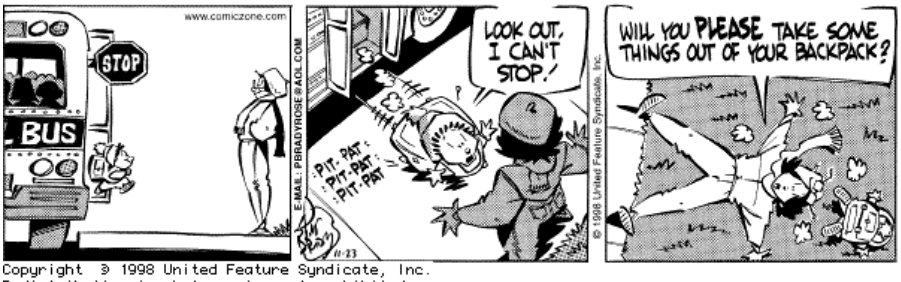
October 19, 2011 Physics 131 Prof. E. F. Redish

## ■Theme Music: Aimee Mann

***Momentum***

## ■Cartoon: Pat Brady

***Rose is Rose***

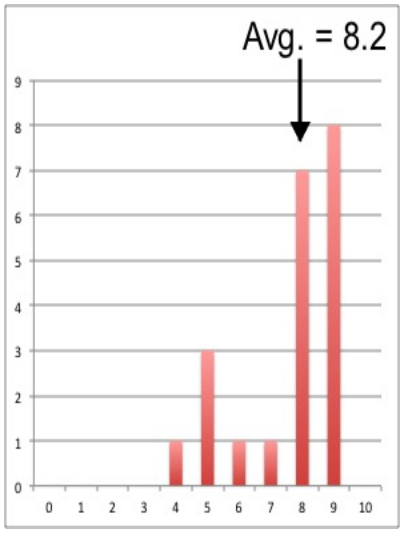







# Quiz 5

| | 5.1 | 5.2 | 5.3 | 5.4 |
|---|---|---|---|---|
| a | 10% | 0% | 5% | **57%** |
| b | **48%** | 5% | 19% | **90%** |
| c | 0% | 0% | 0% | **24%** |
| d | 0% | 0% | **81%** | 5% |
| e | **67%** | 5% | 0% | 0% |
| f | **5%** | **90%** | 0% | 0% |
| n | 0% | 0% | 0% | 5% |



# Momentum: Definition

- We define momentum:

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

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

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

which we can rewrite as

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



# The Impulse-Momentum Theorem

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

# 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:

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

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



# 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.

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

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