

4.5 LADDER FRICTION

In problems involving ladders, draw F.B.D. of ladder and use equilibrium conditions.

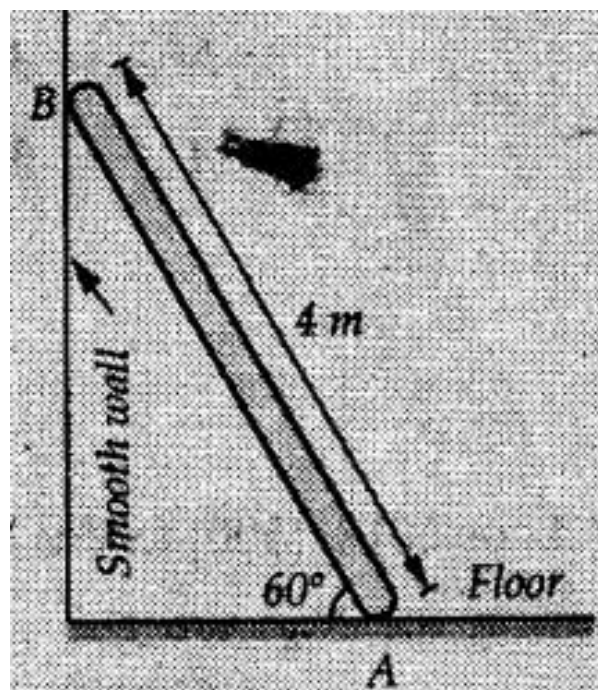
$$\sum F_x = 0$$

$$\sum F_y = 0$$

and $\sum M = 0$

Solved Examples

1. A ladder of weight 1000 N and length 4 m rests as shown in Fig. If a 750 N weight is applied at a distance of 3 m from the top of ladder, it is at the point of sliding. Determine the coefficient of friction between ladder and the floor.



Solution:

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

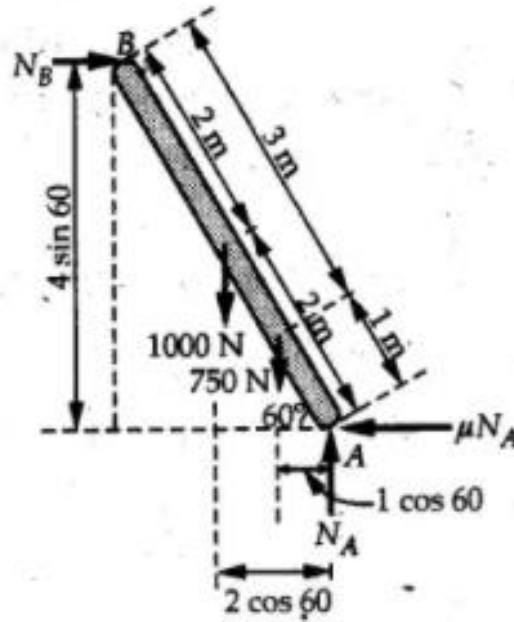


Fig. (a)

$$\begin{aligned} \sum F_y &= 0 : \\ \therefore N_A - 1000 - 750 &= 0 \\ N_A &= 1750 \text{ N} \\ \sum F_x &= 0 : \\ N_B - \mu N_A &= 0 \\ N_B &= 1750 \mu \quad \dots (1) \\ \therefore \sum M_A &= 0 : \\ (750)(1 \cos 60) + (1000)(2 \cos 60) - (N_B)(4 \sin 60) &= 0 \\ 750 \cos 60 + 2000 \cos 60 - 1750 \mu \times 4 \sin 60 &= 0 \\ \therefore \mu &= 0.227 \end{aligned}$$

2.A uniform ladder of length 15 m rests against a vertical wall making an angle of 60° with the horizontal. Coefficient of friction between wall and the ladder is 0.30 and between the ground and the ladder is 0.25. A man weighing 500 N ascends the ladder. How long will he be able to go before the ladder slips? Find the weight that is necessary to be put at the bottom of the ladder so as to be just

sufficient to permit the man to go to the top. Assume weight of the ladder to be 850 N.

Solution:

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

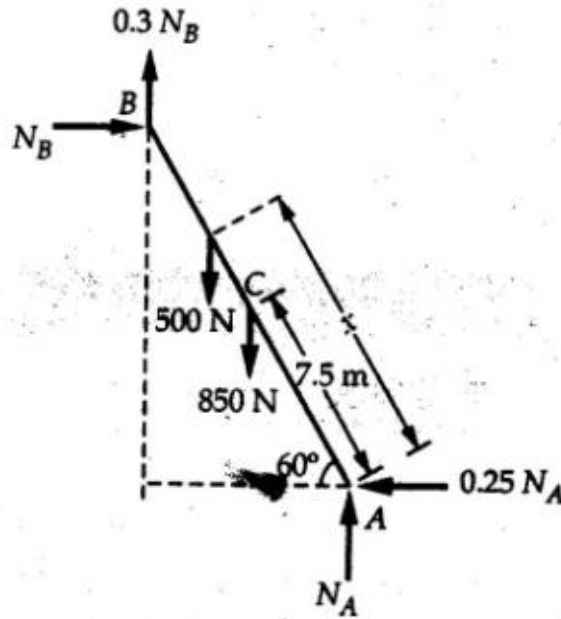


Fig. (a).

