Section 2.14: Friction

Friction is needed to move. Without friction, a car would sit in one spot spinning its tires, and a person would not be able to step forward. However, the motion of an object along a surface with friction causes the production of heat, loss of mechanical energy, and general wear and tear on the object.

Two objects in contact make microscopic connections at various points on their surface. Because the contact points are so close to each other, intermolecular forces form **microscopic welds** that must be broken in order for objects to move. As the object moves, these welds form and break along the length of the path.

Frictional forces are forces that act to **oppose** the direction of motion. These forces act **parallel** to the surface. The **magnitude (size) of the frictional force** is determined by the types of materials in contact and by the normal force exerted by one object on the other.

There are two main types of friction:

1. **Static friction** - The force that tends to prevent a stationary object from starting to move.
   - Sometimes called starting friction: The amount of force needed to start an object's motion.

2. **Kinetic friction** - The force that acts against an object's motion.
   - Occurs once static friction has been overcome and object is moving

There are three type of kinetic friction:

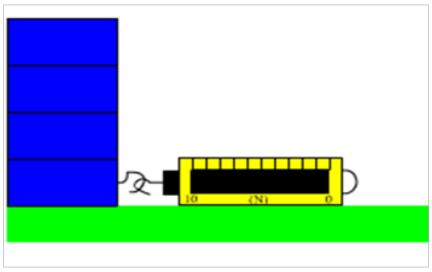
A **Sliding friction** - This is the force that makes it difficult to slide one object over another.

B **Rolling friction** - This is the force that opposes the rolling motion of one surface over another.

C **Fluid friction** - Air and water resistance that opposes the motion of boats and planes.

The theory of frictional forces states that an object at rest experiences more friction than when it is already moving. Thus, **static friction is greater than kinetic friction.**

Measuring Friction Force



- A heavy stack of wooden blocks rests on a table
- We slowly increase the pulling force on the block to the point that the stack of blocks just starts to move (constant speed).
- At that point, the applied force (as read from the spring scale) will be equal in size and opposite in direction to the frictional force. $F_{app} = - F_{fr}$

Normal Force and Friction

- The force that pushes two surfaces together.
- We will study only horizontal surfaces, so the normal force will be caused by the weight of the object.
- As the normal force increases, so will the force of friction, In other words:

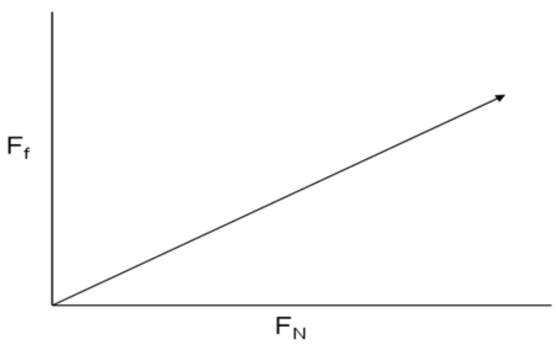
Frictional Force is directly proportional to the Normal Force

$$F_{fr} \propto F_{normal}$$

- The normal force is caused by the weight (F_g), and $F_g = m \cdot g$
- So, $F_{fr} \propto m \cdot g$

Normal force - the force that presses two surfaces together.
If an object is simply sitting on another surface,

$$F_N = F_g = mg$$



MC

Slope = μ, the coefficient of friction

Coefficient of Friction

It is a number used to calculate the force of friction acting on a sliding object.

$\mu = \frac{F_f}{F_N}$ where: μ is the coefficient of friction (no units)
F_f is the force of friction in Newtons
F_N is the normal force in Newtons

Greek letter "mu"

μ is a constant for any surface. It will however, be different for each surface or material. For surfaces where there is very low friction, such as ice, the value of μ is very low. For rough surfaces like concrete, it will be much higher.

Since there are two types of friction, there are two types of coefficients for friction. The **coefficient of static friction (μ_s)** is larger than the **coefficient of kinetic friction (μ_k)**. Although both μ_s and μ_k can be substituted in the same equation, $F_f = \mu F_N$.

A force of friction is involved if there is a:

- A coefficient of friction
- A normal force between two surfaces
- An applied force trying to move the object.

$* \; \frac{\mu}{1} = \frac{F_f}{F_N}$

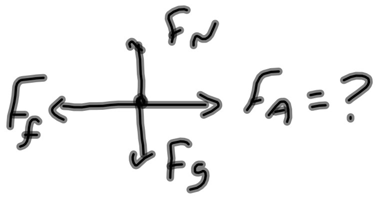
$$\boxed{F_f = \mu F_N}$$

For horizontal surfaces where $F_N = F_g = mg$

$$\boxed{F_f = \mu mg}$$

Examples

1 The coefficient of kinetic friction between a crate and the floor is 0.400. The crate has a mass of 75.0 kg. What force is required to move the crate at a constant speed?



