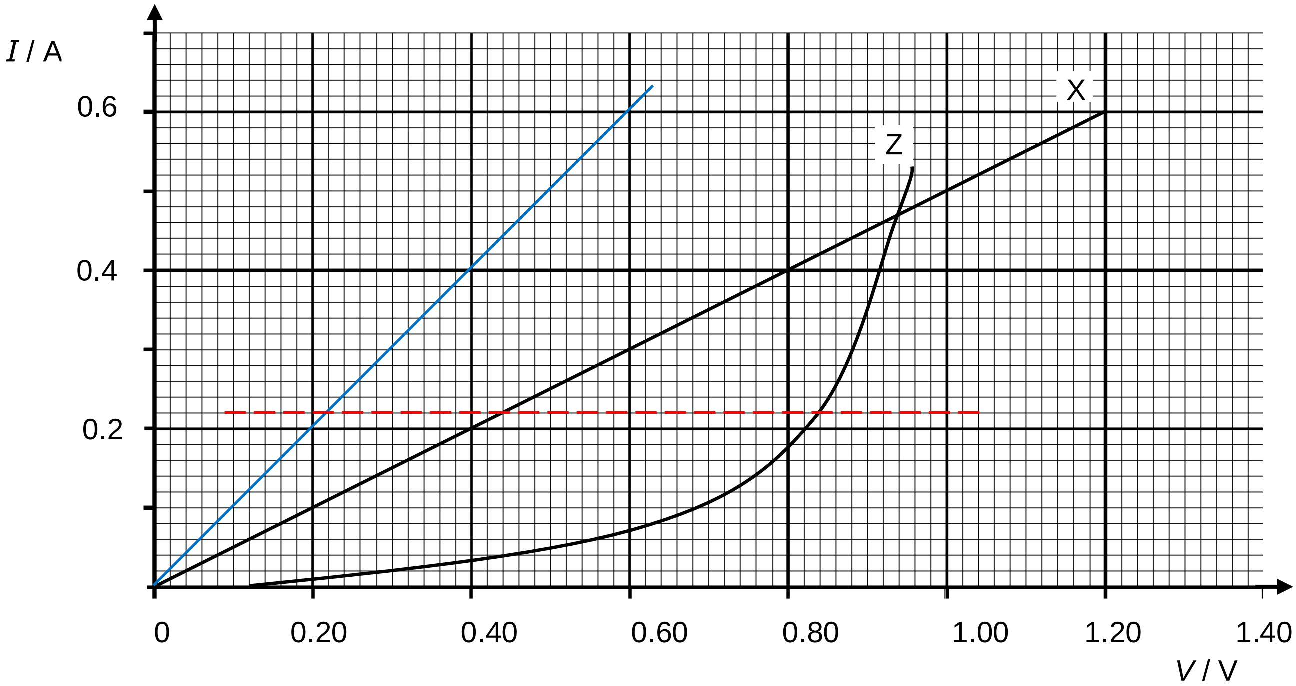


Fig. 6.3

The circuit is now reconnected such that resistor X and component Z are in series with the same cell. Using the Fig. 6.3, or otherwise, determine the potential difference across component Z.

Since the components are connected in series, the current passing through the components are the same, draw a line to find the total p.d. across equal to 1.5 V.

p.d across the X and 1.0 Ω is 0.66V, and p.d across Z is 0.84V

potential difference = ... V [2]

[Total: 10]

7 A magnet rotates inside a shaped soft iron core. A coil is wrapped around the iron core as shown in Fig. 7.1. The coil is connected to an oscilloscope.

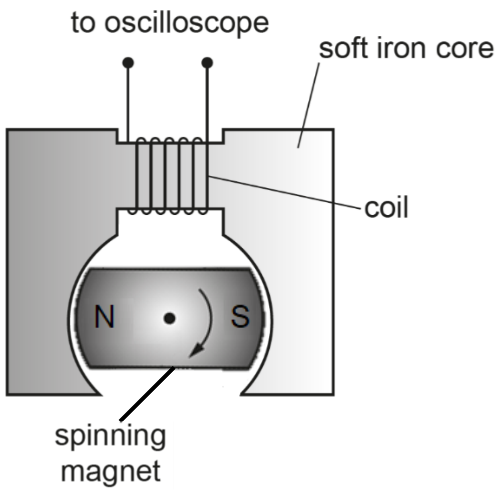


Fig. 7.1

The spinning magnet induces an e.m.f. in the coil.

