 

**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$ |
| permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$ |
| | $(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$ |
| elementary charge | $e = 1.60 \times 10^{-19}\,\mathrm{C}$ |
| the Planck constant | $h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$ |
| unified atomic mass unit | $1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$ |
| rest mass of electron | $m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$ |
| rest mass of proton | $m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$ |
| molar gas constant | $R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$ |
| the Avogadro constant | $N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$ |
| gravitational constant | $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$ |
| acceleration of free fall | $g = 9.81\,\mathrm{m\,s^{-2}}$ |



 

 

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| 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. | $v = v_0 \cos \omega t$<br>$v = \pm \omega\sqrt{(x_0^2 - x^2)}$ |
| Doppler effect | $f_o = \frac{f_s v}{v \pm v_s}$ |
| electric potential | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| capacitors in series | $1/C = 1/C_1 + 1/C_2 + \ldots$ |
| capacitors in parallel | $C = C_1 + C_2 + \ldots$ |
| energy of charged capacitor | $W = \frac{1}{2}QV$ |
| electric current | $I = Anvq$ |
| resistors in series | $R = R_1 + R_2 + \ldots$ |
| resistors in parallel | $1/R = 1/R_1 + 1/R_2 + \ldots$ |
| Hall voltage | $V_H = \frac{BI}{ntq}$ |
| 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)** Define *velocity*.

..............................................................................................................................................

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

**(b)** The drag force $F_D$ acting on a car moving with speed $v$ along a straight horizontal road is given by

$$F_D = v^2 A k$$

where $k$ is a constant and $A$ is the cross-sectional area of the car.

Determine the SI base units of $k$.



SI base units ........................................................ [2]

**(c)** The value of $k$, in SI base units, for the car in **(b)** is 0.24. The cross-sectional area $A$ of the car is $5.1\,m^2$.

The car is travelling with a constant speed along a straight road and the output power of the engine is $4.8 \times 10^4$ W. Assume that the output power of the engine is equal to the rate at which the drag force $F_D$ is doing work against the car.

Determine the speed of the car.

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

[Total: 6]

 

 

**2** **(a)** Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

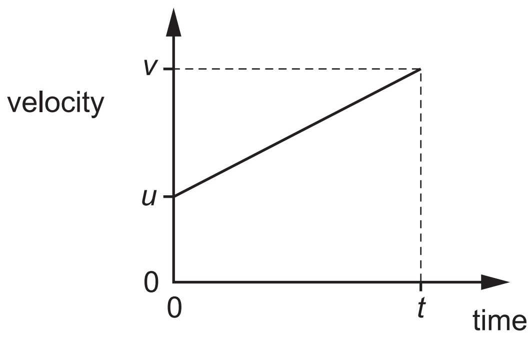


**Fig. 2.1**

**(i)** Determine an expression, in terms of $u$, $v$ and $t$, for the area under the graph.

area = ........................................................ [1]

**(ii)** State the name of the quantity represented by the area under the graph.

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



**(b)** A ball is kicked with a velocity of $15\,\text{m}\,\text{s}^{-1}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

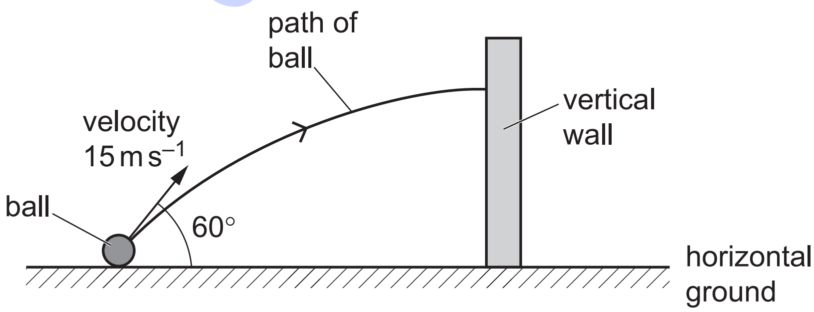


**Fig. 2.2** (not to scale)

Assume that air resistance is negligible.

 

 

**(i)** By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ..................................................... s [3]

**(ii)** Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

...................................................................................................................................

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

**(iii)** Show that the ball strikes the wall with a horizontal velocity of $7.5\,m\,s^{-1}$.

[1]

**(c)** The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of $4.3\,m\,s^{-1}$.

**(i)** Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision.

change in momentum = .......................................... $kg\,m\,s^{-1}$ [2]

**(ii)** Calculate the magnitude of the average force exerted on the ball by the wall.

average force = .................................................... N [1]

[Total: 10]



 

 

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

..............................................................................................................................................

