LESSON 5

- BOOK CHAPTER 6
- (Force and Motion-II)

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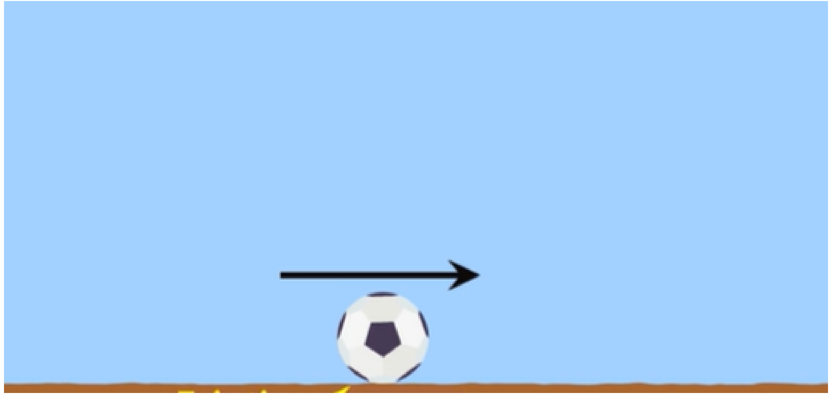
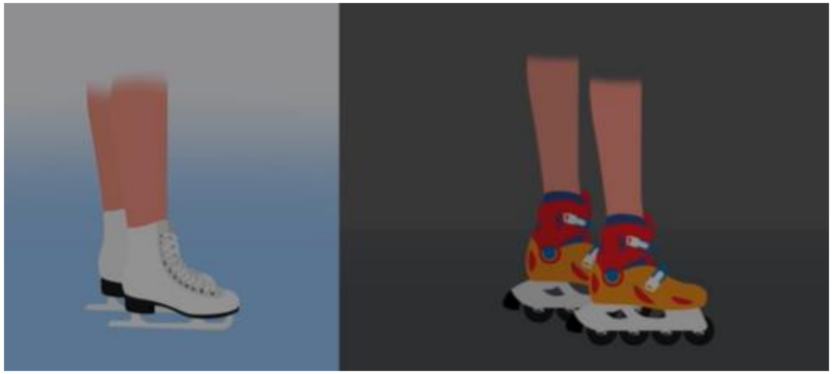


A moving ball eventually will come to a halt. Why?

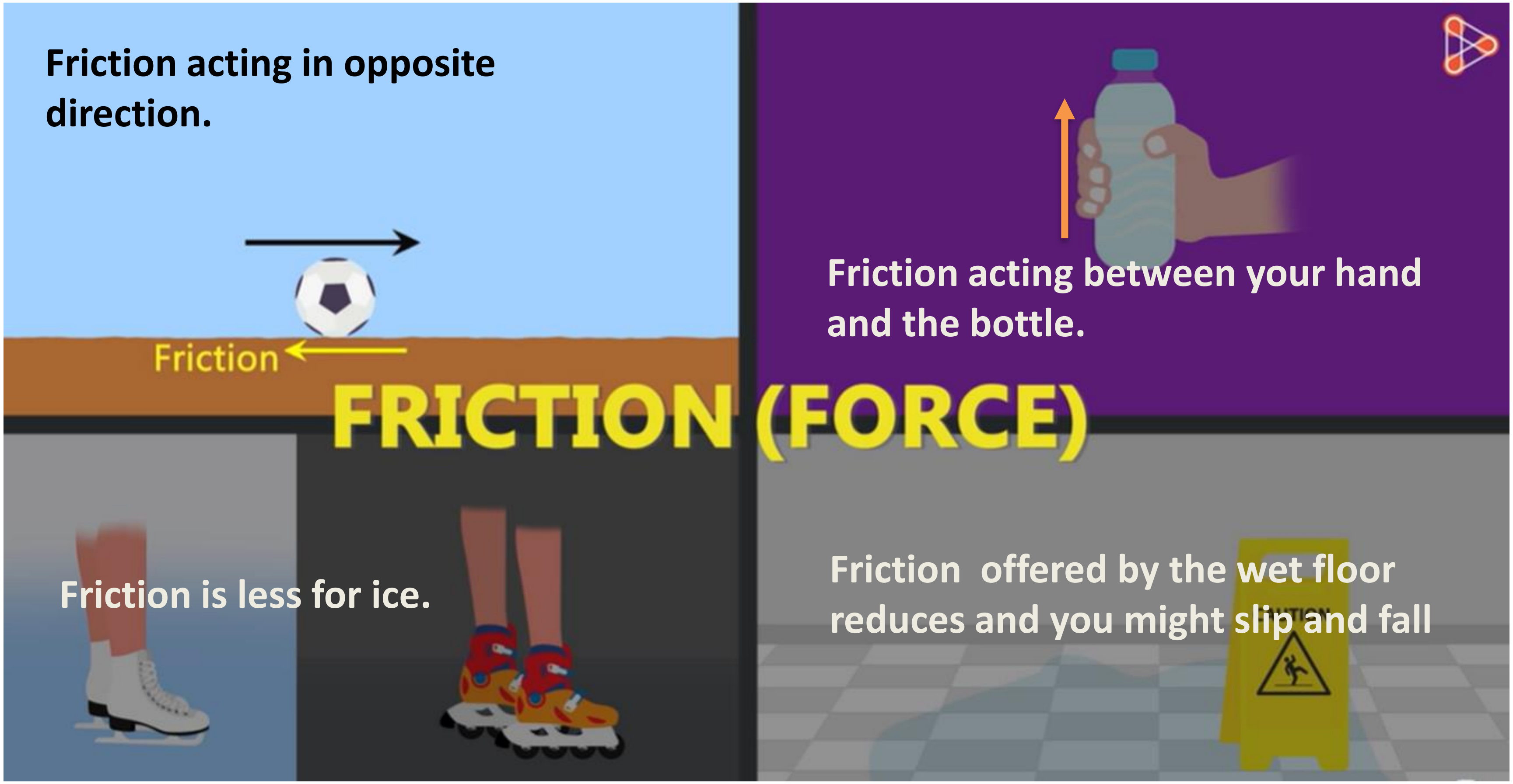
When you are holding a bottle in your hand why doesn't it slip through and fall?



