

CANDIDATE
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PHYSICS

Paper 2 AS Structured Questions

9702/21

May/June 2014

1 hour

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.

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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.

This document consists of **15** printed pages and **1** blank page.

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

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.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel,	$C = C_1 + C_2 + \dots$
energy of charged capacitor,	$W = \frac{1}{2} QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
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) (i) Define *velocity*.

.....
 [1]

- (ii) Distinguish between *speed* and *velocity*.

.....
 [2]

- (b) A car of mass 1500 kg moves along a straight, horizontal road. The variation with time t of the velocity v for the car is shown in Fig. 1.1.

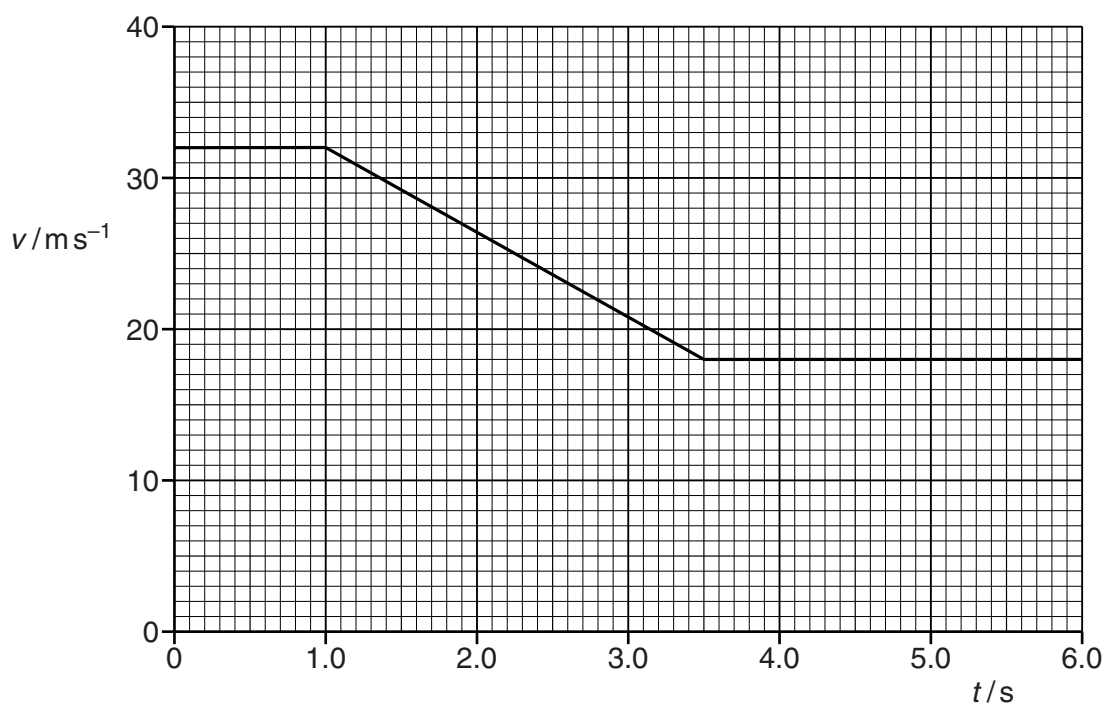


Fig. 1.1

The brakes of the car are applied from $t = 1.0$ s to $t = 3.5$ s.
 For the time when the brakes are applied,

- (i) calculate the distance moved by the car,

distance = ... m [3]

- (ii) calculate the magnitude of the resultant force on the car.

resultant force = ... N [3]

- (c) The direction of motion of the car in (b) at time $t = 2.0$ s is shown in Fig. 1.2.

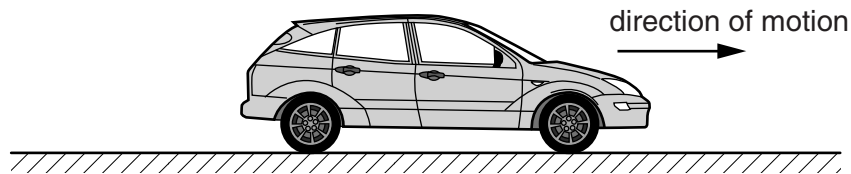


Fig. 1.2

On Fig. 1.2, show with arrows the directions of the acceleration (label this arrow A) and the resultant force (label this arrow F). [1]

BLANK PAGE

- 2 (a) (i) Define *power*.

..... [1]

- (ii) Use your definition in (i) to show that power may also be expressed as the product of force and velocity.

[2]

- (b) A lorry moves up a road that is inclined at 9.0° to the horizontal, as shown in Fig. 2.1.

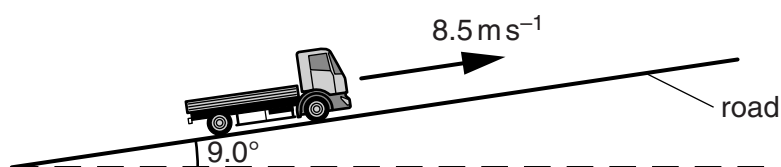


Fig. 2.1

The lorry has mass 2500 kg and is travelling at a constant speed of 8.5 m s^{-1} . The force due to air resistance is negligible.

- (i) Calculate the useful power from the engine to move the lorry up the road.

power = ... kW [3]

- (ii) State two reasons why the rate of change of potential energy of the lorry is equal to the power calculated in (i).

1.

.....

2.

.....

[2]

- 3 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 3.1.