(a) On Fig 7.2, sketch a graph of the variation of the e.m.f. induced in the coil against time. The variation of the induced magnetic flux linkage in the coil is shown as a dotted line. [1]

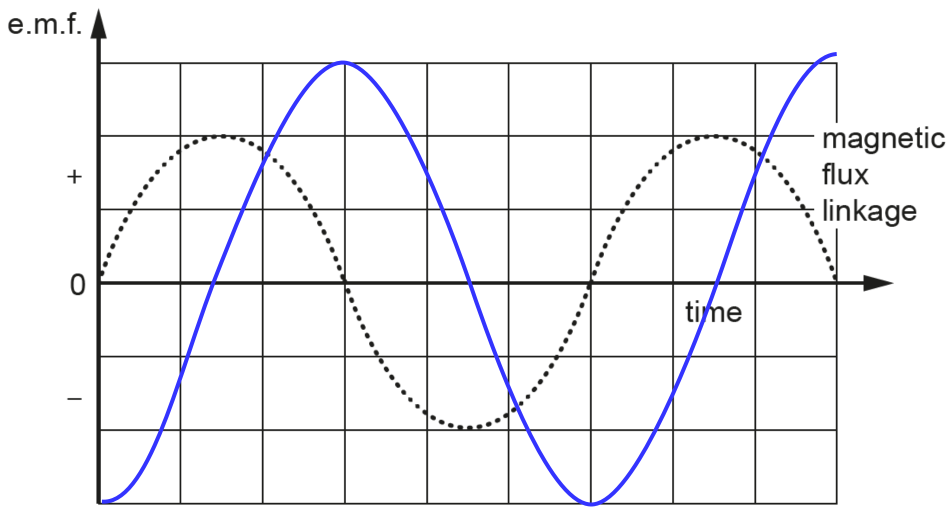


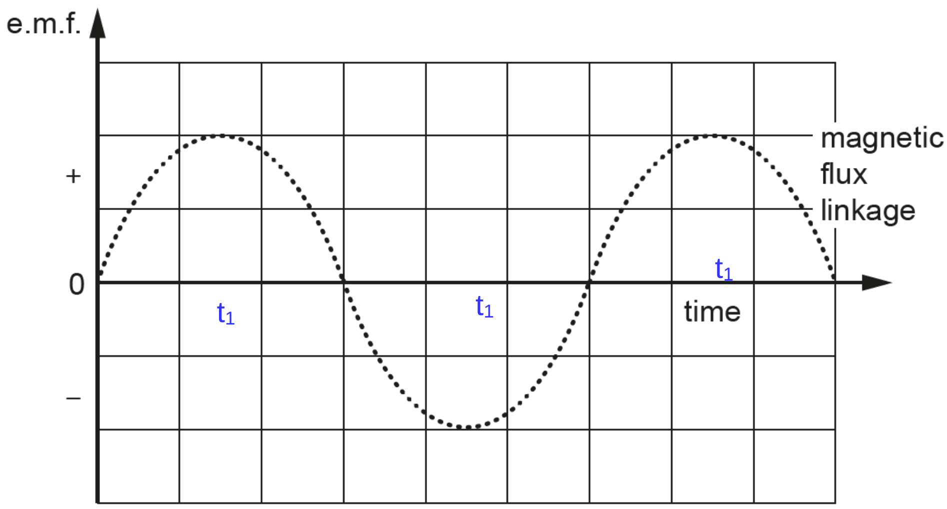
Fig. 7.2

[B1 for cosine or negative cosine curve]

(b) By considering the orientation of the magnet as it spins, explain the variation of the magnetic flux linkage in the coil with time.

1. *Explain maximum and minimum (zero):*
There is maximum flux linkage in the coil is when the magnet is horizontal (with respect to fig 7.1) because the lines of flux from the magnet are parallel with the axis of the coil, and min is when the magnet is vertical, because there are no flux lines through the coil. This variation repeats itself as the magnet continues to rotate.
2. *Explain increase and decrease:*
As the magnet rotates from a horizontal orientation (with respect to fig 7.1) to a vertical orientation, the flux linkage in the coil due to the magnet decreases and as it continues to rotate further to a horizontal orientation, the flux linkage in the coil due to the magnet increases. This variation repeats itself as the magnet continues to spin. [2]
3. *Explain positive and negative:*
When the magnet is in a horizontal orientation (with respect to fig 7.1) with the North pole on the left (with respect to fig 7.1) there is maximum flux linkage in the coil due to the magnet because the lines of flux from the magnet are parallel with the axis of the coil. When the coil has rotated by 180° to being horizontal with the North pole on the right, there is again maximum flux linkage in the coil due to the magnet, but this time it is in the opposite direction, so the magnetic flux linkage at this position has a negative sign compared to when the North pole was on the left. [B1 each for any two features].

(c) At a certain time t_1 the orientation of the spinning magnet is momentarily as shown in Fig 7.1. Mark the time t_1 on the time axis of fig 7.2. [1]



(d) The coil shown in Fig. 5.1 has 150 turns. The maximum induced e.m.f. Vo across the coil is 1.2V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum magnetic flux through the coil.

