Problems

5.1 A force at the end of a spanner applied 300 mm from the centre of the nut is 45 N. What is the maximum turning moment produced by this force? What should be the direction of the force to achieve the maximum turning effect?

5.2 A winding hoist has a drum of 300 mm diameter. Determine the moment about its centreline produced by tension in the cable equal to 0.5 kN.

5.3 A horizontal beam 2 m long is supported at its ends. Determine the moments about each of the supports due to the following loads:
(a) A downward force of 3 kN at mid-point.
(b) A downward force of 3 kN at a point 0.5 m from the left support.
(c) Three downward forces 1 kN each located at 0.5 m, 1 m and 1.5 m from the left support.
(d) A downward force of 1 kN and a downward force of 2 kN located at 0.5 m and 1.5 m from the left support respectively.
(e) A force of 3 kN applied at mid-point and inclined at 60° to the horizontal.

5.4 The beam in Figure 5.8 is built into the wall and carries a load of 10 kN as shown.

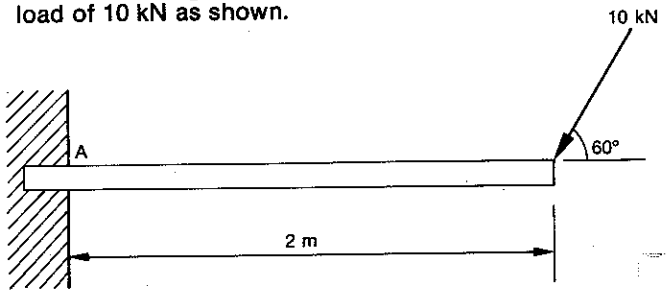

Fig. 5.8

Determine the moment of the force about the support *A*,
(a) by using perpendicular distance to the force,
(b) by using rectangular components of the force.

5.5 The truss shown in Figure 5.9 is subjected to three loads as indicated. Determine the total moment due to the applied forces about
(a) left-hand support *A*,
(b) right-hand support *B*.

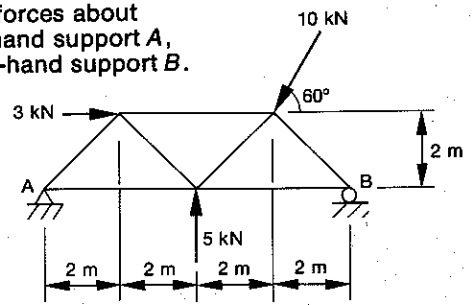

Fig. 5.9

5.6 A car has 750 mm diameter wheels and requires a force of 0.5 kN between each driving wheel and the road surface. What torque must be applied to each of the driving wheels to supply this force?

5.7 A pull in a bicycle chain of 250 N applied to a sprocket of 80 mm diameter provides the necessary torque to the rear wheel. If the wheel is 600 mm diameter, what is the force between the wheel and the ground?

5.8 A 300 mm diameter pulley is subjected to belt tensions equal to 500 N and 200 N. Determine the torque acting on the pulley.

5.9 The arm shown in Figure 5.10 is keyed to a 200 mm diameter shaft. Assuming that the turning effort is transmitted by the key only, determine the force on the key if the load at the end of the arm is 250 N.

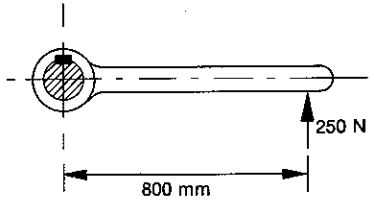

Fig. 5.10

5.10 Determine the force that must be applied to the foot-pedal shown in Figure 5.11 to produce a force in the connecting link of 200 N.

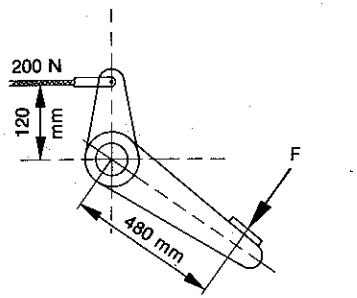

Fig. 5.11

5.11 Determine the force F required to start to tip the cabinet shown in Figure 5.12, if the mass of the cabinet is 50 kg.

