Applications of Newton's Laws

Friction & Drag

Friction

…is a complex phenomenon that is not well understood.

Experimental studies indicate…

- $|f| \propto N$
- $|f|$ is independent of area of contact.
- $|f| \cong$constant (1 cm/s $\leq v \leq$ few m/s)

…for dry unlubricated surfaces.

Types of Friction

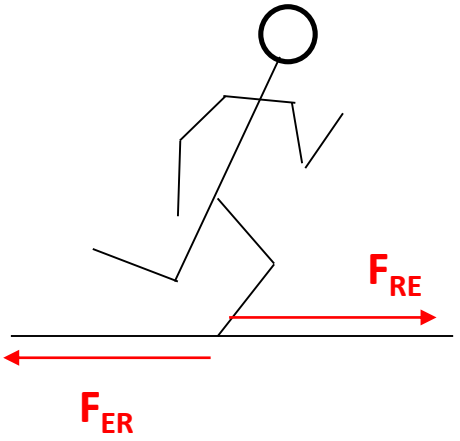
- Static ($v = 0$).
- Kinetic ($v \neq 0$).
- Rolling ($f_r \ll f_k$)
- Drag $|f| \propto v^n$.

Recall Newton's 3rd law of motion:

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

Action-reaction forces act on 2 bodies objects.

NEVER on the same object.



Kinetic vs. Static Friction

Kinetic Friction:

When surface slide past each other: $f_k = \mu_k N$

Static Friction:

When NO sliding occurs: $f_s \leq \mu_s N$

In general: $\mu_s > \mu_k$

Example #1

A 2.0-kg mass is initially at rest on a horizontal surface. The coefficients of static and kinetic friction are 0.20 and 0.15, respectively. The surface is slowly tilted.

- Find the critical angle where the mass "breaks away" and starts to slide down the incline.
- After the mass "breaks away," at this critical angle, what is the acceleration of the mass?
- To what angle should the surface changed so that the mass slides down with zero acceleration?

Example #2

A 3.0-kg object slides upon a horizontal surface when acted upon by a force of 12 N supplied by a cord attached to the front of the object and makes an angle of 20^{o} above the $+x$-axis. The force of (kinetic) friction is 2.0 N.

- Calculate the magnitude of the normal force.
- Calculate the acceleration of the object.
- Calculate the coefficient of (kinetic) friction.

Example #2 (cont'd)

The pulling force caused by the cord is then slowly increased.

- How large can the pulling force get before the block start to lift off of the floor?
- When this occurs, what is the acceleration of the block?

Example #3

A book of mass of 3.0 kg is pressed against a vertical wall and held at rest by a horizontal force. The coefficient of (static) friction is 0.20.

- Calculate the minimum force that can be applied before the book starts to slip and slide down the wall.

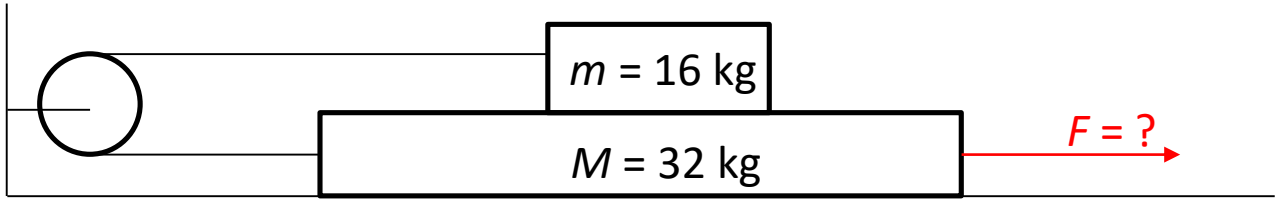
Example #4

A block is kicked to the right such that it has an initial speed of 3.0 m/s when it leaves the kicker's foot. The coefficient of (kinetic) friction between the block and the floor is 0.25.

- Calculate the acceleration of the block after it leaves the kicker's foot.
- How far does the block slide after the kick?

