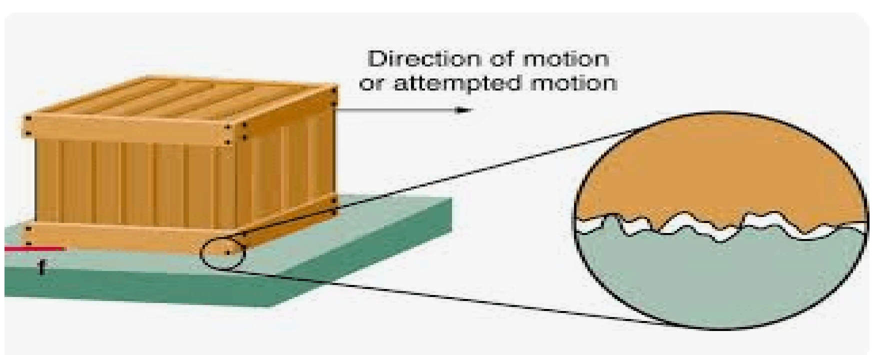
Lesson 3: Frictional force

Key Terms and Concepts

- Friction: a force that opposes the motion of one surface over another.
- Static friction: Friction between two contacting surfaces at rest.
- Kinetic friction: Friction between two surfaces while one slides over the other.
- Free-Body Diagram: The most important step in solving a problem by means of Newton's second law. It is a drawing that includes only those forces that act directly on the object of interest
- **Friction** is the force that resists the relative motion of material elements, solid surfaces, fluid layers from rolling or sliding against each other.
- **Friction** basically arises from the action of irregularities of the harder surface plowing across the softer one.
- Friction is a type of force that We experience in our everyday activity.
- Friction, in simple terms is a force that opposes motion.
- It occurs when two surfaces are in contact with each other and when one surface slides or attempts to slide over the other.
- Friction occurs due to the roughness of the surfaces in contact. Even if the surface seem very smooth,
- it is not so at micro or Nano scale,
- Friction helps us to move while we walk by preventing us from slipping.
- Without friction between the tires and the road we couldn't drive or turn the car.
- Without the frictional force exerted by the air on a body moving through it (air drag),
- parachutes do not work.
- Without friction nails would pull out,
- light bulbs would unscrew effortlessly.



Types of friction

There are two types of friction:

1. Static friction and
2. Kinetic friction.

I. Static friction is the friction between two surfaces when there is no movement. Suppose you pull a block slightly along a table top, Figure 4.19a. The block will not move with such a small force that you apply. What do you think is the reason for this? The force that keeps the block from sliding is the force of static friction denoted by (F_S) and is directed opposite to the applied force.

II. Kinetic friction: Kinetic friction is the friction between two surfaces when one of them is sliding over the other. For example, when the block that you push begins to slide over the table, Figure 4.19b, there is force of kinetic friction denoted by (F_K) between the bottom surface of the block and the table top

- Frictional force is directly related to the normal force and its value depends upon the property of the surfaces in contact. This property of material that resists motion μ is called the coefficient of friction (**μ**), which is defined as the ratio between the friction force and the normal force. Mathematically,
- We write $\mathbf{F_S = \mu_s F_n}$, for static frictional force, where μ_s is coefficient of static friction
- $\mathbf{F_K = \mu_K F_n}$ for kinetic frictional force, where $\mathbf{\mu_K}$ is coefficient of kinetic friction
- $\mu = Ff/FN$

Figure 4.19 Static friction and kinetic friction

The maximum value of static friction

- value being $\mathbf{F_S = \mu_s F_n}$
- Once the static friction gives way to kinetic friction, i.e., the maximum value of static friction is known as limiting friction and it is the frictional force between the surfaces when the body just begins to slide.
- Static friction is less than or equal to the product of coefficient of static friction (μs) and the normal force (F_N).
- The maximum the block is in motion, it is easier to keep it in motion than it was to get it started, indicating that the kinetic frictional force is less than the static frictional force.
- Kinetic friction is less than static friction.

Note that

Unlike the kinetic friction force, the static friction force takes on any value between zero and its maximum value of μ F , depending on the magnitude of the applied

Force. It could take any value between zeros to its limiting value.

$0 \leq \quad F \leq \mu F$

Examples: 3.1 An 8 kg block is placed on a horizontal surface. The coefficient of static friction and that of kinetic friction between the block and surface are 0.4, and 0.35, respectively.

A) What is the horizontal force just enough to start moving the block? B) What horizontal force must be applied on the block to keep it uniformly accelerating at 4 m/s2?

Given:

m = 8 kg, μ = 0.4, μ = 0.3

Solution

A)The block is in a limiting equilibrium, so that the friction force will be

B) $F_s = \mu_s F_N$ (since the block is on a level surface F_N=mg

Therefore, $F = \mu\, mg = (0.4)\ (8\ kg)\ (9.8\ m/s^2) = 31.4\ N$

B). as the block accelerates the net force that accelerates the block is the vector sum of the applied force and the kinetic frictional force.