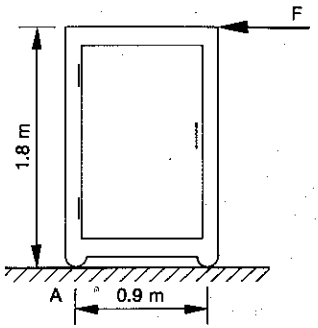

Fig. 5.12

5.6 Equivalent force-moment system

When a force F is applied to a rigid body, such as the spanner shown in Figure 5.15, at a point A, it is sometimes useful to consider the effect of the force viewed from another point, B.

It can be shown that the given force at A can be replaced by an equal force acting at another point, B, and a turning moment, equal to the moment of F, in its original position, about point B. The moment can be represented by the symbol ↻ placed at point B.

The turning moment at B can be interpreted as a pure moment, i.e. torque, or as a couple, as can be seen from the following examples.

Example 5.8

A bolt is being tightened by a force of 60 N applied to a spanner at a distance of 300 mm as shown in Figure 5.15(a). Replace the force by a force-moment system at B.

Solution

The equivalent force-moment system at B comprises a force of 60 N and a turning moment equal to

$$M = 60 \text{ N} \times 0.3 \text{ m} = 18 \text{ N.m clockwise,}$$

as shown in Figure 5.15(b).

This implies that the effect of the force applied at A combines the tendency to push, or shear, the bolt with a force of 60 N and at the same time to turn it clockwise with a turning moment of 18 N.m.

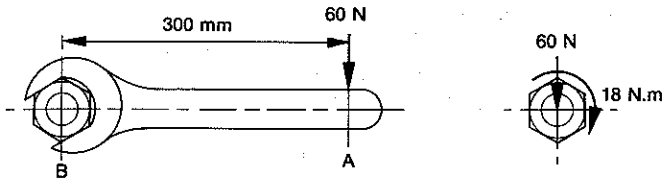

Fig. 5.15

Example 5.9

For the hook shown in Figure 5.16(a), replace the force of 200 N acting in plane A by an equivalent force-moment system at B.

Solution

The equivalent force-moment system at B consists of a force of 200 N and a clockwise turning moment equal to

$$M = 200 \text{ N} \times 0.075 \text{ m} = 15 \text{ N.m,}$$

as shown in Figure 5.16(b).

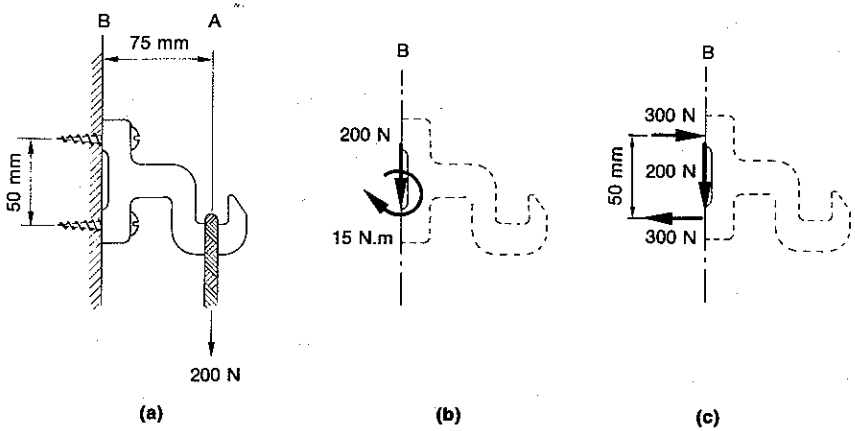

Fig. 5.16

In this case, where the moment is taken by the supports, it may be meaningful to interpret the moment as an equivalent couple with a distance of 50 mm between forces, i.e.

$$M = F \times d$$
$$15 \text{ N.m} = F \times 0.05 \text{ m}$$
$$\text{Hence } F = \frac{15}{0.05} = 300 \text{ N, as in Figure 5.16(c).}$$

Problems

5.13 A screw jack is operated by means of 40 N forces applied at each end of a double arm, at right angles to it. Determine the magnitude of the turning moment if the total length of the double arm is 700 mm.

