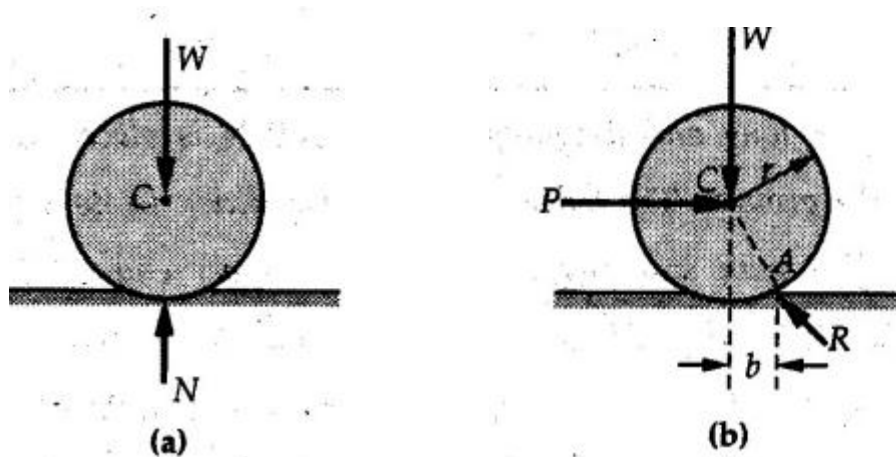## 4.4 ROLLING RESISTANCE

• When a wheel rests on ground, both the wheel and the ground deform due to weight of the wheel as shown in Fig (a).

• To move the wheel at constant speed a horizontal force P is required to be applied at the axle as shown in Fig. (b).

• The resultant R of all forces exerted by ground on the wheel is experimentally found to be slightly in front of line of action of weight W.

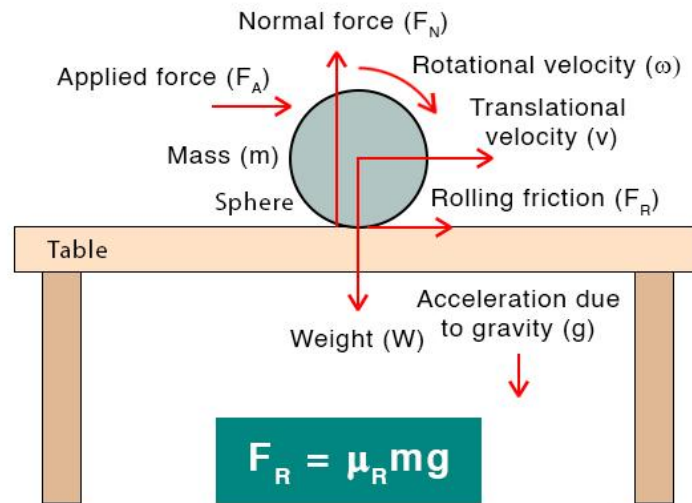• To roll the wheel at constant speed, the moment of W about A has to be balanced by moment of P about A.

$\Box$ Wb = Pr

(a)   (b)

The length b is known as the coefficient of rolling resistance. A larger value of b makes P larger which indicates a larger effort to keep the wheel moving.

People have observed rolling motion without slipping ever since the invention of the wheel. For example, we can look at the interaction of a car's tires and the surface of the road. If the driver depresses the accelerator to the floor, such that the tires spin without the car moving forward, there must be kinetic friction between the wheels and the surface of the road. If the driver depresses the accelerator slowly, causing the car to move forward, then the tires roll without slipping. It is surprising to most people that, in fact, the bottom of the wheel is at rest with respect to the ground, indicating there must be static friction between the tires and the road surface.

Rolling Friction

Normal force (F_N)

Applied force (F_A)

Rotational velocity (ω)

Translational velocity (v)

Mass (m)

Sphere

Rolling friction (F_R)

Table

Weight (W)

Acceleration due to gravity (g)

$$F_R = \mu_R mg$$

Solved Examples

1.A 100 kg cupboard is mounted on small caster wheels which can be locked to prevent their rotation. If μ_s = 0.3 between wheels and floor, determine 'P' to move cupboard to the right when (a) All casters are locked (b) Only casters at B are locked (c) Only casters at A are locked. Refer Fig.

P

800 mm

A

B

600 mm
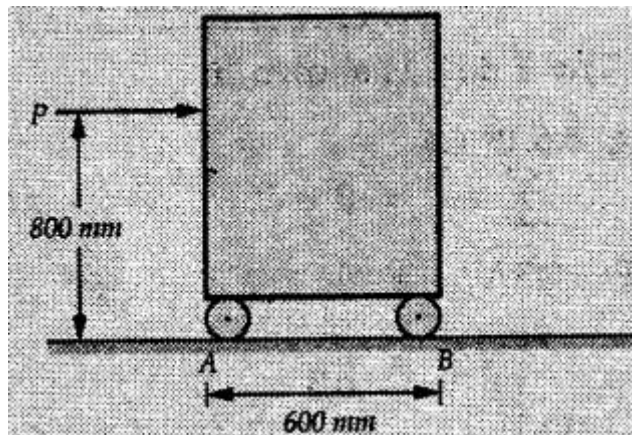
Solution:

If casters are not locked, there will be no frictional force as rolling friction is negligible.