$$\sum F_x = 0$$

$$N_B - 0.25 N_A = 0$$

$$\therefore N_A = 4 N_B$$

$$\sum F_y = 0$$

$$N_A + 0.3 N_B - 850 - 500 = 0$$

$$4 N_B + 0.3 N_B = 1350$$

$$\therefore N_B = 313.95 \text{ N}$$

$$\sum M_A = 0$$

$$(850)(7.5 \cos 60) + (500)(x \cos 60) - (N_B)(15 \sin 60) - (0.3 N_B)(15 \cos 60) = 0$$

Substituting for N_B , we get

$$x = 6.39 \text{ m}$$

The F.B.D. of ladder when weight W is put at the bottom is shown in Fig. (b).

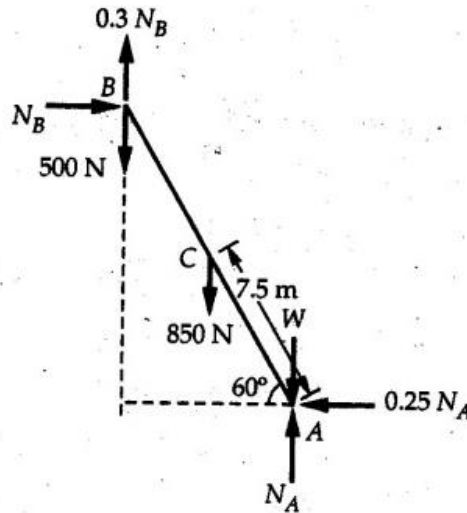


Fig. (b).

$$\sum M_A = 0$$

$$(850)(7.5 \cos 60) + (500)(15 \cos 60) - (N_B)(15 \sin 60) - (0.3 N_B)(15 \cos 60) = 0$$

$$\therefore N_B = 455.205 \text{ N}$$

$$\sum F_x = 0$$

$$N_B - 0.25 N_A = 0$$

$$\therefore N_A = 1820.82 \text{ N}$$

$$\sum F_y = 0$$

$$N_A + 0.3 N_B - 500 - 850 - W = 0$$

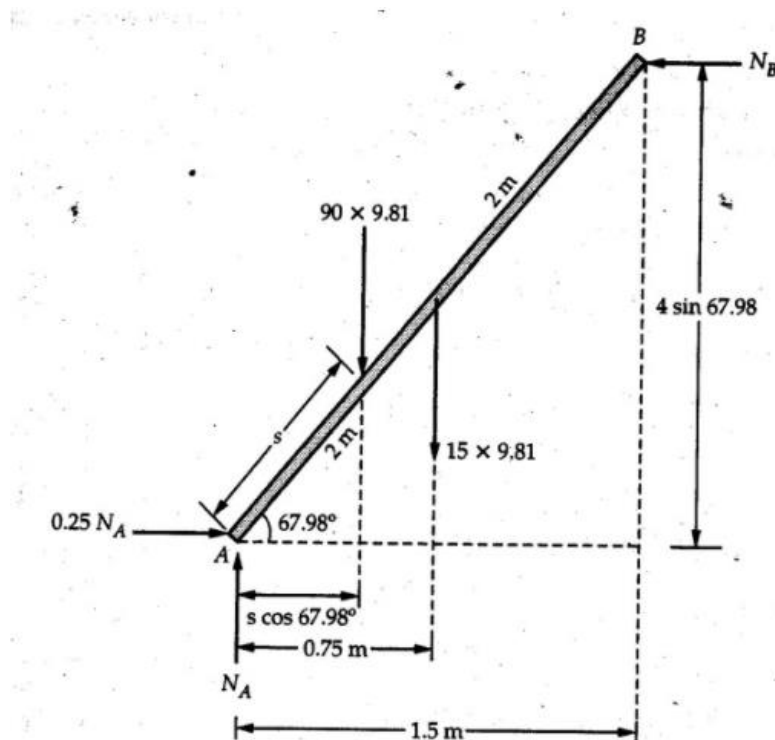
$$\therefore W = 607.38 \text{ N}$$

3. Determine the distance s to which the 90 kg painter can climb without causing the 4-m ladder to slip at its lower end A Fig. The top of the 15 kg ladder has a small roller and at the ground the coefficient of static friction is 0.25. The mass center of the painter is directly above her feet.



Solution:

- (i) The FBD of ladder is shown in Fig. (a).



$$\sum F_y = 0 : \quad N_A - 90 \times 9.81 - 15 \times 9.81 = 0$$

$$\therefore \quad N_A = 1030.05 \text{ N}$$

$$\sum F_x = 0 : \quad 0.25N_A - N_B = 0$$

$$\therefore \quad N_B = 257.51 \text{ N}$$

$$\sum M_A = 0 : \quad -90 \times 9.81 \times s \cos 67.98 - 15 \times 9.81 \times 0.75 + N_B \times 4 \sin 67.98 = 0$$

$$-90 \times 9.81 \times s \cos 67.98 - 15 \times 9.81 \times 0.75 + 257.51 \times 4 \sin 67.98 = 0$$

$$\therefore \quad \boxed{s = 2.55 \text{ m}}$$