* To slide an object at a constant speed, you must overcome the force of friction

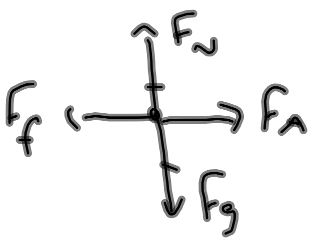
$\therefore F_A = F_f$

$$F_f = \mu m g$$
$$= (0.400)(75\,kg)(9.8\,m/s^2)$$
$$= 294\,N$$

$\therefore F_A = 294\,N$ in the opposite direction.

2 A concrete block has a mass of 15.0 kg. The coefficient of friction between the block and the floor is 0.90. Calculate the frictional force required to keep the block moving uniformly.

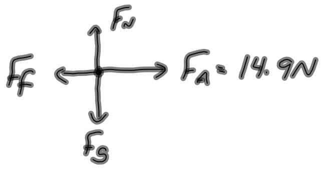
constant speed



$$F_f = \mu m g$$
$$= (.90)(15\,kg)(9.8\,m/s^2)$$
$$= 130\,N$$

$F_f = F_A$

3 A horizontal force of 14.9 N is applied to a block of wood with a mass of 1.5 kg. The coefficient of friction between the block and the surface on which it sits is 0.50. Calculate the acceleration of the block.



$m = 1.5kg$
$a = ?$
$F_{net} = ?$
$F_f = ?$

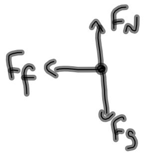
① $F_f = \mu mg$
$F_f = (0.5)(1.5kg)(9.8m/s^2)$
$F_f = 7.35N$

② $F_{net} = F_A - F_f$
$= 14.9N - 7.35N$
$= 7.55N$

③ $a = \frac{F_{net}}{m} = \frac{7.55N}{1.5kg} = 5.0 m/s^2$

$F_{net} = F_A - F_f$
$ma = F_A - \mu mg$
$(1.5kg)a = 14.9 - (0.5)(1.5kg)(9.8m/s^2)$
$a = 5.0 m/s^2$

4 A bike and a rider have a combined mass of 90.0 kg. The ~~bike skids to~~ a stop from 10.0 m/s in 2.0 s. What is the coefficient of kinetic friction between the tires and the road?



$m = 90kg$
$V_1 = 10m/s$
$V_2 = 0m/s$
$t = 2.0s$
$\mu = ?$
$a = ?$
$F_{net} = ?$
$F_f = ?$

① $a = \frac{V_2 - V_1}{t} = \frac{0 - 10m/s}{2.0s}$
$= -5.0m/s^2$

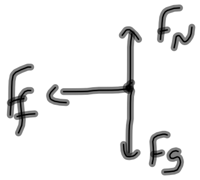
② $F_{net} = ma$
$= (90kg)(-5.0m/s^2)$
$= -450N$

③ $F_f = F_{net} = -450N$

④ $F_f = \mu mg$
$\frac{F_f}{mg} = \mu$ ← *don't put in neg. sign.
$\frac{450N}{(90kg)(9.8m/s^2)} = \mu$
$0.51 = \mu$

$F_{net} = -F_f$
$ma = -\mu mg$ *
$(90kg)(-5m/s^2) = -\mu(90kg)(9.8m/s^2)$
$0.51 = \mu$

5 A snowmobile, m = 240 kg, initially travelling over snow at 70.0 km/h, runs onto an icy pond where the value of coefficient of kinetic friction between the track and the ice is 0.10. Calculate the distance the snowmobile will skid before coming to a stop.



$m = 240\,kg$
$v_1 = 70\,km/h$
$v_2 = 0$
$\mu = 0.10$
$d = ?$
$a = ?$
$F_{net} = ?$
$F_f = ?$

① $F_f = \mu mg$
$= (0.10)(240\,kg)(9.8\,m/s^2)$
$= 235.2\,N$

② $F_{net} = -F_f$
$= -235.2\,N$

③ $a = \frac{F_{net}}{m} = \frac{-235.2\,N}{240\,kg} = -0.98$

④ $d = \frac{v_2^2 - v_1^2}{2a} = \frac{0 - (19.4\,m/s)^2}{2(-0.98\,m/s^2)}$

$d = 192\,m$

$F_{net} = -F_f$
$ma = -\mu mg$
$(240\,kg)a = -(0.10)(240\,kg)(9.8\,m/s^2)$
$a = -0.98\,m/s^2$

6 On a car the coefficient of friction between the tires and the road is 1.8. Calculate the maximum acceleration that the tires can withstand.

Accelerating Force: $F_{net} = ma$

Frictional force: $F_f = \mu mg$

Since the frictional force provides the accelerating force, set

$F_{net} = F_f$
$ma = \mu mg$
$a = \mu g$
$a = (1.8)(9.8\,m/s^2)$
$= 18\,m/s^2$