1 **(a)** The intensity of a progressive wave is defined as the average power transmitted through a surface per unit area.

Show that the SI base units of intensity are $kg\,s^{-3}$.

[2]

(b) **(i)** The intensity I of a sound wave is related to the amplitude x_0 of the wave by

$$I = K\rho c f^2 x_0^{\,2}$$

where ρ is the density of the medium through which the sound is passing,
c is the speed of the sound wave,
f is the frequency of the sound wave
and K is a constant.

Show that K has no units.

[2]

(ii) Calculate the intensity, in $pW\,m^{-2}$, of a sound wave where

$K = 20$,
$\rho = 1.2$ in SI base units,
$c = 330$ in SI base units,
$f = 260$ in SI base units
and $x_0 = 0.24\,nm$.

intensity = ... $pW\,m^{-2}$ [3]

2 A signal generator is connected to two loudspeakers L_1 and L_2, as shown in Fig. 2.1.

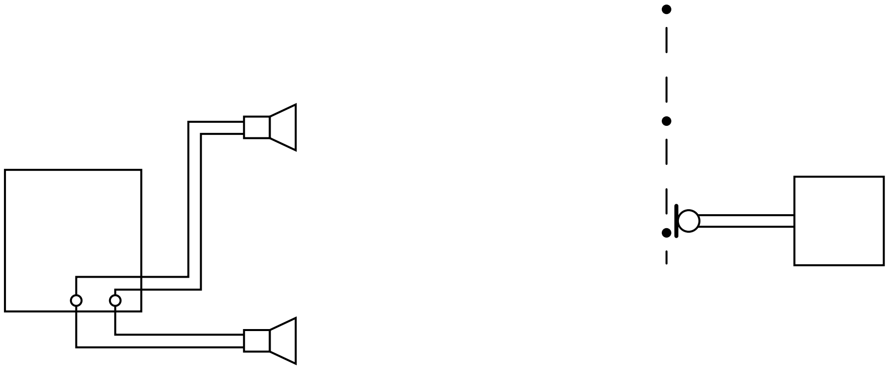
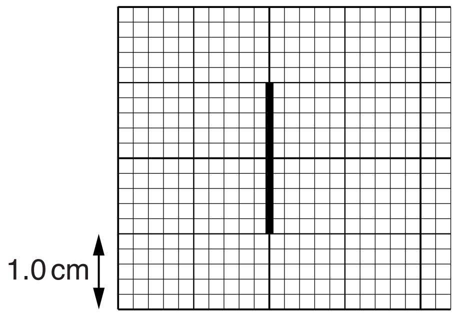


Fig. 2.1

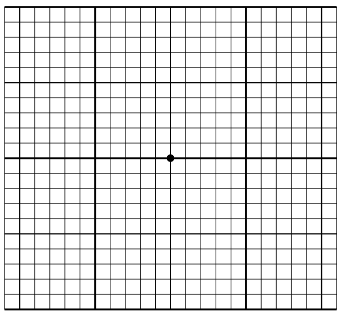
A microphone M, connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.), detects the intensity of sound along the line ABC.
The distances L_1A and L_2A are equal.
The time-base of the c.r.o. is switched off.

The traces on the c.r.o. when M is at A, then at B and then at C are shown on Fig. 2.2, Fig. 2.3 and Fig. 2.4 respectively.



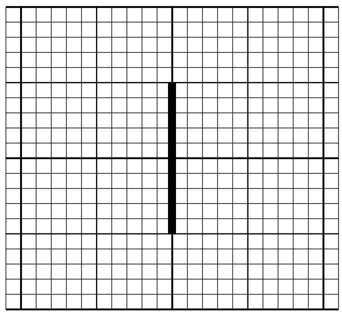
M at A

Fig. 2.2



M at B

Fig. 2.3



M at C

Fig. 2.4

these traces, 1.0 cm represents 5.0 mV on the vertical scale.

(a) **(i)** Explain why coherent waves are produced by the loudspeakers.

....

....

....[1]

(ii) the principle of superposition to explain the traces shown with M at

1. A,

....

....

....[1]

2. B,

....

....

....[1]

3. C.

....

....

....[1]

(b) The sound emitted from L_1 and L_2 has frequency 500 Hz. The time-base on the c.r.o. is switched on.

The microphone M is placed at A.

On Fig. 2.5, draw the trace seen on the c.r.o.

