1 **(a)** Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. ....

2. ....
[2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

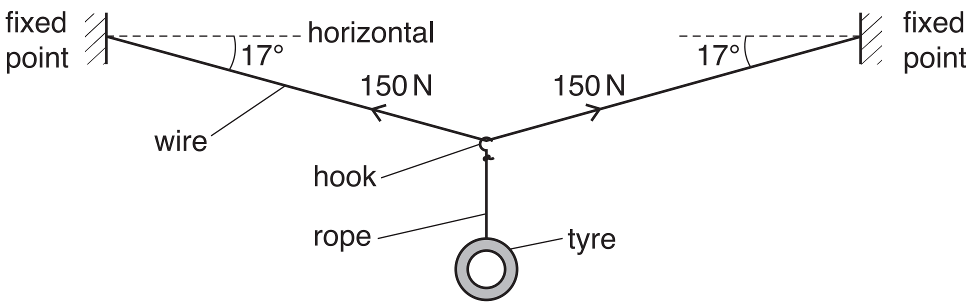

Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,mm^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]

[Total: 8]

2 **(a)** State what is meant by *kinetic energy*.

....

....[1]

(b) A cannon fires a shell vertically upwards. The shell leaves the cannon with a speed of $80\,\text{m}\,\text{s}^{-1}$ and a kinetic energy of 480 J. The shell then rises to a maximum height of 210 m. The effect of air resistance is significant.

(i) Show that the mass of the shell is 0.15 kg.

[2]

(ii) the movement of the shell from the cannon to its maximum height, calculate

1. the gain in gravitational potential energy,

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

2. the work done against air resistance.

work done = ... J [1]

(iii) Determine the average force due to the air resistance acting on the shell as it moves from the cannon to its maximum height.

force = ... N [2]

(iv) The shell leaves the cannon at time $t = 0$ and reaches maximum height at time $t = T$.

On Fig. 2.1, sketch the variation with time t of the velocity v of the shell from time $t = 0$ to time $t = T$. Numerical values of v and t are not required.

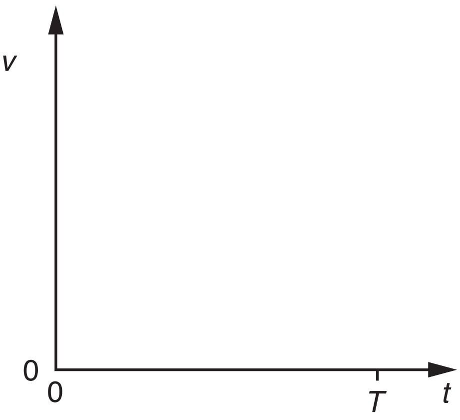

Fig. 2.1

[2]

(v) The force due to the air resistance is a vector quantity.

Compare the force due to the air resistance acting on the shell as it rises with the force due to the air resistance as it falls.

....

....

....

....

....[2]

[Total: 12]

3 **(a)** State Newton's second law of motion.

....

....[1]

(b) A toy rocket consists of a container of water and compressed air, as shown in Fig. 3.1.

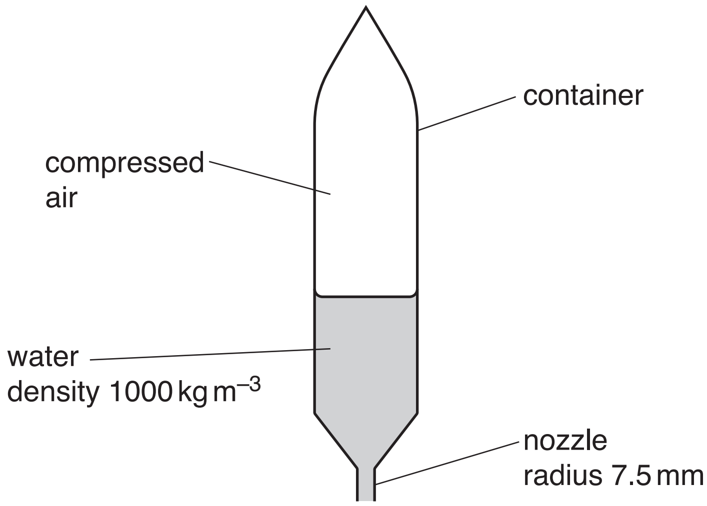

Fig. 3.1

Water is pushed vertically downwards through a nozzle by the compressed air. The rocket moves vertically upwards.

