5. Friction:

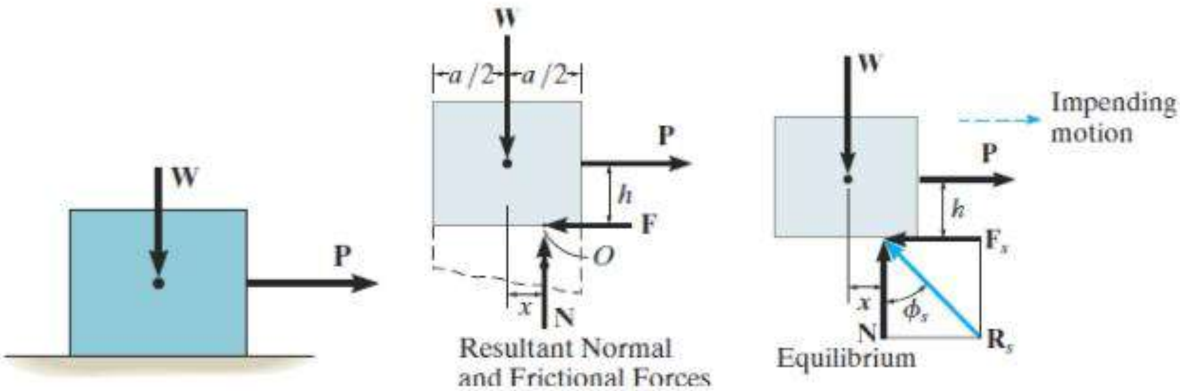
Friction is a force that resists the movement of two contacting surfaces that slide relative to one another.

Considering the effects caused by pulling horizontally force ***P*** on a block of uniform weight ***W*** which is resting on a rough horizontal surface. From equilibrium, two reaction forces generated;

Normal force ***N*** to resist the weight ***W*** and

Friction force ***F*** to resist the pulling force ***P***.

Notice that ***N*** acts a distance ***x*** to the right of the line of action of ***W***, Fig. (b which coincides with geometric center of in order to balance the effect caused by ***P***.



(a) (b) (c)

Impending Motion: If the block will tend to slip, the maximum value called the limiting static frictional force, Fig. (c), which is directly proportional to the resultant normal force ***N***. Expressed mathematically:

Fs=μs.N

- Where: ***μs*** (mu "sub" s), is called the coefficient of static friction. Typical values for ***μs*** are given in Table 8–1.
- When the block is on verge of sliding, the normal force N and frictional force ***Fs*** create a resultant ***Rs*** Fig. (c).

The angle ***ϕs*** (phi "sub" s) that makes with ***N*** is called the *angle of static friction*.

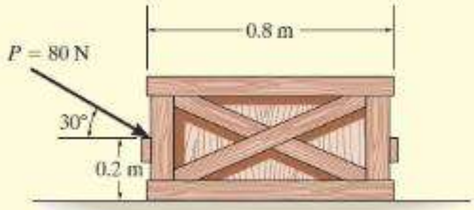
$$\phi_s = \tan^{-1}\left(\frac{F_s}{N}\right) = \tan^{-1}\left(\frac{\mu_s N}{N}\right) = \tan^{-1}\mu_s$$

Table 8–1
Typical Values for μ_s

Contact Materials	Coefficient of Static Friction (μ_s)
Metal on ice	0.03–0.05
Wood on wood	0.30–0.70
Leather on wood	0.20–0.50
Leather on metal	0.30–0.60
Aluminum on aluminum	1.10–1.70

Ex (1):

The uniform crate shown in Fig. 8–7*a* has a mass of 20 kg. If a force $P = 80$ N is applied to the crate, determine if it remains in equilibrium. The coefficient of static friction is $\mu_s = 0.3$.

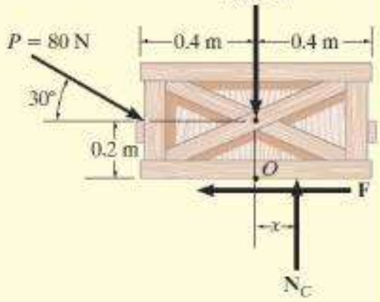


(a)

Fig. 8–7

SOLUTION

Free-Body Diagram. As shown in Fig. 8–7*b*, the *resultant* normal force $\mathbf{N}_C$ must act a distance x from the crate's center line in order to counteract the tipping effect caused by **P**. There are *three unknowns*, F, N_C, and x, which can be determined strictly from the *three* equations of equilibrium.



