H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	

CENTRE NUMBER	S					INDEX NUMBER					

PHYSICS 9749/02

Paper 2 Structured Questions **16 September 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	/ 8
2	/ 8
3	/ 8
4	/ 10
5	/ 10
6	/ 10
7	/ 6
8	/ 20
Total	/ 80

This document consists of **23** 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	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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.

....

....[2]

(b) A hot air balloon is moving at a constant velocity of 11.7 m s^{-1}, at an angle of 59° from the horizontal, as shown in Fig. 1.1 below.

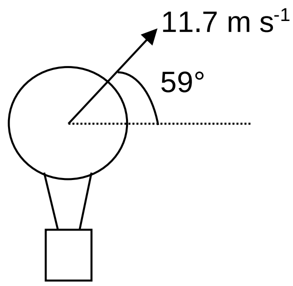

Fig. 1.1

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

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.

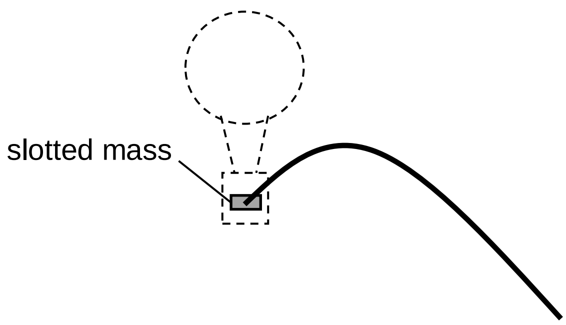

Fig. 1.2

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

....

....[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.

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.

....

....[1]

[Total: 8]

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

....

....

....

....[2]

(b) Fig. 2.1 shows a lamp weighing 5.0 N that is hung from the end of a beam 4.50 m long and weighing 1.0 N, making an angle of 25° below the horizontal.

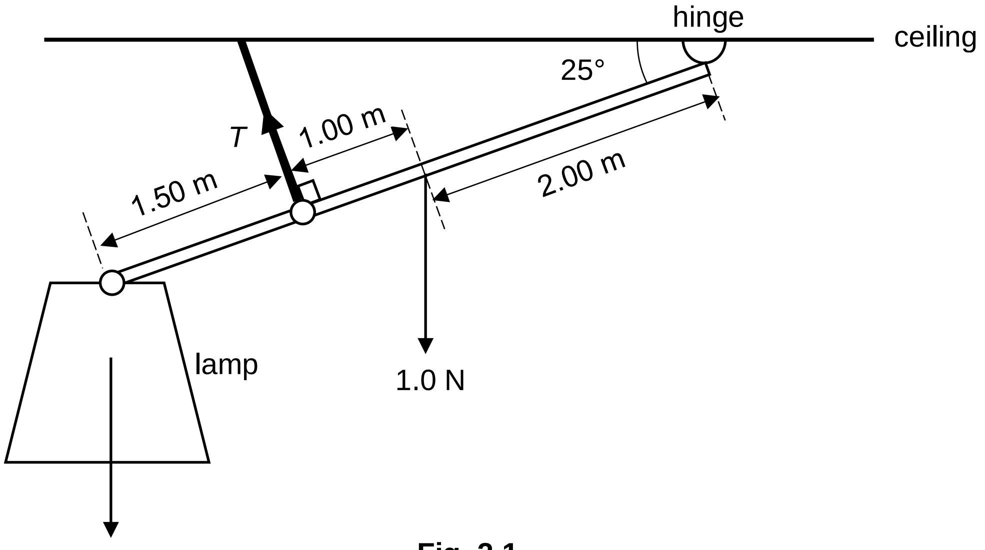

Fig. 2.1

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 along 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.

....

....

.... [1]

(ii) Show that the tension T in the cable is 7.4 N.

[2]

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

magnitude = ... N

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 $0.59g$.

[2]

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

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

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

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.

....

....

....

....[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.