Skating on an ice rink and skating on the road, which one will be smother? Why ?

Sometimes in the mall you may see a caution sign to warn you about the floor being wet. Why?

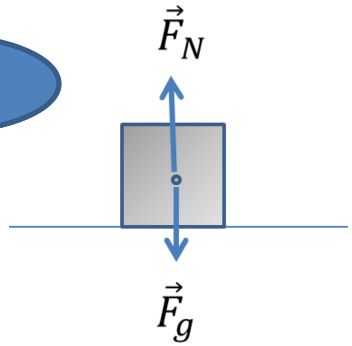
The Answer is ……



- ❑ Friction is a force.
- ❑ It is the force exerted by the surface where an object moves across it.
- ❑ It always act in the opposite direction of the motion of an object.

Properties of friction:

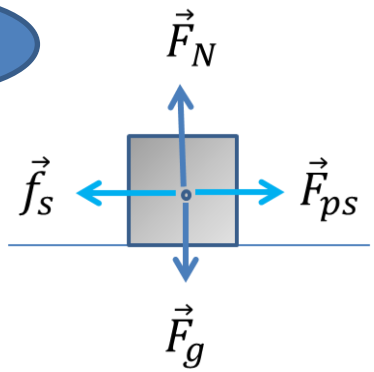
Case 1



No applied force, box at rest.

No friction, $f_s = 0$

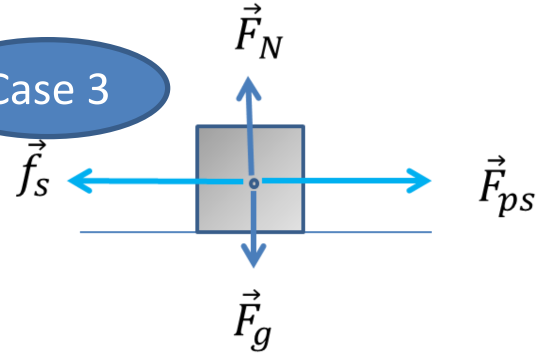
Case 2



Weak applied force, box remains at rest.

$$F_{ps} = f_s$$

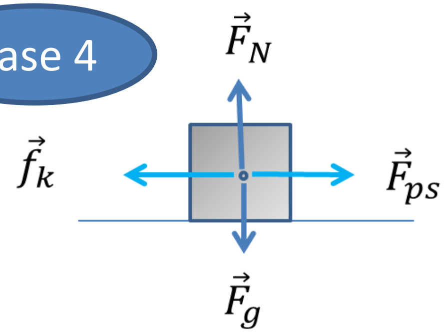
Case 3



Stronger applied force, box just about to slide.

