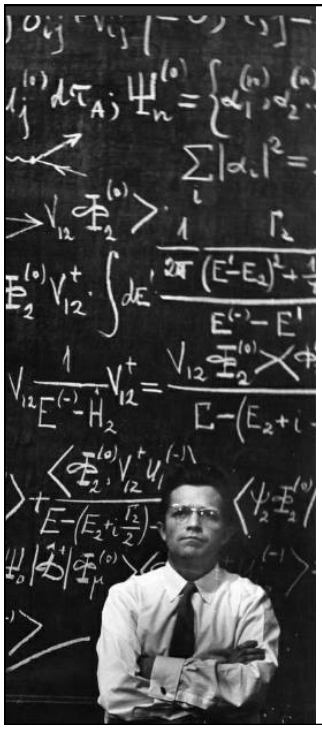
November 21, 2016 Physics 131 Prof. E. F. Redish

- **Theme Music:** Cannonball Adderly
  Work Song
- **Cartoon:** Mike Peters
  Mother Goose & Grimm

11/23/15 Physics 131 **1**



The Equation of the Day

Mechanical energy conservation

$$\Delta\left(\tfrac{1}{2}mv^2 + U\right) = 0$$

8

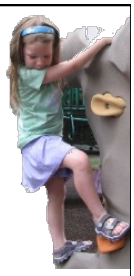
Physics 131

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 $F_{||} \Delta r$ (part of force || to displacement)
- Work-energy theorem: $\Delta(\frac{1}{2}mv^2) = \vec{F}^{net} \cdot \Delta\vec{r}$

11/23/15 Physics 131 **9**

Foothold ideas: Potential Energy



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

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

U is called a *potential energy*.

- Gravity, $U_{gravity} = mgh$ — Flat-earth gravity approximation
- Spring, $U_{spring} = ½\, k(\Delta L)^2$ — Hooke's law approximate model
- Electric Force, $U_{electric} = k_C Q_1 Q_2 / r_{12}$ — Exact for point charges

11/18/16 Physics 131 **10**

Foothold ideas: Conservation of Mechanical Energy

- Mechanical energy
  - The mechanical energy of a system of objects is conserved if resistive forces can be ignored.

$$\Delta(KE + PE) = 0$$

$$KE_{initial} + PE_{initial} = KE_{final} + PE_{final}$$

The PE is the negative of the work in the W-E Theorem!

This is why we define the PE with a negative sign.

- Thermal energy
  - Resistive forces transform coherent energy of motion (energy associated with a net momentum) into *thermal energy* (energy associated with internal chaotic motions and no net momentum)

13

Using Mechanical Energy Conservation

- If resistive forces and deformations can be ignored, mechanical energy is conserved (exchanges with hidden internal energy such as thermal or chemical can be ignored)

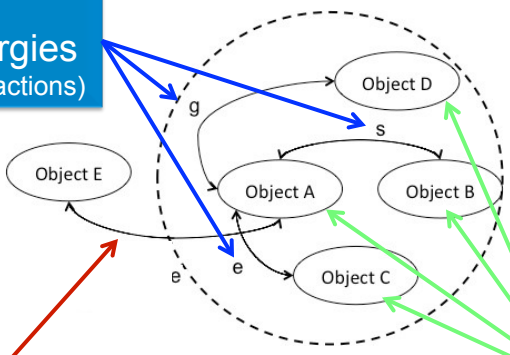
$$KE_i + PE_i = KE_f + PE_f$$

- *KE* may refer to one or more objects
  PE may refer to one or more interactions.
- If only one object's KE is important and only one interaction matters, this can make things really easy.

11/23/15 Physics 131 **14**

Which energies contribute to the total mechanical energy of the system we are considering?

YES
Potential Energies
(Conservative Interactions)



NO
Work done by Interactions that cross System Boundary

YES
Kinetic Energy
(in general, all objects)

Foothold ideas: Energies between charge clusters

- Atoms and molecules are made up of charges.
- The potential energy between two charges is

$$U_{12}^{elec} = \frac{k_C Q_1 Q_2}{r_{12}}$$

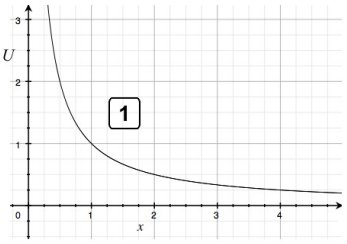
No vectors!

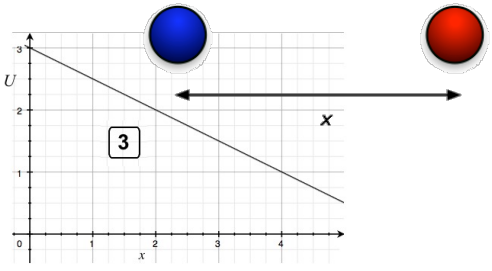
- The potential energy between many charges is

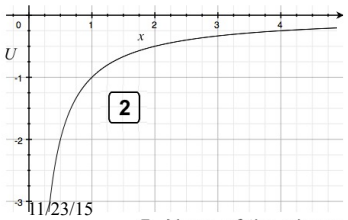
$$U_{12\ldots N}^{elec} = \sum_{i<j=1}^{N} \frac{k_C Q_i Q_j}{r_{ij}}$$

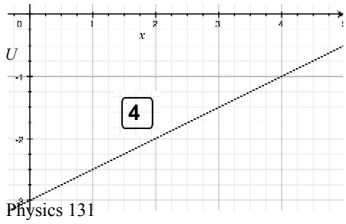
Just add up all pairs!

What does the electric potential energy between two opposite charges look like?









5. None of the above