VICTORIA JUNIOR COLLEGE
2024 JC2 PRELIMINARY EXAMINATION
Higher 2

Name : ____________________________ CT group : _________________

PHYSICS

9749/02

Paper 2 Structured Questions

11 September 2024
WEDNESDAY

Candidates answer on the Question Paper.

8 am to 10 am (2 hours)

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces provided at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's use	
Question	**Mark**
1	
2	
3	
4	
5	
6	
7	
g	
Units	
s.f.	
Total	**/ 80**

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ 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 mol^{-1} K^{-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	$s = ut + (½)\, at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{GM}{r}$
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 gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
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	$V = \frac{Q}{4\pi\epsilon_0 r}$
alternating current/voltage	$x = x_o \sin \omega t$
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	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{1/2}}$

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

1(a) Define the terms *moment of a force* and *torque of a couple*. For each of the terms, draw a labelled sketch to illustrate the meaning of the terms. [4]

Moment of a force:

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Torque of a couple:

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(b) A 1500 kg truck is positioned on an incline that makes an angle of 40° with the horizontal, as shown in Fig. 1.1. The truck is held in place by a frictionless and massless pulley system connected to a counterweight of mass *m*. The smaller pulley at the top of the incline has a radius *r*, and the larger pulley has a radius of 3*r*. The two pulleys at the top are attached together so that they turn together as one. The incline is frictionless.

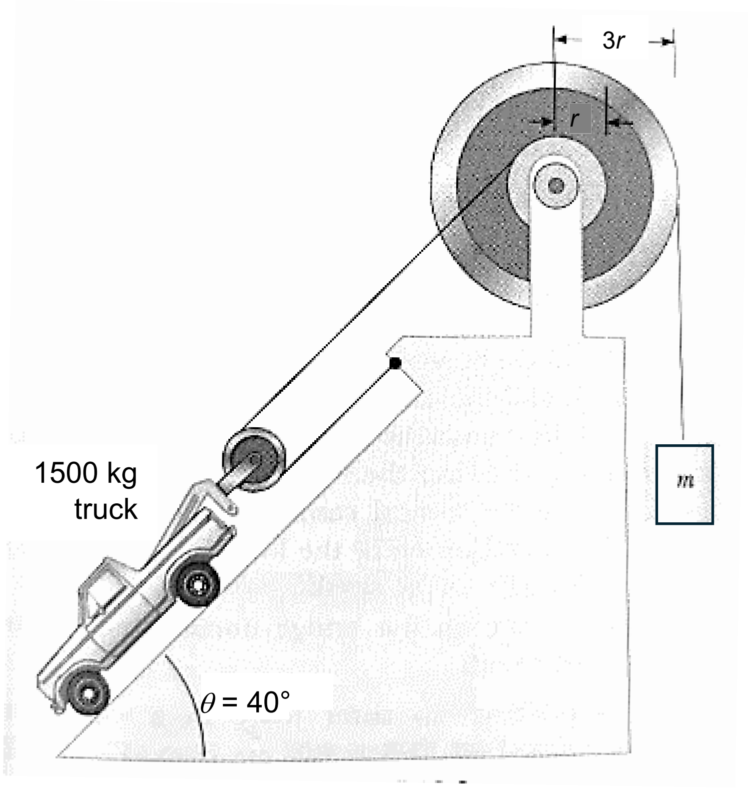

Fig. 1.1

(i) On Fig. 1.2, label all the forces exerted on the truck and the pulley attached to the back of the truck clearly. You do not need to include the internal forces acting between the pulley and the truck. [2]

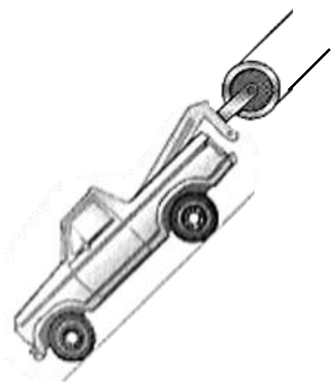

Fig. 1.2

(ii) Determine the mass *m* of the counterweight needed to balance the 1500 kg truck on the incline. [4]

Mass *m* = ...

2 Fig. 2.1 shows an object at rest at the top of a straight slope which makes a fixed angle with the horizontal at a distance *h* above the ground.

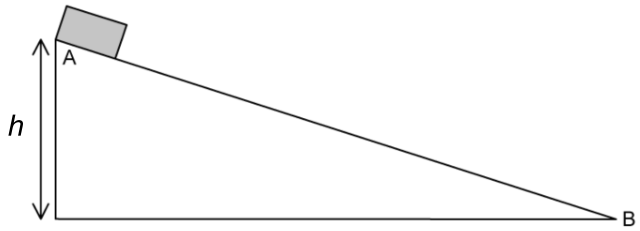

Fig. 2.1

The object is released and slides down the slope from A to B with negligible friction. Assume that the potential energy is zero at B.

(a) Sketch a graph in Fig 2.2 below, showing:
The variation of potential energy along the slope. Label this as P.
The variation of kinetic energy of the object along the slope. Label this as K. [2]

Fig. 2.2

(b) Sketch another graph in Fig 2.2, showing the variation of kinetic energy along the slope when there is a constant frictional force between the object and the surface. Label this F. Explain your graph. [3]

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3 The kinetic theory of gases deals with how molecular movement causes pressure to be exerted by a gas. The pressure of a gas is due to the elastic collision of the gas molecules with the walls of a container.