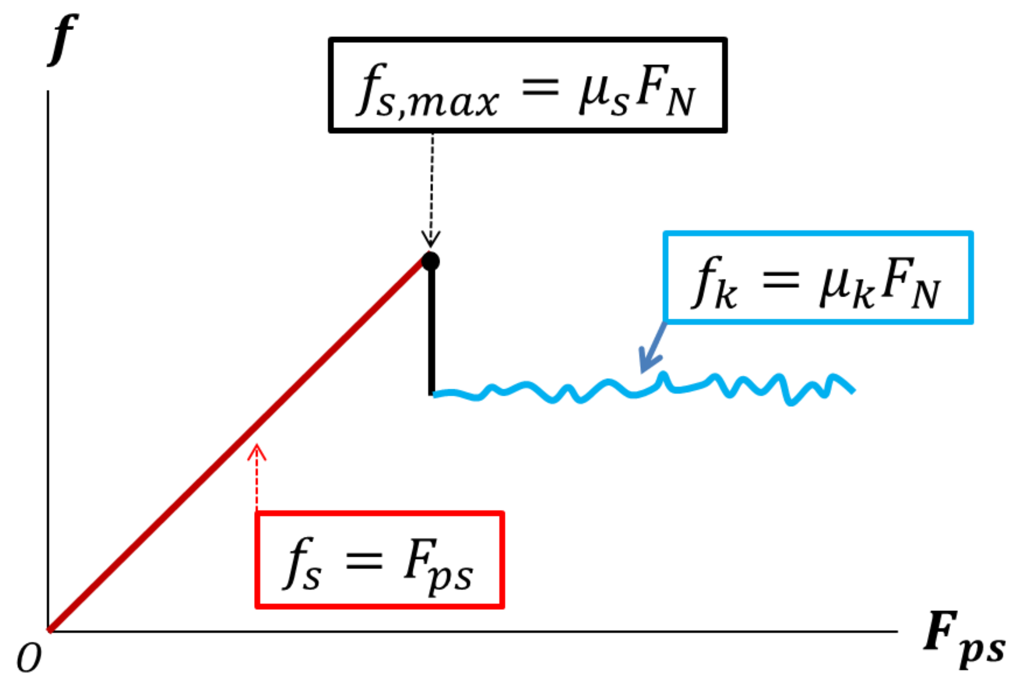
$$f_{s,max} = \mu_s F_N$$

Case 4



Box sliding at approximately constant speed:

$$f_k = \mu_k F_N$$



Friction: When a force tends to slide a body along a surface, a **frictional force** from the surface acts on the body. The frictional force is parallel to the surface ($\vec{\boldsymbol{F}}_{\boldsymbol{ps}}$) and directed so as to oppose the sliding. It is due to bonding between the body and the surface.

If the body does not slide, the frictional force is a **static frictional force ($\vec{\boldsymbol{f}}_{\boldsymbol{s}}$)**.

If there is sliding, the frictional force is a **kinetic frictional force ($\vec{\boldsymbol{f}}_{\boldsymbol{k}}$)**.

Properties of Friction:

- If a body does not move, the static frictional force ($\vec{f}_s$) and the applied force parallel to the surface ($\vec{F}_{ps}$) are equal in magnitude, and $\vec{f}_s$ is directed opposite to that $\vec{F}_{ps}$. If the F_{ps} increases, f_s also increases.

- The magnitude of $\vec{f}_s$ has a maximum value $f_{s,max}$ that is given by

$$f_{s,max} = \mu_s F_N$$

where μ_s is the **coefficient of static friction** and F_N is the magnitude of the normal force on the body from the surface. If the magnitude of the $\vec{F}_{ps}$ exceeds $f_{s,max}$, then the body begins to slide along the surface.

- If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a value f_k given by

$$f_k = \mu_k F_N$$

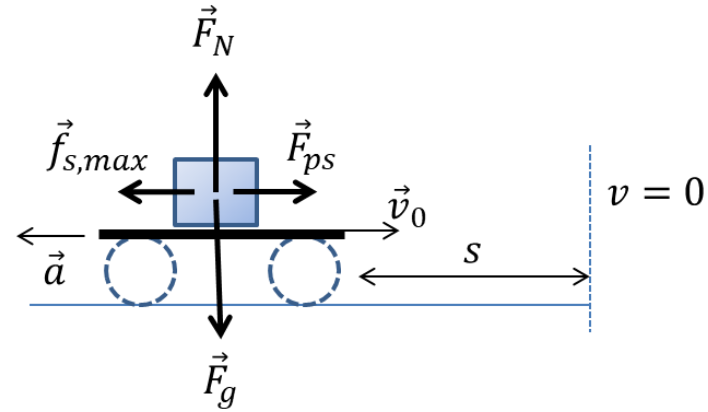
where μ_k is the **coefficient of kinetic friction.** Thereafter, during the sliding, a kinetic frictional force with magnitude f_k opposes the motion.

