- Last Lecture
  - 2D collisions
- Today
  - Power, Impulse, Center of Mass
  - Experiment #5
- Important Concepts
  - Momentum changes due to external forces acting over a period of time (called impulse).
  - Power is change in energy over time.
  - Center of mass and momentum are closely related.

Important Reminders

- Pset # 8 due this Friday.
- Problem Solving session in class this Friday.
- MasteringPhysics due next Monday.
  - My apologies for the confusion inadvertently caused by posting the next MasteringPhysics assignment early.
- NOTE: Class grading guidelines clearly allow discussion of MasterPhysics problems but also clearly prohibit directly working together or copying the answers of other students.

Power

- Power is change in energy per unit time:

$$Power = \frac{dE}{dt}$$

- A concept that has enormous technological impact but very little utility in solving problems.
- One interesting result: Power delivered by a given force increases with velocity in the force direction

$$Power = \vec{F} \bullet \vec{v}$$

Impulse

- Just the change in momentum: $\Delta \vec{p}_{Tot} = \int \vec{F} dt$
  - Note the vectors!
- The change in momentum can be used to find information about the force if the time is known.
- If force and time are known, the change in momentum can be calculated.

Center of Mass

- Definition: $\vec{R}_{C.M.} = {}^{1}\!/_{M_{TOT}} \sum m_i \vec{r}_i$
- As with all vectors, components are the only way to do a quantitative calculation: $x_{C.M.} = {}^{1}\!/_{M_{TOT}} \sum m_i x_i$
- The positions, velocities, and accelerations, as well as $\vec{F} = M\vec{a}$ and other equations we have been studying up to now apply exactly to the center of mass of an extended object.

Center of Mass Velocity

- Definition: $\vec{v}_{C.M.} = \frac{d}{dt}\vec{R}_{C.M.} = {}^{1}\!/_{M_{TOT}} \sum m_i \frac{d}{dt}\vec{r}_i$
  $= {}^{1}\!/_{M_{TOT}} \sum m_i \vec{v}_i = {}^{1}\!/_{M_{TOT}} \sum \vec{p}_i$
- Connection to momentum: $M_{TOT}\vec{v}_{C.M.} = \sum \vec{p}_i = \vec{P}_{TOT}$
- So, if momentum is conserved, the velocity of the center of mass is constant.