

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

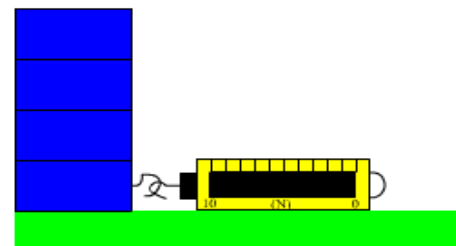
There are three type of kinetic friction:

- 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. $F_{\text{app}} = -F_{\text{fr}}$

Normal Force and Friction

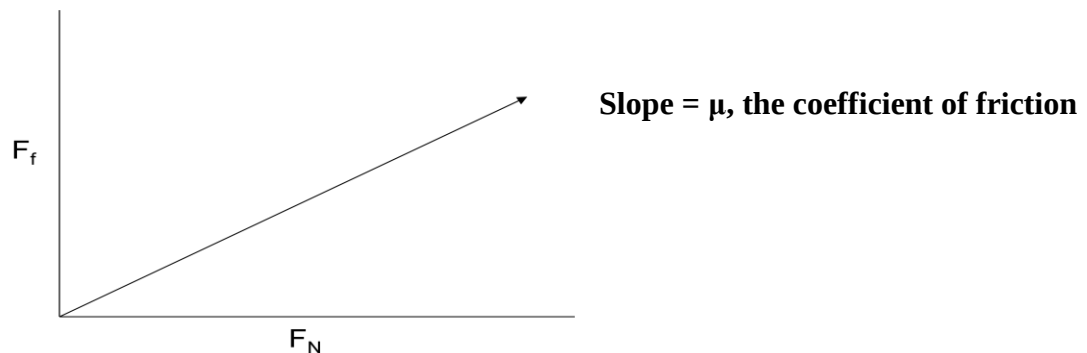
- The force that pushes two surfaces together.
- We will study only horizontal surfaces, so the normal force will be caused by the weight of the object.
- As the normal force increases, so will the force of friction, In other words:

Frictional Force is directly proportional to the Normal Force

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

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

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



Coefficient of Friction

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

$$\mu = \frac{F_f}{F_N} \quad \text{where: } \mu \text{ is the coefficient of friction (no units)}$$

F_f is the force of friction in Newtons

F_N is the normal force in Newtons

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.

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?
- 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.
- 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.

- 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?
- 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.
- 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.

Worksheet on Friction

- 1 What happens to the coefficient of friction when the normal force between two surfaces is tripled?
- 2 The coefficient of friction between a pair of sneakers and the floor is 1.2. If you have a mass of 65 kg and are standing (in your sneakers) on a horizontal floor, what force will be needed to drag you along the floor?
- 3 The coefficient of friction between the tires of your bike and the road is 0.90. If you lock the wheels, what frictional force will be required to drag you along? Assume you and the bike have a combined mass of 120 kg.
- 4 The coefficient of kinetic friction between the tires of a sports car and the TCH si 1.20. The car has a mass of 950.0 kg. Suppose that the driver “locks” the wheels. What frictional (braking) force will be applied to the car as a result?
- 5 A skater has a mass of 72.0 kg. The coefficient of friction between the skates and the ice is 0.012. What force is needed to keep the skater moving uniformly across the ice?
- 6 An applied force of 400 N is needed to keep a sled-load of firewood moving uniformly across the snow. What is the coefficient of friction between the sled runners and the snow if the mass is 200.0 kg?
- 7 An object has a weight of 25 N. An applied force of 15 N causes it to move uniformly. What is the value of μ for the situation?
- 8 An ox exerts a force of 7100 N in the horizontal direction without slipping. If the ox has a weight of 8000 N, what is the minimum coefficient of static friction?
- 9 A crate of mass 20 kg is being pushed by a person with a horizontal force of 63 N, moving with a constant velocity. Find the coefficient of kinetic friction.
- 10 For Problem 9, your good friend watching you do all the work comes over and sits on the crate. His mass is 60 kg. What happens? Justify using values.

- 11 Compare forces required to push a fridge across a floor if, in one case, friction exists and in the other case, friction does not exist. Fridge mass is 100 kg and $\mu_k = 0.4$.
- 12 Calculate the force required to start pushing the fridge in Problem 11 if $\mu_s = 0.46$.
- 13 A force of 13.2 N is applied to a dynamics cart with a mass of 1.50 kg. A frictional force of 4.7 N resists the motion. Calculate the acceleration of the cart.
- 14 A horizontal force of 150.0 N is applied to a block with a mass of 70.0 kg. The resulting acceleration is 1.30 m/s^2 . What is the frictional force which resists the motion?
- 15 A block of wood with a mass of 1.0 kg sits on a table. A horizontal force of 10.0 N is applied to the block. The coefficient of friction between the block and the table is 0.300.
- A Calculate the frictional force that resists the motion.
 - B Calculate the net force that caused the acceleration.
 - C Calculate the acceleration.
- 16 A puck with a mass of 0.200 kg rest on the ice. The coefficient of friction between the ice and the puck is 0.05. What will be the acceleration if a horizontal force of 0.22 N is applied to the puck?
- 17 A force of 10.0 N, when applied to a brick with a mass of 0.500 kg, results in an acceleration of 0.40 m/s^2 .
- A Calculate the net force that caused the acceleration.
 - B Calculate the frictional force.
 - C Calculate the coefficient of friction between the block and table.
- 18 A box of mass 5.7 kg slides across a floor and comes to a complete stop. If its initial speed was 10.0 km/h and $\mu_k = 0.34$, find
- A the friction acting on the box.
 - B the acceleration of the box.
 - C the distance travelled by the box before stopping.
 - D the time it took to stop.
- 19 A
- What force is required to accelerate a lawn mower of mass 12 kg to 4.5 km/h from rest in 3.0 s (neglecting friction)?
 - B If there is friction present and $\mu_k = 0.8$, what force is required now?