Summary

Friction is a force that resists or opposes the relative motion between two objects or materials.
Various reasons are responsible for this opposing force to come into action.
Among various other causes, the main cause of this resistive force or frictional force are -------
(a) molecular adhesion,
(b) surface roughness which depends on the nature of surface and body in contact, and
(c) deformations in the surface or in the moving object.

Problem 1 (Book chapter 6)

The floor of a railroad flatcar is loaded with loose crates having a coefficient of static friction of 0.25 with the floor. If the train is initially moving at a speed of 48 km/h, in how short a distance can the train be stopped at constant acceleration without causing the crates to slide over the floor?



Answer:

Since the crates are not sliding, the net force on the crates along horizontal axis (x-axis) is zero. That is

$$F_{ps} + (-f_{s,max}) = 0$$

$$F_{ps} = f_{s,max}$$

[Assuming the crates facing maximum static friction because they are not sliding]

$$ma = \mu_s F_N = \mu_s mg$$

[Since, along vertical axis (y-axis), $F_N - mg = 0$

$$a = \mu_s g = (0.25)(9.8) = 2.45\ m/s^2$$

To find the value of s for the train, we use the formula

$$v^2 = v_0^2 + 2(-a)s$$

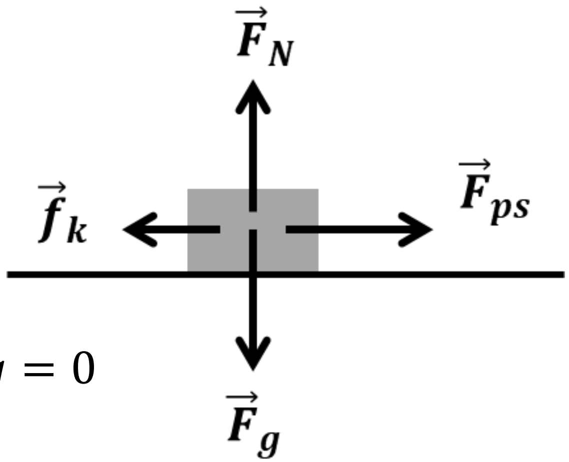
[a is negative for the train]

$$0 = (13.33)^2 + 2(-2.45)s$$

$$s = \frac{177.69}{4.9} = 36.26\ m$$

Problem 7 (Book chapter 6)

A person pushes horizontally with a force of 220 N on a 55 kg crate to move it across a level floor. The coefficient of kinetic friction between the crate and the floor is 0.35. What is the magnitude of (a) the frictional force and (b) the acceleration of the crate?



Answer:

(a) For the kinetic frictional force, we have

$$f_k = \mu_k F_N = \mu_k(mg)$$

[Along y-axis, $F_N - mg = 0$
Therefore, $F_N = mg$]

$$f_k = (0.35)(55)(9.8) = 188.65\ N$$

(b) The net force along x-axis, [where a is the acceleration of the crate along x-axis]

$$F_{ps} - f_k = ma$$

$$220 - 188.65 = (55)a$$

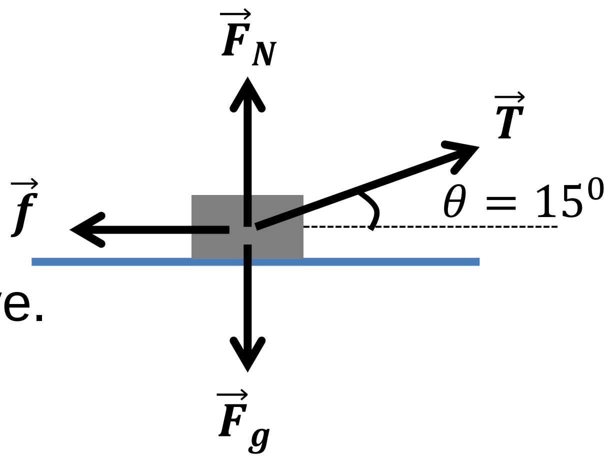
$$31.35 = (55)a$$

Therefore,

$$a = \frac{31.35}{55} = 0.57\ m/s^2$$

Problem 11 (Book chapter 6)

68 kg crate is dragged across a floor by pulling on a rope attached to the crate and inclined 15^0 above the horizontal. (a) If the coefficient of static friction is 0.50, what minimum force magnitude is required from the rope to start the crate moving? (b) If $\mu_k = 0.35$, what is the magnitude of the initial acceleration of the crate?