A single molecule of mass *m* is travelling with speed *u* directly towards a wall of a cubical box of sides *L* is as shown in Fig 3.1.

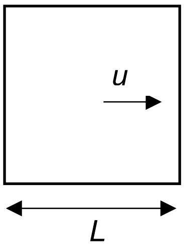

Fig 3.1

(a) Express the following in terms of *L*, *m* and *u*.

Momentum to the right before collision with wall = *mu*

Momentum immediately after an elastic collision = ...

Time between collisions with the same wall = ...

Number of collisions with this wall per unit time = ...

Rate of change of momentum of the molecule = ...

Average force on the wall due to the molecule = ... [5]

(b) The pressure *p* of an ideal gas which contains *N* molecules with different speeds in a container of volume *V* is given by

$$pV = \frac{1}{3}Nm < c^2 >$$

where $<c^2>$ is the mean square speed of the molecules.

(i) State the assumption regarding the type of collision between gas molecules. [1]

....

(ii) The deduction of the relationship stated in **(a)** does not involve collisions between the gas molecules. In practice, gas molecules will collide with one another.

Using your answer in **(b)(i)**, explain why the collision among the molecules do not have an impact on the pressure. [2]

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(c) Using the expression in **(b)** and the ideal gas equation, show that the average kinetic energy of an ideal gas molecule is proportional to the thermodynamic temperature *T*. [2]

(d) The first law of thermodynamics when applied to an ideal gas can be expressed as

$$\Delta U = Q + W$$

where ΔU is the increase in internal energy, Q is the heat supplied to the gas and W is work done on the gas.

(i) The gas undergoes a process from state A to state B in such a way that ΔU is 0 as shown in Fig 3.2.

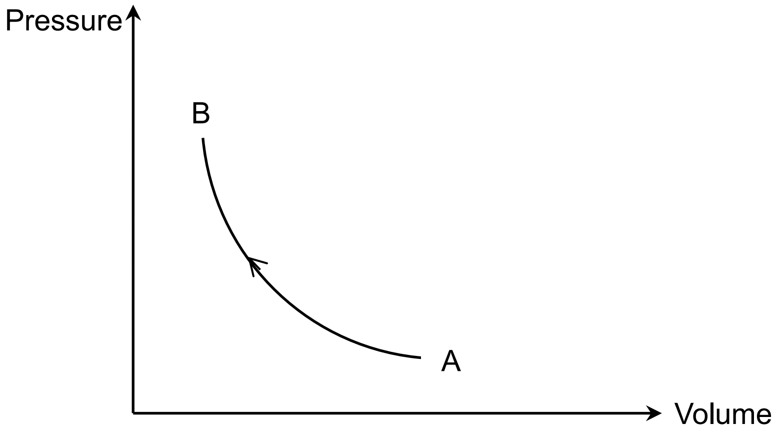

Fig 3.2

1. Shade in Fig 3.2 the area that numerically represents the heat exchange between the gas and its surroundings. [1]

2. State and explain the difference in the product of pressure and volume of the gas at both state A and state B. [2]

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(ii) The change in volume in **(d)(i)** takes place slowly. State and explain the changes to the mean square speed of the gas molecules if the change in volume takes place very quickly instead. [3]

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4 A test-tube is partially loaded with small ball bearings such that it is able to float upright in water of density ρ as shown in Fig 4.1. The bottom of the test-tube is a distance H below the water surface.

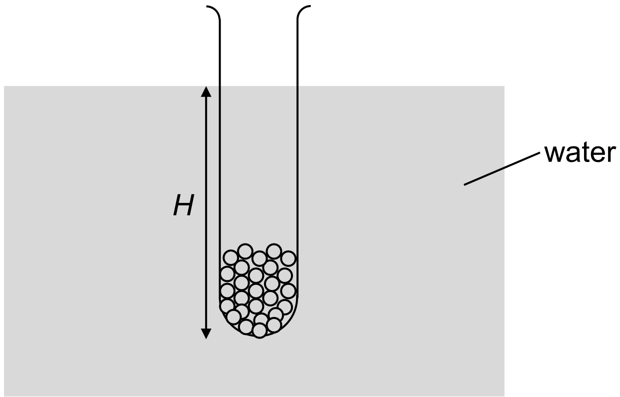

Fig 4.1

Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of cross sectional area A and mass m. The mass of the ball bearings added is M.

(a) Derive an expression that relates H to A, ρ, M and m. [2]

(b) The test-tube is displaced vertically by displacement y and then released. Ignoring dissipative forces, and by considering the net force acting on the loaded test tube, show that the acceleration of the test-tube is given by

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

where g is the acceleration of free fall. [2]

(c) It is given that $\rho = 1.00 \times 10^3$ kg m^{-3}

$A = 6.0 \times 10^{-4}$ m^2

$M = 0.012$ kg

$m = 0.025$ kg

Show that the period of oscillation of the test-tube is 0.50 s. [3]

In practice, it is observed that the variation with time *t* of the vertical displacement *y* of the test-tube is as shown in Fig 4.2.