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

**(b)** A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of 23 m $s^{-1}$.

**(i)** Calculate, for the ball falling from the top of the building to the ground:

**1.** the decrease in gravitational potential energy

decrease in gravitational potential energy = ...................................................... J [2]

**2.** the increase in kinetic energy.

increase in kinetic energy = ...................................................... J [2]

**(ii)** Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

average resistive force = ...................................................... N [2]



 

**(c)** The ball in **(b)** is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is $g$.

On Fig. 3.1, sketch a line to show the variation of the acceleration $a$ of the ball with time $t$ from time $t = 0$ to $t = T$.

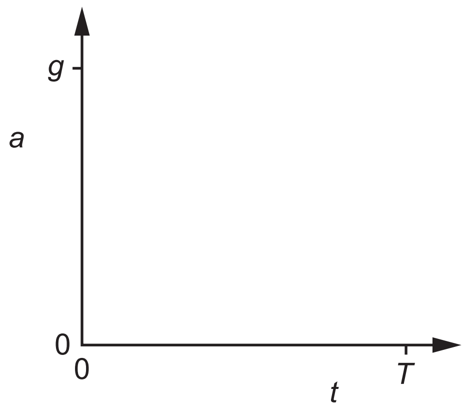


**Fig. 3.1**

[2]

[Total: 9]

 

**4** **(a)** State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

..........................................................................................................................................

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

**(b)** A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

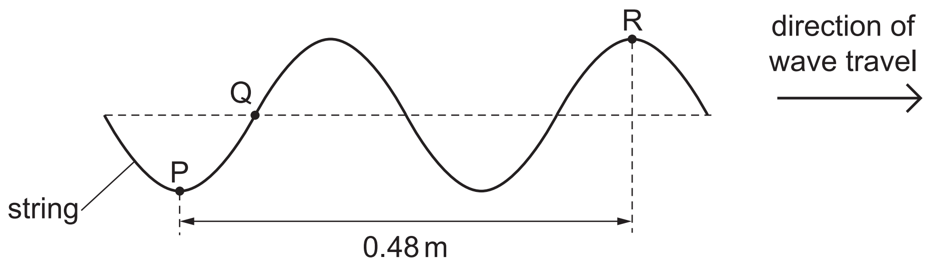


**Fig. 4.1**

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

**(i)** Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ..................................................... m [1]

**(ii)** Calculate the speed of the wave.

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

**(iii)** Determine the phase difference between points Q and R.

phase difference = ........................................................ ° [1]



 

**(iv)** Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

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

**(c)** A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

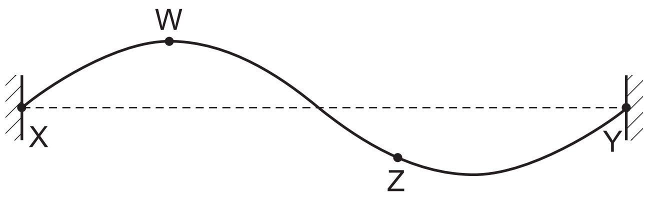


**Fig. 4.2**



**(i)** Explain what is meant by a *node* of a stationary wave.

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

**(ii)** State the number of antinodes of the wave shown in Fig. 4.2.

number = ...................................................... [1]

**(iii)** State the phase difference between points W and Z on the string.

phase difference = ......................................................° [1]

**(iv)** A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

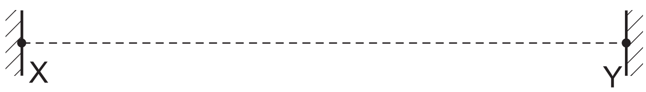


**Fig. 4.3**

[1]

[Total: 11]

 

**5** One end of a wire is attached to a fixed point. A force $F$ is applied to the wire to cause extension $x$. The variation with $F$ of $x$ is shown in Fig. 5.1.

