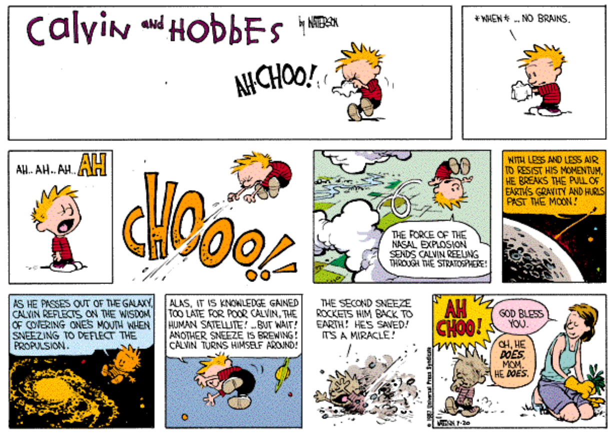
October 21, 2016 Physics 131 Prof. E. F. Redish

- **Theme Music: Kenny Rogers**
  Every time two fools collide
- **Cartoon: Bill Waterson**
  Calvin & Hobbes



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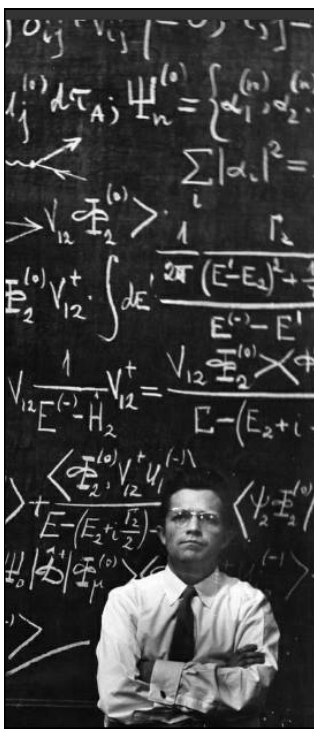

The Equation of the Day

Momentum Conservation

$$\vec{p}_A^{\,i} + \vec{p}_B^{\,i} = \vec{p}_A^{\,f} + \vec{p}_B^{\,f}$$

$$\Delta\vec{p}_A = -\Delta\vec{p}_B$$

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Foothold ideas: Momentum

- We define the momentum of an object, A:

$$\vec{p}_A = m_A \vec{v}_A$$

- This is a way of defining "the amount of motion" an object has.
- Our "delta" form of N2 becomes

$$\vec{F}_A^{net} = m_A \frac{\Delta \vec{v}_A}{\Delta t} = m_A \vec{a}_A$$

which we can rewrite as

$$\vec{F}_A^{net} = \frac{\Delta(m_A \vec{v}_A)}{\Delta t} = \frac{\Delta \vec{p}_A}{\Delta t}$$

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Foothold idea: The Impulse-Momentum Theorem

- Newton 2 $\vec{a}_A = \vec{F}_A^{net} / m_A$
- Put in definition of *a* $\frac{d\vec{v}_A}{dt} = \frac{\vec{F}_A^{net}}{m_A}$
- Multiply up by Δt $m_A \Delta \vec{v}_A = \vec{F}_A^{net} \Delta t$
- Define Impulse $\vec{\mathscr{J}}_A^{net} = \vec{F}_A^{net} \Delta t$
- Combine to get Impulse-Momentum Theorem for any object A

$$\Delta \vec{p}_A = \vec{\mathscr{J}}_A^{net}$$

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Foothold idea: Momentum Conservation: 1

- If two objects, A and B, interact with each other and with other ("external") objects, By the IMθ

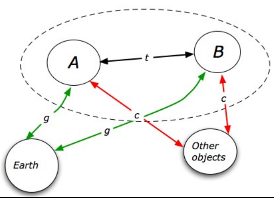
$$m_A\,\Delta\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\Delta t$$

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

- Adding:

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

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



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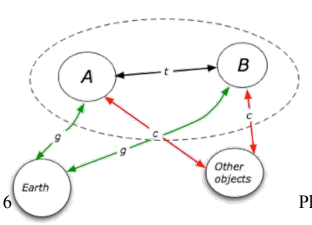
Foothold idea: Momentum Conservation: 2

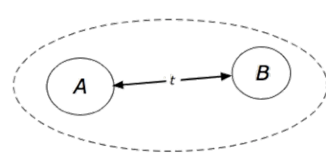
- So: If two objects interact with each other in such a way that the <u>external</u> forces on the pair cancel, then their momentum is conserved.

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

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



$\Rightarrow$



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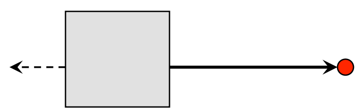
Example: Recoil

- 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)

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