On the vertical scale, 1.0 cm represents 5.0 mV. On the horizontal scale, 1.0 cm represents 0.10 ms.

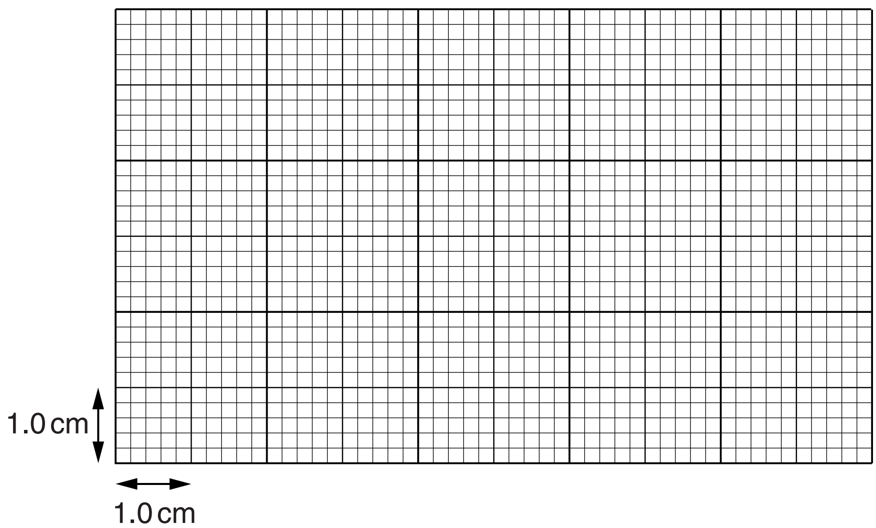


Fig. 2.5

[3]

3 A steel ball falls from a platform on a tower to the ground below, as shown in Fig. 3.1.

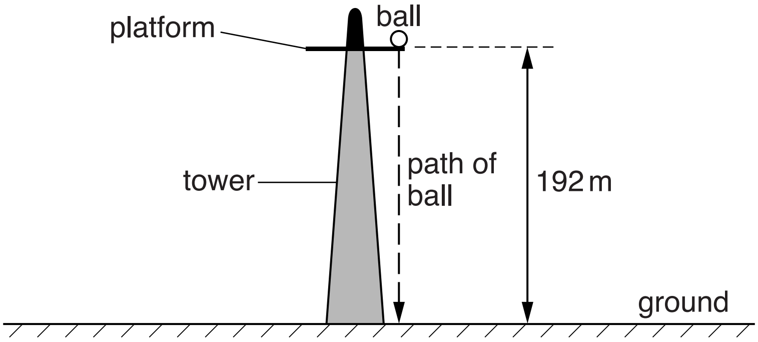


Fig. 3.1

The ball falls from rest through a vertical distance of 192 m. The mass of the ball is 270 g.

(a) Assume air resistance is negligible.

(i) Calculate

1. the time taken for the ball to fall to the ground,

time taken = ... s [2]

2. the maximum kinetic energy of the ball.

maximum kinetic energy = ... J [2]

(ii) State and explain the variation of the velocity of the ball with time as the ball falls to the ground.

....

....[1]

(iii) Show that the velocity of the ball on reaching the ground is approximately 60 m s^{-1}.

[1]

(b) In practice, air resistance is not negligible. The variation of the air resistance R with the velocity v of the ball is shown in Fig. 3.2.