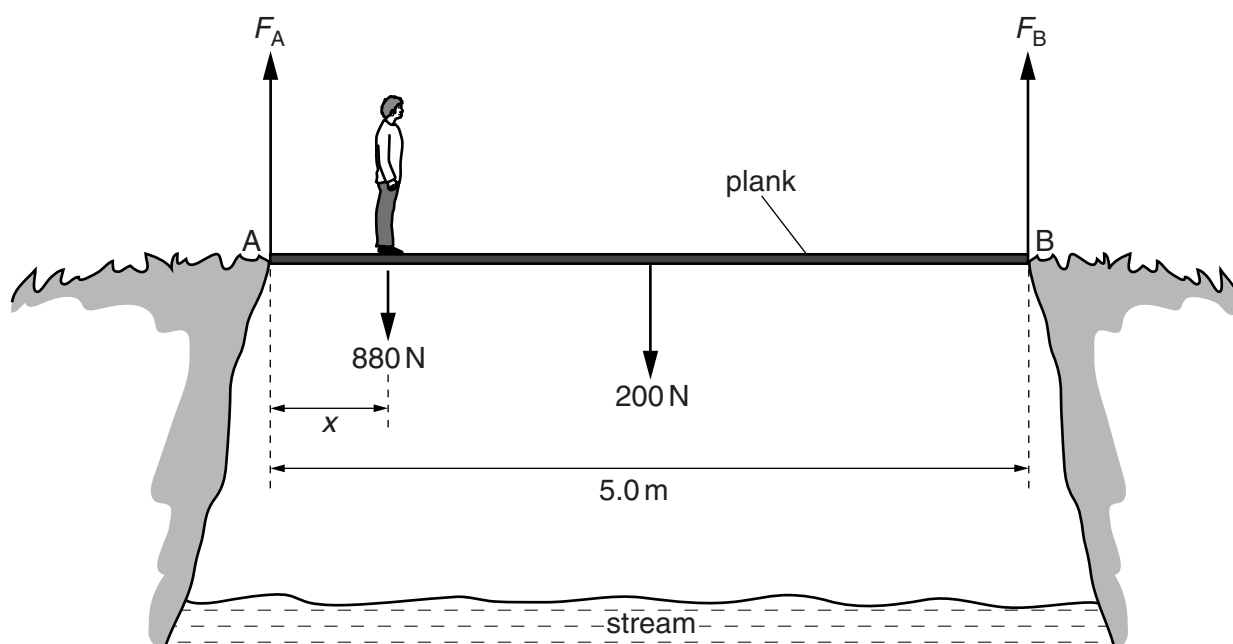


Fig. 3.1

A man of weight 880 N stands a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B. As the man moves along the plank, the plank is always in equilibrium.

- (a) (i) Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

.....

 [2]

- (ii) The man stands a distance $x = 0.50$ m from end A. Use the principle of moments to calculate the magnitude of F_B .

$F_B = \dots\dots\dots$ N [4]

(b) The variation with distance x of force F_A is shown in Fig. 3.2.

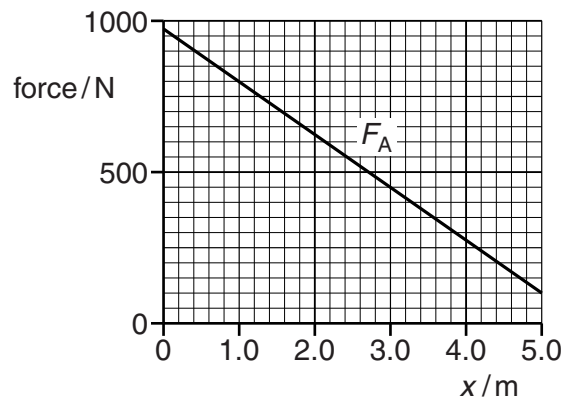


Fig. 3.2

On the axes of Fig. 3.2, sketch a graph to show the variation with x of force F_B .

[3]

- 4 A metal ball of mass 40 g falls vertically onto a spring, as shown in Fig. 4.1.

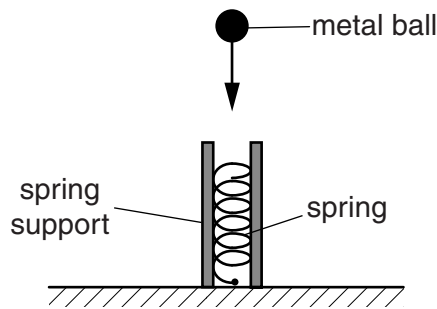


Fig. 4.1 (not to scale)

The spring is supported and stands vertically. The ball has a speed of 2.8 m s^{-1} as it makes contact with the spring. The ball is brought to rest as the spring is compressed.

- (a) Show that the kinetic energy of the ball as it makes contact with the spring is 0.16 J.

[2]

- (b) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 4.2.

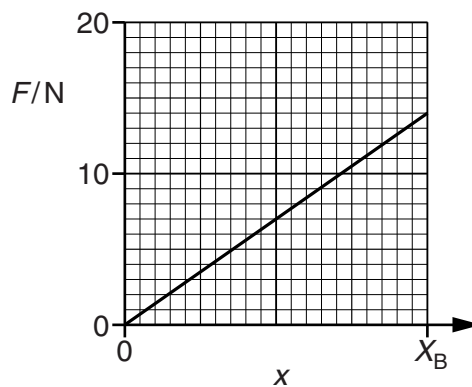


Fig. 4.2

The ball produces a maximum compression X_B when it comes to rest. The spring has a spring constant of 800 N m^{-1} .

Use Fig. 4.2 to

- (i) calculate the compression X_B ,

$$X_B = \dots\dots\dots \text{ m [2]}$$

- (ii) show that not all the kinetic energy in (a) is converted into elastic potential energy in the spring.

[2]

5 (a) Explain what is meant by the following quantities for a wave on the surface of water:

(i) displacement and amplitude,

displacement

amplitude

[2]

(ii) frequency and time period.

frequency

time period

[2]

(b) Fig. 5.1 represents waves on the surface of water in a ripple tank at one particular instant of time.

