Friction

When one object slides over the surface of another, its motion is always opposed by a force that resists this motion. This force is called **friction**.

The frictional force (F_f):

1. always acts opposite to the direction of motion.
2. is independent of the area of contact.
3. is proportional to the normal force between the two surfaces.
4. depends on the materials that make up the surfaces.

Friction is typically classified into one of two types:

1. **Static Friction**
   - exists between objects that **are not in relative motion**
   - has a maximum value
     - while the applied force is less than the maximum value, the object will not move (the frictional force and the applied force will have equal magnitudes during this time)
     - once the applied force exceeds the maximum value, the object will move
     - mathematically
       $$F_f \leq \mu_s F_N$$

2. **Kinetic Friction**
   - exists between objects that **are in relative motion**
   - has a value that is less than that of static friction
   - mathematically
     $$F_f = \mu_k F_N$$

The symbol μ represents the **coefficient of friction**. The value of μ depends on the nature of the two surfaces.

Example 1

A horizontal force of $100\ N$ is applied to a box of books of mass $20\ kg$ resting on a wooden table. Does the box slide if the coefficient of static friction of the box on the table is 0.40?

Example 2

A 20 kg box is pulled across a horizontal surface by a 200 N force applied at 30° to the horizontal. If the coefficient of kinetic friction is 0.25, what is the acceleration of the box?

Example 3
A child sits on a sled that rests on a snow-covered hill making an angle of θ with the horizontal. If the coefficient of friction is 0.10, what is the maximum angle at which the sled remains at rest?

Dynamics Worksheet #3

1. A horizontal force of $50\ N$ is required to pull an $8\ kg$ block of aluminum at a uniform velocity across a horizontal wooden desk. What is the coefficient of kinetic friction? (0.64)

2. The driver of a $2000\ kg$ car applies the brakes on a dry concrete roadway. Calculate the force of friction between the tires and the road surface (the coefficient of friction is 1.02). ($-19992\ N$)

3. A $20\ kg$ box is dragged across a level floor with a force of $100\ N$. The force is applied at an angle of $40°$ above the horizontal. If the coefficient of kinetic friction is 0.32, what is the acceleration of the box? ($1.72\ m/s^2$)

4. A boy on a toboggan is sliding down a snow-covered hillside. The boy and toboggan together have a mass of $50\ kg$, and the slope is at an angle of $30°$ to the horizontal. Find the boy's acceleration if

   a) there is no friction. ($4.9\ m/s^2$)

   b) the coefficient of kinetic friction is 0.15. ($3.6\ m/s^2$)

5. It takes a $50\ N$ horizontal force to pull a $20\ kg$ object along the ground at a constant velocity. What is the coefficient of kinetic friction? (0.26)

6. If the coefficient of friction is 0.30, how much horizontal force is needed to pull a mass of $15\ kg$ across a level board at a uniform velocity? ($44.1\ N$)

7. A cart with a mass of $2\ kg$ is pulled across a level desk by a horizontal force of $4\ N$. If the coefficient of kinetic friction is 0.12, what is the acceleration of the cart? ($0.82\ m/s^2$)

8. A girl pushes a light ($m = 0$) snow shovel at a uniform velocity across a sidewalk. If the handle of the shovel is inclined at $55°$ to the horizontal, and she pushes along the handle with a force of $100\ N$,

   a) What is the force of friction? ($57.4\ N$)

   b) What is the coefficient of kinetic friction? (0.70)

9. A $10\ kg$ block of ice slides down a ramp $20\ m$ long, inclined at $10°$ to the horizontal.

   a) If the ramp is frictionless, what is the acceleration of the block of ice? ($1.70\ m/s^2$)

   b) If the coefficient of kinetic friction is 0.10, how long will it take the block to slide down the ramp, if it starts from rest? ($7.37\ s$)

10. A skier has just begun descending a $20°$ slope. Assuming that the coefficient of kinetic friction is 0.10, calculate

   a) the acceleration of the skier. ($2.43 \ m/s^2$)

   b) his final velocity after $8 \ s$. ($19.4 \ m/s$)