Al-Ayen University
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Mechanics

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Title: Friction

Lec. Number: 3

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Friction

There are two types of friction: dry friction, sometimes called Coulomb friction, and fluid friction. Fluid friction develops between layers of fluid moving at different velocities. Fluid friction is of great importance in problems involving the flow of fluids through pipes and orifices or dealing with bodies immersed in moving fluids. It is also basic in the analysis of the motion of lubricated mechanisms. Such problems are considered in texts on fluid mechanics. The present study is limited to dry friction, i.e., to problems involving rigid bodies which are in contact along non-lubricated surfaces.

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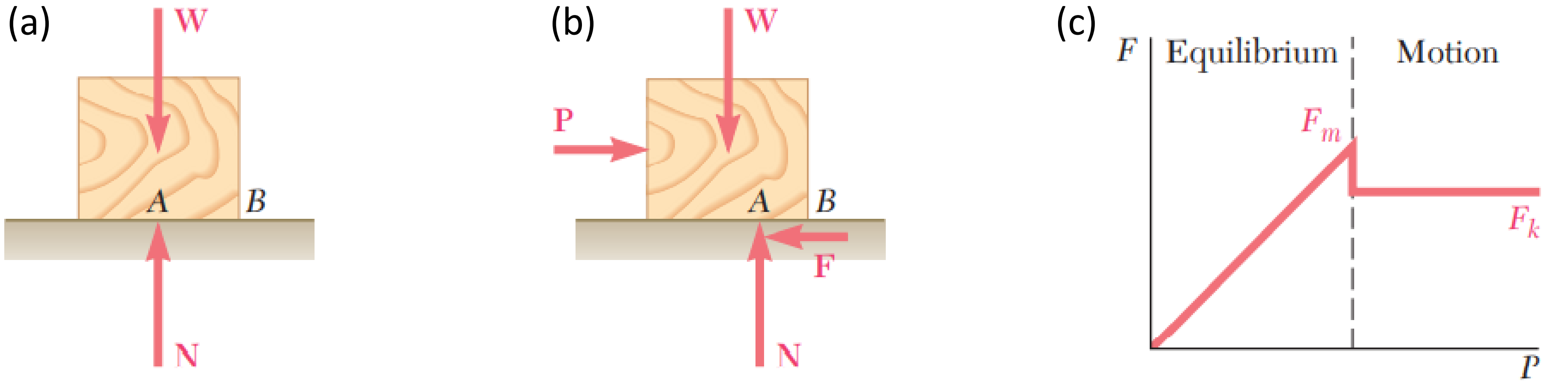
Equilibrium and motion states



(a) No external force

(b) With an external force

(c) Schematic representation

If P is further increased, the friction force cannot balance it any more and the block starts sliding. As soon as the block has been set in motion, the magnitude of F drops from F_m to a lower value F_K. This is because there is less interpenetration between the irregularities of the surfaces in contact when these surfaces move with respect to each other. From then on, the block keeps sliding with increasing velocity while the friction force, denoted by F_K and called the kinetic-friction force, remains approximately constant

Laws of Friction

<u>Static friction</u>

$$F_m = \mu_s N$$

where μ_s is a constant called the coefficient of static friction

Experimental evidence shows that the maximum value F_m of the static-friction force is proportional to the normal component N of the reaction of the surface.