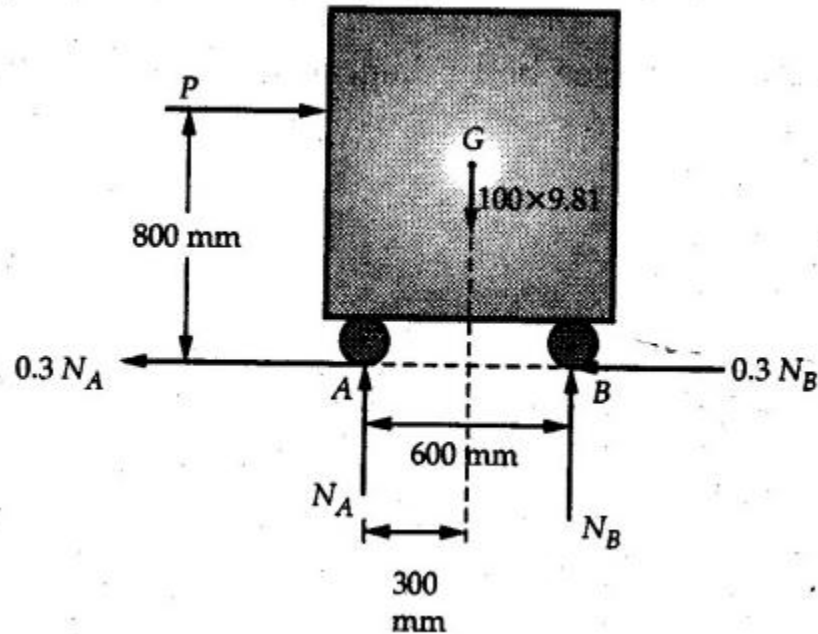a) The F.B.D. of cupboard is shown in Fig. (a)

Fig.(a)

$$\Sigma F_y = 0$$

$$N_A + N_B - 100 \times 9.81 = 0$$

$$\therefore \qquad N_A + N_B = 981$$

$$\Sigma F_x = 0$$

$$P - 0.3 N_A - 0.3 N_B = 0$$

$$P = 0.3 (N_A + N_B) = 0.3 \times 981$$

$$\therefore \qquad \boxed{P = 294.3 \text{ N}}$$

b) As casters at B are locked, there will be frictional force at B and 0 friction at A as these casters are free to roll. The F.B.D. is shown in Fig. (b).
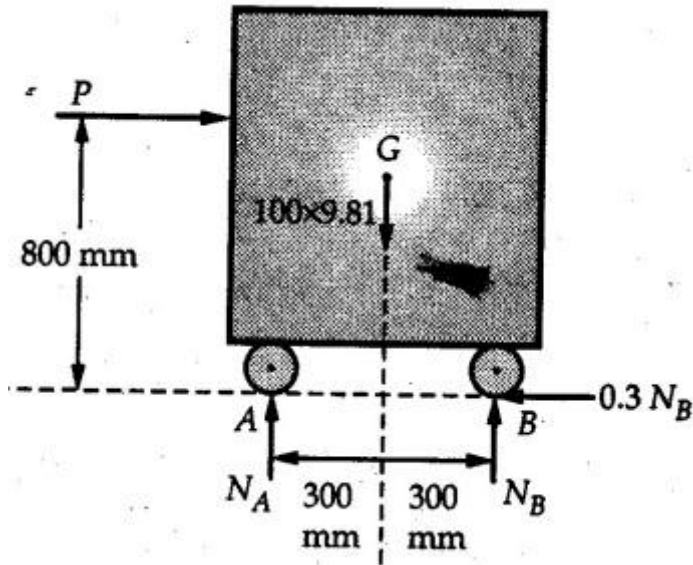
Fig.(b)