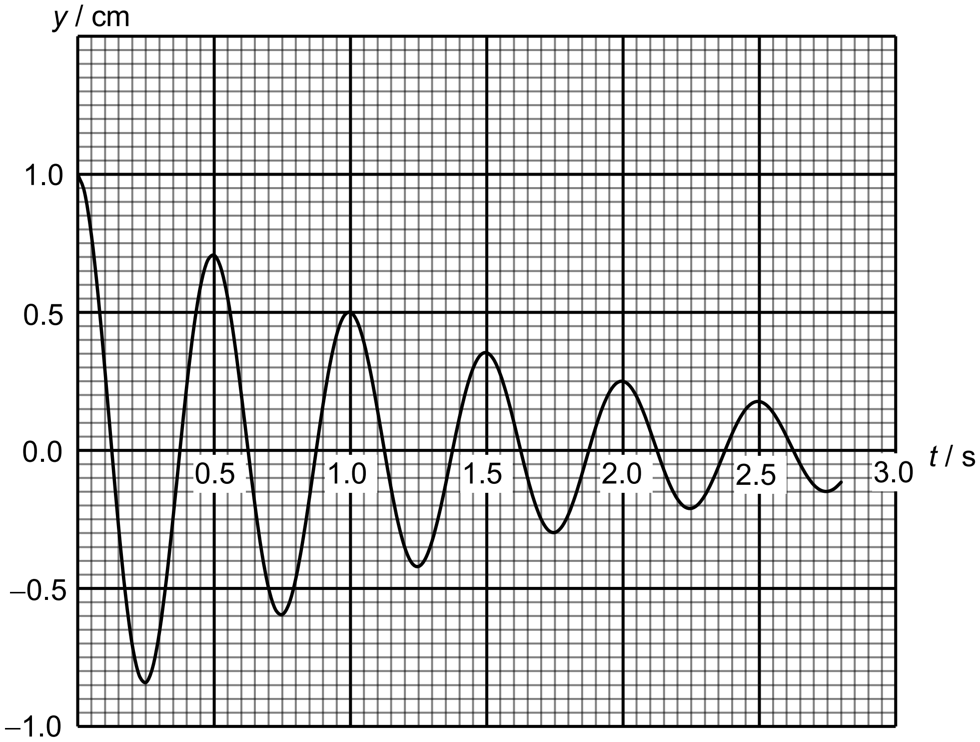

Fig. 4.2

(d) Explain why the amplitude of the oscillations decreases gradually over time. [1]

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(e) To sustain the oscillations of the test-tube, low-amplitude water waves of frequency 0.30 Hz are generated on the surface of the water.

(i) Sketch a graph to show the variation with time t of the vertical displacement y of the test-tube when it is oscillating steadily. Show appropriate numerical values on the time axis of the graph. [2]

(ii) It is observed that the amplitude of the vertical oscillations of this test-tube is rather small. Without changing the water waves, suggest with reasoning how the amplitude of the oscillations of this test-tube may be increased. [2]

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5(a) State Lenz's law of electromagnetic induction. [1]

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(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 5.1.

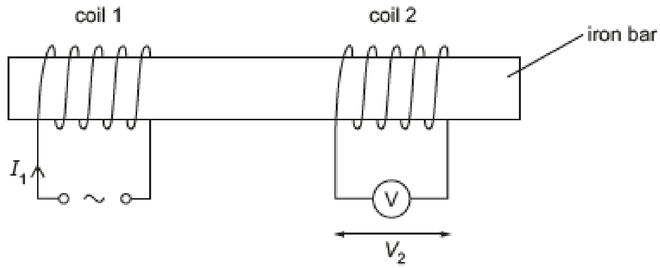

Fig. 5.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig.5.2.

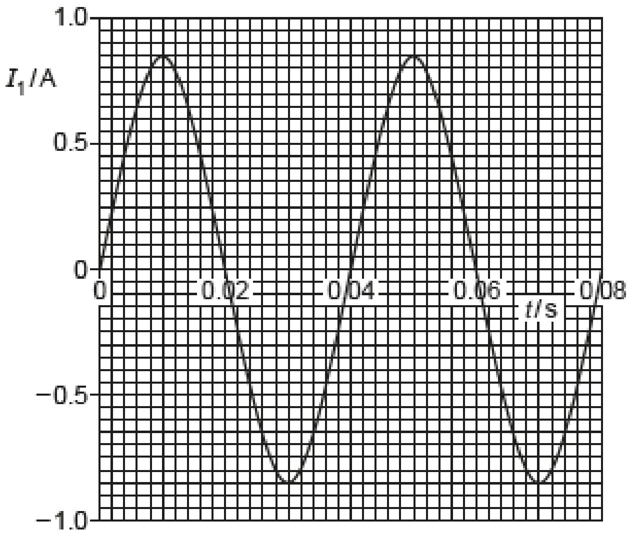

Fig. 5.2

(i) The variation with t of I_1 can be represented by the equation

$I_1 = X \sin Yt,$ where X and Y are constants.

Use Fig. 5.2 to determine the values of X and Y. Give units with your answers. [3]

X = ……………………….