<u>Kinetic friction</u>

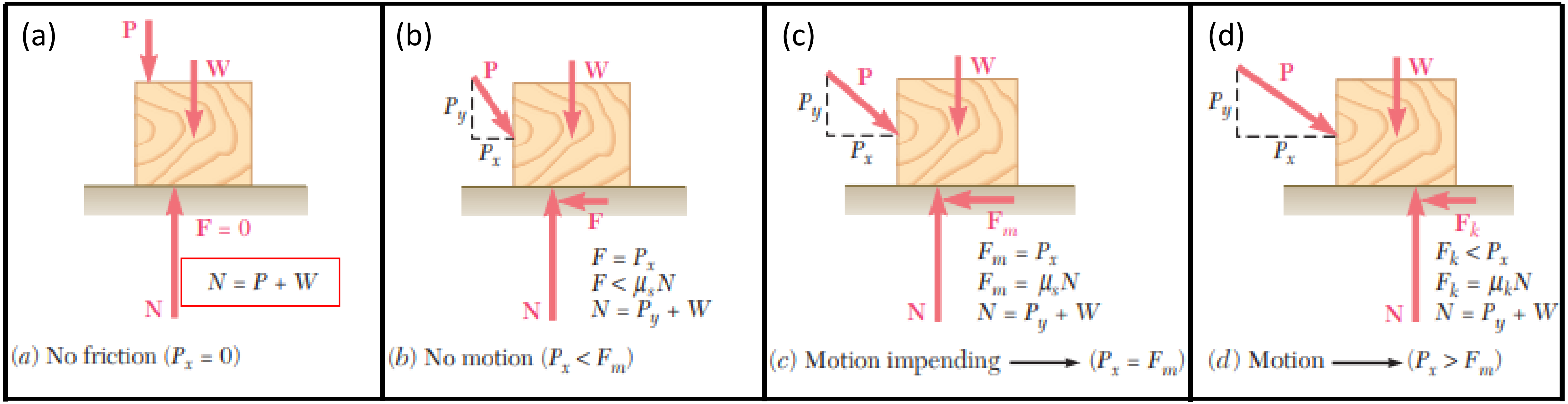
$$F_k = \mu_k N$$

where μ_K is a constant called the coefficient of kinetic friction

<u>Note:</u>

The coefficients of friction μ_s and μ_K do not depend upon the area of the surfaces in contact. Both coefficients, however, depend strongly on the nature of the surfaces in contact.

Contact cases: Not inclined surfaces



(*a*) No friction ($P_x = 0$)

(*b*) No motion ($P_x < F_m$)

(*c*) Motion impending ⟶ ($P_x = F_m$)

(*d*) Motion ⟶ ($P_x > F_m$)

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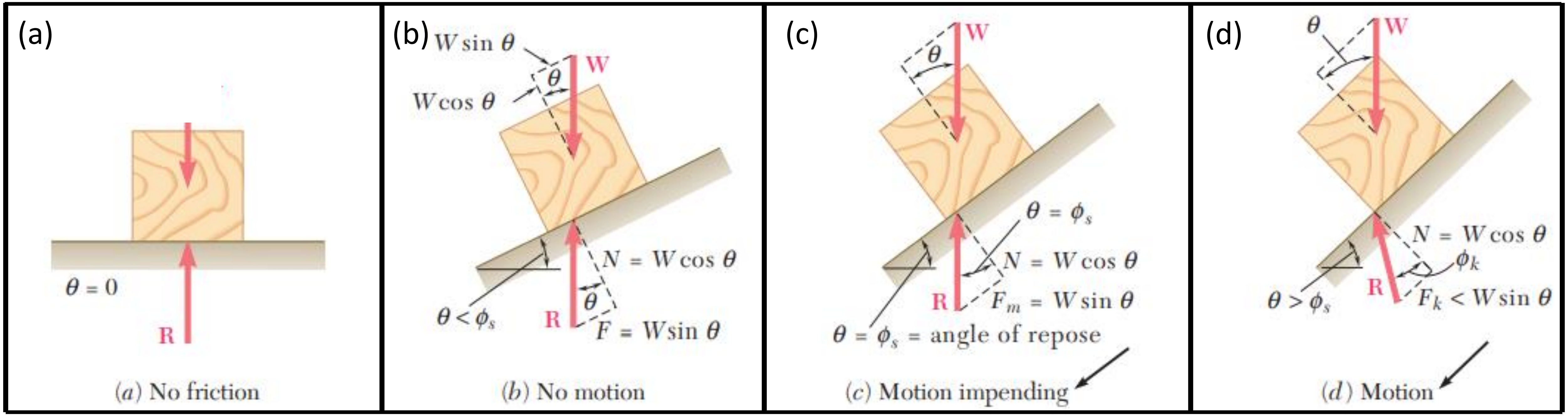
Contact cases: Inclined surfaces



