Friction

Knowledge/Understanding Goals:
• difference between static & kinetic friction
• direction of the vector representing friction

Skills:
• calculate the frictional force on an object
• calculate net force in problems involving friction

Notes and definitions:
friction: a contact force caused by the roughness of the materials in contact, deformations in the materials, and molecular attraction between materials. Frictional forces are always parallel to the plane of contact between two surfaces, and opposite to the direction of motion or applied force. As shown in the figures real surfaces are rough not perfectly smooth. They resist motion in what we call friction. Friction has two types kinetic and static. Friction is defined as:

\[ F_{\text{friction}} = \mu F_{\text{Normal}} \]

static friction: friction acting on an object at rest that resists its ability to start moving.

kinetic friction: friction resisting the motion of an object. In almost all situations, static friction is a stronger force than kinetic friction.

coefficient of friction: a constant that relates the frictional force on an object to its mass. The coefficient of friction is represented by the Greek letter \( \mu \).

coefficient of static friction: \( \mu_s \) represents the coefficient of friction for an object that is stationary (not moving)
coefficient of kinetic friction: $\mu_k$ represents the coefficient of friction for an object that is moving.

The coefficient of friction takes into account the surface areas and surface characteristics of the objects in contact (see above pictures).

The force of friction on an object is given by the equations:

\[
F_f = \mu_s F_N \quad \text{for an object that is stationary, and}
\]
\[
F_f = \mu_k F_N \quad \text{for an object that is moving},
\]

Where $F_f$ is the vector representing the force of friction, $\mu_s$ and $\mu_k$ are the coefficients of static and kinetic friction, respectively, and $F_N$ is the vector representing the normal force.

**Examples: Friction Problems**

Because friction is a contact force, all friction problems involve the frictional force in addition to some other (usually externally applied) force.

To calculate the force from friction, you need to:

1. **Calculate the normal force.** If the object is resting on a horizontal surface (which is usually the case), the normal force is usually equal in magnitude to the force of gravity. [Recall that $F_g = mg = m(9.8).$] This means that for an object sliding across a horizontal surface:

   \[
   F_N = F_g = m(9.8)
   \]

2. **Figure out whether the friction is static (there is an applied force, but the object is not moving), or kinetic (the object is moving).** Look up the appropriate coefficient of friction ($\mu_s$ for static friction, or $\mu_k$ for kinetic friction).

3. **Calculate the force of friction from the equation:**

   \[
   F_f = \mu F_N
   \]

4. **If the problem is asking for net force, remember to go back and calculate it now that you have calculated the force of friction.** In most friction problems, friction is opposing the applied force, which means the net force would be:

   \[
   F_{net} = F_{applied} - F_f
   \]
Example Problems:

Q: A person pushes a box at a constant velocity across a floor as shown in picture:

The box has a mass of 40 kg, and the coefficient of kinetic friction between the box and the floor is 0.35. What is the magnitude of the force that the person exerts on the box?

A: The box is moving at a constant velocity, which means there is no acceleration, and therefore no net force on the box. This means the force exerted by the person is exactly equal to the force of friction.

The force of friction between the box and the floor is given by the equation:

\[ \vec{F}_f = \mu_k \vec{F}_N \]

The normal force is equal in magnitude to the weight of the box \((F_g)\), which is given by the equation:

\[ F_N = F_g = ma = (40)(9.8) = 392 \text{ N} \]

Therefore, the force of friction is:

\[ \vec{F}_f = \mu_k \vec{F}_N \]

\[ \vec{F}_f = (0.35)(392) = 137 \text{ N} \]

In the figure below is shown a book lying on a table. The force of \( F_{friction} = F_f \) is balanced with the applied force \( F \). The book is not moving. However, if the applied force gets bigger than the \( F_f \) then the book will move.
Q: The force of friction opposes all motion. If you are pushing on an object and it is not moving then there is present an opposing force called Static Friction $F_s$. If the object is moving while you are pushing on it then there is still friction but it is now kinetic friction $F_k$. The picture below illustrates the two frictional forces differences.