$\Phi = \Phi_o \sin\theta = \Phi_o \sin\omega t$
Using Faraday's Law
$E = d\Phi/dt = \Phi_o\, \omega \cos\omega t$
Maximum E occurs when $\cos\omega t = 1$
$E_{max} = \Phi_o\, \omega = (2 \times \pi \times f)\, \Phi_o$
$1.2 = (2 \times \pi \times 24)\, \Phi_o$
$\Phi_o = 5.3 \times 10^{-5}$ Wb

maximum flux = ... [2]

[Total: 6]

8 The range of frequencies which can be heard by different people varies, but most can hear sounds in the range 20 Hz to 20 kHz.

Loudness is the human mental response to the intensity of sound. For a sound frequency of 1 kHz, the lowest sound intensity which can be heard by normal healthy adult is 1.0×10^{-12} W m^{-2}. This intensity is known as the *threshold intensity* I_0 and any increase from this intensity will be perceived as an increase in the loudness of the sound.

The *intensity level* of a sound is a comparison of its intensity and the threshold intensity, and is given by

$$\text{Intensity Level} = 10 \lg \frac{I}{I_o}$$

where I is the intensity of the sound incident on the eardrums. The unit of intensity level is the *decibel* (dB).

Fig. 8.1 below shows the typical values of intensity levels for a sound frequency of 1 kHz from a variety of sources measured at various distances.

Source	distance from source / m	Intensity Level / dB
Jet engine at takeoff	30.0	140
Speakers at a rock concert	10.0	120
Diesel generator	3.0	100
Vacuum Cleaner	1.0	80
Normal conversation	1.0	60
Whispered conversation	1.0	30
Healthy hearing threshold	-	0

Fig. 8.1

For a sound frequency of 1 kHz, long term exposure to intensity levels above 90 dB may result in noise-induced deafness. The onset of pain in eardrums typically occurs at an intensity level of 120 dB while an intensity level of 160 dB will cause eardrums to rupture.

(a) The earphones attached to a portable music player can produce up to 0.30 μW of power. When the earphones are fitted to the ears, all the sound energy propagates through the auditory canal and is collected by the eardrums with an effective area 1.8×10^{-5} m^2.

For a sound of frequency 1 kHz,

(i) Calculate the intensity of the sound incident on the eardrums.

$$\text{Intensity} = \frac{\text{power}}{\text{area}}$$

$$= \frac{0.30 \times 10^{-6}}{1.8 \times 10^{-5}} \text{ [M1]}$$

$$= 0.0167 \text{ W m}^{-2} \text{ [A1]}$$

intensity = ... W m^{-2} [2]

(ii) Determine the intensity level of the sound incident on the eardrums.

$$\text{Intensity Level} = 10 \lg \frac{0.0167}{1.0 \times 10^{-12}}$$

$$= 102 \text{ dB [A1]}$$

intensity level = ... dB [1]

(iii) Using your answer obtained in **(a)(ii)**, comment on the use of the earphones at maximum power.

As the intensity level is greater than 90 dB, prolonged use of earphones at maximum volume will induce deafness. [B1]

.... [1]

(b) Show that if the intensity of sound is doubled, the change in intensity level is 3 dB. [2]

$$\Delta \text{ intensity level} = 10 \lg\left(\frac{2I}{I_0}\right) - 10 \lg\left(\frac{I}{I_0}\right) \text{ [M1]}$$

$$= 10 \lg\left(\frac{2I}{I_0} \times \frac{I_0}{I}\right)$$

$$= 10 \lg 2$$

$$= 3.01 \text{ [A1]}$$

(c) (i) Using data in Fig. 8.1, determine the sound power of the diesel generator. Assume that the sound is emitted uniformly in all directions

Intensity of sound $= 10^{10} I_0 = 1.0 \times 10^{-2}$ W m^{-2} [C1]

Sound power $= \left(1.0 \times 10^{-2}\right)\ 4\pi\left(3.0\right)^2$ [M1]

$= 1.13$W [A1]

sound power = ... W [3]

(ii) For occupational health and safety reasons, all personnel are required to wear ear protection if the intensity level at the ear exceeds 85 dB.

Determine the minimum distance from the diesel generator such that no ear protection is required.

Intensity of sound $= 10^{8.5} I_0 = 3.16 \times 10^{-4}$ W m^{-2}

Minimum distance $= \sqrt{\dfrac{1.13}{\left(4\pi\right)3.16 \times 10^{-4}}}$ [M1]

$= 16.9$ m [A1]

minimum distance = ... m [2]

The loudness of a sound not only depends on the intensity level of the sound but also on its frequency. The *phon* is the unit of measurement of *loudness level*. In order to define this unit of measurement, sound frequency of 1 kHz is chosen as the standard for comparison. Hence, a source is said to have a loudness of 40 phon if a 1 kHz standard source has an intensity level of 40 dB.