Y = ……………………….

(ii) The current in coil 1 gives rise to a magnetic field in the iron bar.
Assume that the flux density of this magnetic field is proportional to I_1.
An alternating electromotive force (e.m.f.) is induced across coil 2. The p.d. across coil 2 is measured using the voltmeter and has a root-mean-square (r.m.s.) value of 4.6 V.

On Fig. 5.3, sketch a line to show the variation with t of V_2 between t = 0 and t = 0.08 s. [3]

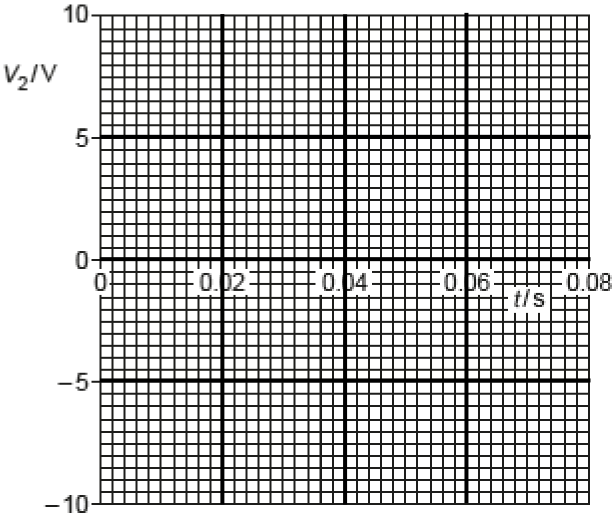

Fig. 5.3

(iii) Use the laws of electromagnetic induction to explain the shape of your line in (b)(ii). [3]

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6(a) The graph in Fig 6.1 shows the spectrum of the visible light coming from a bright star. These lines correspond to the Balmer series for hydrogen gas which are transitions from higher energy levels to level $n = 2$.

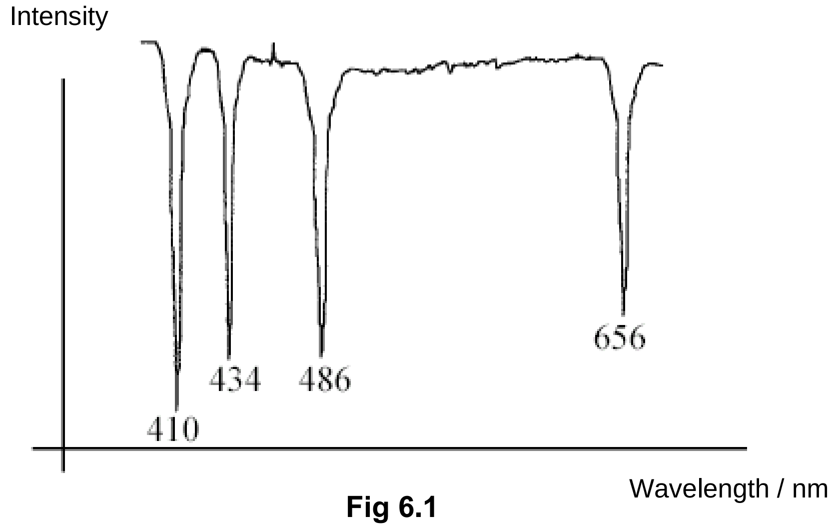

Fig 6.1

(i) State and explain the type of spectrum shown in Fig. 6.1 [2]

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(ii) Given that the energy of level $n = 2$ is -5.44×10^{-19} J, calculate the energy in eV of level $n = 3$, E_3. [3]

E_3 = ………………………… eV

(b) Ultra-violet radiation of wavelength 184 nm is shone on a cathode within a vacuum tube as shown in Fig 6.2 and photoelectrons are observed to be emitted.

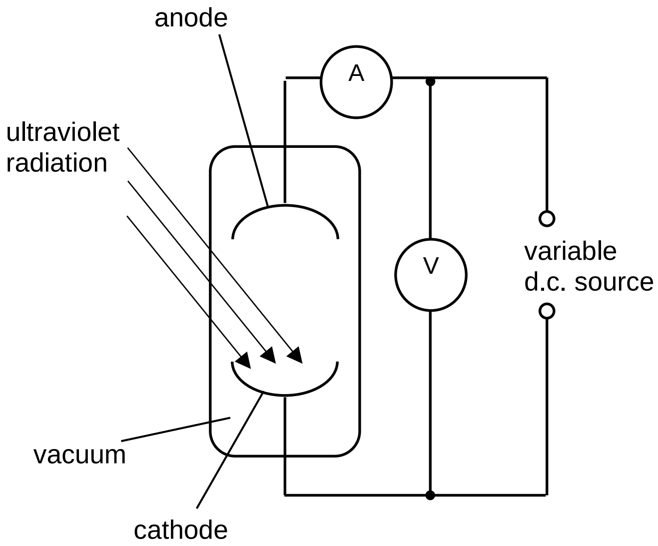

Fig 6.2

The potential difference across the cathode and anode is varied and the corresponding value of the current is measured with the ammeter. Fig 6.3 shows the relationship between these two quantities.

