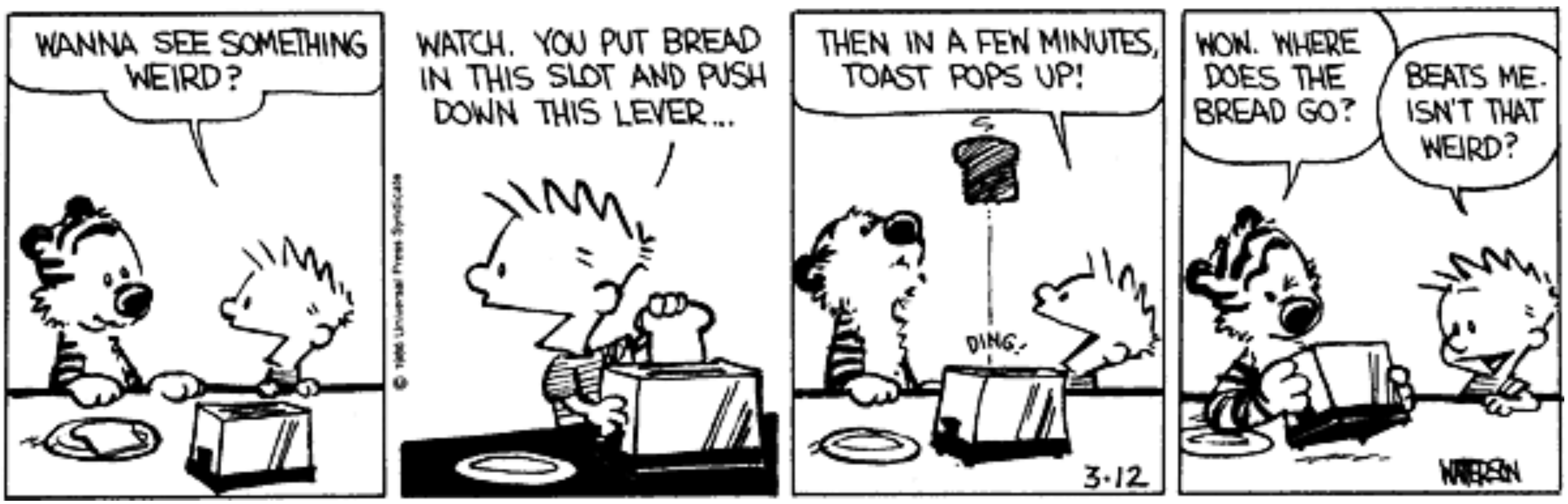
October 18, 2010 Physics 121 Prof. E. F. Redish

- **Theme Music:** **Toby Mac**

  Momentum

- **Cartoon:** **Bill Watterson**

  Calvin & Hobbes



The Impulse-Momentum Theorem

- Newton 2 $\vec{a} = \vec{F}^{net} / m$
- Put in definition of *a* $\dfrac{\Delta \vec{v}}{\Delta t} = \dfrac{\vec{F}^{net}}{m}$
- Multiply up by Δt $m\Delta \vec{v} = \vec{F}^{net} \Delta t$
- Define Impulse $\vec{I}^{net} = \vec{F}^{net} \Delta t$
- Combine to get Impulse-Momentum Theorem $\Delta \vec{p} = \vec{I}^{net}$

Momentum Conservation: 1

- Consider a system of two objects, A and B, interacting with each other and with other ("external") objects. By the IMT

$$m_A \Delta\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\Delta t$$

$$m_B \Delta\vec{v}_B = (\vec{F}_B^{ext} + \vec{F}_{A\to B})\Delta t$$

- Adding:

$$m_A \Delta\vec{v}_A + m_B \Delta\vec{v}_B = \left[\vec{F}_A^{ext} + \vec{F}_B^{ext} + \left(\vec{F}_{A\to B} + \vec{F}_{B\to A}\right)\right]\Delta t$$

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = \vec{F}^{ext}\Delta t$$

Momentum Conservation: 2

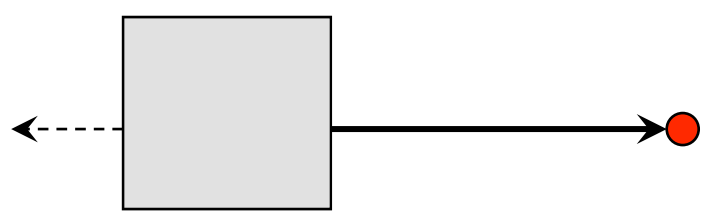
- So: If two objects interact with each other in such a way that the external forces on the pair cancel, then momentum is conserved.

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = 0$$

$$m_A\vec{v}_A^{\,i} + m_B\vec{v}_B^{\,i} = m_A\vec{v}_A^{\,f} + m_B\vec{v}_B^{\,f}$$

Example: Recoil

- When an object at rest emits a part of itself, in order to conserve momentum, it must go back in the opposite direction.
- What forces are responsible for this motion?



(object goes backwards)

Do it!