4. Forces, Density and Pressure

4.3 Density and pressure

Paper 2

Question Paper

1 **(a)** Define density.

.....

..... [1]

(b) Fig. 1.1 shows a cuboidal glass block.

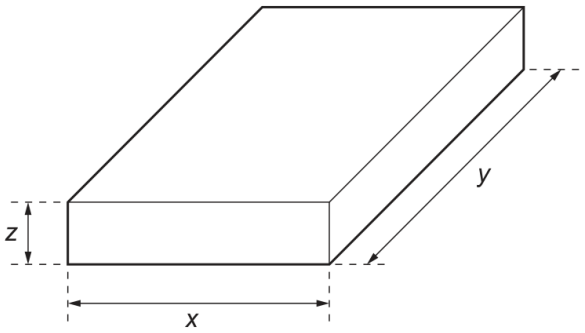


Fig. 1.1 (not to scale)

A student measures the mass m of the block and the side lengths x, y and z. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement
m	(0.243 ± 0.001) kg
x	(5.41 ± 0.01) cm
y	(11.09 ± 0.01) cm
z	(1.62 ± 0.01) cm

(i) Determine the density of the glass.

density = ... $kg\,m^{-3}$ [2]

2 **(b)** A sphere falls vertically through a liquid that has density 830 kg m^{-3}. The sphere has radius r and constant velocity v, as shown in Fig. 1.1.

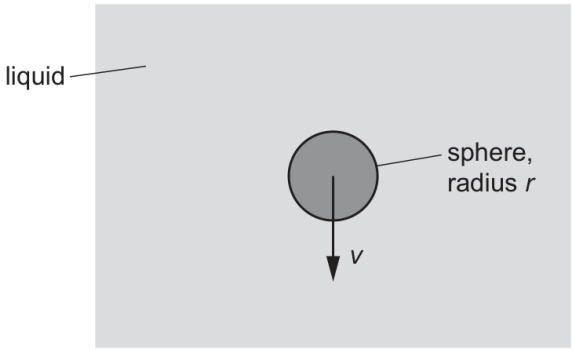


Fig. 1.1

(iii) The volume of the sphere is 4.6 cm^3. The drag force D is 0.32 N.

Calculate the weight of the sphere.

weight = ... N [2]

3 A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A, as shown in Fig. 4.1.

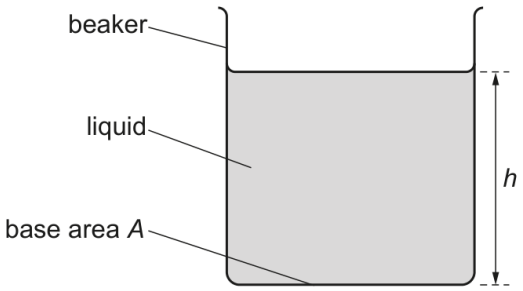


Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h.

(a) By using the definitions of pressure and density, show that

$$p = \rho g h$$

where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

(b) Suggest why the equation in **(a)** does not give the total pressure on the base of the beaker.

.....

..... [1]

(c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

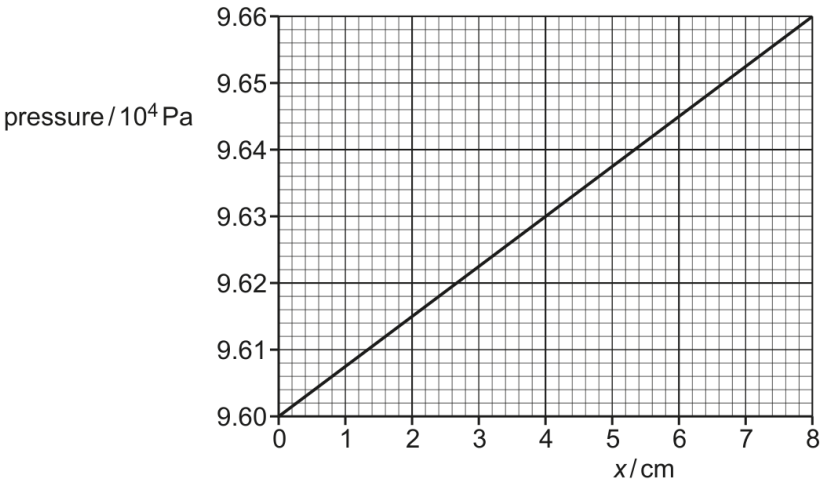


Fig. 4.2

Determine the density of the liquid.