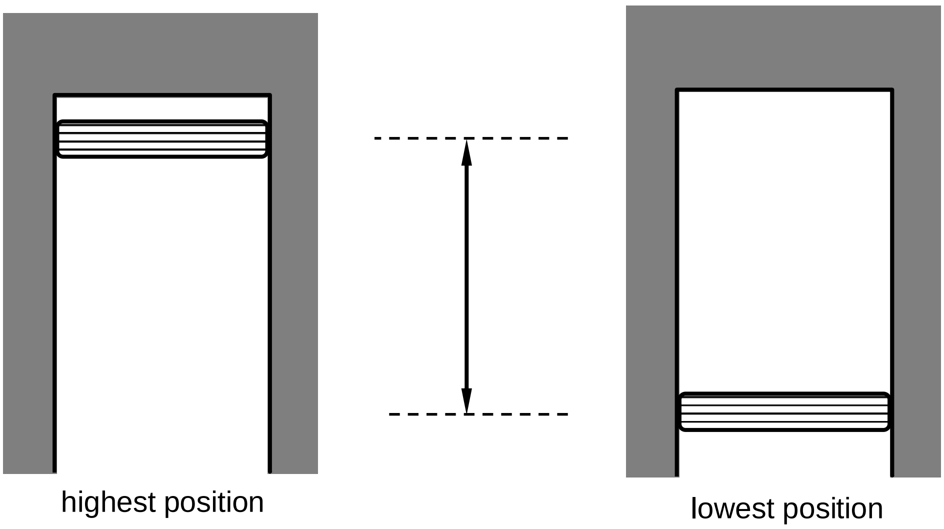

Fig. 4.1

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

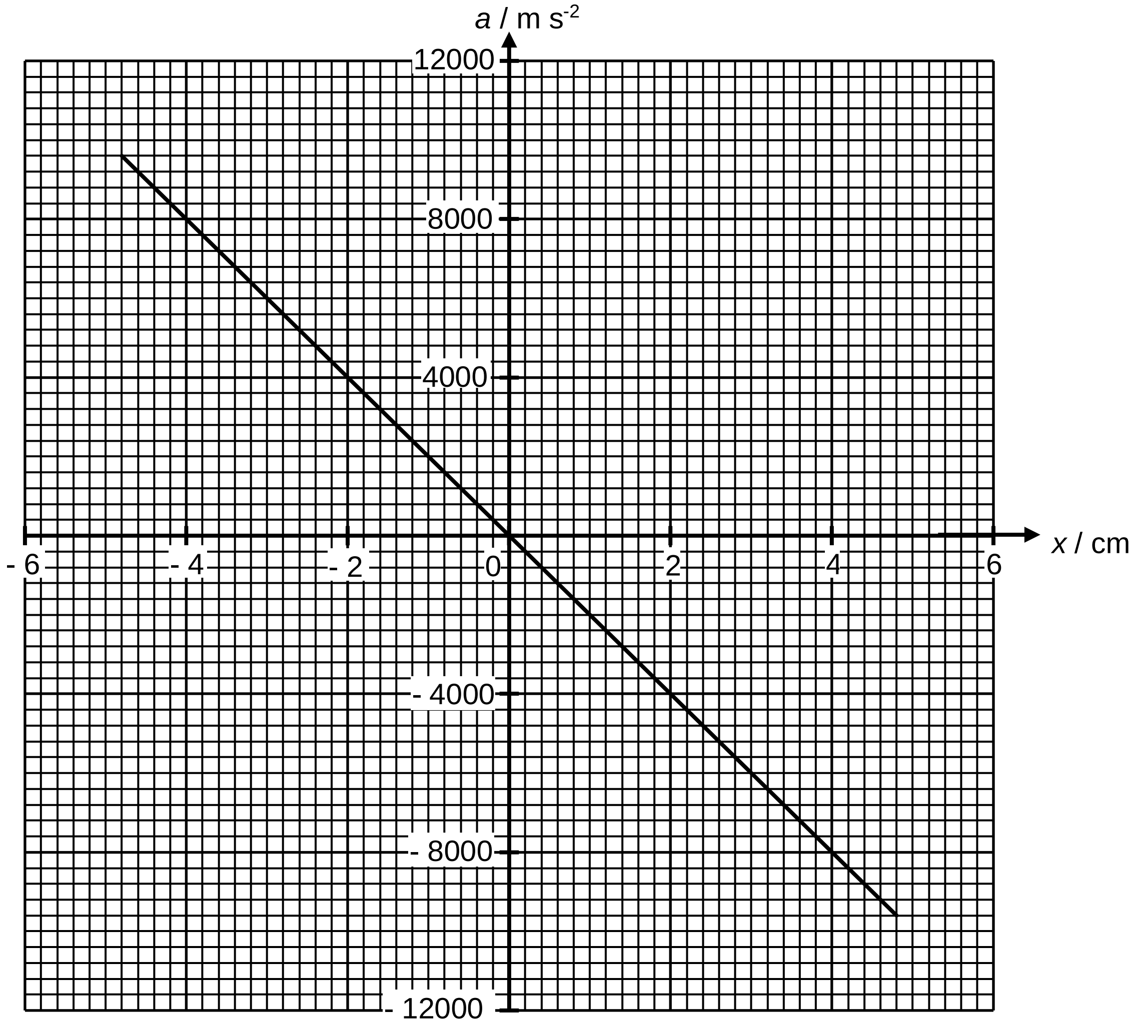

Fig. 4.2

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

....

....

....

....[2]

(b) Determine the maximum speed of the piston.

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.

....

....

