Linear Momentum and Collisions

- Conservation of Energy
- Momentum
- Impulse
- Conservation of Momentum
- 1-D Collisions
- 2-D Collisions
- The Center of Mass

Simplest Case

- $\Delta E = \Delta K + \Delta U = 0$ if conservative forces are the only forces that working on the system.

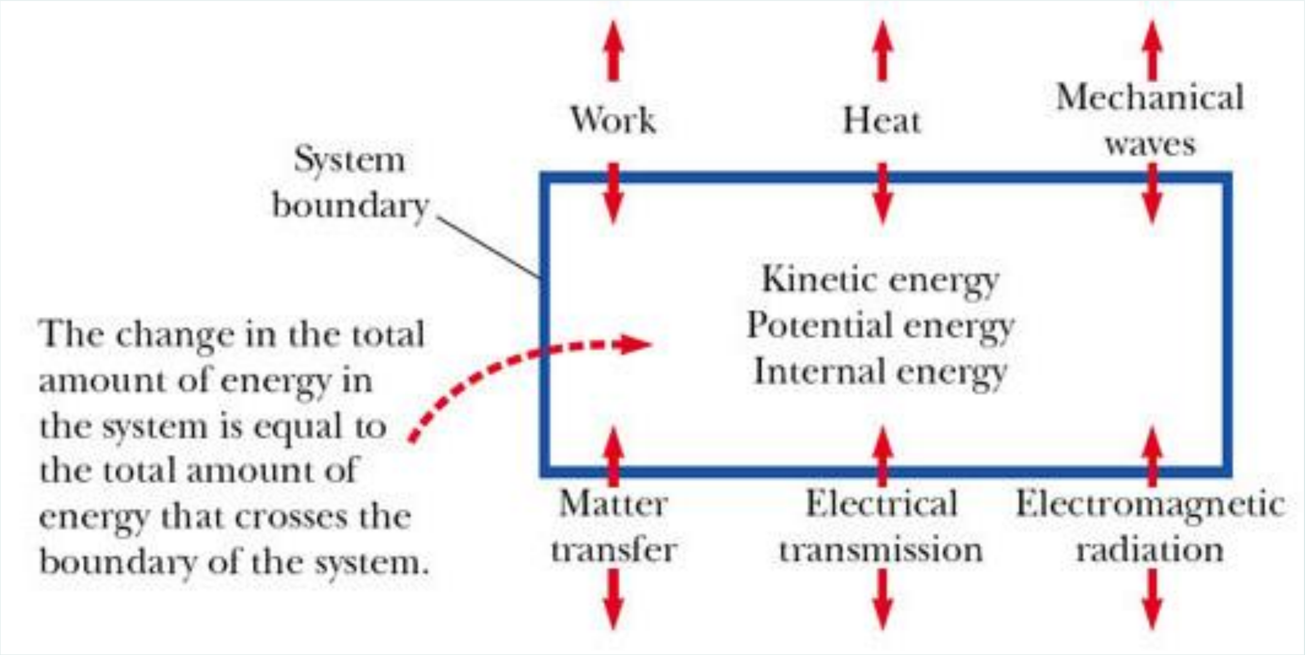
- The total amount of energy in the system is fixed.

$$\frac{1}{2}mv_f^2 + mgy_f + \frac{1}{2}kx_f^2 = \frac{1}{2}mv_i^2 + mgy_i + \frac{1}{2}kx_i^2$$

Types of Forces

- Conservative forces
  - Work and energy associated with the force can be recovered
  - Examples: Gravity, Spring Force, EM forces
- Nonconservative forces
  - The forces are generally dissipative and work done against it cannot easily be recovered
  - Examples: Kinetic friction, air drag forces, normal forces, tension forces, applied forces …

- $\Delta K + \Delta U + \Delta E_{int} = W + Q + T_{MW} + T_{MT} + T_{ET} + T_{ER}$
- The Work-Kinetic Energy theorem is a special case of Conservation of Energy $\Delta K + \Delta U = W$



Linear Momentum

- A new fundamental quantity, like force, energy
- The linear momentum of a rapidly moving mass m object is defined as $\vec{\mathbf{v}}$ the product of p, mass and velocity :
  - $$\vec{p} = m\vec{v}$$
  - Momentum depend on an object's mass and velocity