Example #5

Consider the situation below:

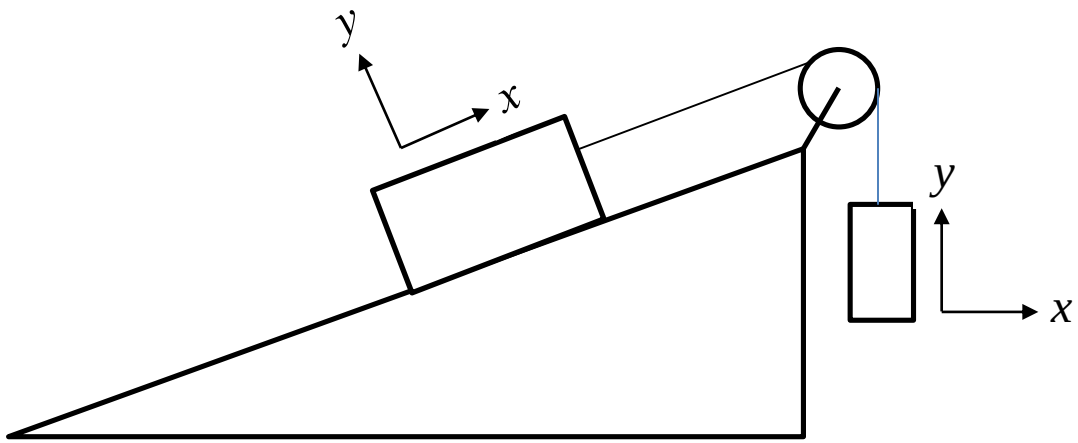


The coefficient of kinetic friction is 0.20 between all surfaces in contact. (The pulley is frictionless.)

- Find the magnitude of the force F such that the lower block accelerates to the right at 2.0 m/s^2.
- Calculate the tension in the string that connects the two blocks.

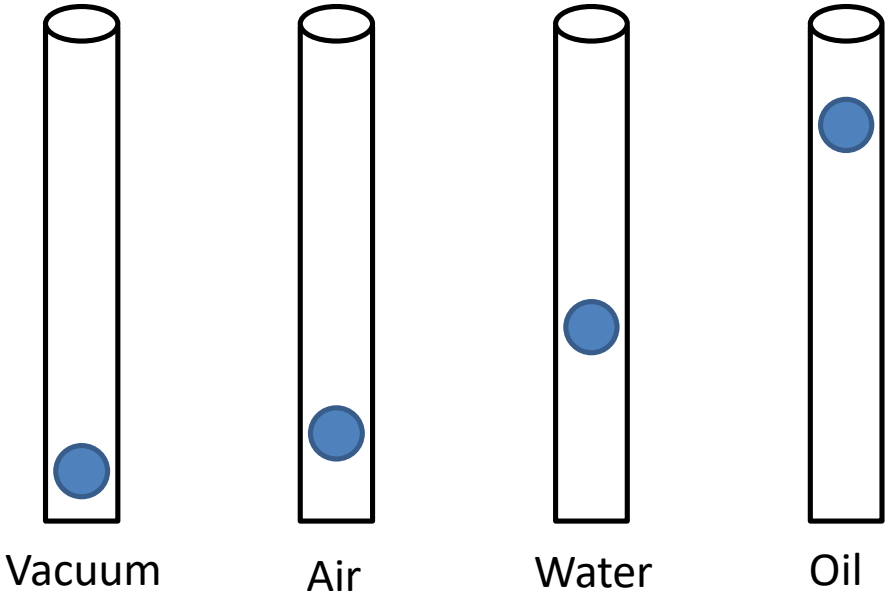
Can you use different coordinates in the same problem?

YES!



Drag Force & Terminal Speed

Take a steel ball and drop in vacuum, air, water...



$$D = \frac{1}{2} C \rho A v^2$$

Initially (when the object is released from rest), the drag force is zero.

As the object falls, D increases until $D = mg$.

That is, $\sum F_y = 0$.

Acceleration becomes zero and the object falls with a constant velocity (the *terminal velocity*).

$$\frac{1}{2} C\rho A v^2 = mg \quad \Longrightarrow \quad v_t = \sqrt{\frac{2mg}{C\rho A}}$$