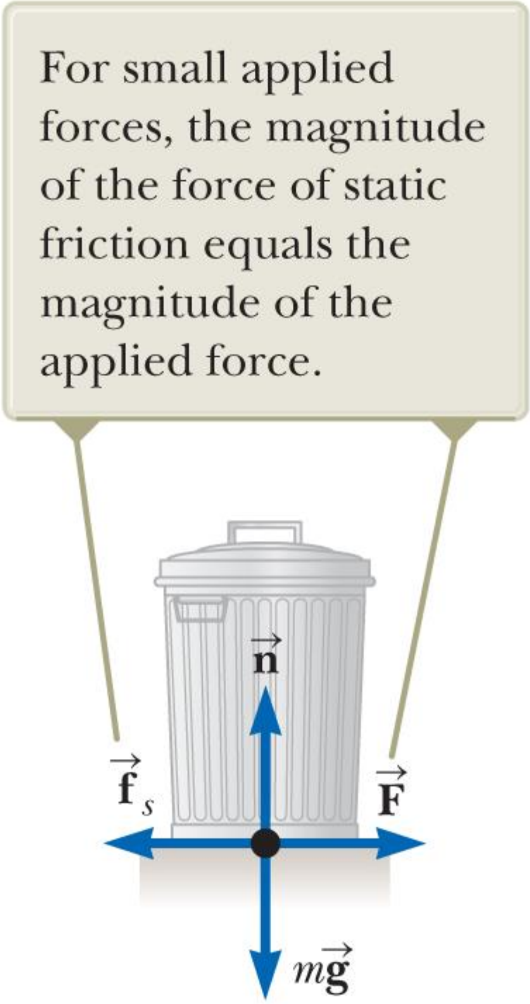
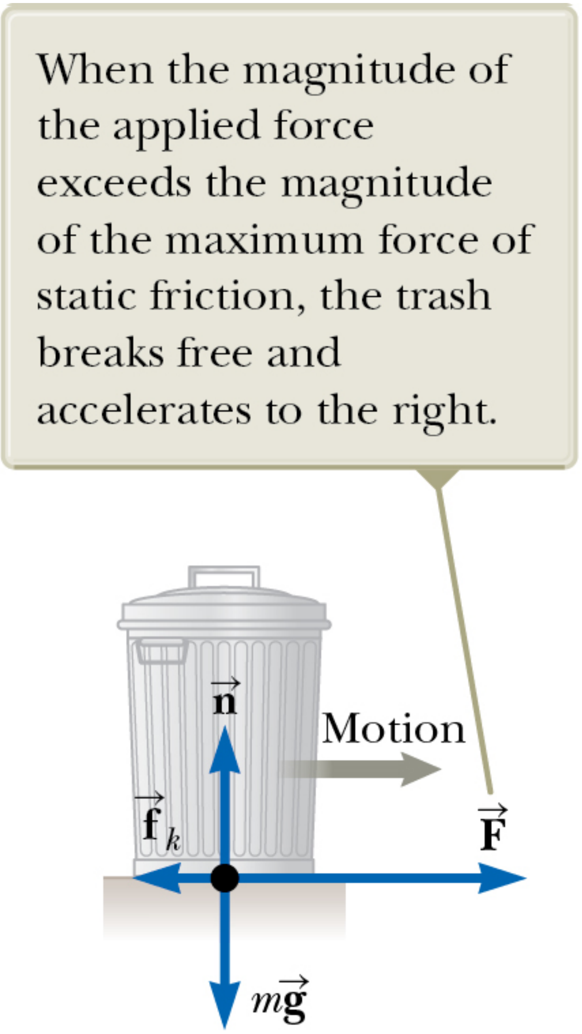
The Laws of Motion : Forces of Friction