....

....[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.

....

....

....

....[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.

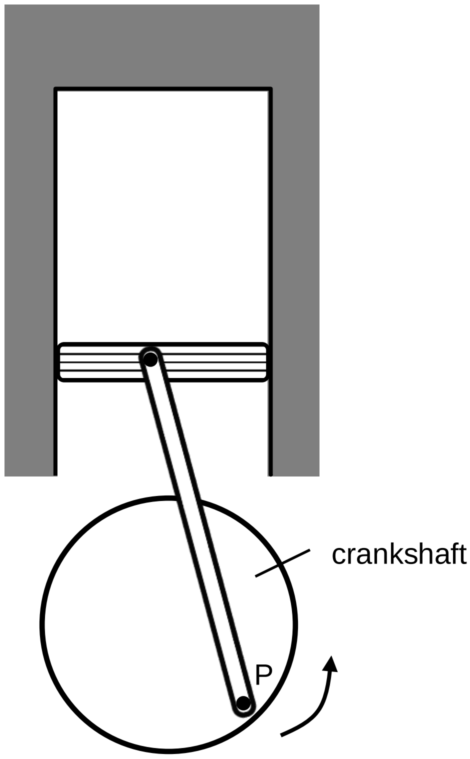

Fig. 4.3

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.

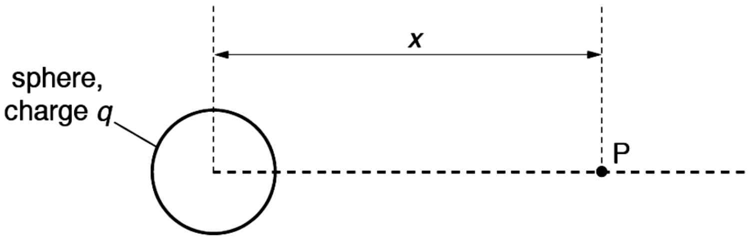

Fig. 5.1

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.

