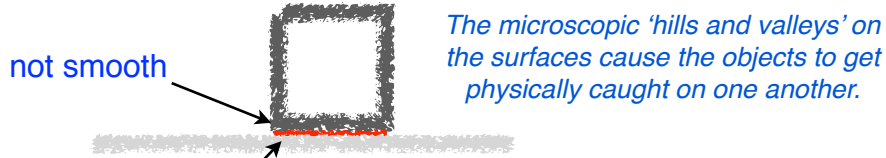


The relationship between the **normal force** and the **friction force** are a good approximation for the friction between two dry surfaces.

Friction is both a **surface** and an **electromagnetic** phenomenon.



The microscopic 'hills and valleys' on the surfaces cause the objects to get physically caught on one another.

The picoscopic electromagnetic interaction between the electrons in both objects act like of 'hills and valleys'.

**static friction:** The **reactive force** that keeps an object from sliding on a surface when given a push.

**kinetic friction:** a **retarding force** between two surfaces moving relative to one another.

The **Friction Equation** is an empirical formula. A formula derived from experiment not theory.

It takes more force (**coefficient of static friction**) to get an object to move than to keep it moving (**coefficient of kinetic friction**).

# FRICITION

**coefficient of static friction**

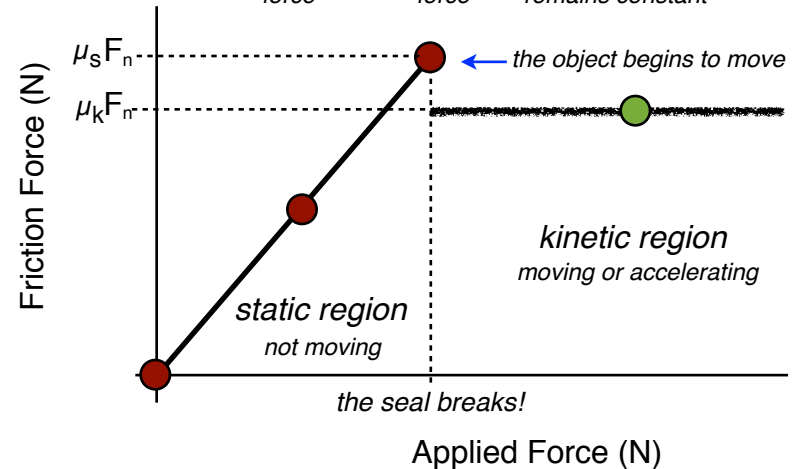
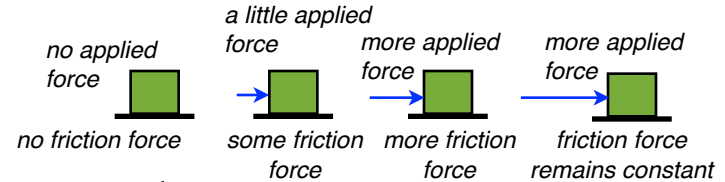
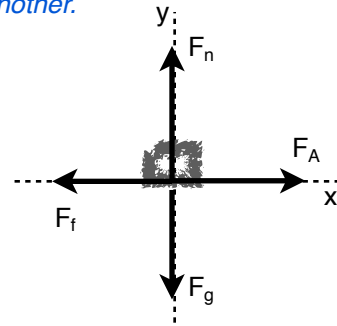
$$\mu_s = \frac{\text{Friction Force}}{\text{Normal Force}} = \frac{F_f}{F_n}$$

**Friction Equation**

$$F_f = \mu F_n$$

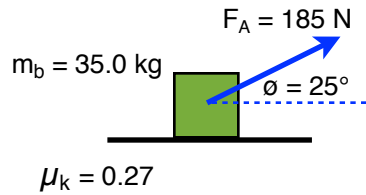
Newton's 3rd Law

$$F_n = -F_g = mg$$



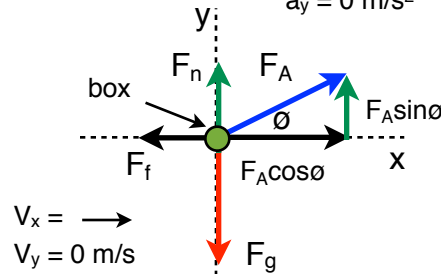
#1 pg 141

1 **Picture/Diagram**



coefficient of kinetic friction

2 **FBD**  
 our target  
 $a_x = ?$   
 $a_y = 0 \text{ m/s}^2$



draw all the forces on the object

3 **Sum of the Forces (F = ma)**

- $\Sigma F_x = F_A \cos \theta - F_f = ma_x$
- $\Sigma F_y = F_A \sin \theta + F_n - F_g = ma_y = 0$

