02 Forces and Moments

PROBLEM SET

These problems are for both H1 Physics and H2 Physics.
Duration: 2.5 hours

1 Fig. 1.1 shows a force diagram that represents a boat that is being lifted by two ropes so that the boat remains horizontal and travels vertically upwards at a constant speed after leaving the water.

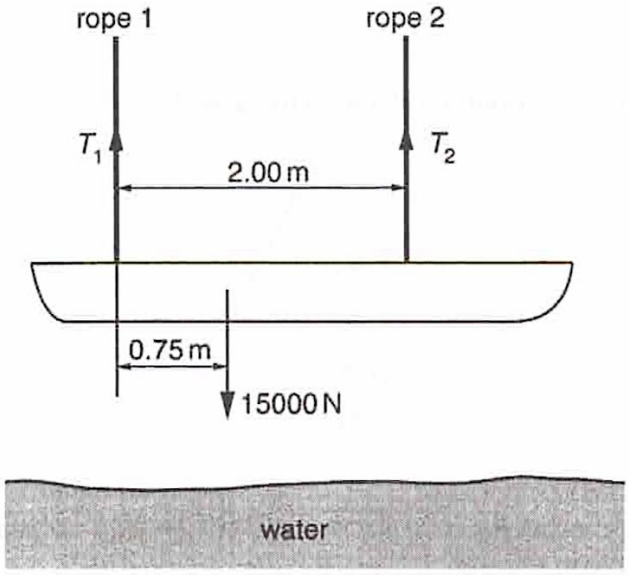

Fig. 1.1

The weight of the boat is 15000 N and the tensions in the ropes 1 and 2 are T_1 and T_2 respectively.

(a) The position of the centre of gravity of the boat is not at its midpoint. Suggest what this implies about the distribution of mass in the boat. [1]

(b) Explain two conditions required for the boat to be in a state of equilibrium while it is moving upwards. [2]

(c) Use the principle of moments to determine the tensions in the two ropes. [4]

(2009 P2 Q3)

2 **(a)** State the principle of moments. [1]

(b) A metal sign of uniform thickness and of width 1.00 m at its upper edge hangs from two vertical, rigid supports, as shown in Fig. 2.1.

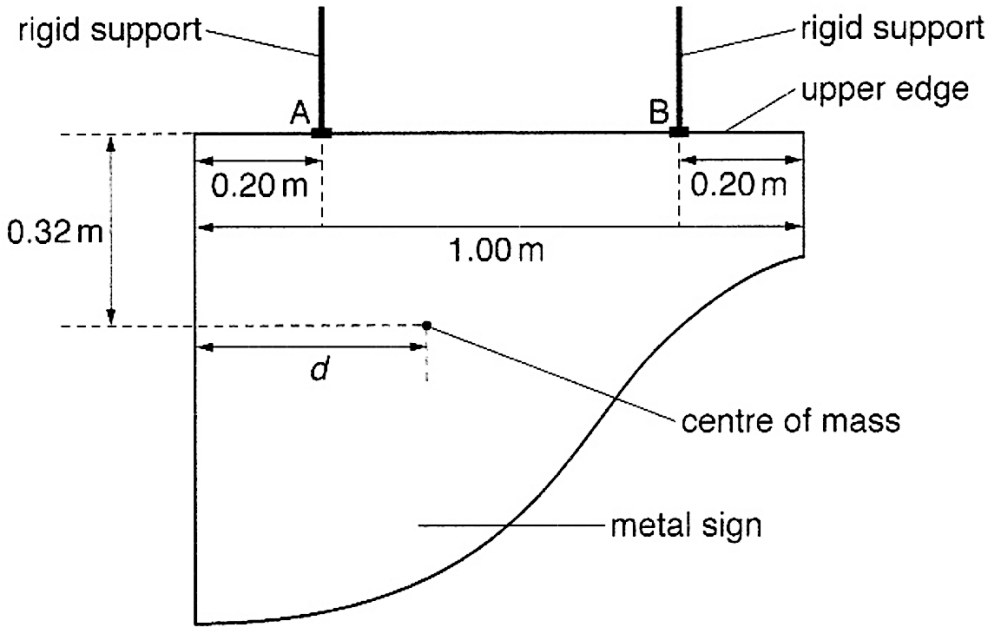

Fig. 2.1

The sign is hinged and swings freely from the rigid supports at points A and B.