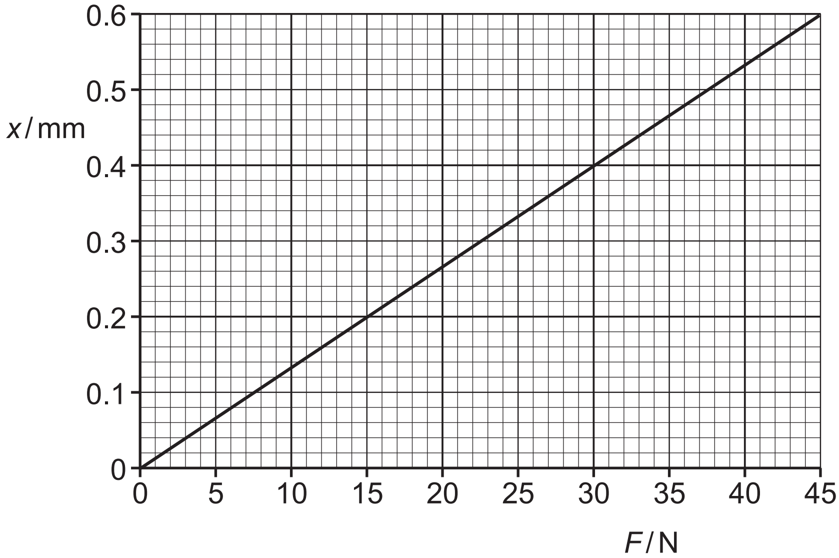


**Fig. 5.1**



The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus $1.7 \times 10^{11}\,Pa$. Assume that the cross-sectional area of the wire remains constant as the wire extends.

**(a)** State the name of the law that describes the relationship between $F$ and $x$ shown in Fig. 5.1.

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

**(b)** The wire has an extension of 0.48 mm.

Determine:

**(i)** the stress

stress = ..................................................... Pa [2]

**(ii)** the strain.

strain = ........................................................ [2]

 

 

**(c)** The resistivity of the metal of the wire is $3.7 \times 10^{-7}\,\Omega\,m$.

Determine the change in resistance of the wire when the extension $x$ of the wire changes from $x = 0.48\,mm$ to $x = 0.60\,mm$.

change in resistance = .................................................... Ω [3]

**(d)** A force of greater than 45 N is now applied to the wire.

Describe how it may be checked that the elastic limit of the wire has not been exceeded.

..........................................................................................................................................

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

[Total: 9]



 

 

**6** **(a)** A battery of electromotive force (e.m.f.) 7.8 V and internal resistance $r$ is connected to a filament lamp, as shown in Fig. 6.1.

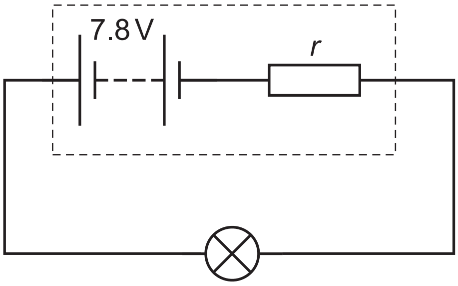


**Fig. 6.1**

A total charge of 750 C moves through the battery in a time interval of 1500 s. During this time the filament lamp dissipates 5.7 kJ of energy. The e.m.f. of the battery remains constant.

**(i)** Explain, in terms of energy and without a calculation, why the potential difference across the lamp must be less than the e.m.f. of the battery.

...................................................................................................................................

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

**(ii)** Calculate:

**1.** the current in the circuit

current = ...................................................... A [2]

**2.** the potential difference across the lamp

potential difference = ...................................................... V [2]

**3.** the internal resistance of the battery.

internal resistance = ...................................................... Ω [2]



 

 

**(b)** A student is provided with three resistors of resistances 90 Ω, 45 Ω and 20 Ω.

**(i)** Sketch a circuit diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 30 Ω between the terminals shown. Label the values of the resistances on your diagram.

[1]

**(ii)** A potential divider circuit is produced by connecting the three resistors to a battery of e.m.f. 9.0 V and negligible internal resistance. The potential divider circuit provides an output potential difference $V_{OUT}$ of 3.6 V. The circuit diagram is shown in Fig. 6.2.

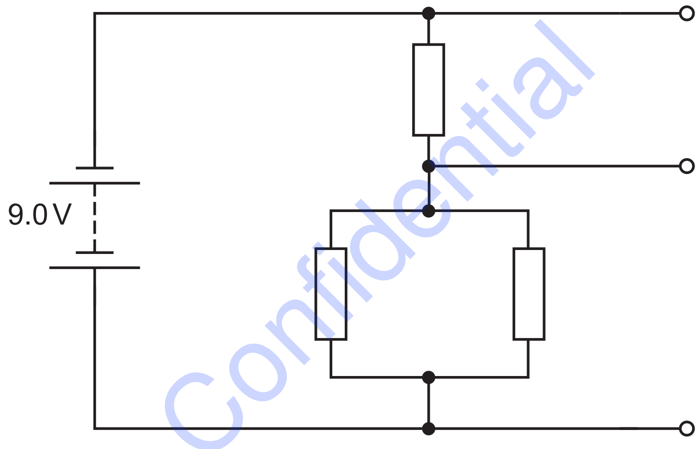




**Fig. 6.2**

On Fig. 6.2, label the resistances of all three resistors and the potential difference $V_{OUT}$.
[2]

[Total: 10]

 