Center of Mass

- Center of mass is “average” position of a group of masses, or an extended object

$$x_{cm} = \frac{1}{M}\sum m_i x_i \qquad y_{cm} = \frac{1}{M}\sum m_i y_i \qquad z_{cm} = \frac{1}{M}\sum m_i z_i$$

- Continuous objects made out of too many atoms/molecules to count, approximate by integral instead

$$x_{cm} = \frac{1}{M}\int x\, dm$$

dm: Amount of mass in infinitesimal slice of object

Momentum

- Momentum represents inertia of object $\vec{p} = m\vec{v}$
- Net force on object is time derivative of momentum
  - Change in momentum is integral of force over time
    - Also called impulse especially if force is only applied over a short period $\vec{J} = \Delta\vec{p} = \int_{t_i}^{t_f} \vec{F}\, dt$

Conservation of Momentum

- If a system of object(s) isolated, and no net force, no change in *total* momentum
  - Individual objects can still change momentum if they're exerting forces on each other
  - Sometimes easier to say total momentum before is same as total after
    - Ex: two objects in system $m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = m_1 \vec{v}_{1f} + m_2 \vec{v}_{2f}$

Conservation of Momentum

- Like conservation of energy, convenient if you don’t care what happened in between two points, just need before and after
- Conservation of momentum often more useful than conservation of energy, since energy can go to unexpected places, like heating/deforming objects
- Unlike conservation of energy, relates vector quantities (velocity), sometimes need more than one equation for more than one component