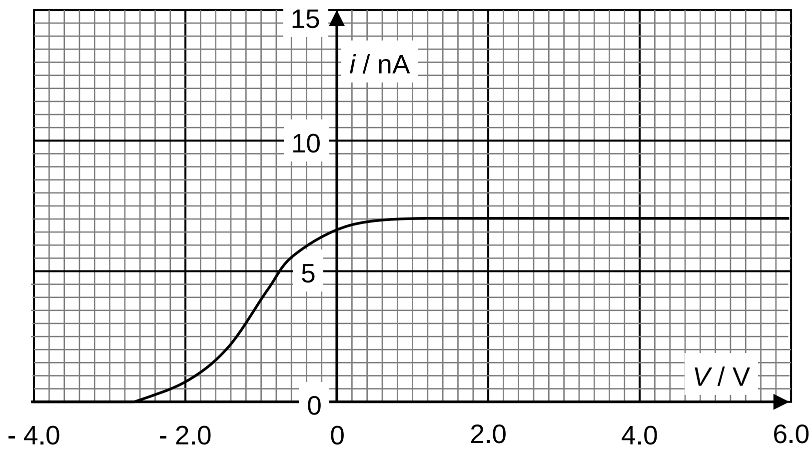

Fig 6.3

(i) The presence of a threshold frequency is an evidence for the particulate nature of electromagnetic radiation.

Explain why the wave nature of electromagnetic radiation does not support this observation. [2]

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(ii) Determine the work function in joules of the cathode. [3]

Work function = ………………………….. J

(iii) The cathode is replaced with a metal with **lower** work function.
Sketch, on Fig. 6.3, the new *i*-*V* graph. [1]

7 An **earthquake** is the perceptible shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's crust. This sudden motion causes shock waves (seismic waves) to radiate from their point of origin called the focus and travel through the Earth. It is these seismic waves that can produce ground motion which people call an earthquake.

Vibrations from an earthquake are categorised as P, S or L seismic waves. They travel through the Earth in different ways and at different speeds. They can be detected and analysed.

P-waves (P stands for **primary**) arrive at the detector first. They are *longitudinal waves*. These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves.

S-waves (S stands for **secondary**) arrive at the detector of a seismometer seconds later. They are *transverse waves*. S-waves can travel only through solids.

L-waves (L stands for **long**) are the slowest, travel over the surface and causes the most damage.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with depth and rock type. P waves travel between 6.0 and 13 km s^{-1} and S waves are slower and travel between 3.5 and 7.5 km s^{-1}.

In earthquake seismology, the time interval between the first arrivals of transverse (S) and longitudinal (P) waves, is proportional to the distance from the earthquake source.

In order to locate the epicenter of an earthquake you will need to examine its seismograms as recorded by at least three different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). The S - P time interval will then be used to determine the distance the waves have traveled from the epicenter to that station.

(a) Distinguish between longitudinal and transverse waves. [2]

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(b) **Fig. 7.1** shows a structure of the Earth's interior and regions where P or S-waves may not be detected.

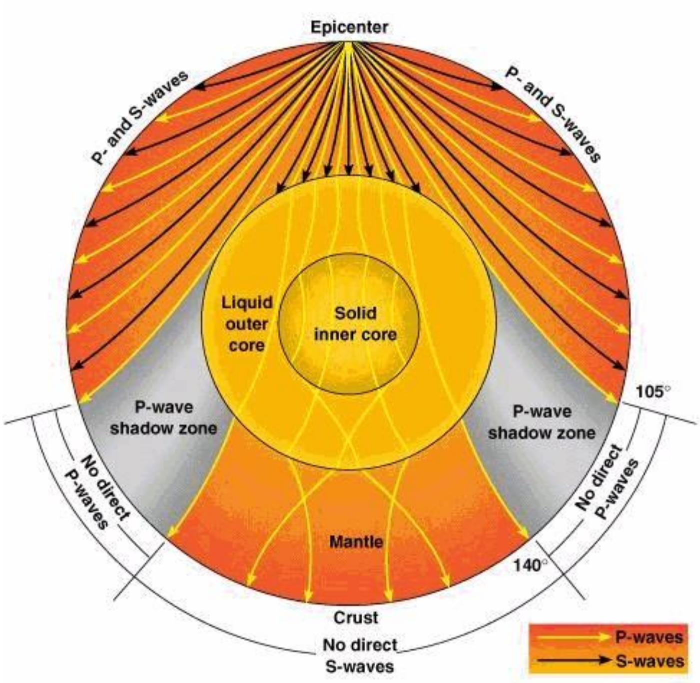

Fig. 7.1

Explain why no S-waves are detected directly opposite the epicenter. [1]

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(c) Fig. 7.2 shows the variation with distance (in kilometers) from the epicenter of the time (in seconds) taken for the S and P waves to reach the seismic station from the epicenter.

Fig 7.3 shows three seismographs from **Akita, Pusan and Tokyo Seismic Stations** of the earthquake that occurred in 1995, in the Kansai area of Japan near Kobe, called the Kobe earthquake. This earthquake took place near major population centers and caused significant loss of life and property damage.

