Chapter 5 The Laws of Motion

Forces

- Can cause a change in velocity of an object, as it can cause an acceleration
- The **net force** (or resultant force or total force or unbalanced force) is the vector sum of all the forces acting on an object
- Is a Vector, so must use the rules for vector.

Zero Net Force

- When the net force is equal to zero:
  - The acceleration is equal to zero
  - The velocity is constant
- **Equilibrium** occurs when the net force is equal to zero
  - The object, if at rest, will remain at rest
  - If the object is moving, it will continue to move

Inertial Frames

- An inertia frame can be stationary or moving with a constant velocity.
- Any reference frame that moves with *constant velocity* relative to an inertial frame is itself also an inertial frame.

Newton's First Law

- In the absence of net force, when viewed from an inertial reference frame, an object at rest remains at rest and an object in motion continues in motion with a constant velocity
  - **Newton's First Law** describes what happens in the absence of the net external forces (*resultant force is zero*)
  - It tells us that when the **net** force acts on an object is zero, acceleration of the object is zero (*acceleration = 0 does not mean that the object is not moving*)

Inertia and Mass

The tendency of an object to resist any attempt to change its velocity is called **inertia**
Mass is that property of an object that specifies how much resistance an object exhibits to change in its velocity

> Bigger mass -> bigger inertia
> Smaller mass -> smaller inertia

Mass

- Mass is an inherent property
- Independent of the object's surroundings
- Independent of the method used to measure it
- Scalar, SI unit is kg

Mass vs. Weight

- Weight is equal to the magnitude of the gravitational force exerted on the object
- It varies with location.

Newton's Second Law

- When viewed from an inertial frame:
  - $acceleration \propto netforce$
  - $acceleration \propto \frac{1}{mass}$
  - *Force is the cause of the change in motion.* And the **change in motion is measured by the acceleration.**
- $\therefore \sum F = ma$
  - Vector sum of all the forces acting on the object
  - Can be expressed in terms of 3 components:
    - $\sum F_x = ma_x$
    - $\sum F_y = ma_y$
    - $\sum F_z = ma_z$
- SI Unit is Newton (N) which is equal to $kg \cdot m/s^2$

Gravitational Force

- The gravitational force, F_g is the force that the Earth exerts on an object
- Directed towards the center of Earth
- Magnitude is called *weight*
- $Weight = |F_g| = mg$

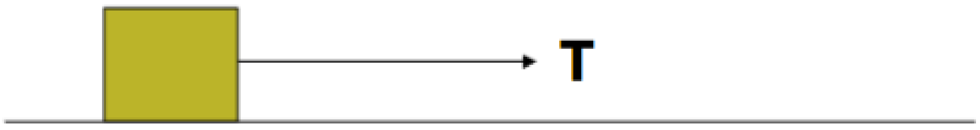
Newton's Third Law

- Force always occurs in pairs (*action-reaction*)
- Thus $F_{12} = -F_{21}$

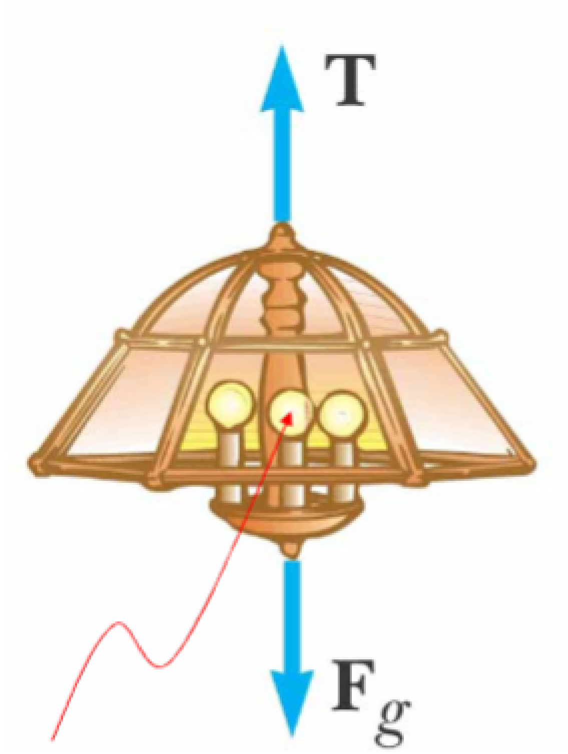
Applications of Newton's Law

Assumptions

- Objects can be modeled as particles
- Masses of strings or ropes are assumed to be negligible
    - When a rope attached to an object, the magnitude of that force T is the tension in the rope.



Equilibrium



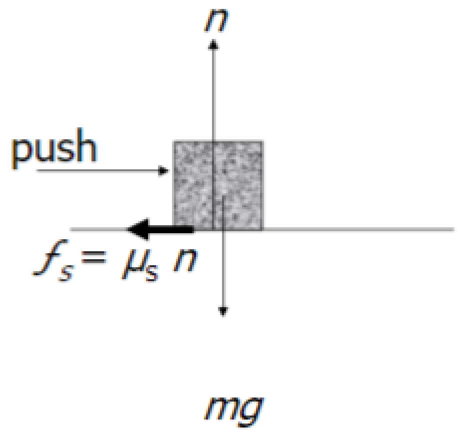
Net force on the lamp is 0. So the lamp does not accelerate
$\sum F_y = 0 \rightarrow T - F_g = 0 \rightarrow T = F_g$

Object Experiencing a Net Force

If an object that can be modeled as a particle experiences an *acceleration*, there must be a *non-zero net force* acting on it.

Forces of Friction

- When an object is in motion on a surface or through a viscous (sticky-ness) medium, there will be a resistance to the motion
- This resistance is called *force of friction*
- $f_s \leq \mu_s n$ and $f_k = \mu_k n$
- The force of static friction is generally greater than the force of kinetic friction
- The coefficient of friction (μ) depends on the surfaces in contact
- μ is an empirical value, can be greater than 1



- The direction of the frictional force is *opposite* to the direction of motion and is *parallel* to the surface in contact
- The coefficients of friction are independent of the area of contact

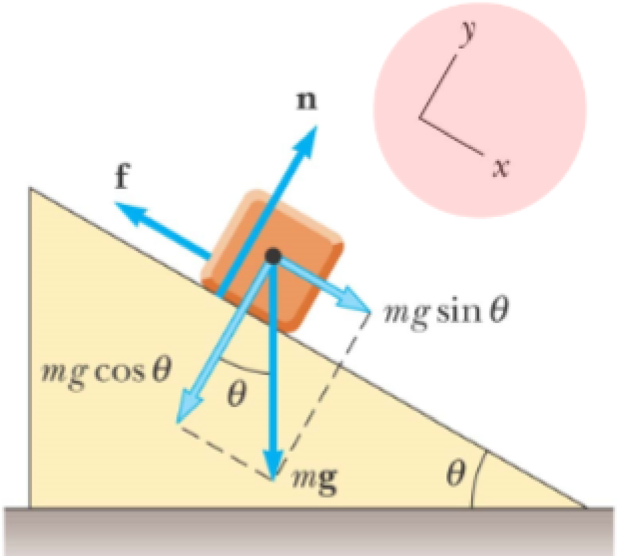
Static Friction

- Static friction acts to keep the object from moving
- $F \propto f_s$

Kinetic Friction

- The force of kinetic friction acts when the object is in motion
- $f_k = \mu_k n$

Sliding Block



- The block is sliding down the plane, so friction acts up the plane
- Can be used to determine the coefficient of friction
- $\mu = \tan\theta$
  - μ_s use the angle where the block just slips
  - μ_k use the angle where the block slides down at a constant speed