







- By definition, force is always the result of an interaction of two or more objects.
  - No object possesses force on its own.
- No object can exert force on itself.
- Force is a vector quantity measured in Newtons (N).









- The body is represented by a single isolated point (or free body), and only those forces acting on the body from the outside (external forces) are shown.
  - These forces are the only ones shown, because only external forces acting on the body affect its motion. We can ignore any internal forces within the body.





### Newton's 1<sup>st</sup> Law (Law of Inertia)

• There exists an inertial frame of reference such that a body at rest remains at rest, or, if in motion, remains in motion at a constant velocity unless acted on by a net external force.

 An object is said to be in translational equilibrium if the net force acting on the object is zero.

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#### $\Sigma F = 0$

• Objects in translational equilibrium may either be stationary or moving with a constant velocity.

#### Mass

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- The property of a body to remain at rest or to remain in motion with constant velocity is called **inertia**.
- Some objects have more inertia than others.
  - It is more difficult to change the motion of a large boulder than that of a basketball.
- The inertia of an object is measured by its mass.

## Newton's 2<sup>nd</sup> Law

• The acceleration of a system is directly proportional to and in the same direction as the net external force acting on the system, and inversely proportional to its mass.

$$\vec{a}_{sys} = \frac{\sum \vec{F}}{m_{sys}} = \frac{\vec{F}_{net}}{m_{sys}}$$



# System

 A system is defined by the boundaries of an object or collection of objects being observed; all forces originating from outside of the system are considered external forces.





- When we describe the acceleration of a system, we are modeling the system as a single point which contains all the mass of that system.
- The point we choose for this is the point about which the system's mass is evenly distributed (center of mass).

$$\vec{x}_{cm} = \frac{\sum m_i x_i}{\sum m_i}$$





$$\vec{x}_{cm} = \frac{\sum m_i x_i}{\sum m_i}$$

 $x_{cm} = \frac{m_{Earth} x_{Earth} + m_{Moon} x_{Moon}}{m_{Earth} + m_{Moon}}$ 

We will use a coordinate system with the center of the Earth as the origin. ( $x_{Earth} = 0$ )

$$x_{cm} = \frac{(7.36 \times 10^{22})(3.82 \times 10^8)}{(5.97 \times 10^{24} + 7.36 \times 10^{22})}$$

 $x_{cm} = 4.64 \times 10^6 \text{ m}$ 

# Weight

• Weight is defined as the force of gravity acting on an object.

weight =  $F_g = mg$ 

# Newton's 3rd Law

- Whenever one body exerts a force on a second body, the first body experiences a force that is equal in magnitude and opposite in direction to the force that it exerts.
  - Forces always come in pairs.







# **Normal Force**

- When an object is sitting on a surface the surface must support the load by exerting an upwards force equal to the weight.
- If the force supporting a load is perpendicular to the surface of contact between the load and its support, this force is defined to be a normal force.









## Fundamental Forces of Nature

- Strong Nuclear Force
  - Holds nucleus of atom together
- Weak Nuclear Force
  - Between subatomic particles
- Gravitational Force
  - Between all objects
- Electromagnetic Force
  - Between charged particles



 Friction exists between two solid surfaces because even the smoothest looking surface is quite rough on a microscopic and atomic scale.



 As we try to slide an object across another surface the atoms of each surface rub against each other impeding the motion and generating heat.

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Kinetic Friction     Static Friction							
$F_f = \mu_k F_n$	$F_f \leq$	$\mu_s F_n$					
<ul> <li>μ is the coefficient of friction.</li> <li>The value of μ depends on the surfaces in contact with each other.</li> </ul>							
System	$\mu_k$	$\mu_s$					
Rubber on dry concrete	0.7	1.0					
Rubber on wet concrete	0.5	0.7					
Steel on ice	0.02	0.04					

## **Drag Force**

 $\left|\vec{F}_{f}\right| \leq \mu \left|\vec{F}_{n}\right|$ 

- The drag force always opposes the motion of an object as it moves through a fluid.
- The drag force is proportional to some function of the velocity of the object in that fluid.
  - This functionality is complicated and depends upon the shape of the object, its size, its velocity, and the fluid it is in.

- When objects fall through the air, gravity pulls down and the air pushes up on the falling object.
- This reduces the net acceleration of the object.
- The drag force due to the air will increase the longer the object falls.



- Eventually, the drag force will equal the force of gravity resulting in a net acceleration of zero.
- The object will continue to fall but will no longer accelerate.



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