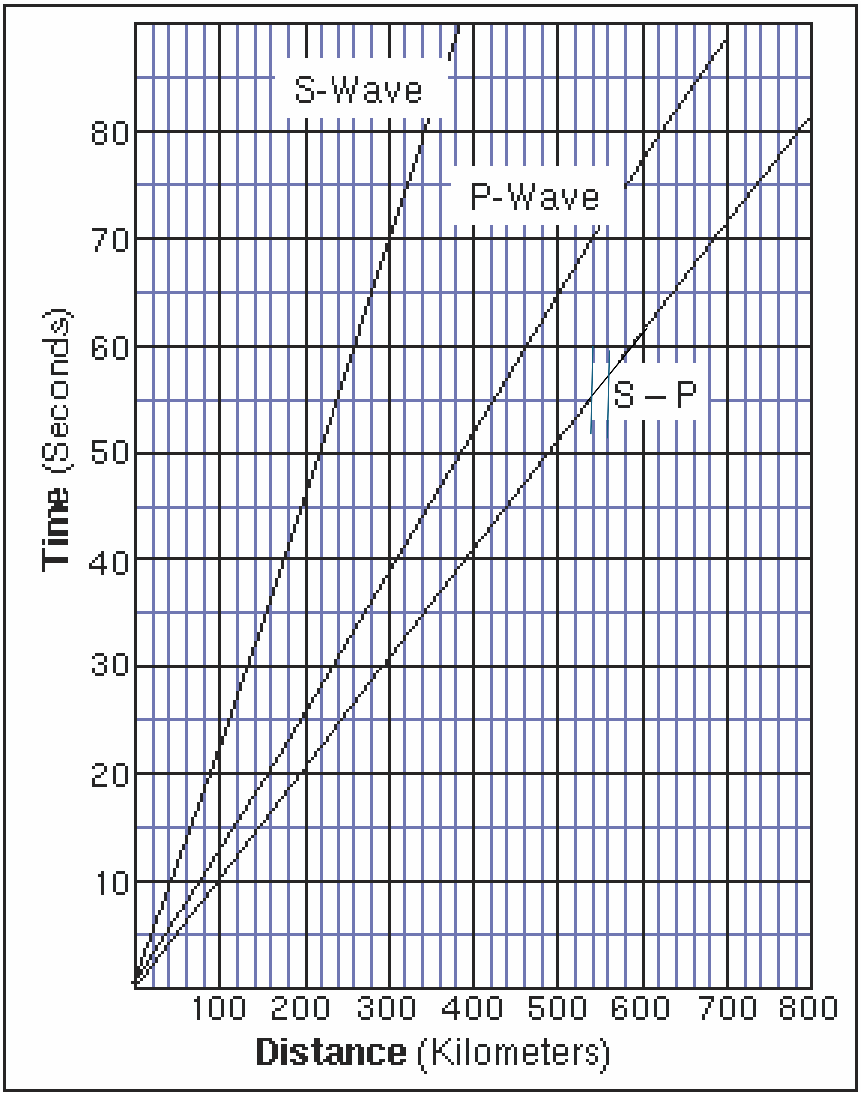
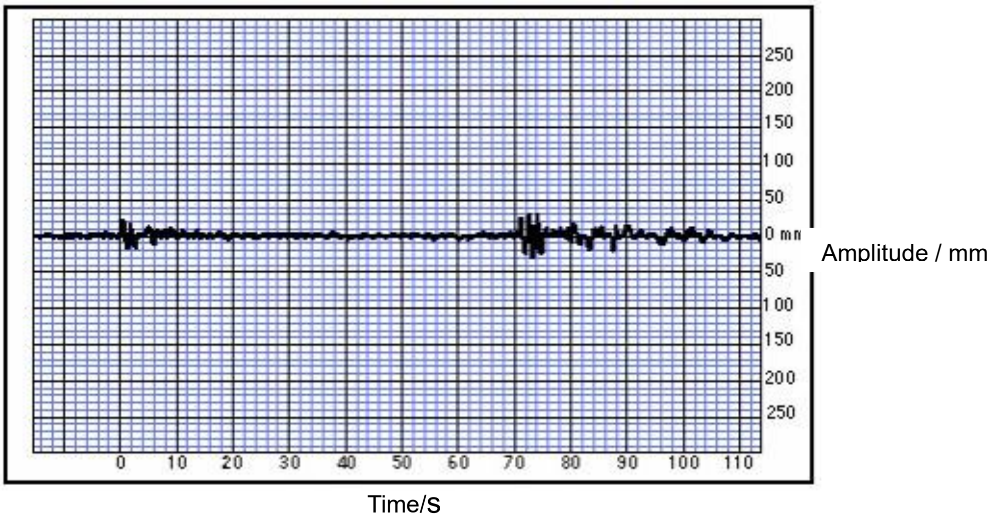
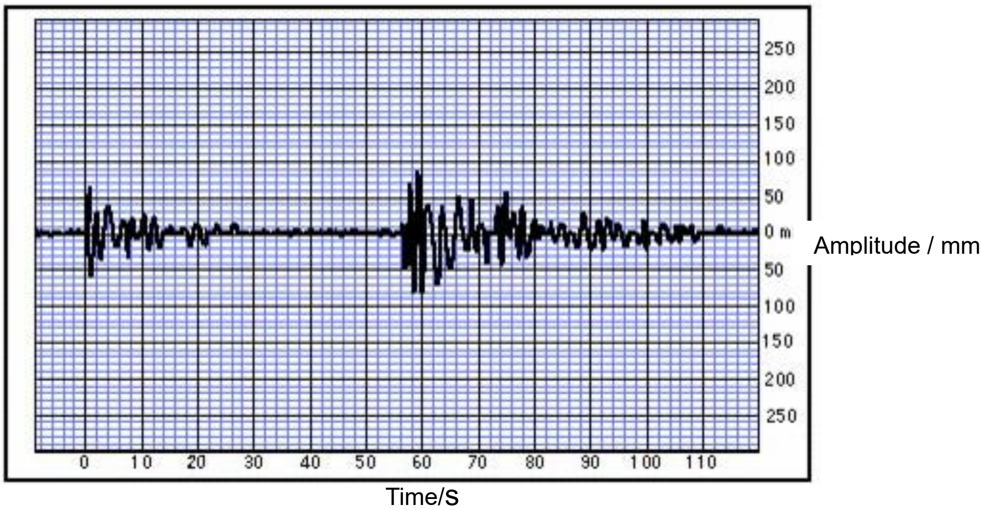


