October 21, 2010 Physics 121 Prof. E. F. Redish

- **Theme Music: Cannonball Adderly**

  The Work Song

- **Cartoon: Pat Brady**

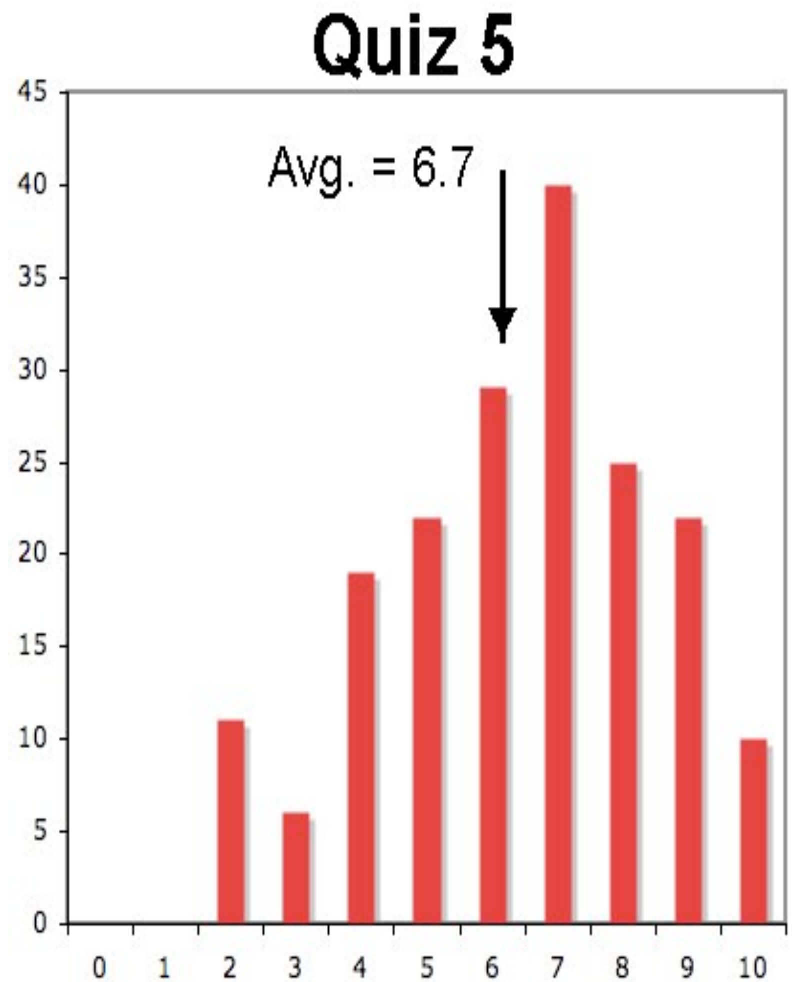
  Rose is Rose

Outline

- Go over Quiz 5
- Energy
- The Work-Energy Theorem
- Example: Gravity

Quiz 5

	a	b	c	d	e	f
5.1	38%	39%	90%	68%	1%	0%
5.2	52%	7%	4%	95%	10%	16%
5.3	26%	66%	1%	6%	0%	0%
5.4	23%	60%	7%	10%	0%	0%



Energy

- N2 tells us that a force can change an object's velocity in one of two ways:
  - It can change the speed
  - It can change the direction
- Analyzing changes in speed leads us to study energy.
- Analyzing changes in direction leads us to study rotations.

Kinetic Energy and Work

- Consider an object moving along a line feeling a single force, *F*. When is moves a distance Δx, how much does its speed change?

$$a = F^{net} / m$$

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

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

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

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

$$\langle v \rangle \Delta v = \frac{F^{net} \Delta x}{m}$$

$$\frac{v_i + v_f}{2}(v_f - v_i) = \frac{F^{net} \Delta x}{m}$$

$$\tfrac{1}{2}(v_f^2 - v_i^2) = \frac{F^{net} \Delta x}{m}$$

$$\tfrac{1}{2} m(v_f^2 - v_i^2) = F^{net} \Delta x$$

Definitions:

