**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

$$F_D = v^2Ak$$

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.

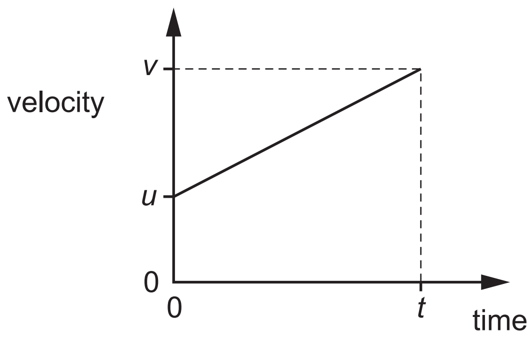


**Fig. 2.1**

**(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.

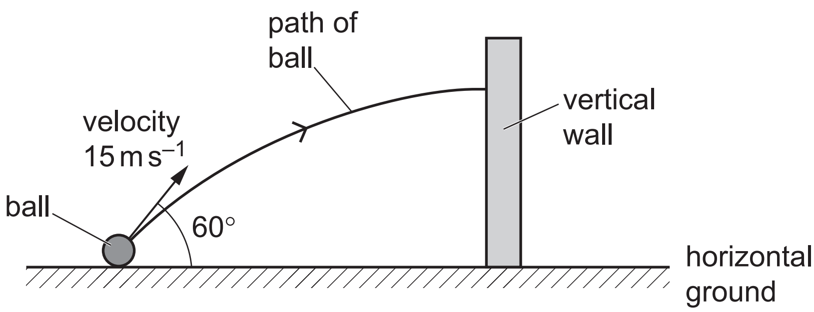


**Fig. 2.2** (not to scale)

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)** 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)** 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 $t$ = $T$.

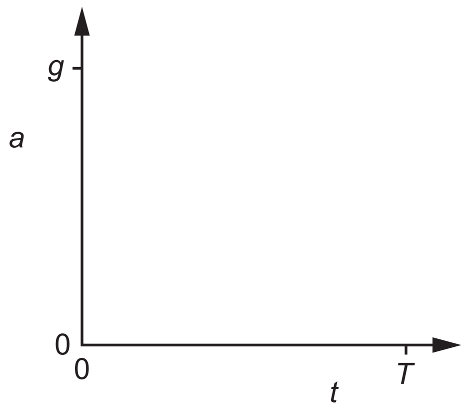


**Fig. 3.1**

[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.

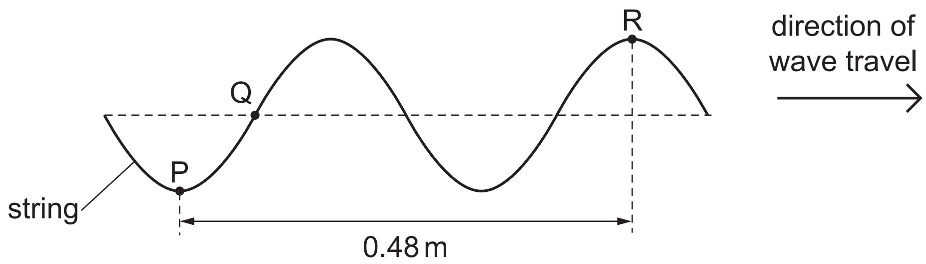


**Fig. 4.1**

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)** 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.

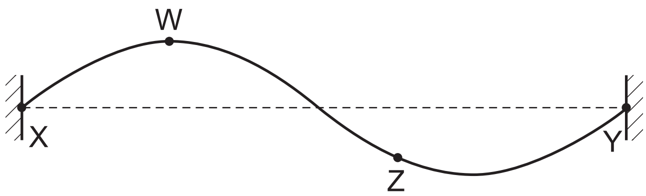


**Fig. 4.2**

**(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.

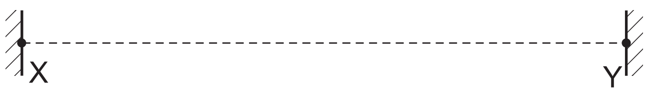


**Fig. 4.3**

[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.