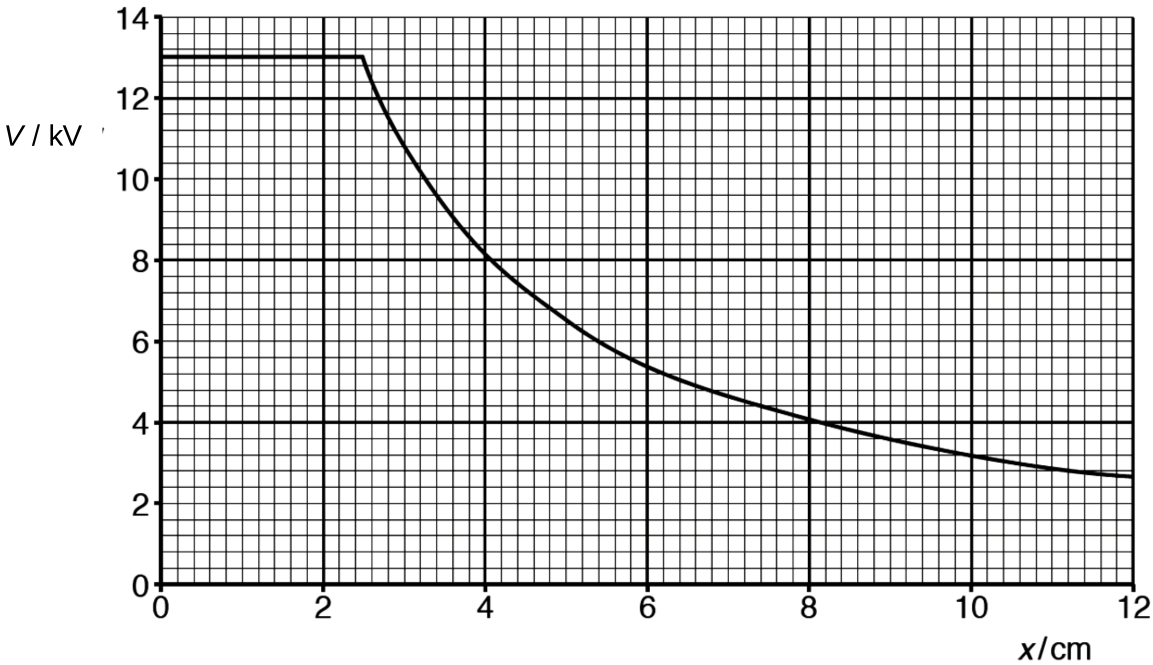

Fig. 5.2

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

....

....

....

....[2]

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

acceleration = ... 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.

....

....

....

....[2]

(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.

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.

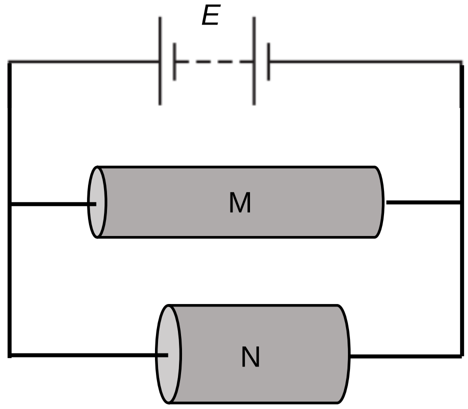

Fig. 6.1 (not to scale)

Determine the ratio

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

ratio = ... [2]

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

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.

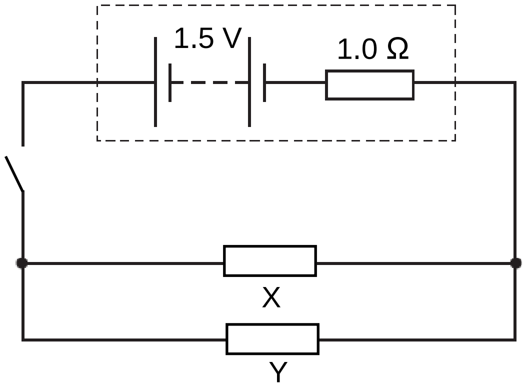

Fig. 6.2

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.

[2]

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

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.

....

....

....[1]