Sounds of different frequencies having the same loudness fall on the same equal-perceived-loudness contour. Fig. 8.2 shows different equal-perceived-loudness contours for a healthy 18-year-old man, as a function of frequency of the sound.

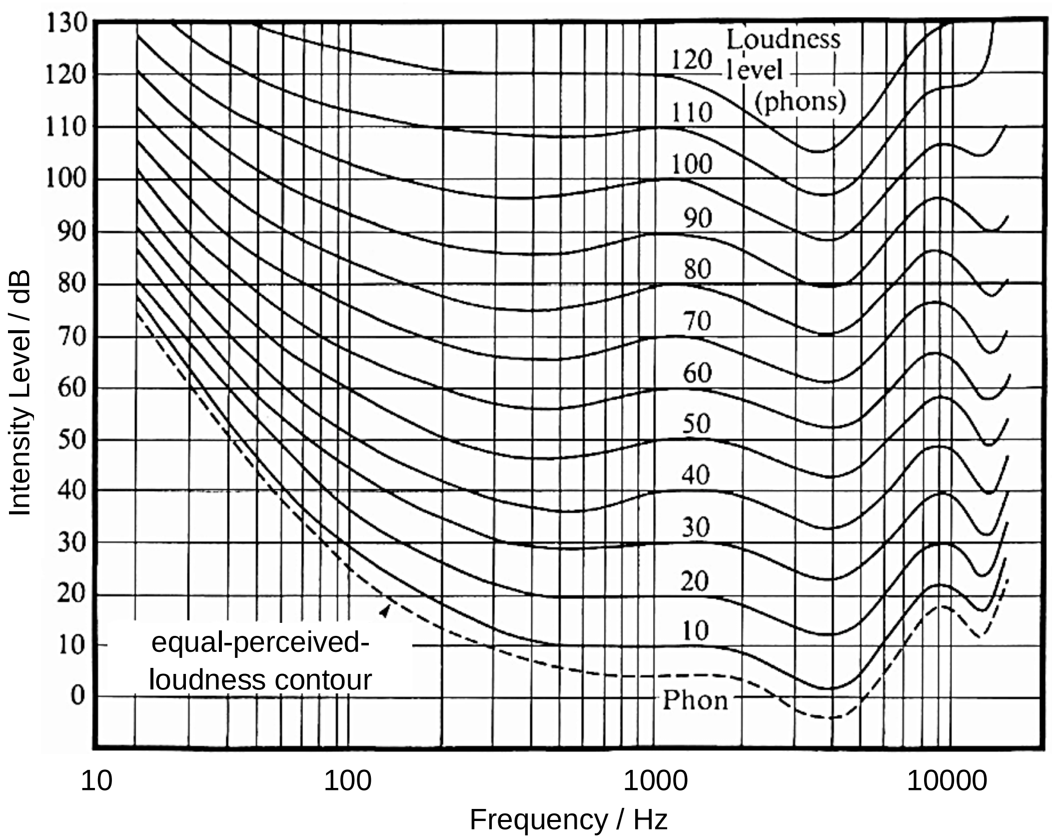


Fig. 8.2

(d) (i) The frequency axis on Fig. 8.2 is plotted on a logarithmic scale. Suggest why this is so.

This is to allow a large range (3 orders of magnitude) of frequencies to be compressed within the graph. [B1]

.... [1]

(ii) Using Fig. 8.2,

1. state the intensity level for a sound wave of 100 Hz for it to have the same perceived loudness as a sound wave of 1000 Hz at 50 dB.

intensity level = ...60 [A1] dB [1]

2. state and explain which of the following sounds louder:
a sound wave of 50 Hz at 60 dB, or
a sound wave of 2000 Hz at 45 dB

A sound wave of 50 Hz at 60 dB is less than 40 phons while a sound wave of 2000 Hz at 40 dB is more than 40 phons. [M1]

Hence the sound wave of 2000 Hz at 40 dB sounds louder. [A1]

.... [2]

(iii) Suggest and explain any changes in the equal-perceived-loudness contours for a 80-year-old man when compared to that for a healthy 18-year-old man.

A 80-year-old man will experience hearing loss and thus will require a higher intensity level for the same perceived loudness. [M1]

Thus, the equal-perceived-loudness contours will be higher / shifted up. [A1]

.... [2]

(e) **(i)** Using Fig. 8.2, state and explain the frequency range that a human will be most sensitive to.

The intensity level is the lowest in this range for the same (equal-perceived-loudness) contour. [M1]

3.5 kHz to 4 kHz [A1]

.... [2]

(ii) In movie theatres, sound of all frequencies may be heard with equal loudness. Suggest how this is achieved.

Sounds in the low and high frequency regions are amplified. [B1]

.... [1]

End of Paper