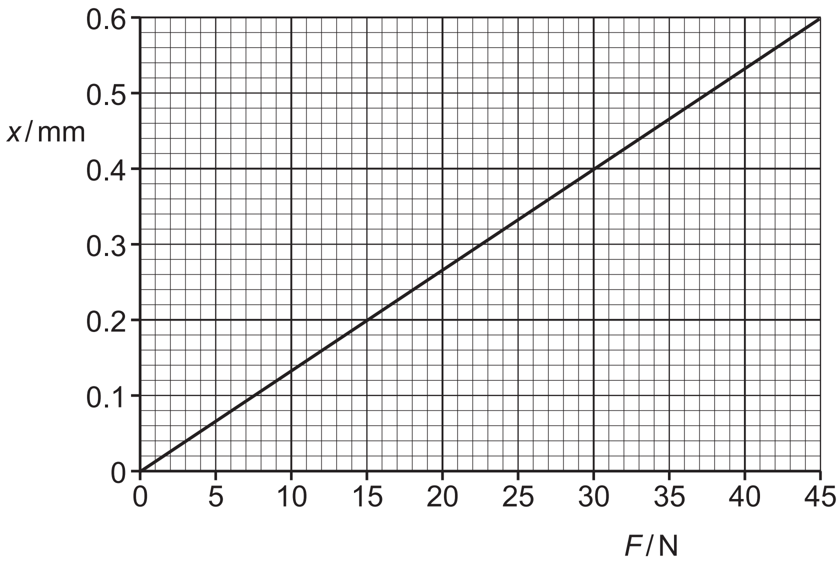


**Fig. 5.1**

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.

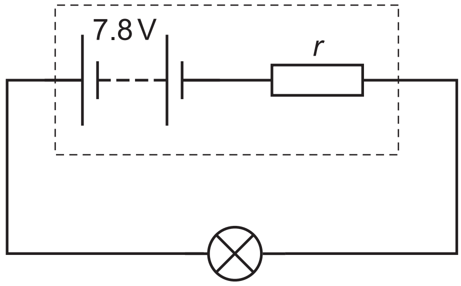


**Fig. 6.1**

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.

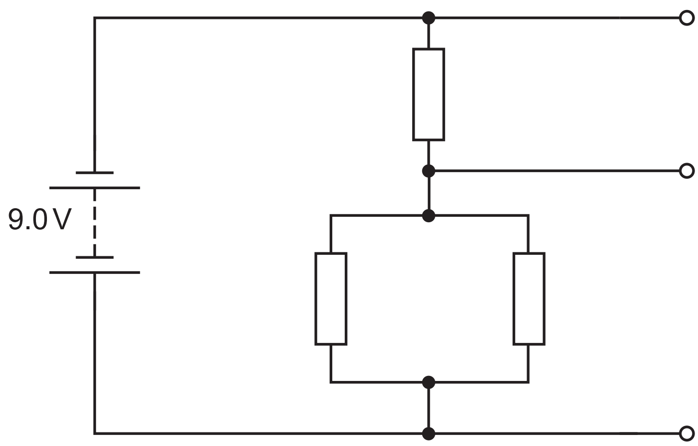


**Fig. 6.2**

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

[Total: 10]

7 **(a)** A nucleus of an element X decays by emitting a $\beta^+$ particle to produce a nucleus of potassium-39 ($^{39}_{19}K$) and a neutrino. The decay is represented by

$$^{Q}_{S}X \longrightarrow {}^{39}_{19}K + {}^{P}_{R}\beta^+ + {}^{0}_{0}\nu.$$

**(i)** State the number represented by each of the following letters.

P ..............................

Q ..............................

R ..............................

S ..............................

[2]

**(ii)** State the name of the interaction (force) that gives rise to $\beta^+$ decay.

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

**(b)** A hadron is composed of three identical quarks and has a charge of $+2e$, where $e$ is the elementary charge.

Determine a possible type (flavour) of the quarks.
Explain your working.

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

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

[Total: 5]