Kinetic energy = $\tfrac{1}{2} mv^2$

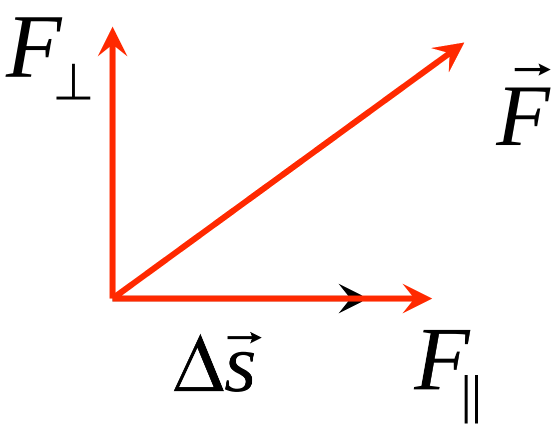
Work done by a force F = $F \; \Delta x$

Result

$$\Delta(\tfrac{1}{2} mv^2) = F^{net} \; \Delta x$$

Work in another direction: The dot product

- Suppose we are moving along a line, but the force we are interested in in pointed in another direction? (How can this happen?)
- Only the part of the force in the direction of the motion counts to change the speed (energy).



$$\text{Work} = F_\parallel \, \Delta s = F\cos\theta \, \Delta s \equiv \vec{F}\cdot\Delta\vec{s}$$

Calculating dot products

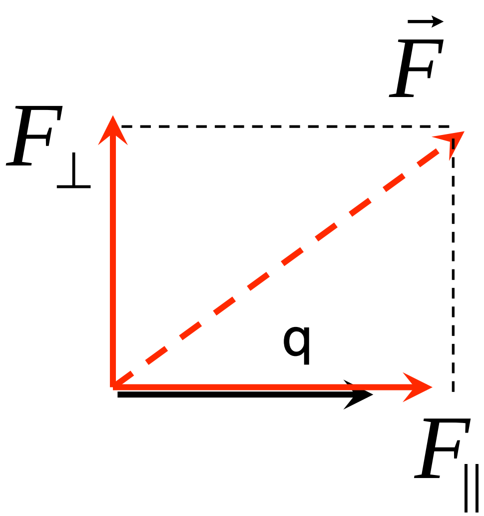
$$F_{\parallel}\,\Delta s \equiv \vec{F}\cdot\Delta\vec{s}$$

$$\vec{F}\cdot\Delta\vec{s} = F\cos\theta\,\Delta s$$

In general, for any two vectors that have an angle q between them, the dot product is defined to be

$$\vec{a}\cdot\vec{b} = ab\cos\theta$$

$$\vec{a}\cdot\vec{b} = a_x b_x + a_y b_y$$



The dot product is a scalar.
Its value does not depend on the coordinate system we select.

Example: Gravity

- Whenever we have a force
  we can see what work it does.
- Consider our work-energy result
  for a special case: **free-fall**
  (only force is gravity).

$$\Delta(\tfrac{1}{2}mv^2) = \vec{F}^{net} \cdot \Delta\vec{s}$$

$$= m\vec{g} \cdot \Delta\vec{s}$$

$$= -mg\ \Delta h$$

Potential Energy: Gravity

- Since the work term also looks like a change, we can bring it to the left and get a *conservation law*.

$$\Delta(\tfrac{1}{2} mv^2 + mgh) = 0$$

$$U_g = mgh$$

- We interpret the quantity *mgh* as a new kind of energy — *gravitational potential energy*.

Conservation Laws

- A conservation law is a statement that, under certain conditions, something that can be measured or calculated doesn't change, even though the numbers that go into calculating it might.
- Such laws are extremely valuable in figuring out motions.

An Energy Conservation Theorem

- Suppose the only force that has a component along the direction of motion is gravity.
  - The only force that changes the object's speed is gravity.
  - Other forces (normal forces) can change direction.
  - Friction must be negligible.
- Examples:
  - free fall
  - object rolling on a track.

$$\Delta(\tfrac{1}{2}mv^2 + mgh) = 0$$

$$\tfrac{1}{2}mv_i^2 + mgh_i = \tfrac{1}{2}mv_f^2 + mgh_f$$