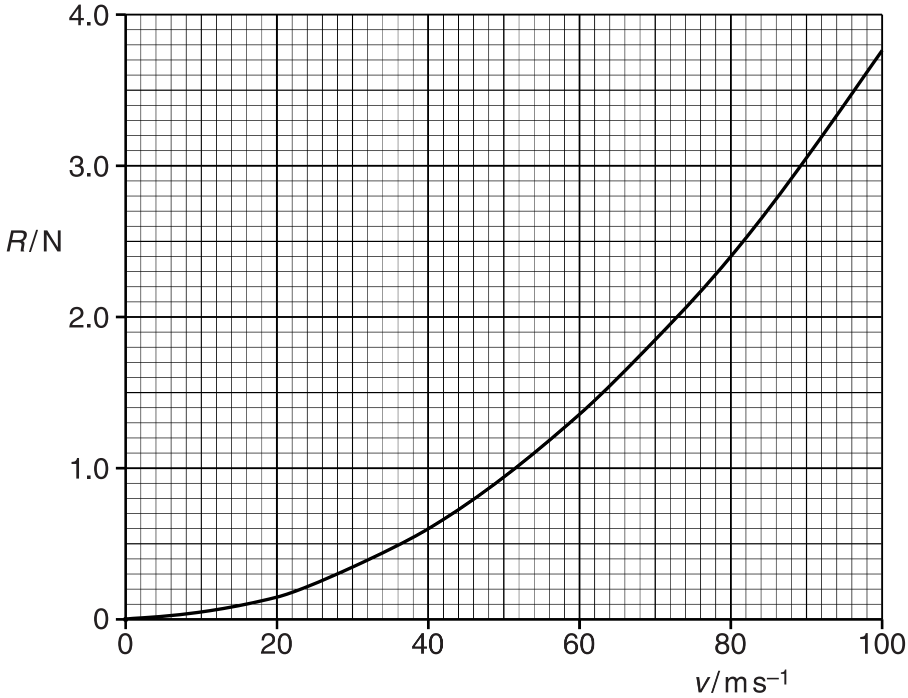


Fig. 3.2

(i) Fig. 3.2 to state and explain qualitatively the variation of the acceleration of the ball with the distance fallen by the ball.

....

....

....

....[3]

(ii) The speed of the ball reaches $40\,\mathrm{m\,s^{-1}}$. Calculate its acceleration at this speed.

acceleration = ... $\mathrm{m\,s^{-2}}$ [2]

(iii) information from **(a)(iii)** and Fig. 3.2 to state and explain whether the ball reaches terminal velocity.

....

....

....[2]

4 A block is pulled on a horizontal surface by a force P as shown in Fig. 4.1.

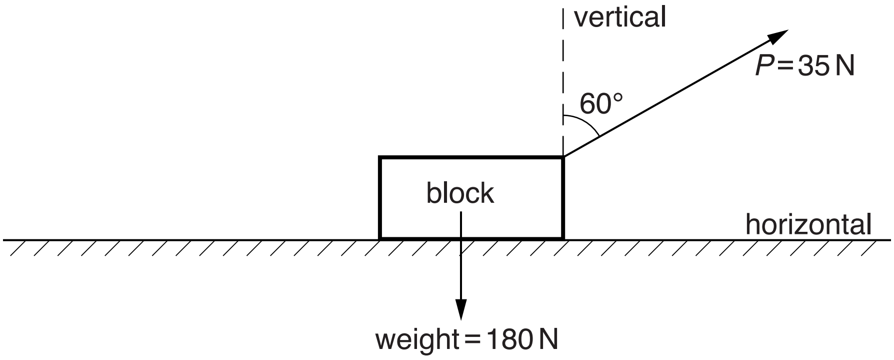


Fig. 4.1

The weight of the block is 180 N. The force P is 35 N at 60° to the vertical.
The block moves a distance of 20 m at constant velocity.

(a) Calculate

(i) the vertical force that the surface applies to the block (normal reaction force),

force = ... N [2]

(ii) the work done by force P.

work done = ... J [2]

(b) (i) Explain why the block continues to move at constant velocity although work is done on the block by force *P*.

....

....

....[1]

(ii) Explain, in terms of the forces acting, why the block remains in equilibrium.

....

....

....

....[2]

5 **(a)** The I-V characteristic of a semiconductor diode is shown in Fig. 5.1.