density = ... kg m^{-3} [2]

(d) A solid cylinder is held stationary by a wire so that the base of the cylinder is level with the surface of the liquid, as shown in Fig. 4.3.

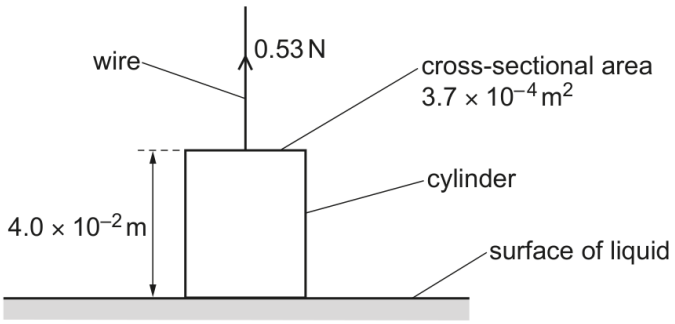


Fig. 4.3 (not to scale)

The cylinder has length 4.0×10^{-2} m and cross-sectional area 3.7×10^{-4} m^2. The tension in the wire is 0.53 N.

The cylinder is now lowered and then held stationary by the wire so that the top of the cylinder is level with the surface of the liquid.

Calculate the new tension in the wire.

tension = ... N [2]

4 **(a)** **(i)** Define pressure.

.....

..... [1]

5 A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

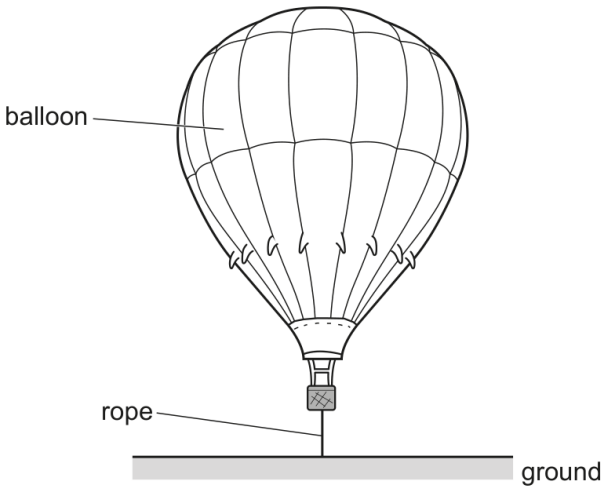


Fig. 2.1

The balloon has a weight W of 3.39×10^4 N. The tension T in the rope is 4.00×10^2 N.
Upthrust U acts on the balloon.
The density of the surrounding air is $1.23\,\text{kg}\,\text{m}^{-3}$.

(a) **(i)** On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]

(ii) Calculate the volume, to three significant figures, of the balloon.

volume = ... m^3 [3]

6 A high-altitude balloon is stationary in still air. A solid sphere is suspended from the balloon by a string, as shown in Fig. 2.1.

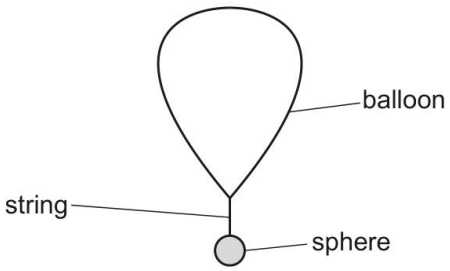


Fig. 2.1 (not to scale)

The volume of the balloon is 7.5 m^3. The total weight of the balloon, string and sphere is 65 N. The upthrust acting on the string and sphere is negligible.

