1 **(a)** The diameter d of a cylinder is measured as 0.0125 m ± 1.6%.

Calculate the absolute uncertainty in this measurement.

absolute uncertainty = ... m [1]

(b) The cylinder in **(a)** stands on a horizontal surface. The pressure p exerted on the surface by the cylinder is given by

$$p = \frac{4W}{\pi d^2}.$$

The measured weight W of the cylinder is 0.38 N ± 2.8%.

(i) Calculate the pressure p.

p = ... $\mathrm{N\,m^{-2}}$ [1]

(ii) Determine the absolute uncertainty in the value of p.

absolute uncertainty = ... $\mathrm{N\,m^{-2}}$ [2]

[Total: 4]

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

.....

.....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

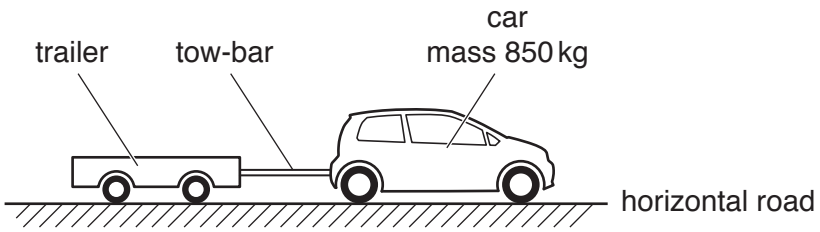

Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

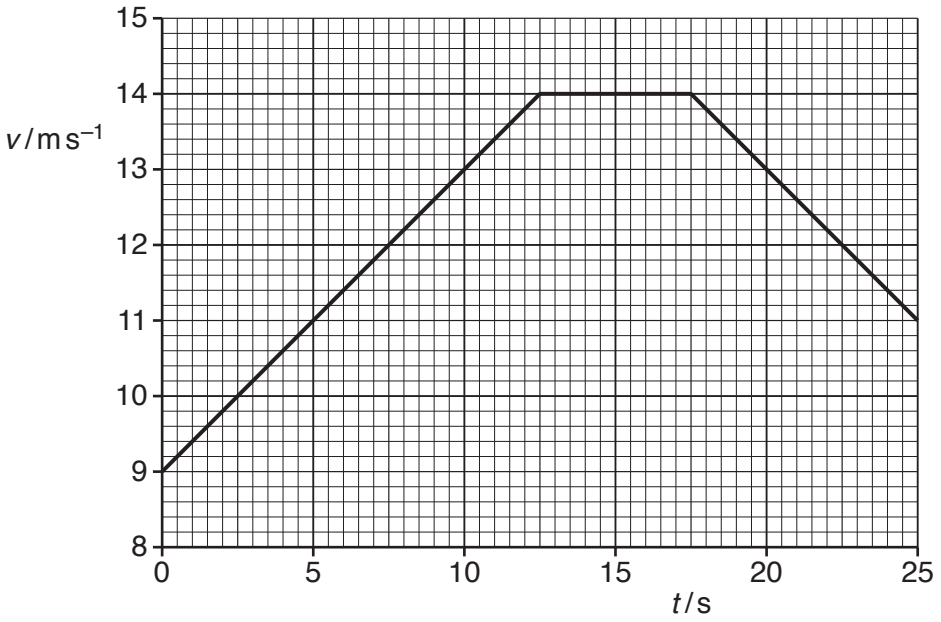

Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,s$.

distance = ... m [2]

(ii) At time $t = 10\,s$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

the car at time $t = 10\,s$:

1. use Fig. 2.2 to calculate the acceleration

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

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m^2

Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

[Total: 14]

3 **(a)** State what is meant by the *centre of gravity* of a body.

.....

.....[1]

(b) A uniform square sign with sides of length 0.68 m is fixed at its corner points A and B to a wall. The sign is also supported by a wire CD, as shown in Fig. 3.1.

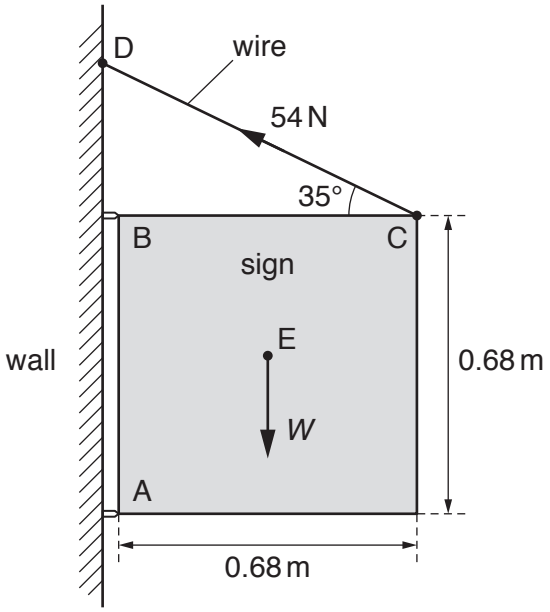

Fig. 3.1 (not to scale)

The sign has weight *W* and centre of gravity at point E. The sign is held in a vertical plane with side BC horizontal. The wire is at an angle of 35° to side BC. The tension in the wire is 54 N.

