Phys141 – Fri 10/7

- **Today: Chapter 9 Linear Momentum**
- **<u>Administrative:</u>**
- **Pre class quiz again Mon**
- **HW due Fri next week**
- **Midterm should be graded by Mon (reviewed +handed out in recitation)**
- **Reading for Mon: Rest of chapter 9.4-6 (skip 9.7)**
- **Clickers required**

Chapter 9: Linear Momentum

(Linear) momentum of an object of mass *m* moving with a velocity **v:**

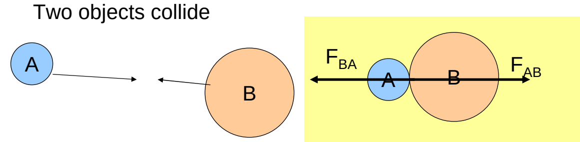
$\mathbf{p} = m\,\mathbf{v}$

The total momentum of n objects: $P = \sum_{i}^{n} m_i v_i$

New concept: Conservation of momentum

Using momentum

Two objects collide



Newton's third law: $F_{AB} = -F_{BA}$

$or: F_{AB} + F_{BA} = 0$

Use Newtons second law: $F_A = m_A \frac{dv_A}{dt}; F_B = m_B \frac{dv_B}{dt}$

$m_A \frac{dv_A}{dt} + m_B \frac{dv_B}{dt} = 0$

Mass is constant-> rewrite $m_A \frac{dv_A}{dt} = \frac{d}{dt}(m_A v_B)$

$\frac{d}{dt}(m_A v_A + m_B v_B) = 0$

Two objects interacting with a force: Total momentum is conserved (for an isolated system, i.e. a system with no other outside forces)!

$$\frac{d}{dt}\mathbf{P} = 0$$

$$\mathbf{P} = const$$

$$P_x = const; P_y = const; P_z = const$$

- **For two particles:**

  $\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}$

  $p_{ix} = p_{fx}$ $p_{iy} = p_{fy}$ $p_{iz} = p_{fz}$

- The momentum of the *system* is conserved, not necessarily the momentum of an individual particle

Conservation of Momentum, examples

Example 1:

- Two sleds running on a frictionless surface (air track)
- Physical Laws to understand motion:
  - Newton's Second Law – but no information about *F* or *a*
  - Energy approach – but no information about work or energy
  - Momentum – yes

Example 2: Perpendicular collision

External forces

Example gravity - blackboard

Newtons Second Law revisited

- More general form of Newton's Second Law using momentum:

$$\Sigma \mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = \frac{d(m\mathbf{v})}{dt} = \frac{d\mathbf{p}}{dt}$$

Per object: The time rate of change of the linear momentum of an object is equal to the net force acting on the object

For system: The time rate of change of the linear momentum of a system is equal to the net force acting on each object in the system, excluding internal forces!

Impulse and Momentum

From Newton's Second Law: $d\mathbf{p} = \mathbf{F}dt$

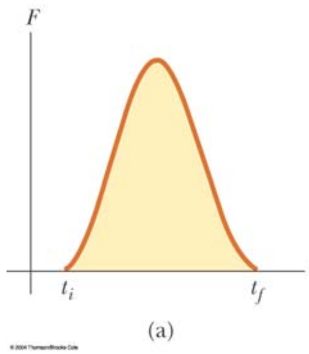
Integrating to find the change in momentum over some time interval

$$\Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = \int_{t_i}^{t_f} \mathbf{F}dt = \mathbf{I}$$

- The integral is called the *impulse, **I**,* of the force **F** acting on an object over Δt

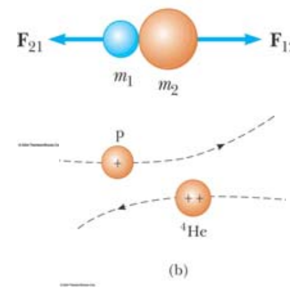
More About Impulse

- Impulse: vector quantity
- Magnitude of impulse: area under force-time curve
- Dimensions of impulse:
  M L / T
- Impulse not particle property, but a measure of the change in momentum of the particle



Collisions – Examples

- Collisions may be the result of direct contact forces, or forces that act over a distance (e.g. electromagnetic)
- The impulsive forces may vary in time in complicated ways
  - This force is internal to the system
- Momentum is conserved



Types of Collisions

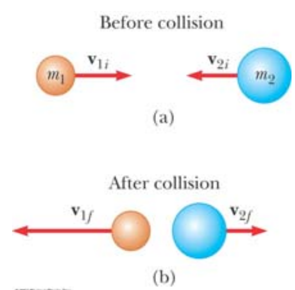
- In an ***elastic*** collision, momentum and kinetic energy are conserved
- In an ***inelastic*** collision, kinetic energy is not conserved, but momentum is still conserved
  - If the objects stick together after the collision, it is a ***perfectly inelastic*** collision

Elastic Collisions

- Both momentum and kinetic energy are conserved

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

$$\frac{1}{2}m_1\mathbf{v}_{1i}^2 + \frac{1}{2}m_2\mathbf{v}_{2i}^2 = \frac{1}{2}m_1\mathbf{v}_{1f}^2 + \frac{1}{2}m_2\mathbf{v}_{2f}^2$$



Elastic Collisions, examples

- Example of some special cases
  - $m_1 = m_2$ – the particles exchange velocities
  - When a very heavy particle collides head-on with a very light one initially at rest, the heavy particle continues in motion unaltered and the light particle rebounds with a speed of about twice the initial speed of the heavy particle
  - When a very light particle collides head-on with a very heavy particle initially at rest, the light particle has its velocity reversed and the heavy particle remains approximately at rest

Perfectly Inelastic Collisions

- Since the objects stick together, they share the same velocity after the collision
- $m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = (m_1 + m_2)\,\mathbf{v}_f$