The nozzle has a circular cross-section of radius 7.5 mm. The density of the water is 1000 kg m^{-3}. Assume that the water leaving the nozzle has the shape of a cylinder of radius 7.5 mm and has a constant speed of 13 m s^{-1} relative to the rocket.

(i) Show that the mass of water leaving the nozzle in the first 0.20 s after the rocket launch is 0.46 kg.

[2]

(ii) Calculate

1. the change in the momentum of the mass of water in **(b)(i)** due to leaving the nozzle,

change in momentum = ... N s

2. the force exerted on this mass of water by the rocket.

force = ... N
[3]

(iii) State and explain how Newton's third law applies to the movement of the rocket by the water.

....

....

....[2]

(iv) The container has a mass of 0.40 kg. The initial mass of water before the rocket is launched is 0.70 kg. The mass of the compressed air in the rocket is negligible. Assume that the resistive force on the rocket due to its motion is negligible.

the rocket at a time of 0.20 s after launching,

1. show that its total mass is 0.64 kg,

2. calculate its acceleration.

acceleration = ... $m\,s^{-2}$
[3]

[Total: 11]

4 **(a)** On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A, the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

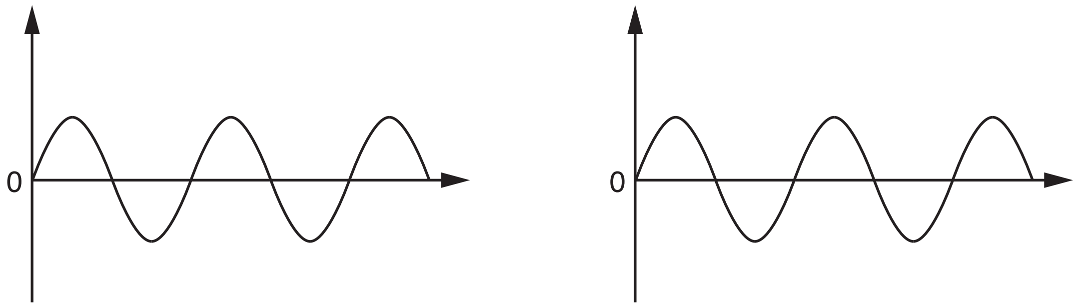

Fig. 4.1

[3]

(b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.

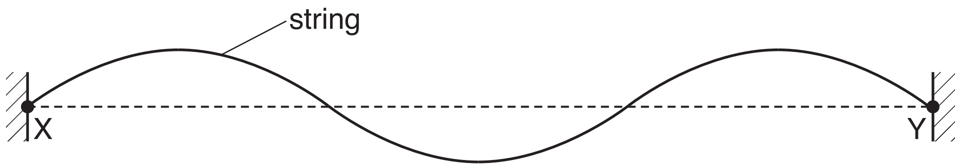

Fig. 4.2

The speed of a progressive wave along the string is $30\,\text{m}\,\text{s}^{-1}$. The stationary wave has a period of 40 ms.

(i) Explain how the stationary wave is formed on the string.

....

....

....

....[2]

(ii) A particle on the string oscillates with an amplitude of 13 mm. At time t, the particle has zero displacement.

Calculate

1. the displacement of the particle at time (t + 100 ms),

displacement = ... mm

2. the total distance moved by the particle from time t to time (t + 100 ms).

distance = ... mm
[3]

(iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]

[Total: 12]

5 A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

(b) The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4\,\mathrm{V\,m^{-1}}$. The acceleration of the particle is $1.5 \times 10^{12}\,\mathrm{m\,s^{-2}}$.

the expression in **(a)** to show that the mass of the particle is 9.0 u.

[2]

(c) The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...
[1]

(d) A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

....

....[1]

(ii) acceleration.

....

....[1]

[Total: 7]

6 **(a)** Define the *coulomb*.

....

....[1]

(b) An electric current is a flow of charge carriers.

In the following list, underline the possible charges for a charge carrier.

8.0×10^{-19} C $\quad$ 4.0×10^{-19} C $\quad$ 1.6×10^{-19} C $\quad$ 1.6×10^{-20} C [1]

(c) The diameter of a wire ST varies linearly with distance along the wire as shown in Fig. 6.1.

