Frictional Force

Two types:
- Static friction, $f_s$
- Kinetic friction, $f_k$

Friction is due to the surfaces interacting with each other on the microscopic level.
- sliding over bumps
- chemical bonds

Frictional Force: Empiricism

*Empirical* statements about friction:
- The magnitude of the frictional force, $f$, is proportional to the magnitude of the normal force, $N$.
  \[
  f \leq \mu N \\
  f_s = \mu_s n
  \]
- $\mu_s$ and $\mu_k$: coefficients of static and kinetic friction, respectively
- Direction of frictional force is opposite to direction of relative motion
- Values of $\mu_s$ and $\mu_k$ depend on nature of surface.
- $\mu_s$ and $\mu_k$ don’t depend on the area of contact
- $\mu_s$ and $\mu_k$ don’t depend on speed.

Example I

A brick is placed on an inclined board as shown in the figure. The angle of incline is increased until the block starts to move.

Determine the static friction coefficient from the critical angle, $\theta_c$, at which the block starts to move.
A hockey puck is given an initial speed of 20.0 m/s. It slides 115 m before coming to rest. Determine the coefficient of kinetic friction between the puck and the ice.

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Objects interact with the fluid through which they move:
- Air
- Water, oil, liquids.
Object experience different resistive forces depending on their sizes, shapes and speeds, and the fluid.

\[ F \sim v: \text{small/slow objects} \]
\[ F \sim v^2: \text{Large fast objects} \]

What is “fast” depends on the fluid!

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Objects reach a terminal velocity.
- When the resistive force of the falling object is equal to the gravitational force on the object.

**Examples:**
- skydivers
- soap bubbles falling in air
- small spheres dropping in liquid.
Resistive force

For blunt objects moving at high speeds:

Resistive force:

\[ R = \frac{1}{2} D \cdot \rho \cdot A \cdot v^2 \]

Where:
- \( D \)… Drag coefficient of object (depends on shape)
- \( \rho \)… density of air
- \( A \)… cross-sectional area of object
- \( v \)… velocity of object

Uniform Circular Motion (reminder)

\[ a_r = \frac{v^2}{r} \]

- The acceleration points towards the center of the circle.
- Centripetal acceleration

Newton’s Second Law applied to circular motion

\[ \vec{F}_r = m \cdot \vec{a}_r = m \cdot \frac{v^2}{r} \]
A particle is moving in a circular path. If the force on the particle would suddenly vanish (string cut) in which direction would the ball fly off?

Quiz

Example I

I rotate a ball \( m = 0.50 \text{ kg} \) that is attached to the end of a 1.5 m cord above my head in a horizontal circle. If the cord can withstand 50 N of tension, at what speed will it rupture?

Example II

A speeding car turns into a curve, the radius of the curve is 1000.0 m and the coefficient of static friction between the tires and the dry pavement is 0.500. What is the maximum speed the car can have and still make the turn?