(a) Calculate the density of the air surrounding the balloon.

density = ... $kg\,m^{-3}$ [2]

7 **(c)** The sphere in **(b)** is now immersed in a liquid in a container, as shown in Fig. 2.2.



Fig. 2.2

The density of the liquid is 1100 kg m^{-3}. The upthrust acting on the sphere due to the liquid is 2.5 N. The magnitude of F is unchanged so that the horizontal rod is **not** in equilibrium.

(i) Use Archimedes' principle to determine the radius r of the sphere.

r = ... m [3]

8 A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

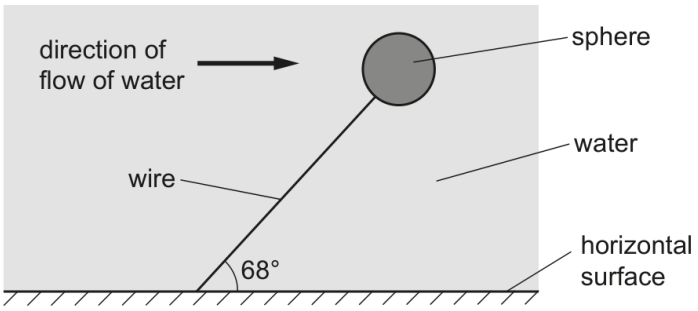


Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is 1.0×10^3 kg m^{-3}.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(b) For the sphere, calculate:

(i) the volume

volume = ... m^3 [1]

(ii) the density.

density = ... kg m^{-3} [2]

9 A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

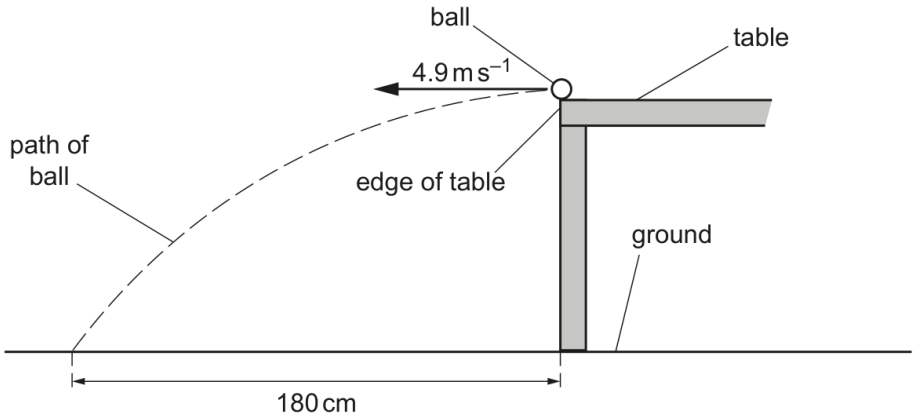


Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of 4.9 m s^{-1}. The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

Assume that air resistance is negligible.