The supports are 0.20 m from each edge of the sign.

The mass of the sign is 4.5 kg.

The centre of mass of the sign is 0.32 m below its upper edge.

(i) The ratio of the tensions in the two supports is $\frac{3}{7}$.

Calculate the magnitude of each tension. [2]

(ii) Using your answers to **(b)(i)**, determine the horizontal distance d of the centre of mass from the left edge of the metal sign. [2]

(c) A horizontal wind now blows on the face of the sign so it hangs at an angle θ to the vertical, as shown in Fig. 2.2.

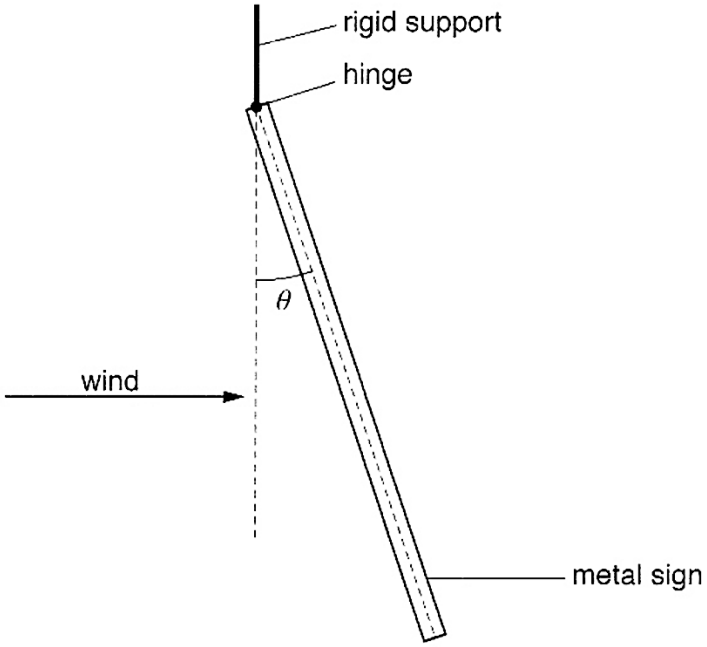

Fig. 2.2

Explain why the force exerted by each support on the sign now has a horizontal component. [1]

(2018 P2 Q1)