The force exerted on the sign at B is only in the vertical direction.

(i) Calculate the vertical component of the tension in the wire.

vertical component of tension = ... N [1]

(ii) Explain why the force on the sign at B does not have a moment about point A.

.....

.....[1]

(iii) By taking moments about point A, show that the weight W of the sign is 150 N.

[2]

(iv) Calculate the total vertical force exerted by the wall on the sign at points A and B.

total vertical force = ... N [1]

(c) The sign in **(b)** is held together by nuts and bolts. One of the nuts falls vertically from rest through a distance of 4.8 m to the pavement below. The nut lands on the pavement with a speed of $9.2\,m\,s^{-1}$.

Determine, for the nut falling from the sign to the pavement, the ratio

$$\frac{\text{change in gravitational potential energy}}{\text{final kinetic energy}}.$$

ratio = ... [4]

[Total: 10]

4 **(a)** a progressive water wave, state what is meant by:

(i) *displacement*

.....

.....[1]

(ii) *amplitude*.

.....

.....[1]

(b) Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity I. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of I, the resultant intensity at the meeting point.

intensity = ... [2]

(c) **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

.....

.....

.....[2]

(ii) A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing d of the diffraction grating.

d = ... m [3]

(iii) The beam of light in **(c)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

.....

.....

.....[2]

[Total: 11]

5 **(a)** State Kirchhoff's second law.

.....

.....[2]

(b) A battery of electromotive force (e.m.f.) 5.6 V and internal resistance *r* is connected to two external resistors, as shown in Fig. 5.1.

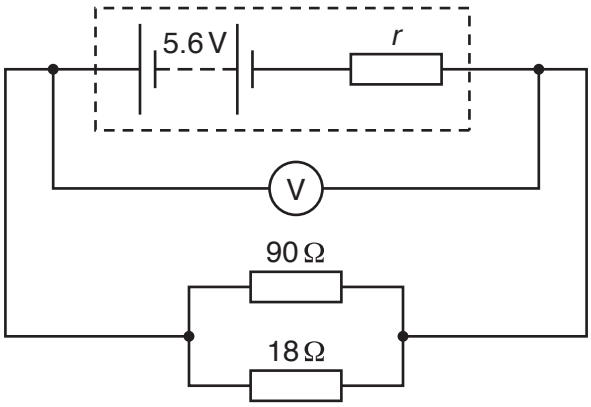

Fig. 5.1

The reading on the voltmeter is 4.8 V.

(i) Calculate:

1. the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [2]

2. the current in the battery.

current = ... A [2]

(ii) Show that the internal resistance *r* is 2.5 Ω.

[2]

(iii) Determine the ratio

$$\frac{\text{power dissipated by internal resistance } r}{\text{total power produced by battery}}.$$

ratio = ... [3]

(c) The battery in **(b)** is now connected to a battery of e.m.f. 7.2 V and internal resistance 3.5 Ω. The new circuit is shown in Fig. 5.2.

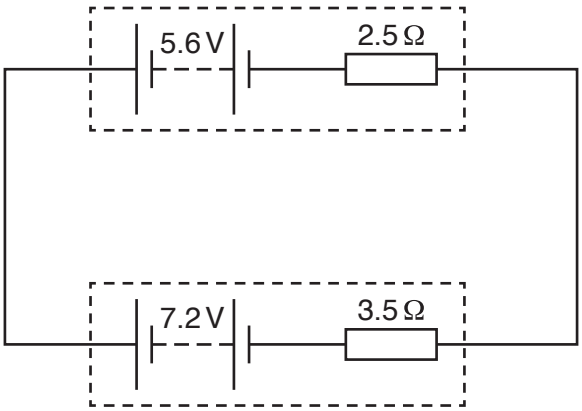

Fig. 5.2

Determine the current in the circuit.

current = ... A [2]

[Total: 13]

6 **(a)** State what is meant by a *field line* (*line of force*) in an electric field.

.....

.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....

.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α-particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}}.$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....

.....[3]

[Total: 8]