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

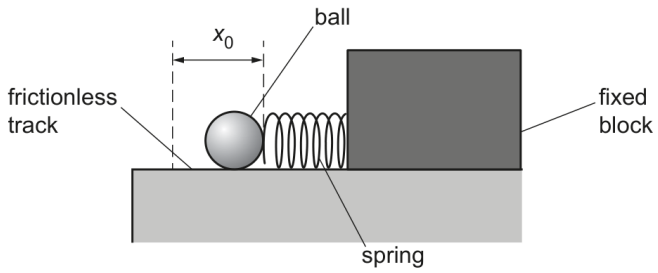


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

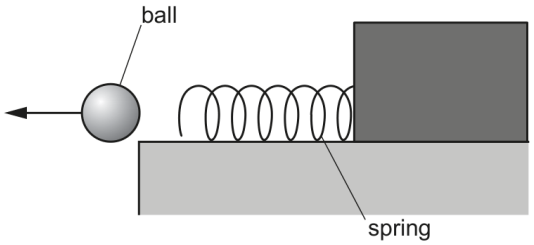


Fig. 2.3

The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

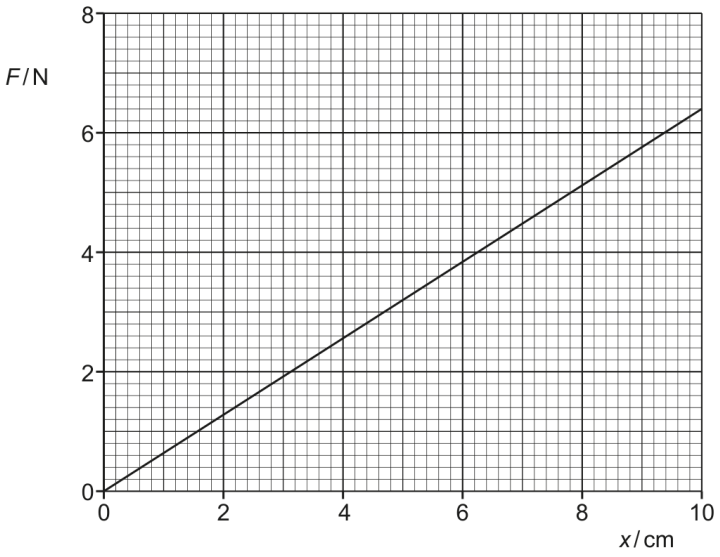


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

10 A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

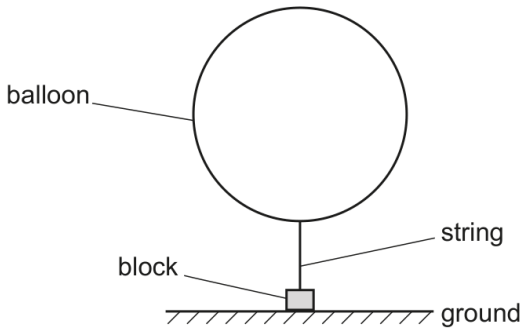


Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is $1.2\,\text{kg}\,\text{m}^{-3}$. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius r of the balloon.

r = ... m [2]

11 (a) Define *density*.

.....

..... [1]

(b) Fig. 1.1 shows a solid pyramid with a square base.

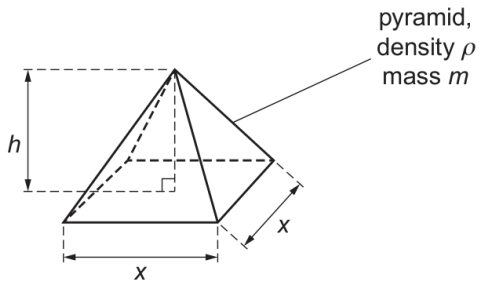


Fig. 1.1

The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho h x^2$$

where ρ is the density of the material of the pyramid,
h is the height, and
x is the length of each side of the base.

Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5 g	±2%
x	4.0 cm	±5%
h	4.8 cm	±4%

(c) The square base of the pyramid in **(b)** rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]

12 (c) A floating solid cylinder is attached by a wire to the sea bed, as shown in Fig. 1.1.

