

January 28-30, 2013

Physics 132

Prof. E. F. Redish

# ■ Theme Music: Earth, Wind, & Fire

## *Energy*

### Cartoon: Bob Thaves

## *Frank & Ernest*



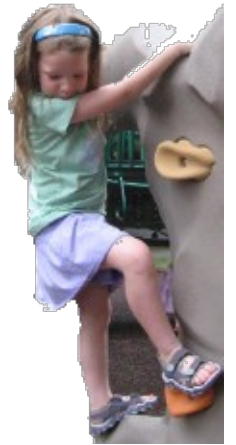
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# Foothold ideas: Kinetic Energy and Work



- Newton's laws tell us how velocity changes. The Work-Energy theorem tells us how speed (independent of direction) changes.
- Kinetic energy =  $\frac{1}{2}mv^2$
- Work done by a force =  $F_x\Delta x$  or  $F_{\parallel}\Delta r$  (part of force  $\parallel$  to displacement)
- Work-energy theorem:  $\Delta(\frac{1}{2}mv^2) = F_{\parallel}^{net} \Delta r$  (small step)  
 $\Delta(\frac{1}{2}mv^2) = \int_i^f F_{\parallel}^{net} dr$  (any size step)

# Foothold ideas: Potential Energy



- The work done by some forces only depends on the change in position. Then it can be written

$$\vec{F} \cdot \Delta\vec{r} = -\Delta U$$

$U$  is called a *potential energy*.

- For gravity,  $U_{gravity} = mgh$

For a spring,  $U_{spring} = \frac{1}{2} kx^2$

For electric force,  $U_{electric} = k_C Q_1 Q_2 / r_{12}$

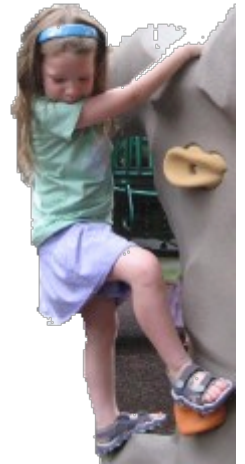
- Potential to force: 
$$\vec{F} = -\frac{\Delta U}{\Delta\vec{r}} = -\left( \frac{\partial U}{\partial x} \hat{i} + \frac{\partial U}{\partial y} \hat{j} + \frac{\partial U}{\partial z} \hat{k} \right) = -\vec{\nabla} U$$

*The force associated with a PE at a given place points “downhill” – in the direction where the PE falls the fastest.*

# Reading questions

- I guess I don't understand why we say energy is thermal is we are looking at macroscopic objects, but we differentiate for microscopic objects with respect to each individual energy type. Doesn't it matter in macro too?
- I am confused about the definitions of chemical and thermal energies. If they are both types of combos of kinetic and potential energy, why are they considered micro rather than macro?

# Foothold ideas: Kinds of Energy and the 1<sup>st</sup> Law



- It's all KE and PE of something!  
But we suppress it into “black boxes”  
if we don't want to talk about some  
degrees of freedom.
  - Thermal
  - Chemical
- First law of thermodynamics
  - Conservation of total energy but ...
  - What matters is how it divides and moves  
from one form to another and  
from one system to another.

# Connection between $\Delta U_{\text{int}}$ and $\Delta E$

Coherent energy  
Kinetic and potential

Internal energy: motion  
of stuff we don't want  
to talk about

$$E = KE + PE + U_{\text{int}}$$

$$\Delta E = \Delta(KE) + \Delta(PE) + \Delta U_{\text{int}}$$

Energy of System  
(not moving coherently)

Thermal energy  
Entering system

Work done  
on system

$$\Delta U_{\text{int}} = Q + W$$