Everyday Forces

Weight
The Normal Force
The Force of Friction
- Kinetic vs. Static
- The Coefficient of Friction

MCHS Honors Physics 2014-15

Weight

- The gravitational force exerted on an object by Earth, F_g, is a vector quantity, directed toward the center of Earth.
- The magnitude of this force, F_g , is a scalar quantity called weight.
- The weight of an object can be calculated using the equation $F_g = ma_g$, where a_g is the magnitude of the acceleration due to gravity, or free-fall acceleration.
- On the surface of Earth, $a_g = g$, and $Fg = mg$ and $g = 9.81\ m/s^2$ unless otherwise specified.

Weight

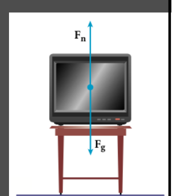
- Weight, is not an inherent property of an object and depends on location.
- If an astronaut in weighs 800 N (180 lb) on Earth, he would weigh only about 130 N (30 lb) on the Moon.
- On the moon, a_g is about 1.6 m/s^2.
- Even on Earth, an object's weight may vary with location. Objects weigh less at higher altitudes than they do at sea level because the value of *ag* decreases as distance from the surface of Earth increases. The value of *ag* also varies slightly with changes in latitude.

The Normal Force

- Newton's law explains why an object sitting on a desk does not fall toward the center of Earth?
- An analysis of the forces acting on the object reveals that all the forces are in equilibrium.
- We know that the gravitational force of Earth, F_g, is acting downward.
- Because the object is in equilibrium, we know that another force, equal in magnitude to F_g but in the opposite direction, must be acting on it.
- The force exerted on the object by the desk is called the normal force, F_n.

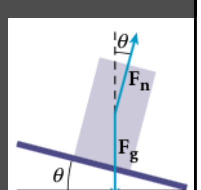
The Normal Force

- The word *normal* is used because the direction of the contact force is per-pendicular to the table surface and one meaning of the word *normal* is "per- pendicular."
- The normal force is always perpendicular to the contact surface but is not always opposite in direction to the force due to gravity.
- The normal force is perpendicular to the ramp, not directly opposite the force due to gravity.



The Normal Force

- In the absence of other forces, the normal force, F_n, is equal and opposite to the component of F_g that is perpendicular to the contact surface.
- The magnitude of the normal force can be calculated as $F_n = m\,g \cos\theta$.
  - The angle θ is the angle between the normal force and a vertical line and is also the angle between the contact surface and a horizontal line.



The Force of Friction

- Friction opposes the applied force
- When an object is at rest on a table, the only forces acting on it are the force due to gravity and the normal force exerted by the table.
- These forces are equal and opposite, so the object is in equilibrium.
- When you push the object with a small horizontal force F, the table exerts an equal force in the opposite direction.
- As a result, the object remains in equilibrium and therefore also remains at rest.

Static Friction Force

- The resistive force that keeps the object from moving is called the force of static friction, abbreviated as F_s.
- As long as the object does not move, the force of static friction is always equal to and opposite in direction to the component of the applied force that is parallel to the surface ($F_s = -F_{applied}$).
- As the applied force increases, the force of static friction also increases
- If the applied force decreases, the force of static friction also decreases.

Static Friction Force

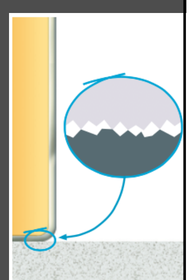
- When the applied force is as great as it can be without causing the object to move, the force of static friction reaches its maximum value, $F_{s,max}$.

Kinetic Friction Force

- Kinetic friction is less than static friction
- When the applied force on an object exceeds $F_{s,max}$, the object begins to move with an acceleration.
- A frictional force is still acting on the object as the object moves, but that force is actually less than $F_{s,max}$.
- The retarding frictional force on an object in motion is called the force of kinetic friction (F_k).
- The magnitude of the net force acting on the object is equal to the differ- ence between the applied force and the force of kinetic friction ($F_{applied} - F_k$).

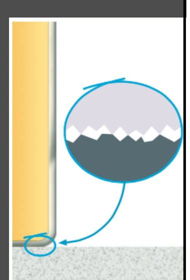
Kinetic Friction Force

- At the microscopic level, frictional forces arise from complex interactions between contacting surfaces.
- Most surfaces, are actually quite rough at the microscopic level.
- When two surfaces are stationary with respect to each other, the surfaces stick together somewhat at the contact points.



Kinetic Friction Force

- This *adhesion* is caused by electrostatic forces between molecules of the two surfaces.



Kinetic Friction Force

- The force of friction is proportional to the normal force.
- It is easier to push a chair across the floor at a constant speed than to push a heavy desk across the floor at the same speed.
- The magnitude of the force of friction is approximately proportional to the magnitude of the normal force that a surface exerts on an object.
- Because the desk is heavier than the chair, the desk also experiences a greater normal force and therefore greater friction.

Calculating Frictional Forces

- Keep in mind that the force of friction is really a macroscopic effect caused by a complex combination of forces at a microscopic level.
- However, we can approximately calculate the force of friction with certain assumptions.
- The relationship between normal force and the force of friction is one factor that affects friction.
- For instance, it is easier to slide a light textbook across a desk than it is to slide a heavier textbook.

Calculating Frictional Forces

- The relationship between the normal force and the force of friction approximates the friction between dry, flat surfaces that are at rest or sliding past one another.
- The force of friction also depends on the composition and qualities of the surfaces in contact: it is easier to push a desk across a tile floor than across a floor covered with carpet.
- The normal force on the desk is the same in both cases, yet the force of friction between the surfaces is not.

Calculating Frictional Forces

- The quantity that expresses the dependence of frictional forces on the particular surfaces in contact is called the coefficient of friction.
- The coefficient of friction between a waxed snowboard and the snow will affect the acceleration of the snowboarder.
- The coefficient of friction is represented by the symbol m, the lowercase Greek letter "*mu*" and it looks like this: μ.

Calculating Frictional Forces

- The coefficient of friction is defined as the ratio of the force of friction to the normal force between two surfaces.
- The *coefficient of kinetic friction* is the ratio of the force of kinetic friction to the normal force.

$$\mu_k = \frac{F_k}{F_n}$$

Calculating Frictional Forces

- The *coefficient of static friction* is the ratio of the maximum value of the force of static friction to the normal force.

$$\mu_s = \frac{F_{s,max}}{F_n}$$

- If the value of μ and the normal force on the object are known, then the magnitude of the force of friction can be calculated directly.

$$F_f = \mu F_n$$

Some Example Values of μ

- Below are some experimental values of μ_s and μ_k for different materials.

	μ_s	μ_k		μ_s	μ_k
steel on steel	0.74	0.57	waxed wood on wet snow	0.14	0.1
aluminum on steel	0.61	0.47	waxed wood on dry snow	—	0.04
rubber on dry concrete	1.0	0.8	metal on metal (lubricated)	0.15	0.06
rubber on wet concrete	—	0.5	ice on ice	0.1	0.03
wood on wood	0.4	0.2	Teflon on Teflon	0.04	0.04
glass on glass	0.9	0.4	synovial joints in humans	0.01	0.003

- Kinetic friction is less than or equal to the maximum static friction, so the coefficient of kinetic friction is less than or equal to the coefficient of static friction.