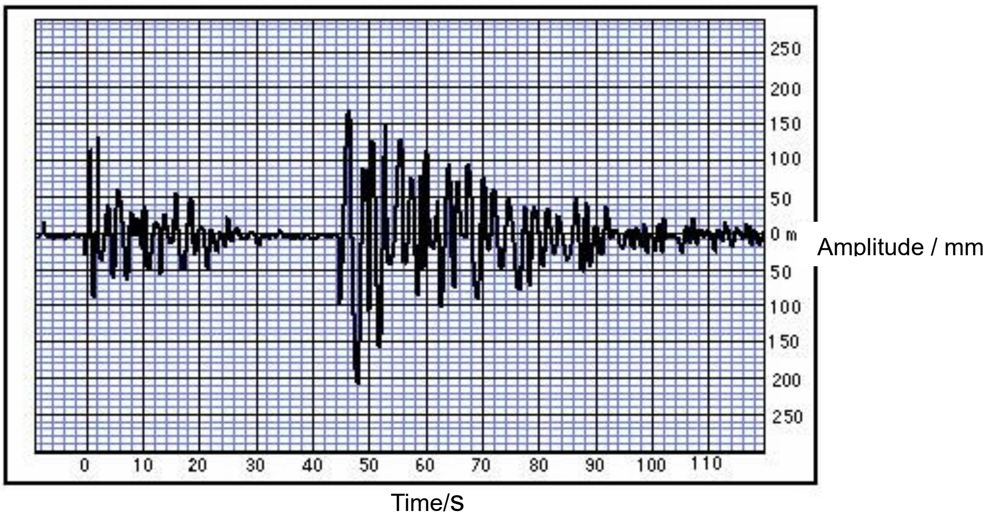
Fig. 7.2
(Source: http://engineeringseismologywithmearul.blogspot.sg/)



Akita Seismic Station



Pusan Seismic Station



Tokyo Seismic Station

Fig 7.3 Seismograms from Akita, Pusan and Tokyo Stations
(Source: http://www.geo.umass.edu)

(i) Using the data given in Fig. 7.2 and Fig. 7.3, complete Fig. 7.4 [3]

SEISMOGRAPH STATION	Difference in Arrival Time between P and S waves / s	Distance to Epicenter / km	Amplitude of the S wave /mm
AKITA	71	695	
PUSAN			90
TOKYO	44		

Fig. 7.4

(ii) Hence determine the approximate location of the epicenter of the earthquake on the location map in Fig. 7.5. Label your location "**X**". [3]