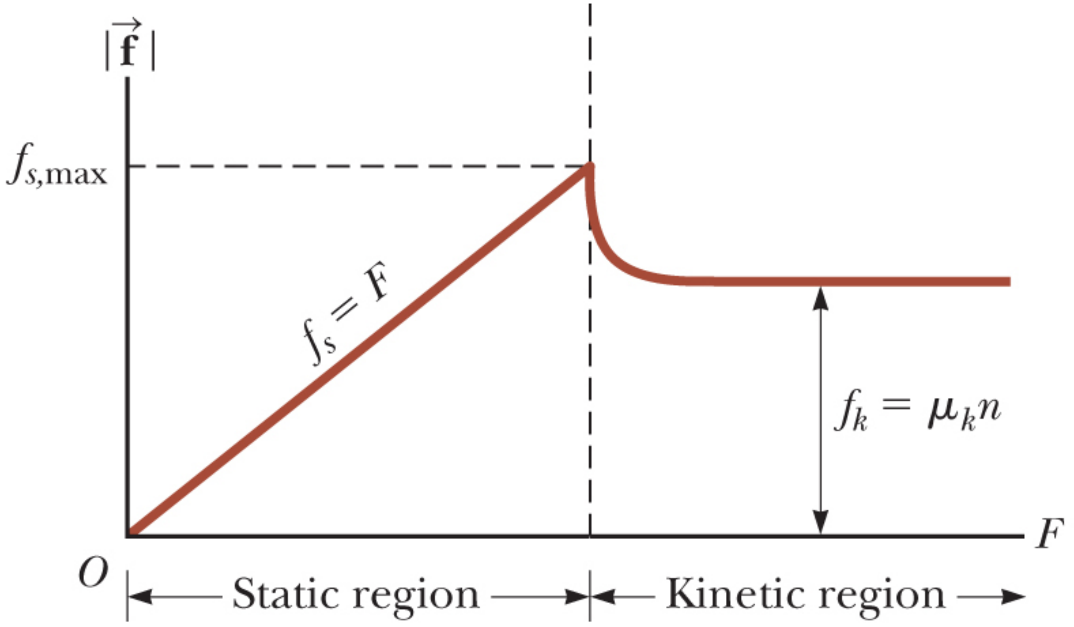


- When object in motion on surface or in viscous medium (i.e., air, water) → resistance to motion because object interacts with surroundings
  - This resistance: **force of friction**
- Friction important: allows us to walk or run and necessary for motion of wheeled vehicles
- Imagine dragging full trash can across rough surface:
- Apply external horizontal force **F** to right→ can remains stationary when **F** small
  - Force that counteracts **F** and keeps it from moving acts toward left: **force of static friction $\mathbf{f}_s$**
  - As long as trash can not moving: $f_s = F$

Forces of Friction (2 of 2)



- Increase magnitude of **F** (left figure) → trash can eventually slips
  - When trash can on verge of slipping: f_s maximum value $f_{s,\max}$ (figure (b))
  - When F exceeds $f_{s,\max}$ trash can moves and accelerates to right



Coefficients of Friction

$$f_s \leq \mu_s n$$

$$f_s = f_{s,\max} = \mu_s n$$

$$f_k = \mu_k n$$

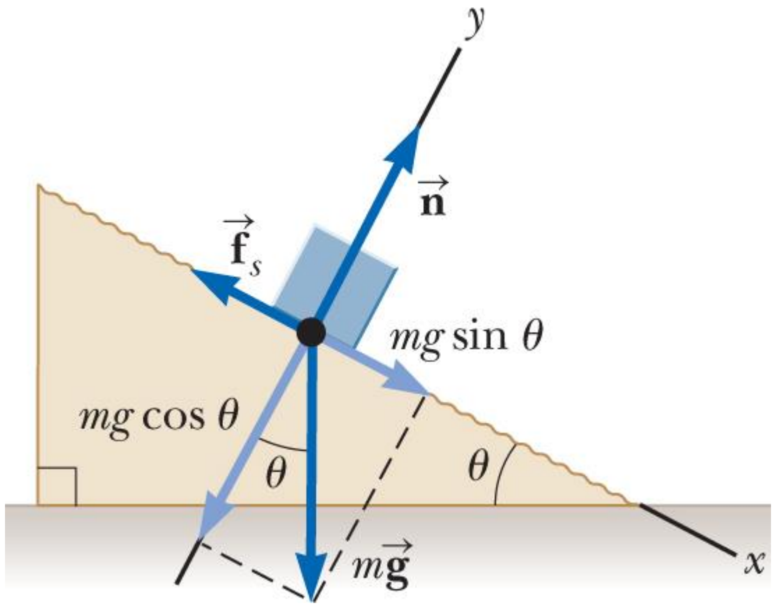
Table 5.1 Coefficients of Friction

	μ_s	μ_k
Rubber on concrete	1.0	0.8
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Glass on glass	0.94	0.4
Copper on steel	0.53	0.36
Wood on wood	0.25–0.5	0.2
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Teflon on Teflon	0.04	0.04
Ice on ice	0.1	0.03
Synovial joints in humans	0.01	0.003

Note: All values are approximate. In some cases, the coefficient of friction can exceed 1.0.

Example 5.11: Experimental Determination of μ_s and μ_k (1 of 2)

The following is a simple method of measuring coefficients of friction. Suppose a block is placed on a rough surface inclined relative to the horizontal as shown in the figure. The incline angle is increased until the block starts to move. Show that you can obtain μ_s by measuring the critical angle θ_c at which this slipping just occurs.



Example 5.11: Experimental Determination of μ_s and μ_k (2 of 2)