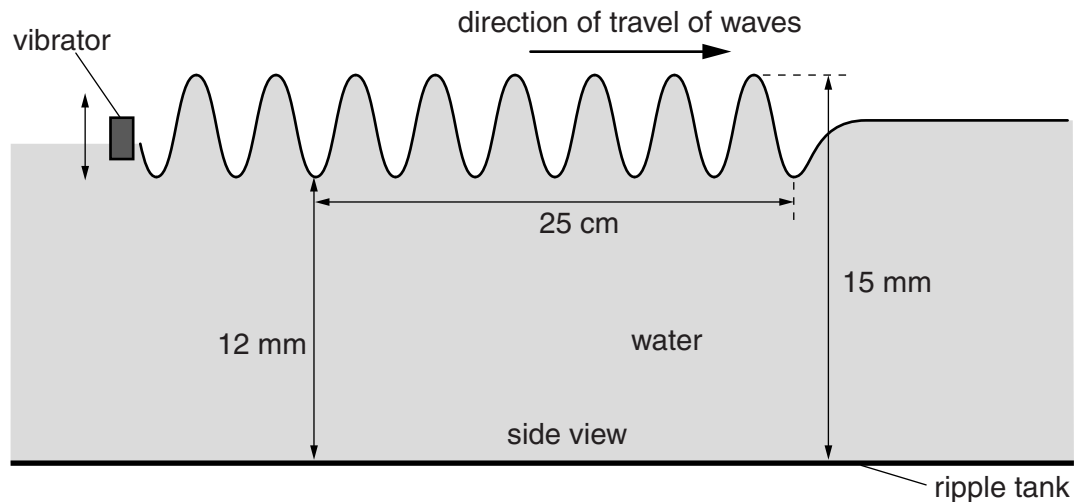


Fig. 5.1 (not to scale)

A vibrator moves the surface of the water to produce the waves of frequency f . The speed of the waves is 7.5 cm s^{-1} . Where the waves travel on the water surface, the maximum depth of the water is 15 mm and the minimum depth is 12 mm.

(i) Calculate, for the waves,

1. the amplitude,

amplitude = ... mm [1]

2. the wavelength.

wavelength = ... m [2]

(ii) Calculate the time period of the oscillations of the vibrator.

time period = ... s [2]

(c) State and explain whether the waves on the surface of the water shown in Fig. 5.1 are

(i) progressive or stationary,

.....
 [1]

(ii) transverse or longitudinal.

.....
 [1]

- 6 (a) Distinguish between *electromotive force* (e.m.f.) and *potential difference* (p.d.).

.....

 [2]

- (b) A battery of e.m.f. 12V and internal resistance $0.50\ \Omega$ is connected to two identical lamps, as shown in Fig. 6.1.

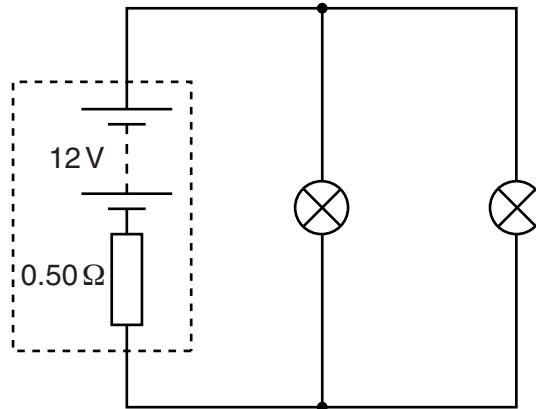


Fig. 6.1

Each lamp has constant resistance. The power rating of each lamp is 48W when connected across a p.d. of 12V.

- (i) Explain why the power dissipated in each lamp is not 48W when connected as shown in Fig. 6.1.

.....

 [1]

- (ii) Calculate the resistance of one lamp.

resistance = ... Ω [2]

- (iii) Calculate the current in the battery.

current = ... A [2]

- (iv) Calculate the power dissipated in one lamp.

power = ... W [2]

- (c) A third identical lamp is placed in parallel with the battery in the circuit of Fig. 6.1. Describe and explain the effect on the terminal p.d. of the battery.

.....
.....
.....
..... [2]

Please turn over for Question 7.

7 (a) State what is meant by α -particle: β -particle: γ -radiation: [2]**(b)** Describe the changes to the proton number and the nucleon number of a nucleus when emission occurs of**(i)** an α -particle,

.....

..... [1]

(ii) a β -particle,

.....

..... [1]

(iii) γ -radiation.

.....

..... [1]

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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) Show that the SI base units of power are $\text{kg m}^2 \text{s}^{-3}$.

[3]

- (b) The rate of flow of thermal energy $\frac{Q}{t}$ in a material is given by

$$\frac{Q}{t} = \frac{CA\Delta T}{x}$$

where A is the cross-sectional area of the material,
 ΔT is the temperature difference across the thickness of the material,
 x is the thickness of the material,
 C is a constant.

Determine the SI base units of C .

base units [4]

- 2 A coin is made in the shape of a thin cylinder, as shown in Fig. 2.1.

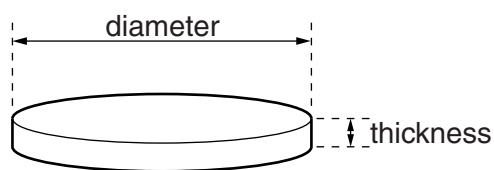


Fig. 2.1

Fig. 2.2 shows the measurements made in order to determine the density ρ of the material used to make the coin.

quantity	measurement	uncertainty
mass	9.6 g	± 0.5 g
thickness	2.00 mm	± 0.01 mm
diameter	22.1 mm	± 0.1 mm

Fig. 2.2

- (a) Calculate the density ρ in kg m^{-3} .

$$\rho = \dots\dots\dots \text{kg m}^{-3} \quad [3]$$

- (b) (i) Calculate the percentage uncertainty in ρ .

$$\text{percentage uncertainty} = \dots\dots\dots [3]$$

- (ii) State the value of ρ with its actual uncertainty.

$$\rho = \dots\dots\dots \pm \dots\dots\dots \text{kg m}^{-3} \quad [1]$$

- 3 (a) State Newton's first law of motion.

.....
 [1]

- (b) A box slides down a slope, as shown in Fig. 3.1.

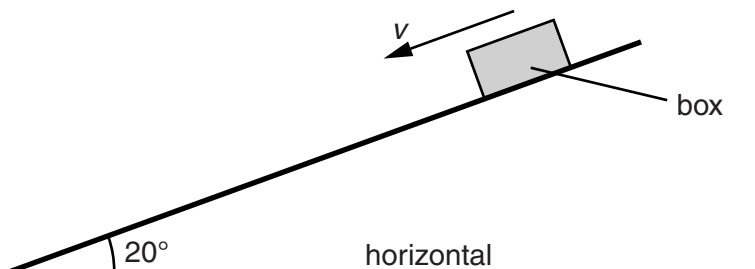


Fig. 3.1

The angle of the slope to the horizontal is 20° . The box has a mass of 65 kg. The total resistive force R acting on the box is constant as it slides down the slope.

- (i) State the names and directions of the other two forces acting on the box.

1.
 2.

[2]

- (ii) The variation with time t of the velocity v of the box as it moves down the slope is shown in Fig. 3.2.

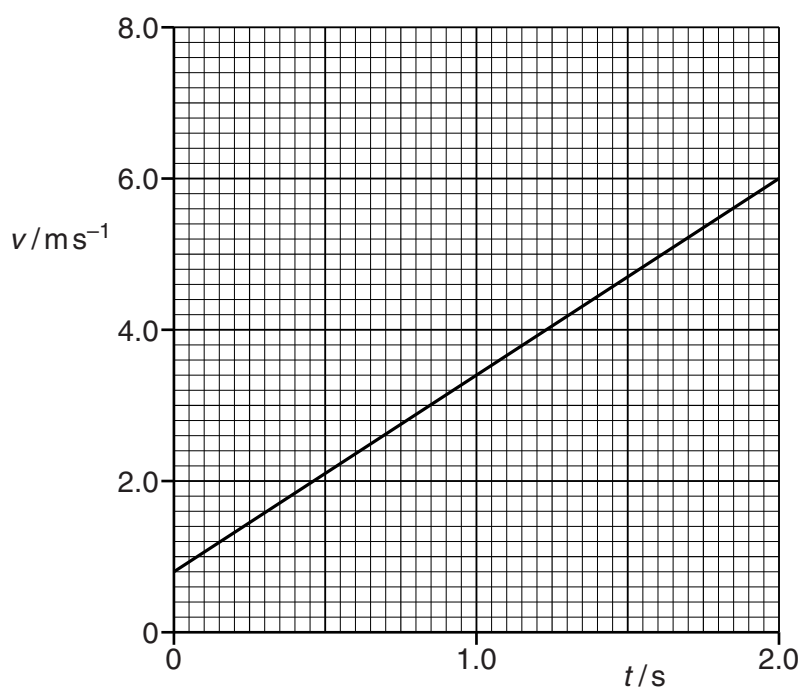


Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 ms^{-2} .

[2]

2. Calculate the resultant force on the box.

resultant force = ... N [1]

3. Determine the resistive force R on the box.

$R =$ N [3]

- 4 (a) Explain what is meant by *gravitational potential energy* and *kinetic energy*.

gravitational potential energy:

.....

kinetic energy:

.....

[2]

- (b) A ball of mass 400 g is thrown with an initial velocity of 30.0 m s^{-1} at an angle of 45.0° to the horizontal, as shown in Fig. 4.1.

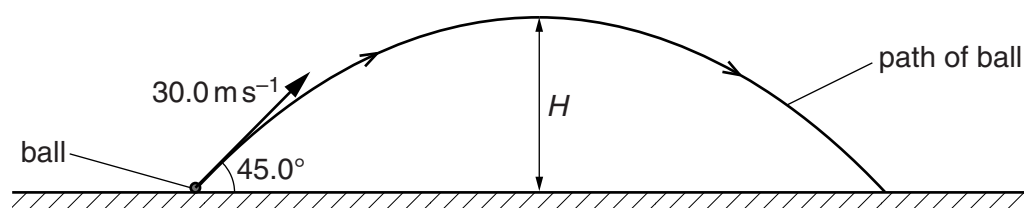


Fig. 4.1

Air resistance is negligible. The ball reaches a maximum height H after a time of 2.16 s.

- (i) Calculate

1. the initial kinetic energy of the ball,

kinetic energy = ... J [3]

2. the maximum height H of the ball,

$H =$ m [2]

3. the gravitational potential energy of the ball at height H .

potential energy = ... J [2]

- (ii) 1. Determine the kinetic energy of the ball at its maximum height.

kinetic energy = ... J [1]

2. Explain why the kinetic energy of the ball at maximum height is not zero.

.....
..... [1]

- 5 (a) Define the *Young modulus*.

.....
 [1]

- (b) Two wires P and Q of the same material and same original length l_0 are fixed so that they hang vertically, as shown in Fig. 5.1.

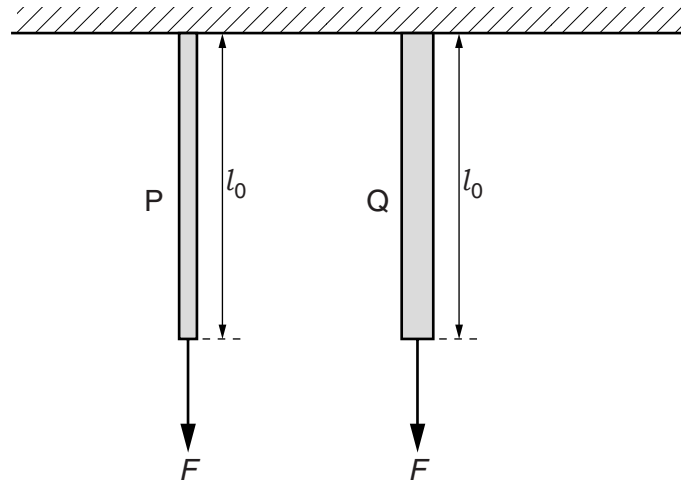


Fig. 5.1 (not to scale)

The diameter of P is d and the diameter of Q is $2d$. The same force F is applied to the lower end of each wire.

Show your working and determine the ratio

- (i) $\frac{\text{stress in P}}{\text{stress in Q}}$,

ratio = ... [2]

- (ii) $\frac{\text{strain in P}}{\text{strain in Q}}$.

ratio = ... [2]

- 6 A battery is connected in series with resistors X and Y, as shown in Fig. 6.1.

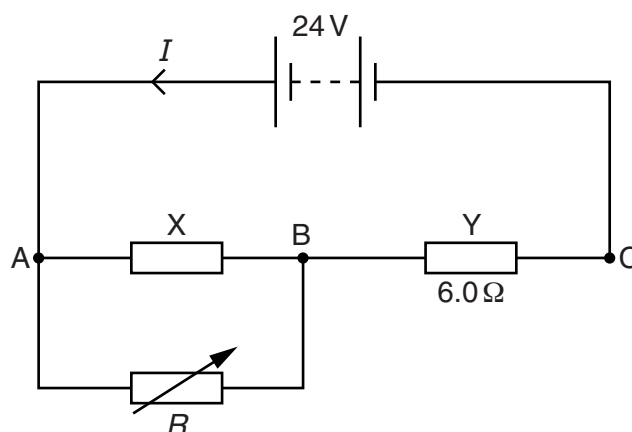


Fig. 6.1

The resistance of X is constant. The resistance of Y is 6.0Ω . The battery has electromotive force (e.m.f.) 24V and zero internal resistance. A variable resistor of resistance R is connected in parallel with X.

The current I from the battery is changed by varying R from 5.0Ω to 20Ω . The variation with R of I is shown in Fig. 6.2.

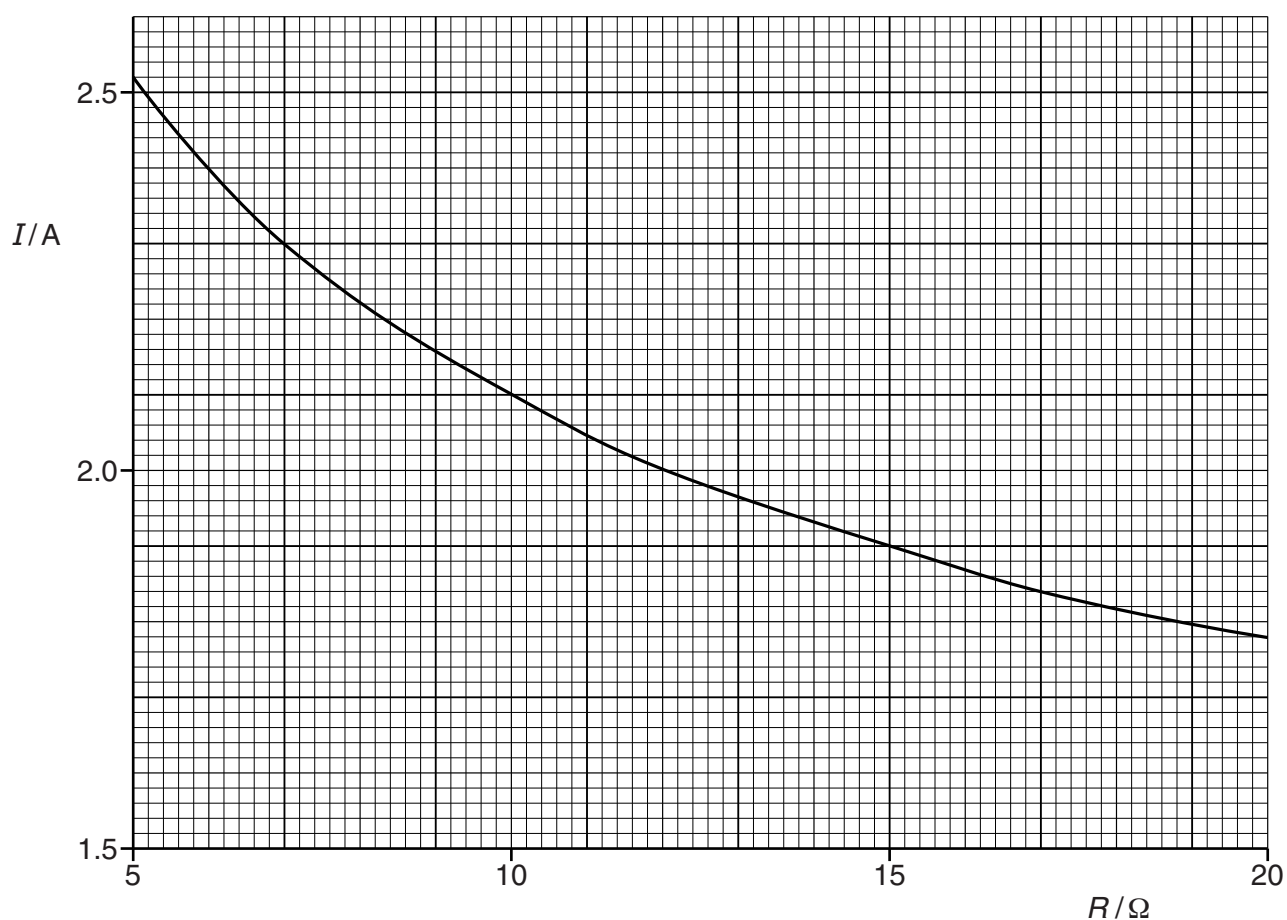


Fig. 6.2

- (a) Explain why the potential difference (p.d.) between points A and C is 24V for all values of R .

.....
 [1]

- (b) Use Fig. 6.2 to state and explain the variation of the p.d. across resistor Y as R is increased. Numerical values are not required.

.....