(b)

Equations of Equilibrium.

$$\xrightarrow{+} \Sigma F_x = 0; \qquad 80 \cos 30^\circ \text{ N} - F = 0$$

$$+\uparrow \Sigma F_y = 0; \qquad -80 \sin 30^\circ \text{ N} + N_C - 196.2 \text{ N} = 0$$

$$\circlearrowleft + \Sigma M_O = 0; \qquad 80 \sin 30^\circ \text{ N}(0.4 \text{ m}) - 80 \cos 30^\circ \text{ N}(0.2 \text{ m}) + N_C(x) = 0$$

Solving,

$$F = 69.3 \text{ N}$$

$$N_C = 236 \text{ N}$$

$$x = -0.00908 \text{ m} = -9.08 \text{ mm}$$

Since x is negative it indicates the *resultant* normal force acts (slightly) to the *left* of the crate's center line. No tipping will occur since $x < 0.4$ m. Also, the *maximum* frictional force which can be developed at the surface of contact is $F_{max} = \mu_s N_C = 0.3(236 \text{ N}) = 70.8$ N. Since $F = 69.3 \text{ N} < 70.8$ N, the crate will *not slip*, although it is very close to doing so.

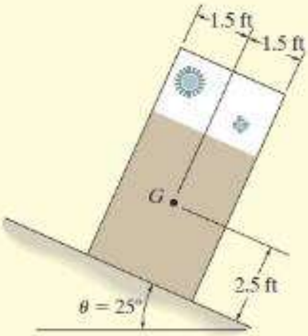
Ex (2):

(a)

It is observed that when the bed of the dump truck is raised to an angle of $\theta = 25°$ the vending machines will begin to slide off the bed, Fig. 8–8*a*. Determine the static coefficient of friction between a vending machine and the surface of the truckbed.

SOLUTION

An idealized model of a vending machine resting on the truckbed is shown in Fig. 8–8*b*. The dimensions have been measured and the center of gravity has been located. We will assume that the vending machine weighs W.



(b)

Free-Body Diagram. As shown in Fig. 8–8*c*, the dimension x is used to locate the position of the resultant normal force **N**. There are four unknowns, N, F, μ_s, and x.

Equations of Equilibrium.

$$+\searrow \Sigma F_x = 0; \qquad W \sin 25° - F = 0 \qquad (1)$$

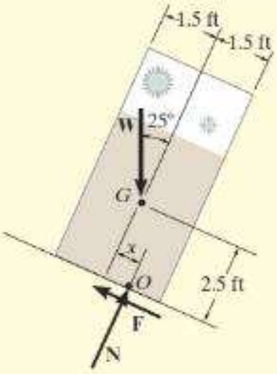
$$+\nearrow \Sigma F_y = 0; \qquad N - W \cos 25° = 0 \qquad (2)$$

$$\circlearrowleft + \Sigma M_O = 0; \quad -W \sin 25°(2.5\text{ ft}) + W \cos 25°(x) = 0 \qquad (3)$$

Since slipping impends at $\theta = 25°$, using Eqs. 1 and 2, we have

$$F_s = \mu_s N; \qquad W \sin 25° = \mu_s(W \cos 25°)$$

$$\mu_s = \tan 25° = 0.466 \qquad \textit{Ans.}$$



(c)

Fig. 8–8

The angle of $\theta = 25°$ is referred to as the *angle of repose*, and by comparison, it is equal to the angle of static friction, $\theta = \phi_s$. Notice from the calculation that θ is independent of the weight of the vending machine, and so knowing θ provides a convenient method for determining the coefficient of static friction.

NOTE: From Eq. 3, we find $x = 1.17$ ft. Since $1.17\text{ ft} < 1.5\text{ ft}$, indeed the vending machine will slip before it can tip as observed in Fig. 8–8*a*.

Ex (3):

The uniform 10-kg ladder in Fig. 8–9*a* rests against the smooth wall at *B*, and the end *A* rests on the rough horizontal plane for which the coefficient of static friction is $\mu_s = 0.3$. Determine the angle of inclination θ of the ladder and the normal reaction at *B* if the ladder is on the verge of slipping.