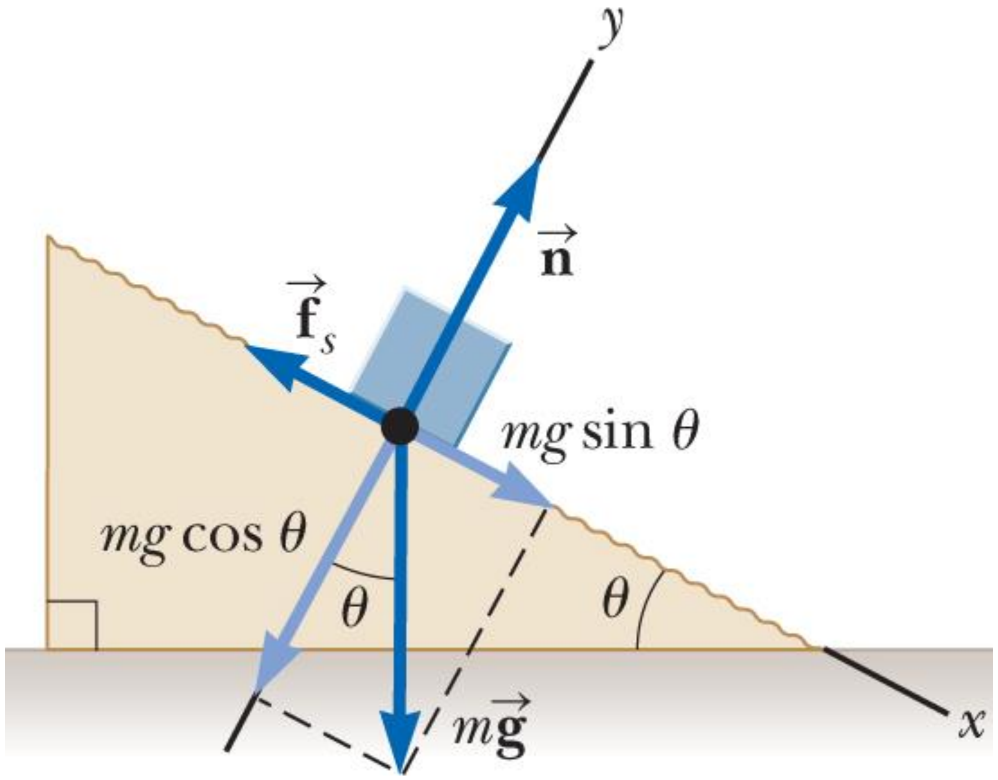
$$\sum F_x = mg\sin\theta - f_s = 0$$

$$\sum F_y = n - mg\cos\theta = 0$$

$$f_s = mg\sin\theta = \left(\frac{n}{\cos\theta}\right)\sin\theta = n\tan\theta$$

$$\mu_s n = n\tan\theta_c$$

$$\mu_s = \tan\theta_c$$



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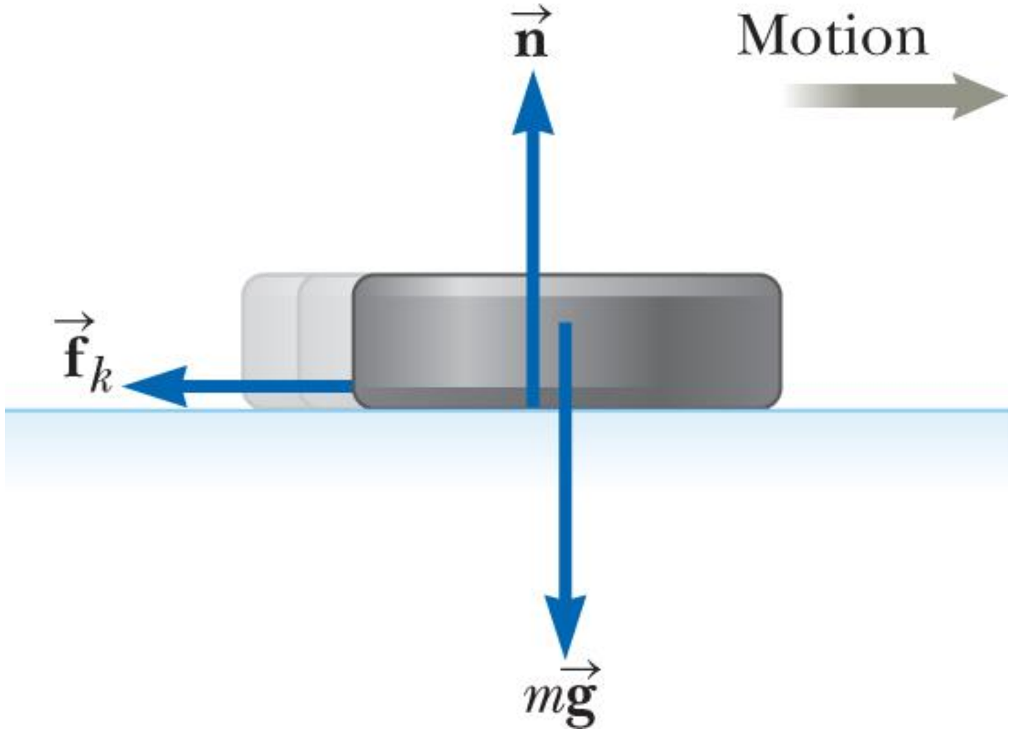
Example 5.12: The Sliding Hockey Puck (1 of 2)

A hockey puck on a frozen pond is given an initial speed of 20.0 m/s. If the puck always remains on the ice and slides 115 m before coming to rest, determine the coefficient of kinetic friction between the puck and ice.



Example 5.12: The Sliding Hockey Puck (2 of 2)

$$\sum F_x = -f_k = ma_x \qquad \sum F_y = n - mg = 0$$