5.14 A 400 mm × 300 mm plate is subjected to forces as shown in Figure 5.17. Show that the turning effects of the forces add up to zero at any point.

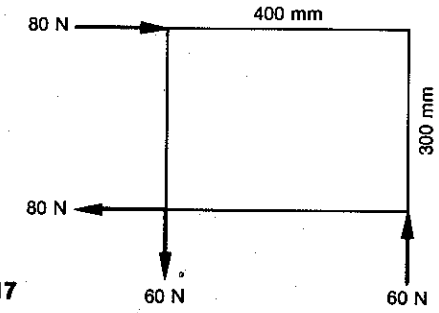

Fig. 5.17

5.15 A horizontal bar is subjected to a number of forces as shown in Figure 5.18. Prove that the bar is in rotational equilibrium:
(a) by adding the moments of all forces about any point on the bar and then repeating for one other point;
(b) by recognising pairs of forces as couples and adding their moments.

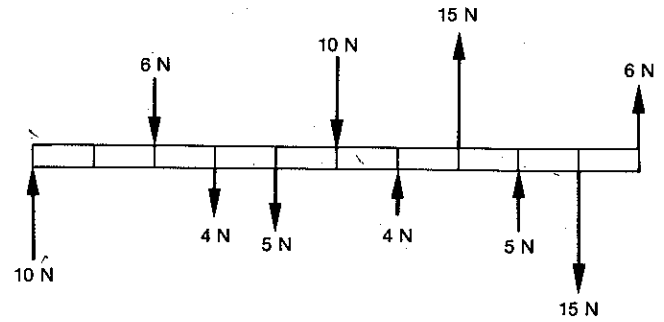

Fig. 5.18

5.16 Determine the force F at each end of the bar AB (Fig. 5.19) required to maintain equilibrium, if the force in the string which is passed around the pulleys is 160 N.

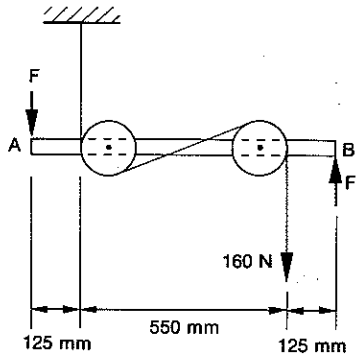

Fig. 5.19

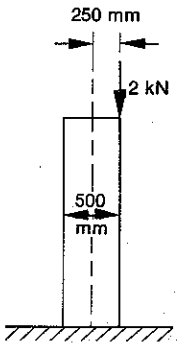

Fig. 5.20

5.17 A column 0.5 m wide carries a 2 kN force as shown in Figure 5.20. Reduce the force to an equivalent axial load and a moment.

5.18 Determine the eccentricity d of a load which can be represented as an axial load of 1 kN and a moment of 15 N.m acting on a column.

5.19 Determine the equivalent force-moment system at the built-in end of a cantilever beam shown in Figure 5.21.

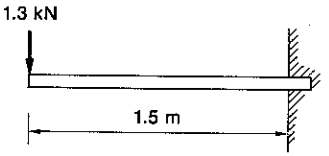

Fig. 5.21

5.20 If the mass supported by the bracket in Figure 5.22 is 5 kg, interpret the load as a force and a couple acting through the bolts.

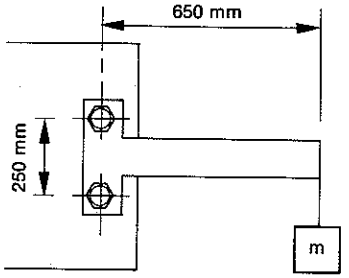

Fig. 5.22

Review questions

1. Define moment of a force.
2. What is the SI unit of moment of a force?
3. Does moment of a force have directional sense?
4. What is the principle known as the Varignon Theorem?
5. What is the condition of rotational equilibrium of a system of forces?
6. Define torque and state the SI unit of torque.
7. Define moment of a couple.
8. What is an equivalent couple?
9. What is meant by an equivalent force-moment system?