Linear Momentum, cont

- Linear momentum is a vector quantity $\vec{\mathbf{p}} = m\vec{\mathbf{v}}$
  - Its direction is the same as the direction of the velocity
- The dimensions of momentum are ML/T
- The SI units of momentum are kg · m / s
- Momentum can be expressed in component form:

$$p_x = mv_x \qquad p_y = mv_y \qquad p_z = mv_z$$

Newton's Law and Momentum

- Newton's Second Law can be used to relate a cistern momentum to the resulting force that affects it

$$\vec{F}_{net} = m\vec{a} = m\frac{\Delta\vec{v}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t}$$

- The change in the momentum of the object is divided by the amount of time that equals the constant net force acting on the object

$$\frac{\Delta\vec{p}}{\Delta t} = \frac{\text{change in momentum}}{\text{time interval}} = \vec{F}_{net}$$

Impulse

- When a single constant force is applied to the object, there is an impulse transmitted to the object

$$\vec{I} = \vec{F}\Delta t$$

  - $\vec{\mathbf{I}}$ is defined as the *impulse*
  - Vector quantity, the direction is the same as the direction of the force

$$\frac{\Delta \vec{p}}{\Delta t} = \frac{\text{change in momentum}}{\text{time interval}} = \vec{F}_{net}$$

Impulse-Momentum Theorem

- The theorem states that the impulse that affects a system is equal to the change in the system's momentum

$$\Delta\vec{p} = \vec{F}_{net}\Delta t = \vec{I}$$

$$\vec{I} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$$

Calculating the Change of Momentum

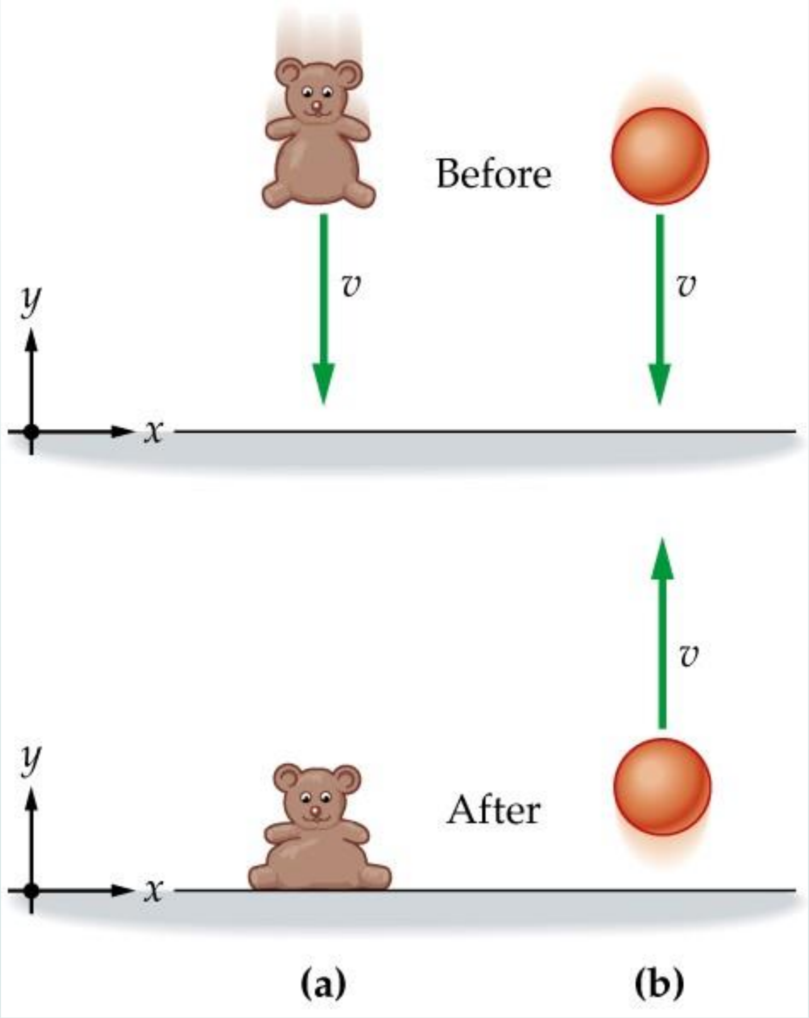
$$\Delta\vec{p} = \vec{p}_{after} - \vec{p}_{before}$$
$$= mv_{after} - mv_{before}$$
$$= m(v_{after} - v_{before})$$

For the teddy bear

$$\Delta p = m[0-(-v)] = mv$$

For the bouncing ball

$$\Delta p = m[v-(-v)] = 2mv$$



Impulse-Momentum Theorem

- The theorem states that the impulse acting on a system is equal to the change in momentum of the system

$$\Delta\vec{p} = \vec{F}_{net}\Delta t = \vec{I}$$

$$\vec{I} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$$