 [2]

- (c) For $R = 6.0\ \Omega$,

- (i) show that the p.d. between points A and B is 9.6V,

[2]

- (ii) calculate the resistance of X,

resistance = ... Ω [3]

- (iii) calculate the power provided by the battery.

power = ... W [2]

- (d) State and explain qualitatively how the power provided by the battery changes as the resistance R is increased.

.....
 [1]

- 7 A laser is placed in front of a double slit, as shown in Fig. 7.1.

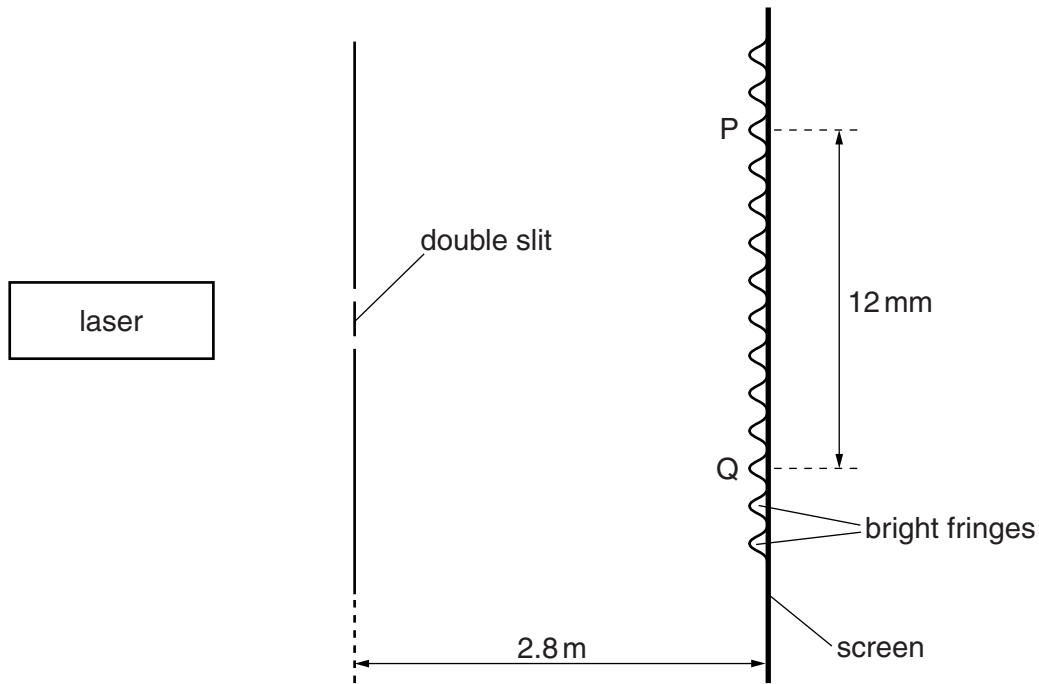


Fig. 7.1 (not to scale)

The laser emits light of frequency 670 THz. Interference fringes are observed on the screen.

- (a) Explain how the interference fringes are formed.

.....

.....

.....

.....

.....

..... [3]

- (b) Show that the wavelength of the light is 450 nm.

[2]

- (c) The separation of the maxima P and Q observed on the screen is 12 mm. The distance between the double slit and the screen is 2.8 m.

Calculate the separation of the two slits.

separation = ... m [3]

- (d) The laser is replaced by a laser emitting red light. State and explain the effect on the interference fringes seen on the screen.

.....
.....
.....
..... [2]

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capacitors in parallel,

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energy of charged capacitor,

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resistors in series,

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resistors in parallel,

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

- 1 (a) Underline **all** the base quantities in the following list.

ampere charge current mass second temperature weight [2]

- (b) The potential energy E_p stored in a stretched wire is given by

$$E_p = \frac{1}{2}C\sigma^2V$$

where C is a constant,
 σ is the strain,
 V is the volume of the wire.

Determine the SI base units of C .

base units[3]

- 2 (a) Explain what is meant by a *scalar* quantity and by a *vector* quantity.

scalar:

.....

vector:

.....

[2]

- (b) A ball leaves point P at the top of a cliff with a horizontal velocity of 15 m s^{-1} , as shown in Fig. 2.1.

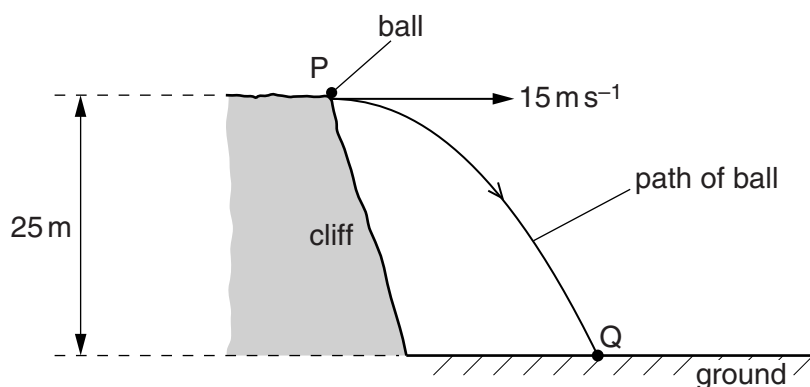


Fig. 2.1

The height of the cliff is 25 m. The ball hits the ground at point Q.
Air resistance is negligible.

- (i) Calculate the vertical velocity of the ball just before it makes impact with the ground at Q.

vertical velocity = ... m s^{-1} [2]

- (ii) Show that the time taken for the ball to fall to the ground is 2.3 s.

[1]

- (iii) Calculate the magnitude of the displacement of the ball at point Q from point P.

displacement = ... m [4]

- (iv) Explain why the distance travelled by the ball is different from the magnitude of the displacement of the ball.

.....
.....
.....[2]

- 3 (a) Explain what is meant by *work done*.

.....
[1]

- (b) A boy on a board B slides down a slope, as shown in Fig. 3.1.