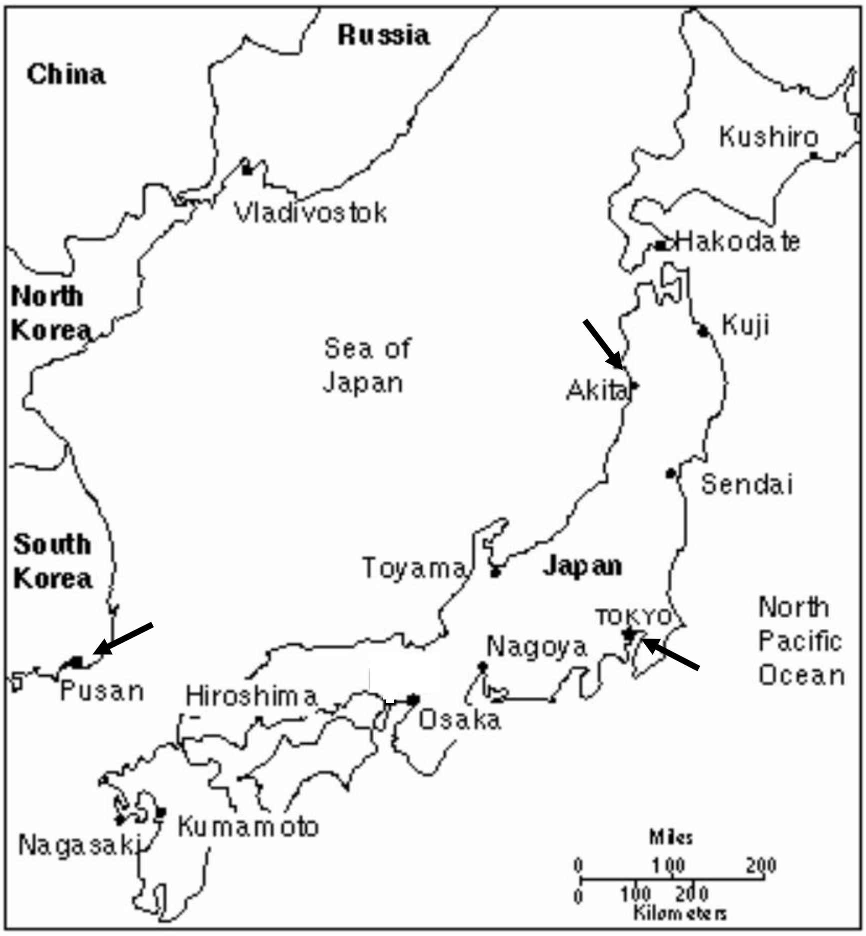


Fig. 7.5

(iii) The intensity of an earthquake on the Richter scale can be easily determined using a nomogram as shown in Fig. 7.6

For each station, connecting the distance on the Distance scale and the amplitude on the Amplitude scale with a straight line, the intersection on the Magnitude scale is the Richter scale reading for the earthquake.

If distance of the station from the earthquake's epicenter is 100 km and amplitude of the earthquake recorded at the station is 1 mm, the magnitude of the earthquake is 3.0 on the Richter scale, as shown in the sample line drawn in Fig. 7.6.

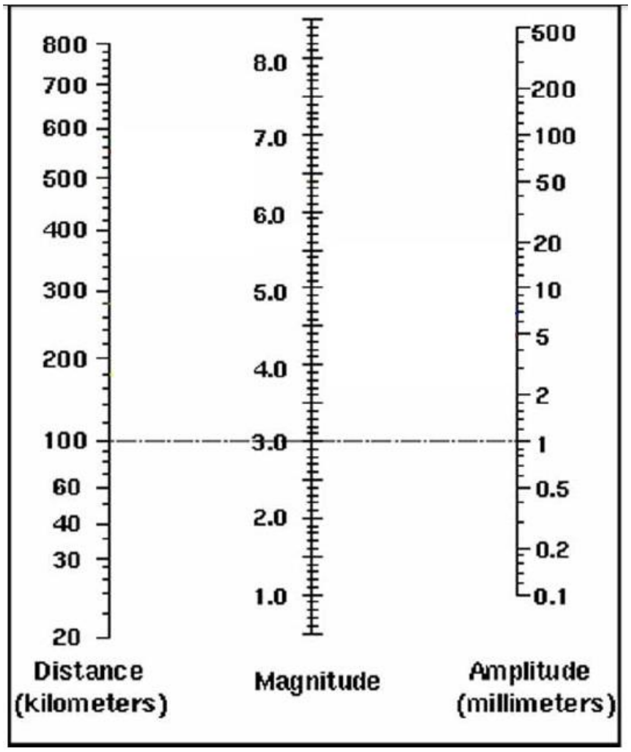


Fig 7.6

1. State one other factor that may affect the amplitude of the S-wave recorded besides the intensity of the Earthquake. [1]

……………………………………………………………………………………

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2. Using your answers from Fig. 7.4 and the nomogram in Fig 7.6, construct and determine the magnitude of the earthquake on the Richter scale. [2]

Magnitude = ……………………..

(d) The Richter magnitude scale used in (c) was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. The magnitude of an earthquake on a Richter Scale M is related to the intensity (I) of the S-wave according to the equation

$$M = \log\left(\frac{I}{I_o}\right)$$

where I_o is a reference intensity.

The amount of energy radiated by an earthquake is a measure of the potential for damage to man-made structures. The Richter magnitude M, is related to the energy released E in ergs (1 erg = 10^{-7} J) through the equation

$$\log E = 1.5\,M + 4.8$$

(i) On 26 Dec 2004, an underwater 9.0-magnitude earthquake off the coast of Aceh, Indonesia, sent giant tidal waves into coastal areas in Indonesia, Thailand, Malaysia, Sri Lanka, Bangladesh, India, Myanmar, the Maldives and Somalia, resulting in at least 159 000 people dead. This is known as the great Sumatra Earthquake

1. Determine the ratio of the intensity of the Sumatra Earthquake to the Kobe Earthquake [1]

Ratio = …………………….

2. Hence explain why we use the Richter scale, which is a logarithmic scale, instead of just a normal scale based on the intensity *I*. [1]

(ii) Determine the ratio of the energy released from the Sumatra Earthquake to the Kobe Earthquake.

Ratio = …………………… [1]

(e) The death toll in the 2015 Chile Illapel Earthquake with magnitude 8.3 was 14 whereas that from the 2015 Nepal Earthquake with magnitude 7.8 was almost 9000.

Suggest a possible reason why higher magnitude earthquakes may not always lead to higher death tolls. [1]

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End of paper