3 A non-uniform bar AB makes an angle of 60° with a horizontal surface, as shown in Fig. 3.1.

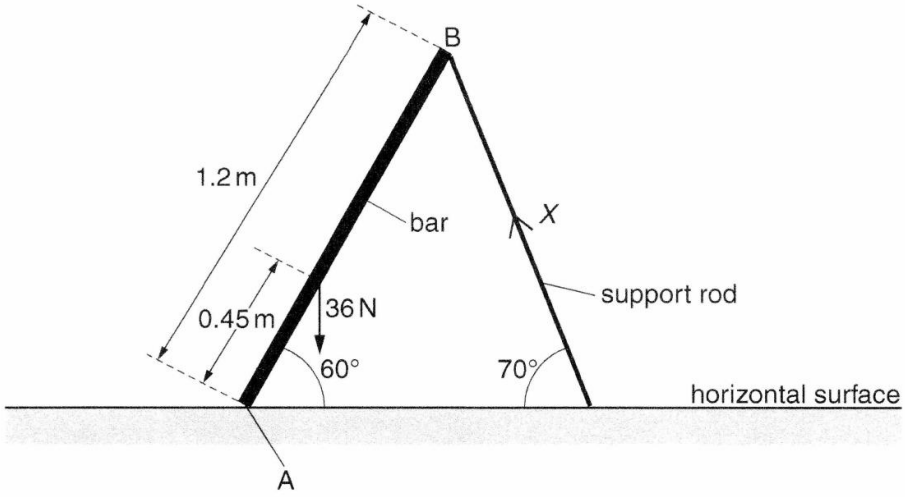

Fig. 3.1

The bar is hinged at A and is supported by a rod at B. The force *X* produced by the rod at B acts at an angle of 70° to the horizontal.
The bar has a length of 1.2 m and a weight of 36 N.
The centre of gravity of the bar is 0.45 m from A.

(a) Use the principle of moments to show that the magnitude of X is 8.8 N. [2]

(b) A force *F* acts on the bar at A.

(i) Explain why a force is required to act on the bar at A to keep the bar in equilibrium.

[2]

(ii) Calculate the magnitude of *F*. [3]

(iii) On Fig. 3.1, draw an arrow to show the approximate direction of *F*. [1]

(2016 P2 Q3)

4 A sign PQ and its support stand are in equilibrium on a horizontal surface, as shown in Fig. 4.1.

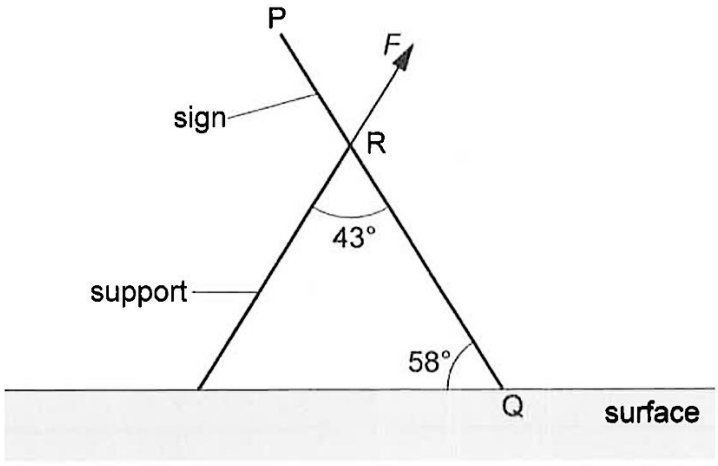

Fig. 4.1 (not to scale)

The sign is uniform and has a mass of 2.3 kg. The sign is at an angle of 58° to the surface.

The support joins to the sign at point R where PR = $\frac{PQ}{3}$. The support is at an angle of 43° to the sign and exerts a force *F* on the sign. Force *F* is parallel to the support.

(a) By taking moments about point Q, determine the force *F*. [3]

(b) Explain why the force acting on the sign at Q is not vertical. [2]

(2021 P2 Q3)

5 An object S of weight 60.0 N is supported by two ropes A and B, as shown Fig. 5.1.

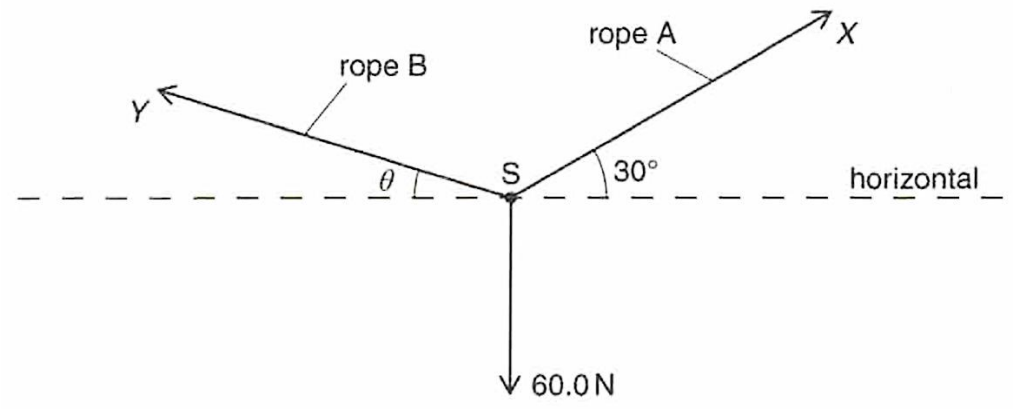

Fig. 5.1

Rope A is at 30° to the horizontal and exerts force X on S. Rope B is at an angle θ to the horizontal and exerts force Y on S.