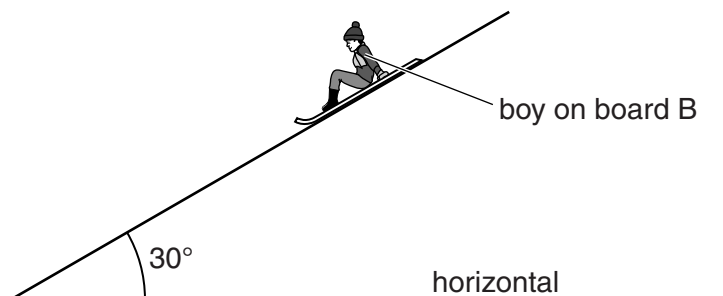


Fig. 3.1

The angle of the slope to the horizontal is 30° . The total resistive force F acting on B is constant.

- (i) State a word equation that links the work done by the force F on B to the changes in potential and kinetic energy.

.....
[1]

- (ii) The boy on the board B moves with velocity v down the slope. The variation with time t of v is shown in Fig. 3.2.

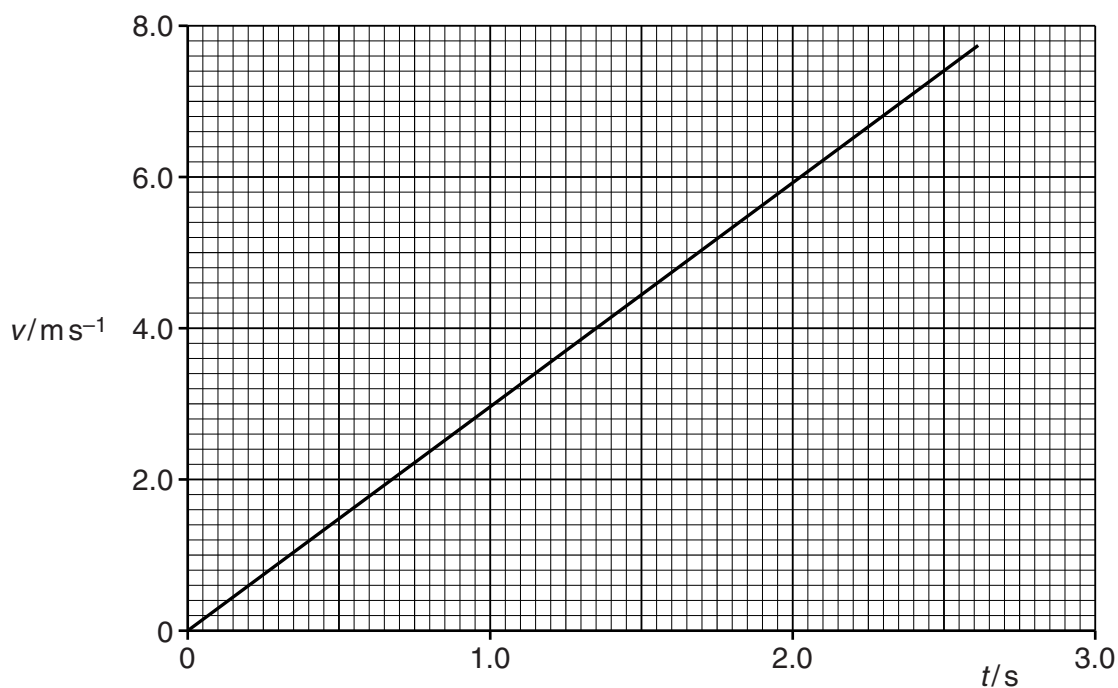


Fig. 3.2

The total mass of B is 75 kg.
For B, from $t = 0$ to $t = 2.5$ s,

1. show that the distance moved down the slope is 9.3 m,

[2]

2. calculate the gain in kinetic energy,

gain in kinetic energy = ... J [3]

3. calculate the loss in potential energy,

loss in potential energy = ... J [3]

4. calculate the resistive force F .

$F =$ N [3]

- 4 A spring hangs vertically from a point P, as shown in Fig. 4.1.

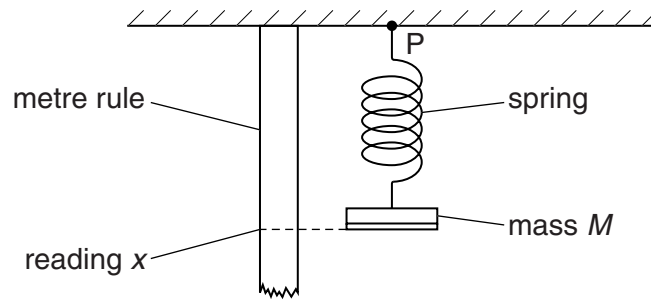


Fig. 4.1

A mass M is attached to the lower end of the spring. The reading x from the metre rule is taken, as shown in Fig. 4.1. Fig. 4.2 shows the relationship between x and M .