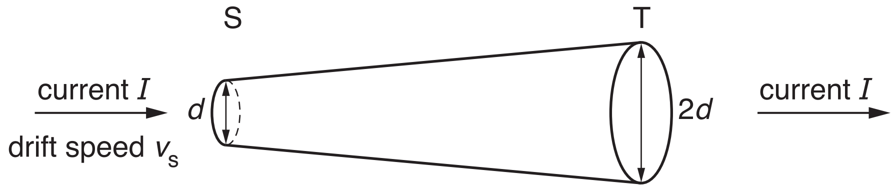

Fig. 6.1

There is a current I in the wire. At end S of the wire, the diameter is d and the average drift speed of the free electrons is v_s. At end T of the wire, the diameter is $2d$.

On Fig. 6.2, sketch a graph to show the variation of the average drift speed with position along the wire between S and T.

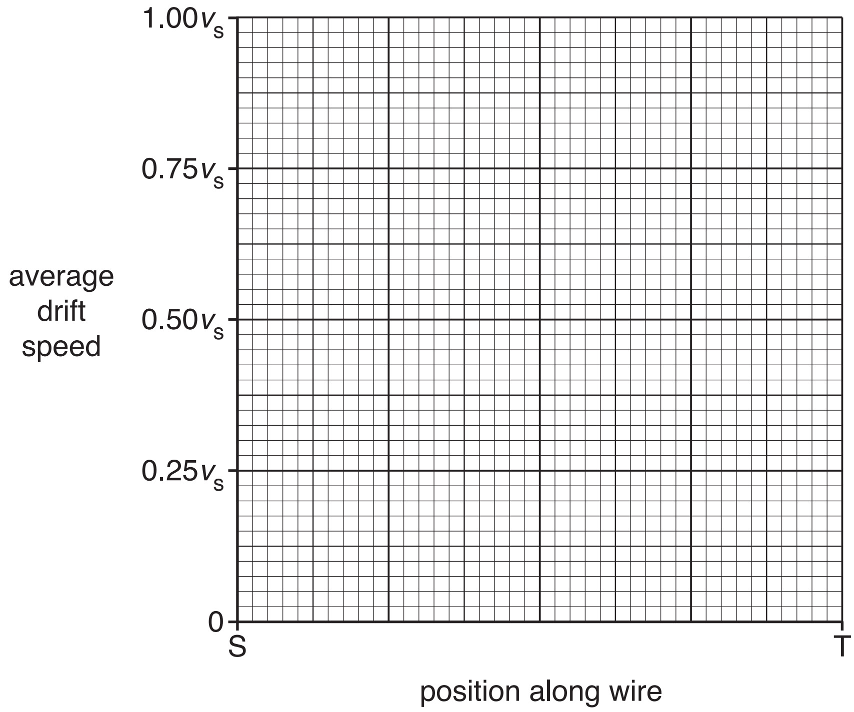

Fig. 6.2

[2]

[Total: 4]

7 **(a)** State Kirchhoff's first law.

....

....[1]

(b) A potentiometer is connected to a battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance, as shown in Fig. 7.1.

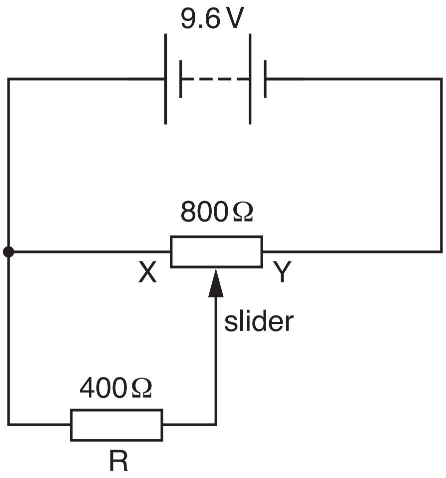

Fig. 7.1

The maximum resistance of the potentiometer is 800 Ω. A resistor R of resistance 400 Ω is connected between the slider and end X of the potentiometer.

(i) State the potential difference across resistor R when the slider is positioned

1. at end X of the potentiometer,

potential difference = ... V

2. at end Y of the potentiometer.

potential difference = ... V
[2]

(ii) Calculate the potential difference across resistor R when the slider is positioned half-way between X and Y.

potential difference = ... V [3]

[Total: 6]