The magnitude of force X is varied from 0 to 200 N. Rope A is always kept at 30° to the horizontal. The force Y is varied in magnitude and direction to keep S in equilibrium.

(a) Determine the magnitude and direction of force Y for the magnitude of force X equal to
(i) zero, [2]
(ii) 200 N [3]

(b) By reference to Fig. 5.1, explain why the rope B cannot be parallel to the weight of S no matter how large the magnitude of X. [2]

(2014 P2 Q1)

6 **(a)** State the conditions required for a body to be in equilibrium. [2]

(b) A person of weight 700 N hangs at rest from a point on a wire, as shown in Fig. 6.1. The tensions in the wire are T_1 and T_2.

The weights of the wire and of the equipment supporting the person are negligible.

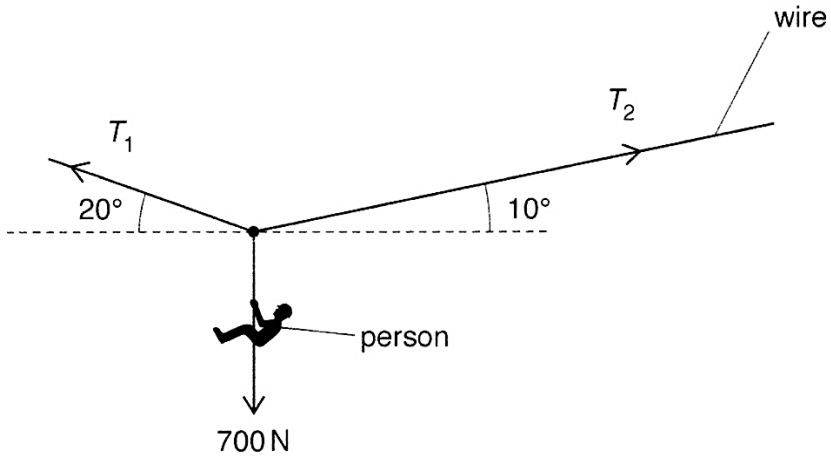

Fig. 6.1

The tension T_1 is at an angle of 20° to the horizontal. The tension T_2 is at an angle of 10° to the horizontal.

Determine the magnitudes of T_1 and T_2. [4]

(c) A wire is supported at one end by a vertical pole of height 1.8 m. The base of the pole rests on the surface of solid ground, as shown in Fig. 6.2.