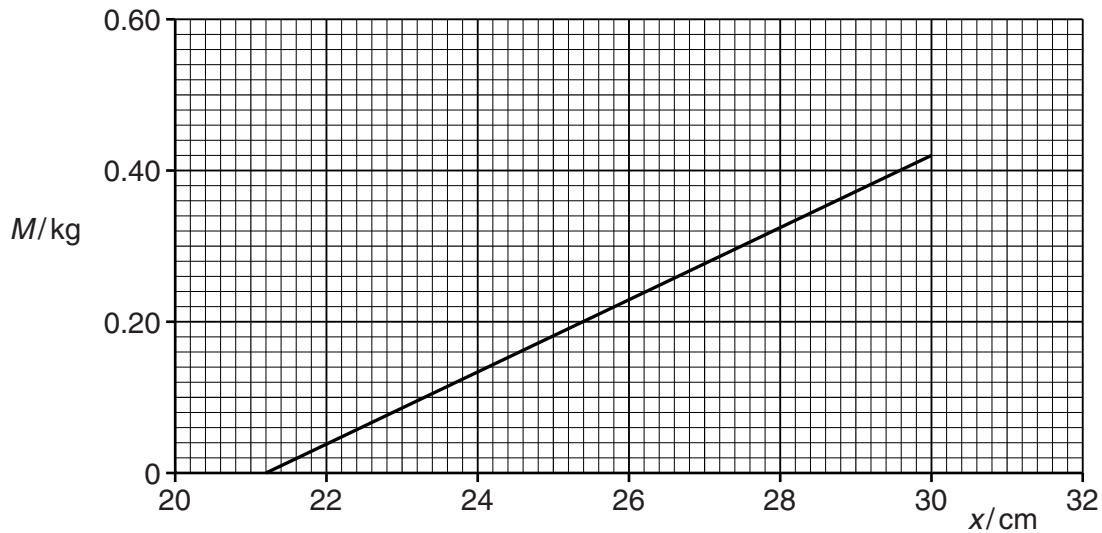


Fig. 4.2

- (a) Explain how the apparatus in Fig. 4.1 may be used to determine the load on the spring at the elastic limit.

.....

[2]

- (b) State and explain whether Fig. 4.2 suggests that the spring obeys Hooke's law.

.....

[2]

(c) Use Fig. 4.2 to determine the spring constant, in N m^{-1} , of the spring.

spring constant = ... N m^{-1} [3]

- 5 (a) Explain why the terminal potential difference (p.d.) of a cell with internal resistance may be less than the electromotive force (e.m.f.) of the cell.

.....

[2]

- (b) A battery of e.m.f. 4.5V and internal resistance r is connected in series with a resistor of resistance 6.0Ω , as shown in Fig. 5.1.

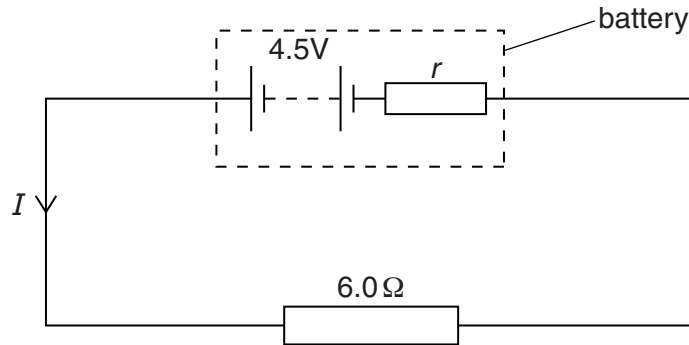


Fig. 5.1

The current I in the circuit is 0.65 A.

Determine

- (i) the internal resistance r of the battery,

$$r = \dots\dots\dots \Omega \text{ [2]}$$

- (ii) the terminal p.d. of the battery,

$$\text{p.d.} = \dots\dots\dots \text{ V [2]}$$

(iii) the power dissipated in the resistor,

power = ... W [2]

(iv) the efficiency of the battery.

efficiency = ... [2]

(c) A second resistor of resistance $20\ \Omega$ is connected in parallel with the $6.0\ \Omega$ resistor in Fig. 5.1.

Describe and explain qualitatively the change in the heating effect within the battery.

.....
.....
.....
.....[3]

- 6 A hollow tube is used to investigate stationary waves. The tube is closed at one end and open at the other end. A loudspeaker connected to a signal generator is placed near the open end of the tube, as shown in Fig. 6.1.

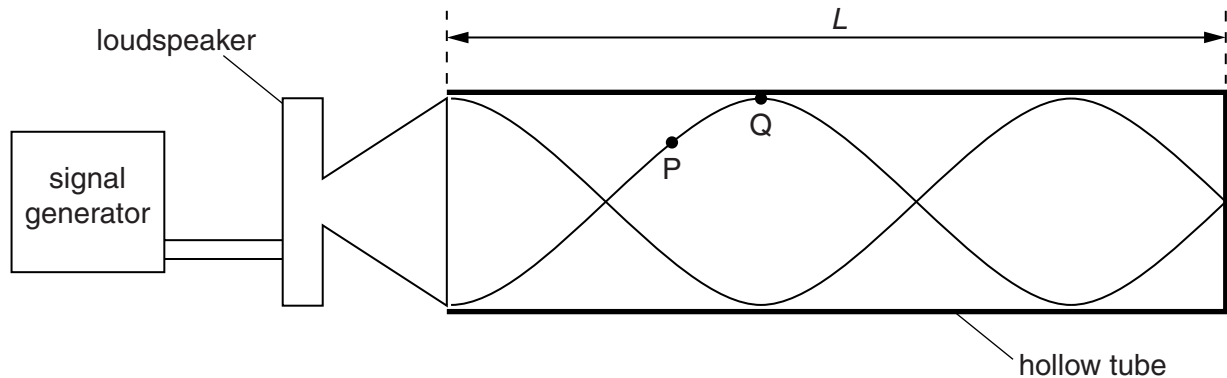


Fig. 6.1

The tube has length L . The frequency of the signal generator is adjusted so that the loudspeaker produces a progressive wave of frequency 440 Hz. A stationary wave is formed in the tube. A representation of this stationary wave is shown in Fig. 6.1. Two points P and Q on the stationary wave are labelled.

- (a) (i) Describe, in terms of energy transfer, the difference between a progressive wave and a stationary wave.

.....
[1]

- (ii) Explain how the stationary wave is formed in the tube.

.....

[3]

- (iii) State the direction of the oscillations of an air particle at point P.

.....
[1]

- (b) On Fig. 6.1 label, with the letter N, the nodes of the stationary wave. [1]

- (c) State the phase difference between points P and Q on the stationary wave.

phase difference = ... [1]

- (d) The speed of sound in the tube is 330 m s^{-1} .

Calculate

- (i) the wavelength of the sound wave,

wavelength = ... m [2]

- (ii) the length L of the tube.

length = ... m [2]

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