$$\sum F_x = 0$$

$$P - 0.3 N_B = 0$$

$$\therefore \quad N_B = \frac{P}{0.3}$$

$$\sum M_A = 0$$

$$-(P)(800) - (100 \times 9.81)(300) + (N_B)(600) = 0$$

$$-P(800) + \left(\frac{P}{0.3}\right)(600) = 100 \times 9.81 \times 300$$

$$\therefore \qquad \boxed{P = 245.25 \text{ N}}$$
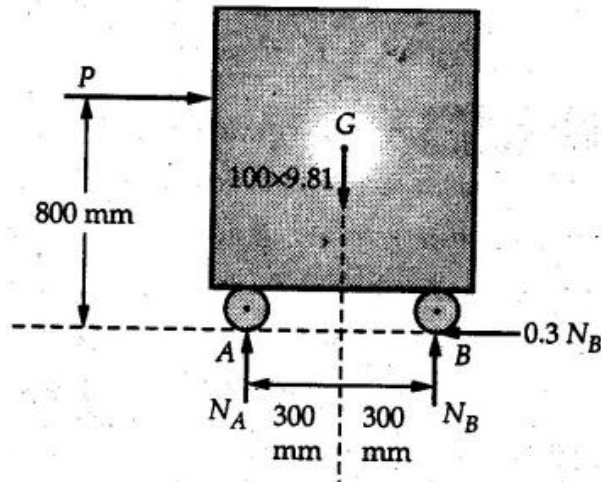
c) The F.B.D. is shown in Fig. (c)

Fig.(c)

$$\sum F_x = 0$$

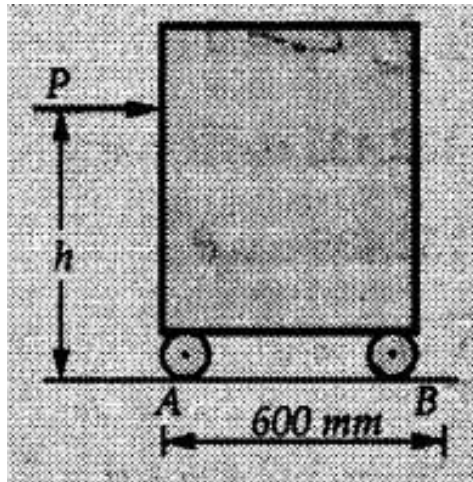$$P - 0.3 N_A = 0$$

$$N_A = \frac{P}{0.3}$$

$$\sum M_B = 0$$

$$-(P)(800) + (100 \times 9.81)(300) - (N_A)(600) = 0$$

$$(P)(800) + \left(\frac{P}{0.3}\right)(600) = 100 \times 9.81 \times 300$$

$$\therefore \quad \boxed{P = 105.11 \text{ N}}$$

2.A 100 kg cupboard is mounted on small caster wheels which are locked to prevent their rotation. If $\mu_s = 0.3$ between wheels and floor, determine the maximum height 'h' at which the force 'P' can be applied to move cupboard to the right. Refer Fig.

Solution:

The F.B.D. of cupboard is shown in Fig. (a). For maximum 'h', NA → 0.
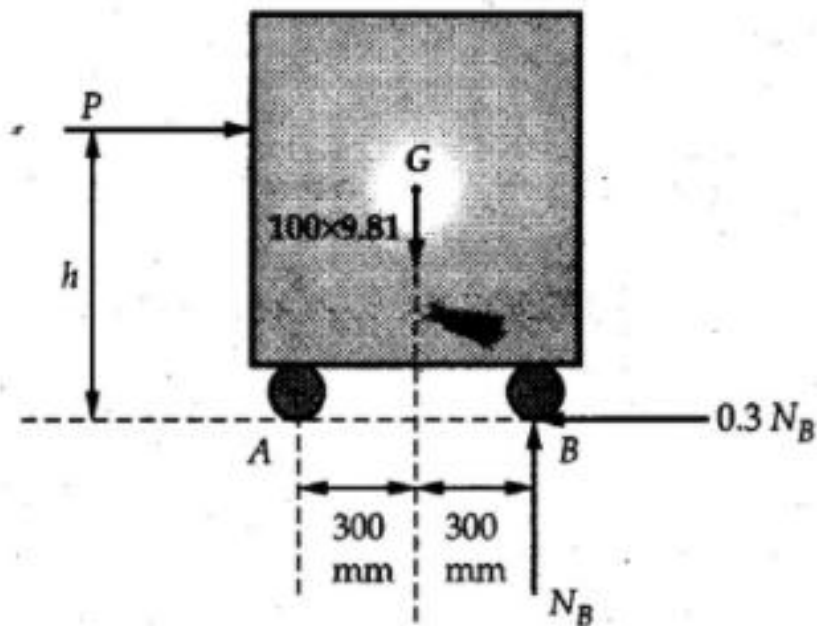

Fig. (a).

$$\sum F_y = 0$$

$$N_B - 100 \times 9.81 = 0$$

$$N_B = 981$$

$$\sum F_x = 0$$

$$P - 0.3 N_B = 0$$

$$P = 0.3 (N_B) = 0.3 \times 981$$

$$\therefore \quad P = 294.3 \text{ N}$$

$$\sum M_B = 0$$

$$-(P)(h) + (100 \times 9.81)(300) = 0$$

$$\therefore \quad h = \frac{100 \times 9.81 \times 300}{294.3}$$

$$\therefore \quad \boxed{h = 1000 \text{ mm}}$$