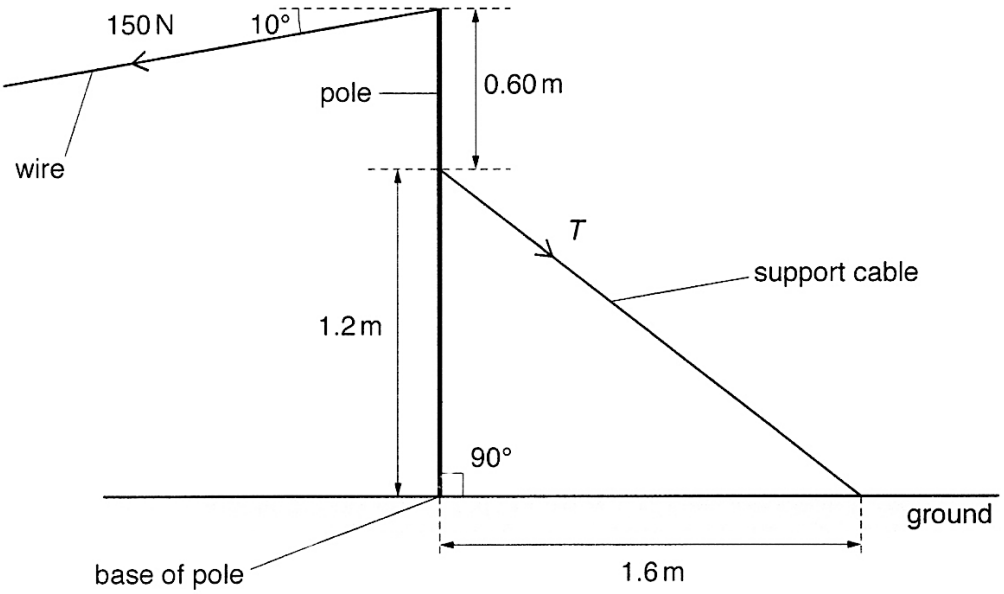

Fig. 6.2

The wire is at an angle of 10° below the horizontal. A cable, attached 1.2 m from the base of the pole, supports the pole. The other end of the cable is attached to the ground at a horizontal distance of 1.6 m from the base of the pole. The tension in the wire is 150 N. The pole is in equilibrium.

Calculate the tension T in the support cable. [3]

(2019 P2 Q1)

7 A spring has an unstretched length of 8.0 cm. The top of the spring is attached to a fixed point. A steel block of mass 140 g is suspended from the lower end so that the length of the spring increases to 10.8 cm, as shown in Fig. 8.1.

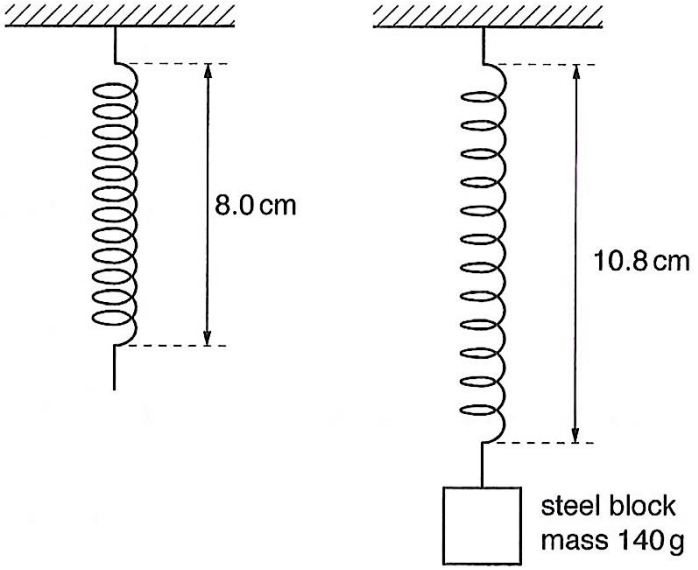

Fig. 8.1 (not to scale)

(a) Calculate the force constant of the spring. [2]

(b) **(i)** The percentage uncertainty in the mass is ±1.0%. The actual uncertainty in each measurement of the length of the spring is ±1 mm.

Calculate the percentage uncertainty in the force constant. [2]

(ii) Use your answers in **(a)** and **(b)(i)** to determine the value of the force constant, with its actual uncertainty, to an appropriate number of significant figures. [1]

(2017 P2 Q1part)

Numerical answers

1 **(c)** T_1 = 9400 N, T_2 = 5600 N

2 **(b)(i)** 31 N at support A, 13 N at support B **(ii)** 0.38 m

3 **(b)(ii)** 27.9 N

4 **(a)** 13 N

5 **(a)(i)** 60.0 N upwards **(ii)** 178 N, 13° below horizontal

6 **(b)** T_1 = 1400 N, T_2 = 1300 N **(c)** 280 N

7 **(a)** 49 N m^{-1} **(b)(i)** 8% **(ii)** (49 ± 4) N m^{-1}