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

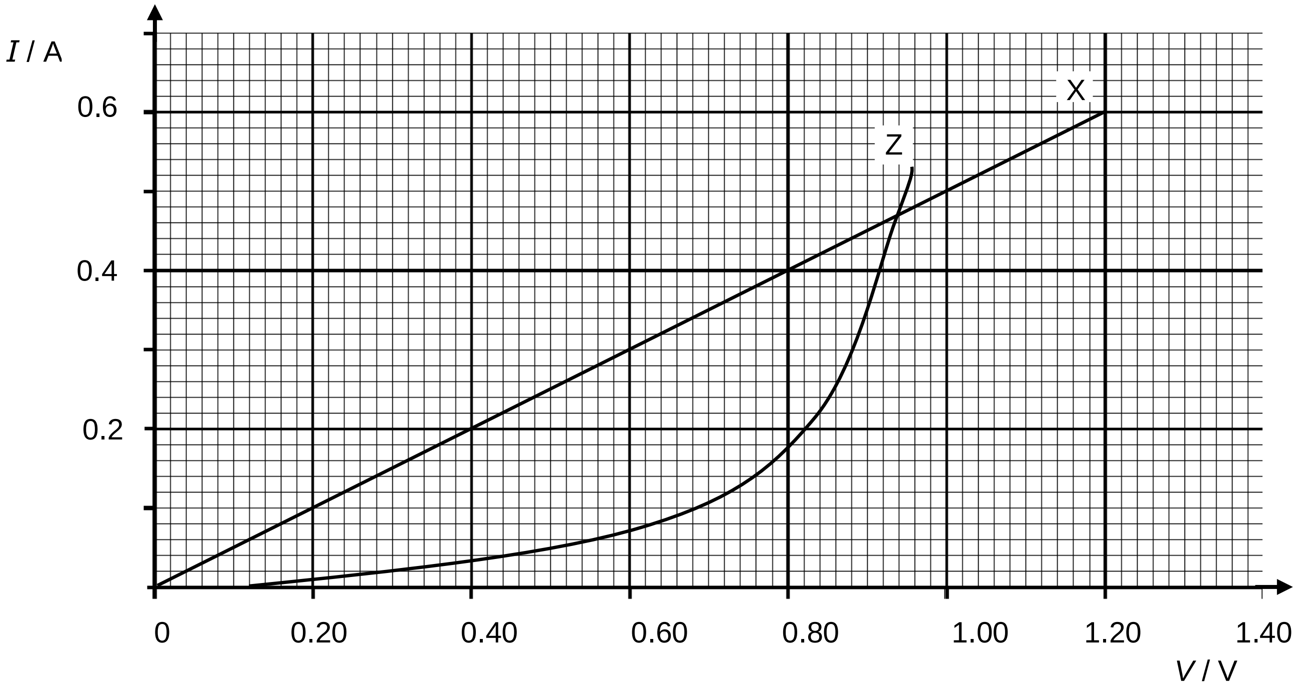

Fig. 6.3

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.

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.

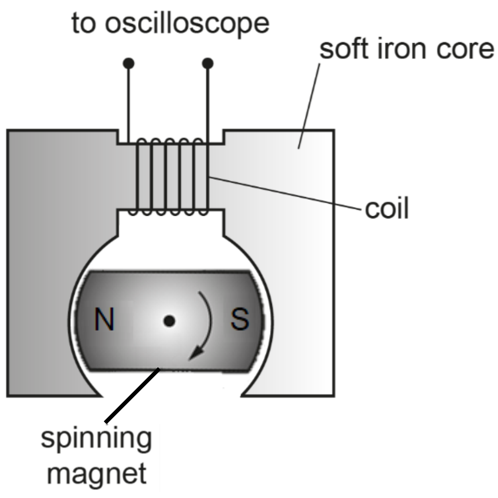

Fig. 7.1

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]

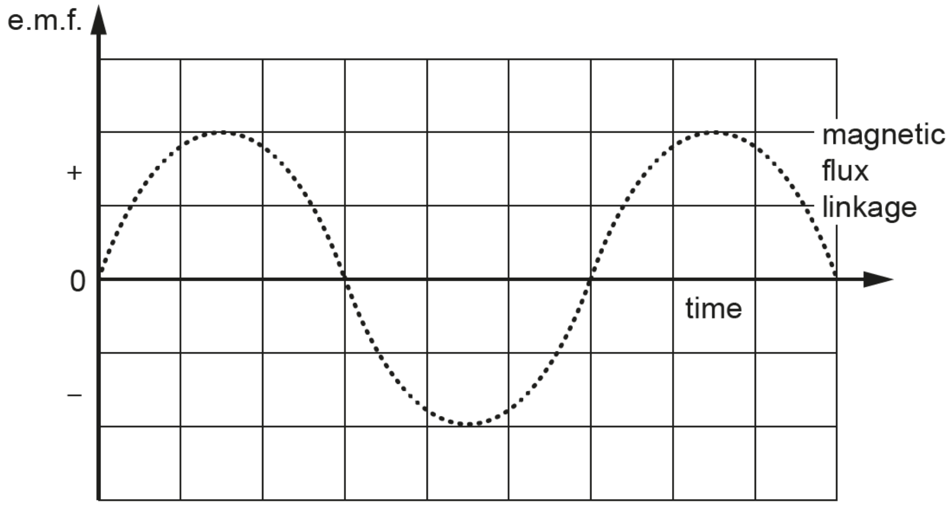

Fig. 7.2

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

....