$$\tan \phi_s = \frac{F_m}{N} = \frac{\mu_s N}{N}$$

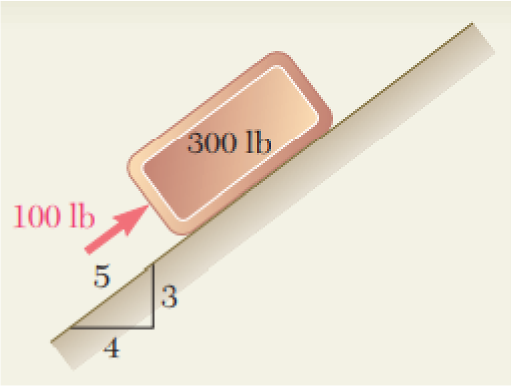
$$\tan \phi_s = \mu_s$$

$$\tan \phi_k = \frac{F_k}{N} = \frac{\mu_k N}{N}$$

$$\tan \phi_k = \mu_k$$

Example

A 100-lb force acts as shown on a 300-lb block placed on an inclined plane. The coefficients of friction between the block and the plane are μ_s = 0.25 and μ_K = 0.20. Determine whether the block is in equilibrium, and find the value of the friction force.



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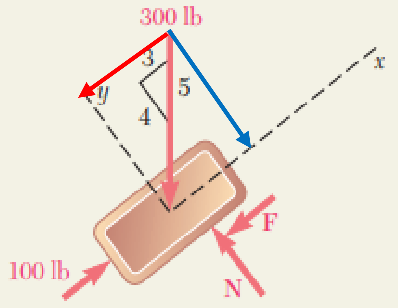
Solution



Force Required for Equilibrium. We first determine the value of the friction force *required to maintain equilibrium*. Assuming that **F** is directed down and to the left, we draw the free-body diagram of the block and write

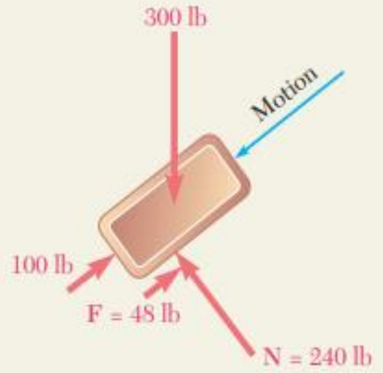
$+\nearrow \Sigma F_x = 0$: $\quad 100 \text{ lb} - \frac{3}{5}(300 \text{ lb}) - F = 0$

$F = -80 \text{ lb} \qquad \mathbf{F} = 80 \text{ lb} \nearrow$

$+\nwarrow \Sigma F_y = 0$: $\quad N - \frac{4}{5}(300 \text{ lb}) = 0$

$N = +240 \text{ lb} \qquad \mathbf{N} = 240 \text{ lb} \nwarrow$

The force **F** required to maintain equilibrium is an 80-lb force directed up and to the right; the tendency of the block is thus to move down the plane.



Actual Value of Friction Force. The magnitude of the actual friction force is obtained as follows:

$$F_{\text{actual}} = F_k = \mu_k N$$
$$= 0.20(240 \text{ lb}) = 48 \text{ lb}$$

The sense of this force is opposite to the sense of motion; the force is thus directed up and to the right:

$$\mathbf{F}_{\text{actual}} = 48 \text{ lb} \nearrow$$

It should be noted that the forces acting on the block are not balanced; the resultant is

$$\tfrac{3}{5}(300 \text{ lb}) - 100 \text{ lb} - 48 \text{ lb} = 32 \text{ lb} \swarrow$$

Maximum Friction Force. The magnitude of the maximum friction force which may be developed is

$$F_m = \mu_s N \qquad F_m = 0.25(240 \text{ lb}) = 60 \text{ lb}$$

Since the value of the force required to maintain equilibrium (80 lb) is larger than the maximum value which may be obtained (60 lb), equilibrium will not be maintained and *the block will slide down the plane.*

Homework

Repeat the above example by considering the following inclined angle: