FRICTION

WHAT IS FRICTION?

Friction is a force that occurs between the surfaces of two objects which are in contact. It is caused by:

- The adhesion forces between the atoms/molecules of the two surfaces in contact
- The interference of the small rough ridges (roughness) of the two surfaces with one another
- The microscopic deformation between the surfaces

Friction is a reaction force; it always opposes motion. It is directed parallel to the surfaces in contact.

TYPES OF FRICTION

Static Friction

Static friction occurs between two objects that are in contact, but not moving relative to one another. For example, we may try to push a box across a table (see Figure 1), but the box does not move.

In order to better understand this problem, construction of a free body diagram is necessary. From our experience, we know that gravity pulls an object downward, $F_g$, the normal force pushes an object upward (perpendicular to the surface), $F_n$, and the applied force pushes the object to the right, $F_{applied}$. But which way does friction push? Remember friction opposes motion. If there were no friction, which way would the box move? To the right. Therefore, the friction force must be opposing the motion and pushing to the left. This is illustrated in Figure 2.

Tip: Imagine the object is on a frictionless surface (i.e. a sheet of ice). Which way would it move? The force of friction then points in the opposite direction.
The block is in static equilibrium. Therefore, the force of friction is equal and opposite to the applied force. This can be easily shown using Newton’s second law.

The force of static friction is defined as:

\[ F_f \leq \mu_s F_n \]

where \( \mu_s \) is the coefficient of static friction.

Why is static friction defined with as “less than or equal to” \( \mu_s F_n \)? Well, if we go back to our example above and we apply a small force to the block, friction pushes back with a small force (that is equal and opposite). Applying a slightly greater force, friction pushes back with a slightly greater force (again, that is equal and opposite). If we keep applying more and more force to the block, we will eventually get to a point where the block begins to move. Therefore, the static friction force has a theoretical maximum.

At its theoretical maximum static friction:

\[ F_{f, \text{max}} = \mu_s F_n \]

As you can see the maximum force of static friction is proportional to the normal force. Why? The normal force in essence is the force between the two contact surfaces. The greater the force, the better the surface contact the surfaces have with one another which in turn amplifies the above stated causes of friction.

If the coefficient of friction is not given but the two materials that are causing friction with one another are specified, find the coefficient of friction in a table.

**Kinetic Friction**

Kinetic friction occurs between two objects that are in contact and sliding with respect to one another. Kinetic friction can be defined as:

\[ F_f = \mu_k F_n \]

where \( \mu_k \) is the coefficient of kinetic friction.

The coefficient of kinetic friction is less than the coefficient of static friction. Why? Two surfaces moving with respect to one another have less time to create the adhesion forces responsible for friction. This is why it is harder to push a couch from rest then to keep it going or why you can pull the table cloth off a table really quickly (rather than slowly), without the glasses and dishes falling down.
Sample Problems

1) A 10 kg box is at rest on a 15° ramp. The coefficient of static friction between the box and the ramp is 0.8. What is the force of friction (magnitude and direction)?

2) A 10 kg box is placed on a 40° ramp. The coefficient of static friction between the box and the ramp is 0.8 and the coefficient of kinetic friction is 0.6. Is the box at rest or in motion? If in motion, what is its acceleration?

3) Two blocks are placed on a ramp as shown in Figure 3. The coefficient of kinetic friction between the 20 kg block and the ramp is 0.1 and the coefficient of kinetic friction between the 10 kg block and the ramp is 0.3. What is the acceleration of the blocks and which way do they move?

Figure 3: Blocks on a ramp