....

....

....[2]

(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. 7.1 has 150 turns. The maximum induced e.m.f. V_0 across the coil is 1.2 V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum magnetic flux through the coil.

maximum magnetic flux = ... Wb [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.

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

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

intensity level = ... dB [1]

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

....

....

.... [1]

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

(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

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.

minimum distance = ... m [2]

Question 8 continues on the following page.

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.

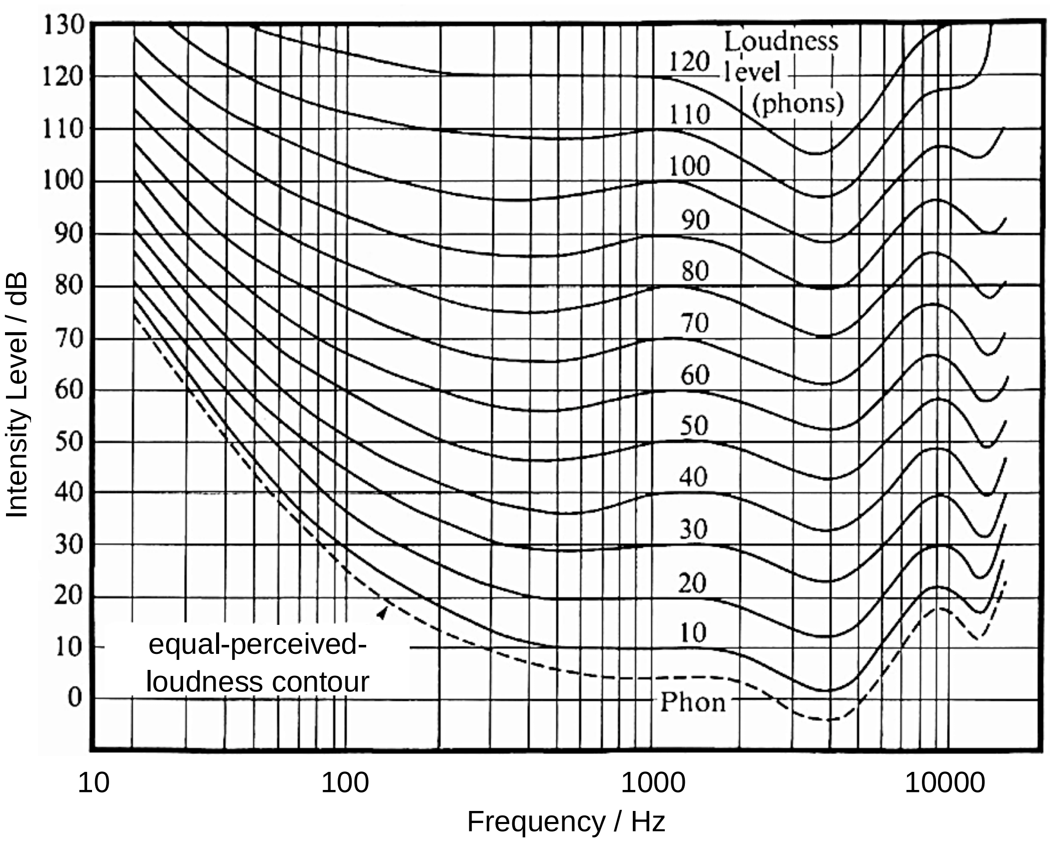

Fig. 8.2

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

....

....

.... [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 = ... 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

....

....

....

.... [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.

....

....

....

.... [2]

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

....

....

.... [2]

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

....

.... [1]

End of Paper