$F_{net} = F_{app} - F_k$

$F_{net} = ma = (8\ kg\ )(4\ m\ /\ s\ ) = 32\ N2$ and

$F_k = \mu_k mg = (0.3)\ (8\ kg)\ (9.8\ m/s\ ) = 23.5\ N$

thus, $F_{app} = F_{net} + F_k = 32\ N + 23.5\ N = 55.5\ N$

Examples: 3.2 two blocks of identical materials are connected by a light string on a level surface (Figure 4.25). Assuming no friction between the blocks and the level surface, find the acceleration of the masses and the tension in the connecting string when the string attached to m is pulled to the right by a 36 N force. Use m = 4 kg and m = 8 kg

Figure 4.25

Solution:

Given: $m_1 = 4$ kg, $m_2 = 8$ kg, F = 36 N

The blocks move together to the right under the action of force F. Writing Newton's second law for each block we have

For m_1, $F - T = m_1 a$

For m_2, $T = m_2 a$

Adding the above equations we get

$$F = m_1 a + m_2 a = (m_1 + m_2) a$$

$$a = \frac{F}{m_1 + m_2}$$

Substituting the given values we obtain $a = 3\ m/s^2$.

Using a $3\ m/s^2$ in $T = m_2 a$ we get T = 24 N

Examples: 3.4

For the system of masses in Example 4.6, find the acceleration of the masses if the coefficient of kinetic friction between each of the blocks and the level surface is 0.25.

Solution

given: $m_1 = 4$ kg, $m_2 = 8$ kg, $F = 36$ N, $\mu_k = 0.25$
This time the free-body diagram will include frictional forces on the blocks as in Figure 4.26.

Figure 4.26 Free-body diagram

Writing Newton's second law of motion for each of the blocks as:

$$\text{For } m_1, F - T - F_{f1} = m_1 a$$

$$\text{For } m_2, F - T - F_{f2} = m_2 a$$

Adding these two equations, we get

$$F - F_{f1} - F_{f2} = (m_1 + m_2)a$$

$$F_{f1} = \mu_k N_1 = \mu_k m_1 g = (0.25)(4\text{kg})(9.8\text{m}/\text{s}^2) = 9.8\text{m}/\text{s}^2$$

$$F_{f2} = \mu_k N_2 = \mu_k m_2 g = (0.25)(8\text{kg})(9.8\text{m}/\text{s}^2) = 19.6\text{m}/\text{s}^2$$

Substituting values, we obtain

$$a = \frac{F - F_{f1} - F_{f2}}{m_1 + m_2} = 0.55\,\text{m}/\text{s}^2$$

Tension Forces

- When an object attached to a string (or a cable) is pulled by means of a pulling force exerted on the string, the force on the string is called a tension force.

- The tension force acts along the direction of the string and exerts a force both on the object and on the person exerting force on the cable, as illustrated in Figure 4.28.
- If the mass of the given cable is neglected, the same tension acts on both the object and the person

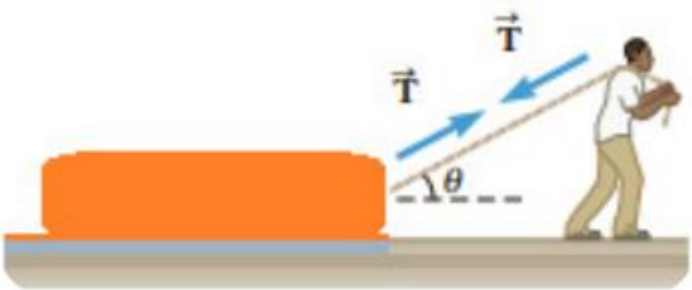
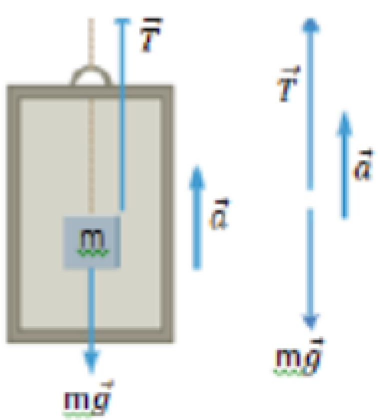


Figure 4.28 A man pulling a block

Vertical Tension force on a static object

The string attached to an object is pulled upward under such tension that it accelerates the object upward (Figure 4.30). In this case the tension supports the weight and also accelerates the object upward. Applying Newton's second law along the y axis we write



$$F_{net} = ma$$
$$T - mg = ma$$
$$T - mg = 0$$
$$T = m(g + a)$$

Figure 4.30 An object hangs by a string in an elevator accelerating upward