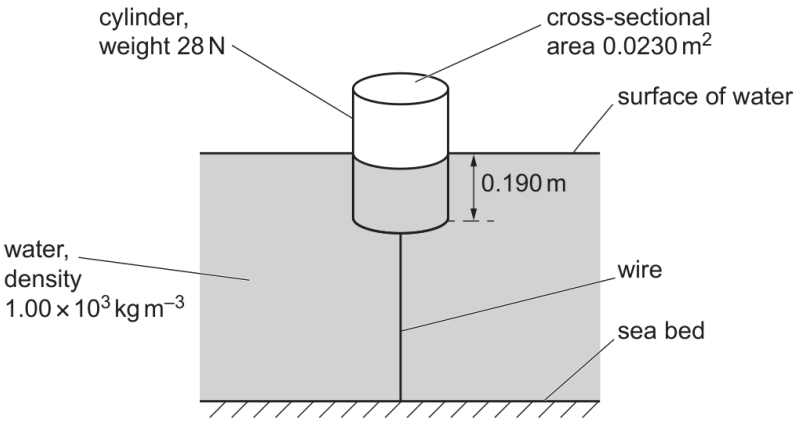


Fig. 1.1 (not to scale)

The density of the water is $1.00 \times 10^3\,\text{kg m}^{-3}$. The base of the cylinder is at a depth of 0.190 m below the surface of the water. The cylinder has a weight of 28 N and a cross-sectional area of $0.0230\,\text{m}^2$.

The wire and the central axis of the cylinder are both vertical. The cylinder is in equilibrium.

(i) Calculate, to three significant figures, the upthrust acting on the cylinder due to the water.

upthrust = ... N [2]

13 (a) Define *density*.

.....

..... [1]

14 (b) A uniform rigid rod of length 2.4 m is shown in Fig. 1.1.

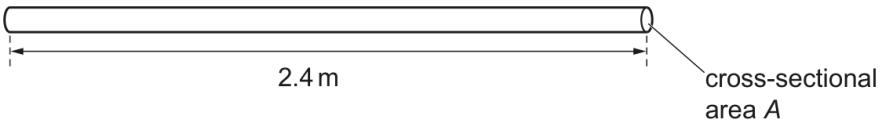


Fig. 1.1

The rod has a weight of 5.2 N and is made of wood of density 790 kg m^{-3}.

Calculate the cross-sectional area A, in mm^2, of the rod.

A = ... mm^2 [3]

15 **(a)** A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

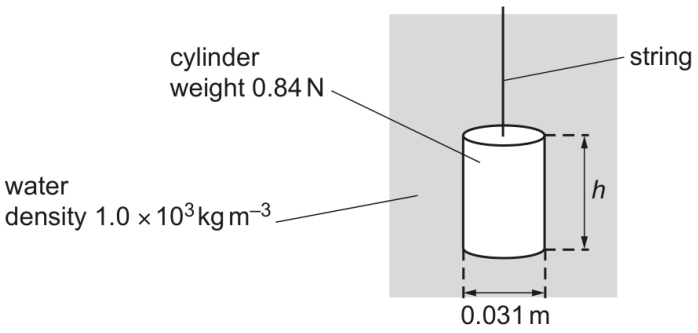


Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is 1.0×10^3 kg m^{-3}. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

16 **(a)** A spherical oil drop has a radius of 1.2×10^{-6} m. The density of the oil is 940 kg m^{-3}.

(i) Show that the mass of the oil drop is 6.8×10^{-15} kg.

[2]

(d) Two types of force, X and Y, can act on an oil drop when it is in air, but cannot act on an oil drop when it is in a vacuum. Force X can act on an oil drop when it is stationary or when it is moving. Force Y can only act on an oil drop when it is moving.

State the name of:

(i) force X

.....[1]

17 **(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]

18 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

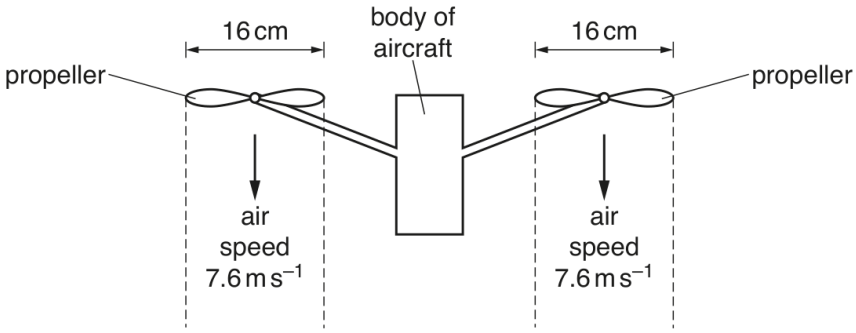


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is 1.2 kg m^{-3}. Assume that the air from each propeller moves with a constant speed of 7.6 m s^{-1} in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

.....