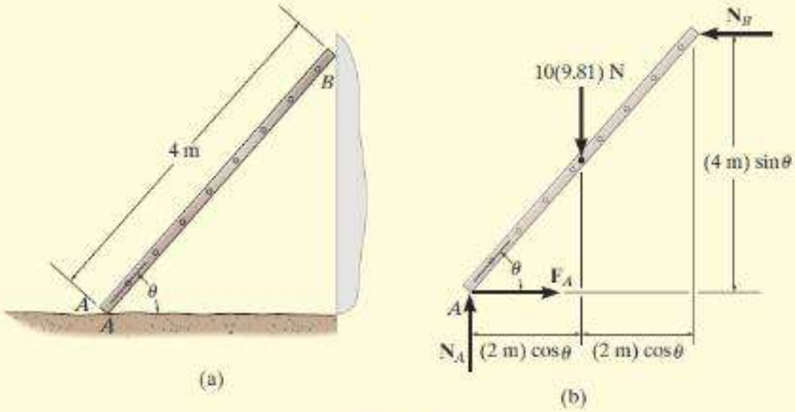


Fig. 8–9

SOLUTION

Free-Body Diagram. As shown on the free-body diagram, Fig. 8–9*b*, the frictional force $\mathbf{F}_A$ must act to the right since impending motion at *A* is to the left.

Equations of Equilibrium and Friction. Since the ladder is on the verge of slipping, then $F_A = \mu_s N_A = 0.3N_A$. By inspection, N_A can be obtained directly.

$$+\uparrow \Sigma F_y = 0; \qquad N_A - 10(9.81)\text{ N} = 0 \qquad N_A = 98.1\text{ N}$$

Using this result, $F_A = 0.3(98.1\text{ N}) = 29.43\text{ N}$. Now N_B can be found.

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 29.43\text{ N} - N_B = 0$$

$$N_B = 29.43\text{ N} = 29.4\text{ N} \qquad \textit{Ans.}$$

Finally, the angle θ can be determined by summing moments about point *A*.

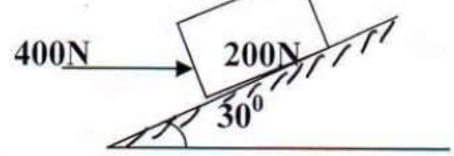
$$\zeta + \Sigma M_A = 0; \qquad (29.43\text{ N})(4\text{ m})\sin\theta - [10(9.81)\text{ N}](2\text{ m})\cos\theta = 0$$

$$\frac{\sin\theta}{\cos\theta} = \tan\theta = 1.6667$$

$$\theta = 59.04^\circ = 59.0^\circ \qquad \textit{Ans.}$$

Q/ The (200N) block shown in Fig . Has impending motion up the plane . coused by على وشك الحركة على السطح the Horizontal force قوة افقية of (400N) .

Determine the coefficient of static friction between the contact surfaces السطوح المتلامسة .

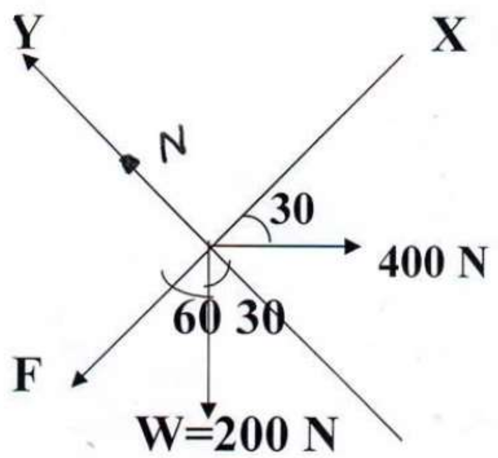


هنا اتزان القوى الملتقية

$R_X = 0 \quad , \quad R_Y = 0$

$F = 400 * 0.866 - 200 * 0.5$

$RX = 400\cos 30 - 200\cos 60 - F = 0$



$$F = 246.4 \text{ N}$$

$R_Y = 0$

$N - 200 \sin 60 - 400 \sin 30 = 0$

$N = 200 * 0.866 + 400 * 0.5$

$N = 173.2 + 200$

$$N = 373.2 \text{ N}$$

نأخذ سطوح التلامس هو X . axix

$F = f * N$

$$f = \frac{F}{N} = \frac{246.4}{373.2} = 0.66$$

f = معامل الاحتكاك خالي من الوحدات