4 **Solve the Problem** What is the acceleration of the box?

solve Eq. 1 for  $a_x$

$$a_x = \frac{F_A \cos \theta - F_f}{m}$$

Friction Equation  $F_f = \mu_k F_n$

$$a_x = \frac{F_A \cos \theta - \mu_k F_n}{m}$$

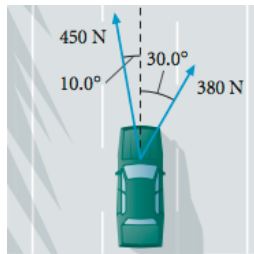
solve Eq. 2 for  $F_n$

$$F_n = F_g - F_A \sin \theta$$

$$a_x = \frac{F_A \cos \theta - \mu_k (F_g - F_A \sin \theta)}{m} = 2.7 \frac{m}{s^2} \hat{x}$$

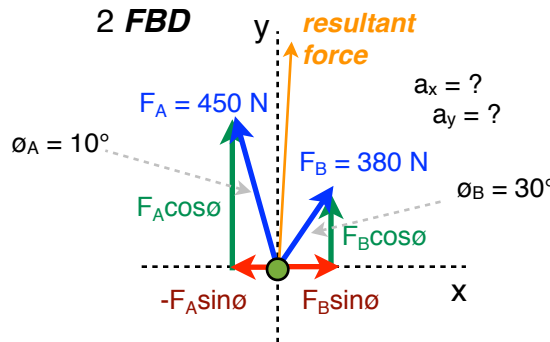
#22 a. What is the resultant force on the car?

1 **Picture/Diagram**



$m_{car} = 3200 \text{ kg}$

2 **FBD**



our target  
 $a_x = ?$   
 $a_y = ?$

3 **Adding two vectors (old way)**

$$F_A = -F_A \sin \theta \hat{x} + F_A \cos \theta \hat{y}$$

$$F_B = F_B \sin \theta \hat{x} + F_B \cos \theta \hat{y}$$

$$F_A + F_B = 111.86 \hat{x} + 772.25 \hat{y}$$

method 1

$$\text{mag } F_A + F_B = \sqrt{(111.86 \text{ N})^2 + (772.25 \text{ N})^2}$$

$$\text{mag } F_A + F_B = 780 \text{ N}$$

$$\text{dir } \theta = \tan^{-1} \frac{772 \text{ N}}{112 \text{ N}}$$

$$\text{dir } \theta = 8.3^\circ \text{ East of North}$$

b. What is the acceleration of the car?

acceleration vector

$$a = \frac{\Sigma F}{m} = \frac{780 \text{ N}}{3200 \text{ kg}} = 0.243 \frac{m}{s^2}$$

3 **Sum of the Forces (F = ma)**

b. What is the acceleration of the car?

$$1. \Sigma F_x = F_B \sin \theta - F_A \sin \theta = ma_x$$

$$2. \Sigma F_y = F_B \cos \theta + F_A \cos \theta = ma_y$$

solve Eq. 1 for  $a_x$

$$a_x = \frac{F_B \sin \theta - F_A \sin \theta}{m} = 0.035 \frac{m}{s^2}$$

solve Eq. 2 for  $a_y$

$$a_y = \frac{F_B \cos \theta + F_A \cos \theta}{m} = 0.241 \frac{m}{s^2}$$

acceleration vector

$$\text{mag } a_x + a_y = \sqrt{(0.035 \frac{m}{s^2})^2 + (0.241 \frac{m}{s^2})^2}$$

$$\text{mag } a_x + a_y = 0.243 \frac{m}{s^2}$$

$$\text{dir } \theta = \tan^{-1} \frac{.243 \frac{m}{s^2}}{.035 \frac{m}{s^2}}$$

$$\text{dir } \theta = 8.3^\circ \text{ East of North}$$

method 2