..... [1]

19 A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

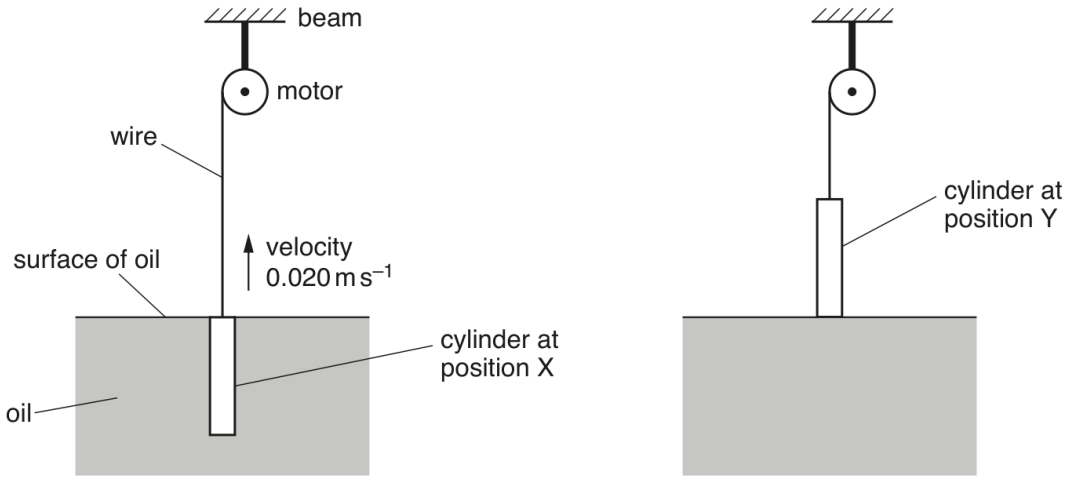


Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area 0.018 m^2, length 1.2 m and weight 560 N.
The density of the oil is 940 kg m^{-3}.

Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of 0.020 m s^{-1}. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

density = ... kg m^{-3} [2]

(b) For the cylinder at position X, show that the upthrust due to the oil is 200 N.

[2]

20 (b) The propulsion system of a toy car consists of a propeller attached to an electric motor, as illustrated in Fig. 3.1.

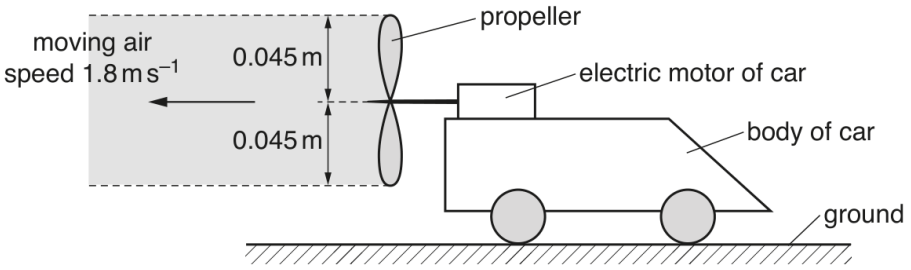


Fig. 3.1

The car is on horizontal ground and is initially held at rest by its brakes. When the motor is switched on, it rotates the propeller so that air is propelled horizontally to the left. The density of the air is 1.3 kg m^{-3}.

Assume that the air moves with a speed of 1.8 m s^{-1} in a uniform cylinder of radius 0.045 m. Also assume that the air to the right of the propeller is stationary.

(i) Show that, in a time interval of 2.0 s, the mass of air propelled to the left is 0.030 kg.

[2]