Physic² 121:
Phundament°ls of Phy²ics I

October 16, 2006

Momentum

Chapter 6

Impulse and Momentum

- The things on the left and right side of the equal sign each have their own name in the world of physics:
  - $F\Delta t$ is called Impulse, I
  - mv is called momentum
  - Momentum usually denoted as p

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

$$\vec{p} = m\vec{v}$$

- So, we can write the last equation from previous slide as:

$$\vec{I} = \Delta\vec{p}$$

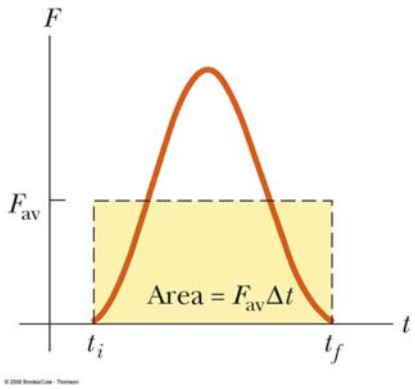
- Note: This is really just N2 written in a different way

Impulse-Momentum Theorem

- The theorem states that the impulse acting on the object is equal to the change in momentum of the object
  - $\vec{\mathbf{F}}\Delta t = \Delta\vec{\mathbf{p}} = m\vec{\mathbf{v}}_f - m\vec{\mathbf{v}}_i$
  - If the force is not constant, use the *average force* applied

Average Force in Impulse

- The average force can be thought of as the constant force that would give the same impulse to the object in the time interval as the actual time-varying force gives in the interval



Average Force cont.

- The impulse imparted by a force during the time interval Δt is equal to the area under the force-time graph from the beginning to the end of the time interval
- Or, the impulse is equal to the average force multiplied by the time interval,

$$\vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

Impulse Applied to Auto Collisions

- The most important factor is the collision time or the time it takes the person to come to a rest
  - This will reduce the chance of dying in a car crash
- Ways to increase the time
  - Seat belts
  - Air bags

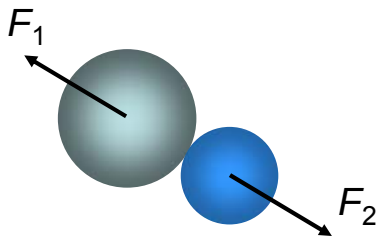
Air Bags

- The air bag increases the time of the collision
- It will also absorb some of the energy from the body
- It will spread out the area of contact
  - decreases the pressure
  - helps prevent penetration wounds

Demonstration

Conservation of Momentum

- Consider the collision of two objects…
- What does N3 tell us about the forces that the two objects exert on each other?
- What about the time during which the forces are exerted?



Conservation of Momentum

- If forces are equal and opposite (N3) and time of contact is same for both objects, then Impulses must also be equal and opposite:
- This means that change in momenta are equal and opposite:
- The **total** momentum doesn't change!
  - It is conserved

$$\vec{I}_1 = \vec{F}_1 \Delta t$$
$$\vec{I}_2 = \vec{F}_2 \Delta t$$
$$\vec{F}_1 = -\vec{F}_2$$
$$\vec{I}_1 = -\vec{I}_2$$

$$\Delta\vec{p}_1 = -\Delta\vec{p}_2$$
$$\vec{p}_{1f} - \vec{p}_{1i} = -\left(\vec{p}_{2f} - \vec{p}_{2i}\right)$$
$$\vec{p}_{1f} + \vec{p}_{2f} = \vec{p}_{1i} + \vec{p}_{2i}$$
$$\left(\vec{p}_{Total}\right)_f = \left(\vec{p}_{Total}\right)_i$$

Comments

- Momentum is ALWAYS conserved in collisions
  - But you must look at TOTAL momentum
    - Sum (vector) of the momenta of all things involved
- Note that we don't need to know anything about the details of the force or the time of contact
  - We just need to be able to measure the masses and velocities of the objects before and after the collision
- Valid in 3 dimensions (must deal with vectors)
- Valid for more than just 2 objects colliding
- Valid not just before and after, but during the entire collision

Conservation of Momentum

- Momentum in an isolated system in which a collision occurs is conserved
  - A collision may be the result of physical contact between two objects
  - "Contact" may also arise from the electrostatic interactions of the electrons in the surface atoms of the bodies
  - An isolated system will have not external forces

Conservation of Momentum, cont

- The principle of conservation of momentum states when no external forces act on a system consisting of two objects that collide with each other, the total momentum of the system remains constant in time
  - Specifically, the total momentum before the collision will equal the total momentum after the collision

Conservation of Momentum, cont.

- Mathematically:

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

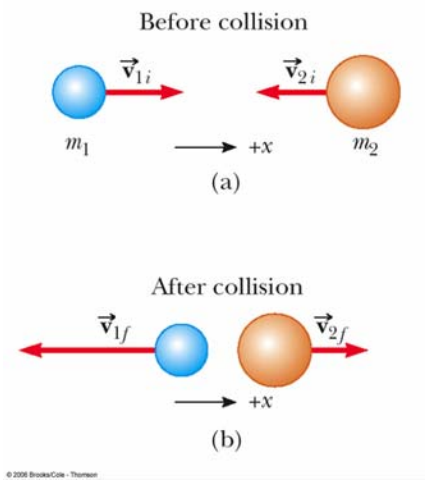
  - Momentum is conserved for the *system* of objects
  - The system includes all the objects interacting with each other
  - Assumes only internal forces are acting during the collision
  - Can be generalized to any number of objects

Notes About A System

- Remember conservation of momentum applies to the *system*
- You must define the isolated system

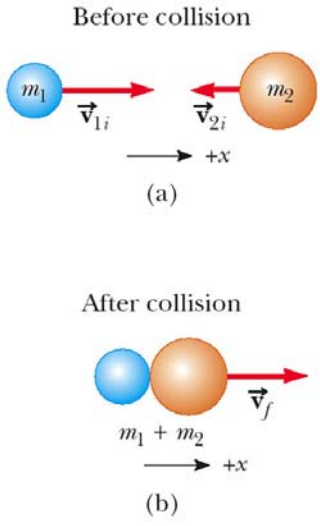
Sketches for Collision Problems

- Draw “before” and “after” sketches
- Label each object
  - include the direction of velocity
  - keep track of subscripts



Sketches for Perfectly Inelastic Collisions

- The objects stick together
- Include all the velocity directions
- The "after" collision combines the masses



Demonstration

Glancing Collisions

- For a general collision of two objects in three-dimensional space, the conservation of momentum principle implies that the *total momentum of the system in each direction is conserved*
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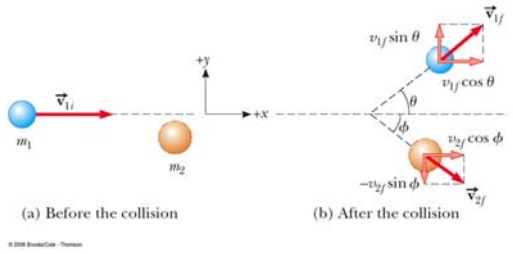
  - Use subscripts for identifying the object, initial and final velocities, and components

$$m_1 v_{1ix} + m_2 v_{2ix} = m_1 v_{1fx} + m_2 v_{2fx} \text{ and}$$
$$m_1 v_{1iy} + m_2 v_{2iy} = m_1 v_{1fy} + m_2 v_{2fy}$$

Glancing Collisions



(a) Before the collision (b) After the collision

- The “after” velocities have x and y components
- Momentum is conserved in the x direction and in the y direction
- Apply conservation of momentum separately to each direction