Answer:

The cerate is facing maximum static frictional force ($f_{s,max}$), because it is just start to move.

Hence, the net force along x-axis is

$$T\cos\theta - f_{s,max} = 0$$

$$T\cos\theta - \mu_s F_N = 0$$

$$T\cos\theta = \mu_s F_N$$

$$T = \frac{\mu_s F_N}{\cos\theta} = \frac{0.50 F_N}{\cos 15^0} = \frac{0.50 F_N}{0.9659}$$

$$T = 0.5176\, F_N \quad \text{-------------------} \quad (1)$$

The net force along y-axis is

$$F_N + T\sin\theta - mg = 0$$

$$F_N = mg - T\sin\theta$$

$$F_N = (68)(9.8) - T\sin 15^0$$

$$F_N = 666.4 - 0.2588\, T \quad \text{-------------------} \quad (2)$$

By substituting the value of F_N $from\ equation\ (2) in\ equation\ (1), we\ get$

$$T = 0.5176(666.4 - 0.2588\,T)$$

$$T = 344.93 - 0.134\,T$$

$$T + 0.134T = 344.93$$

$$1.134\,T = 344.93$$

$$T = \frac{344.93}{1.134} = 304.17\ N$$

(b) Now, we assume that the crate is moving with an acceleration a.

Hence, the net force along x-axis is

$$T\cos\theta - f_k = ma$$

$$T\cos\theta - \mu_k F_N = ma$$

$$a = \frac{T\cos\theta - \mu_k(666.4 - 0.2588\,T)}{m}$$

$$a = \frac{304.17\cos 15^0 - 0.35[666.4 - (0.2588)(304.17)]}{68}$$

$$a = \frac{(304.17)(0.9615) - 233.24 + 27.55)}{68} = \frac{86.769}{68} = 1.276\ m/s^2$$

Let's try ……..

1. A 2.5 kg block is initially at rest on a horizontal surface. A horizontal force ***F*** of magnitude 6.0 N and a vertical force ***P*** are then applied to the block (Fig. 6-17).The coefficients of friction for the block and surface are μ_s =0.40 and μ_k =0.25. Determine the magnitude of the frictional force acting on the block if the magnitude of ***P*** is (a) 8.0 N, (b) 10 N, and (c) 12 N.

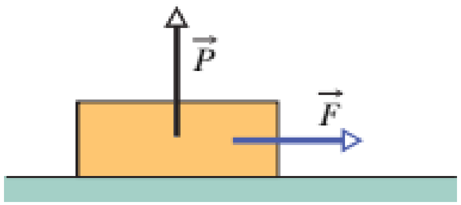


Fig. 6-17 Problem 5.

2. [Chap 6 - problem 10]: Figure 6-20 shows an initially stationary block of mass m on a floor. A force of magnitude 0.500mg is then applied at upward angle $\theta = 20^o$. What is the magnitude of the acceleration of the block across the floor if the friction coefficients are (a) μ_s= 0.600 and μ_k =0.500 and (b) μ_s = 0.400 and μ_k = 0.300?
3. [Chap 6 - example 6.2]: Calculate the typical stopping distances for a car sliding to a stop from an initial speed of 10.0 m/s on a dry horizontal road, an icy horizontal road, and (everyone's favorite) an icy hill.) if the coefficient of kinetic friction is $\mu_k = 0.60$, which is typical of regular tires on dry pavement and that with ice μ_k = 0.10? For the car sliding down an icy hill the inclination is $\theta = 5^0$.

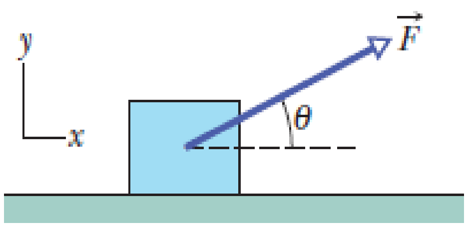


Figure 6-20 Problem 10.