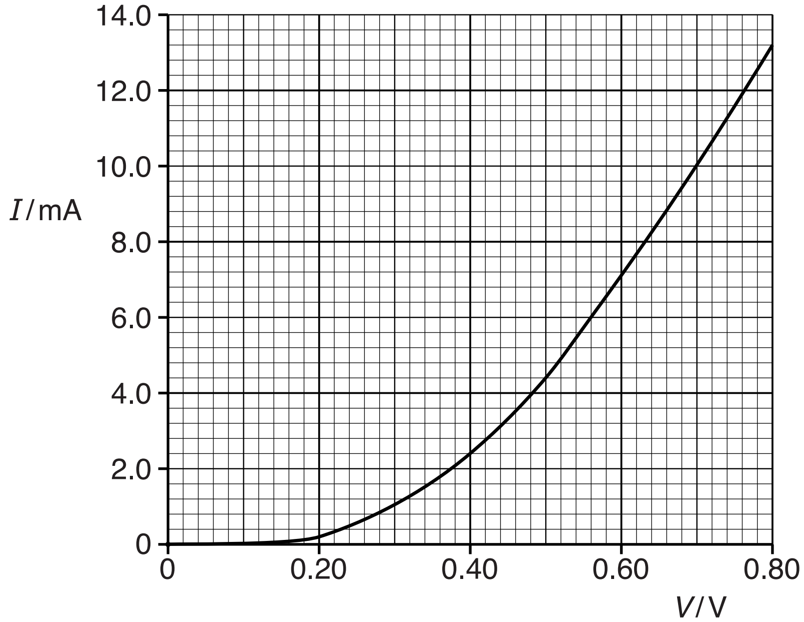


Fig. 5.1

(i) Fig. 5.1 to explain the variation of the resistance of the diode as V increases from zero to 0.8 V.

....

....

....

....

....

....[3]

(ii) Fig. 5.1 to determine the resistance of the diode for a current of 4.4 mA.

resistance = ... Ω [2]

(b) A cell of e.m.f. 1.2 V and negligible internal resistance is connected in series to a semiconductor diode and a resistor R_1, as shown in Fig. 5.2.

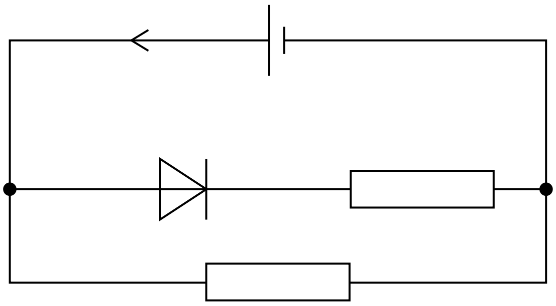


Fig. 5.2

A resistor R_2 of resistance 375 Ω is connected across the cell.
The diode has the characteristic shown in Fig. 5.1. The current supplied by the cell is 7.6 mA.

Calculate

(i) the current in R_2,

current = ... A [1]

(ii) the resistance of R_1,

resistance = ... Ω [2]

(iii) the ratio

$$\frac{\text{power dissipated in the diode}}{\text{power dissipated in } R_2}.$$

ratio = ...[2]

6 An arrangement for producing stationary waves in air in a tube that is closed at one end is shown in Fig. 6.1.

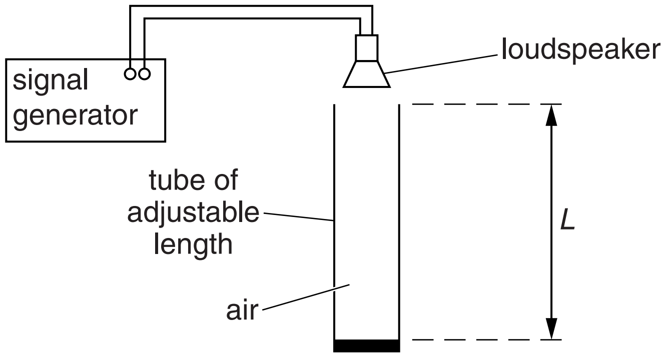


Fig. 6.1

A loudspeaker produces sound waves of wavelength 0.680 m in the tube.
some values of the length *L* of the tube, stationary waves are formed.

(a) Explain how stationary waves are formed in the tube.

....

....

....[2]

(b) The length *L* is adjusted between 0.200 m and 1.00 m.

(i) Calculate two values of *L* for which stationary waves are formed.

L = ... m and *L* = ... m [2]

(ii) On Fig. 6.2, label the positions of the antinodes with an **A** and the nodes with an **N** for the least value of *L* for which a stationary wave is formed.

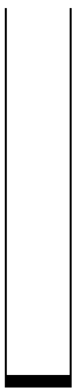


Fig. 6.2

[1]

8 **(a)** State the quantities, other than momentum, that are conserved in a nuclear reaction.

....

....[2]

(b) A stationary nucleus of uranium-238 decays to a nucleus of thorium-234 by emitting an α-particle. The kinetic energy of the α-particle is 6.69×10^{-13} J.

(i) Show that the kinetic energy E_k of a mass m is related to its momentum p by the equation

$$E_k = \frac{p^2}{2m}.$$

[1]

(ii) the conservation of momentum to determine the kinetic energy, in keV, of the thorium nucleus.

kinetic energy = ... keV [3]