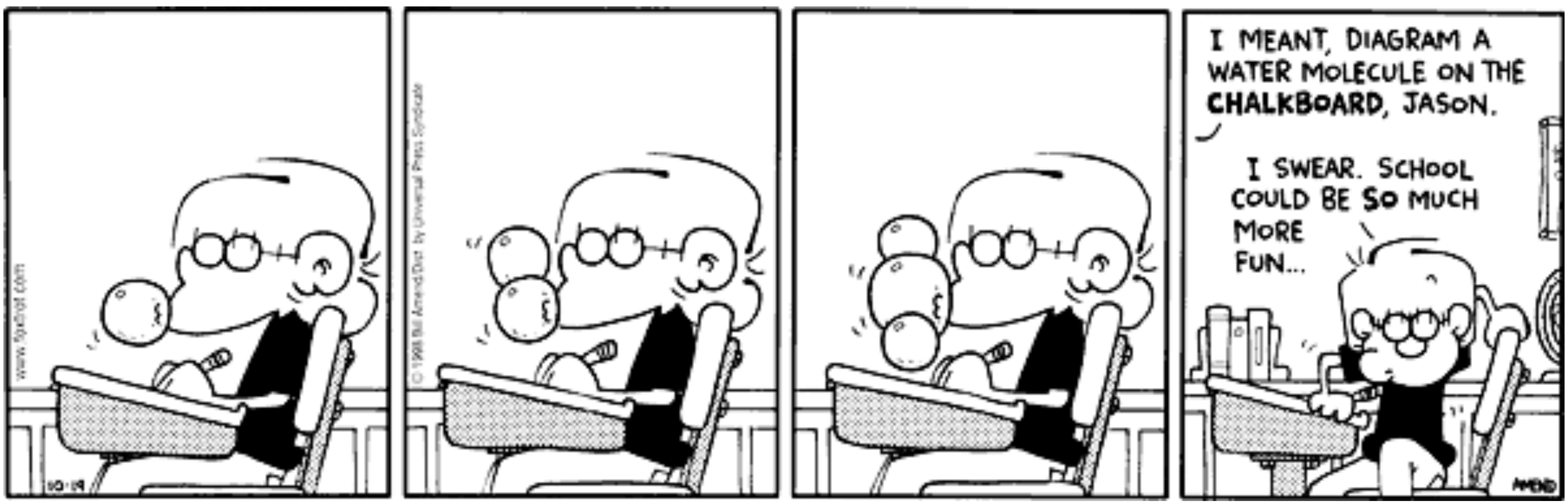
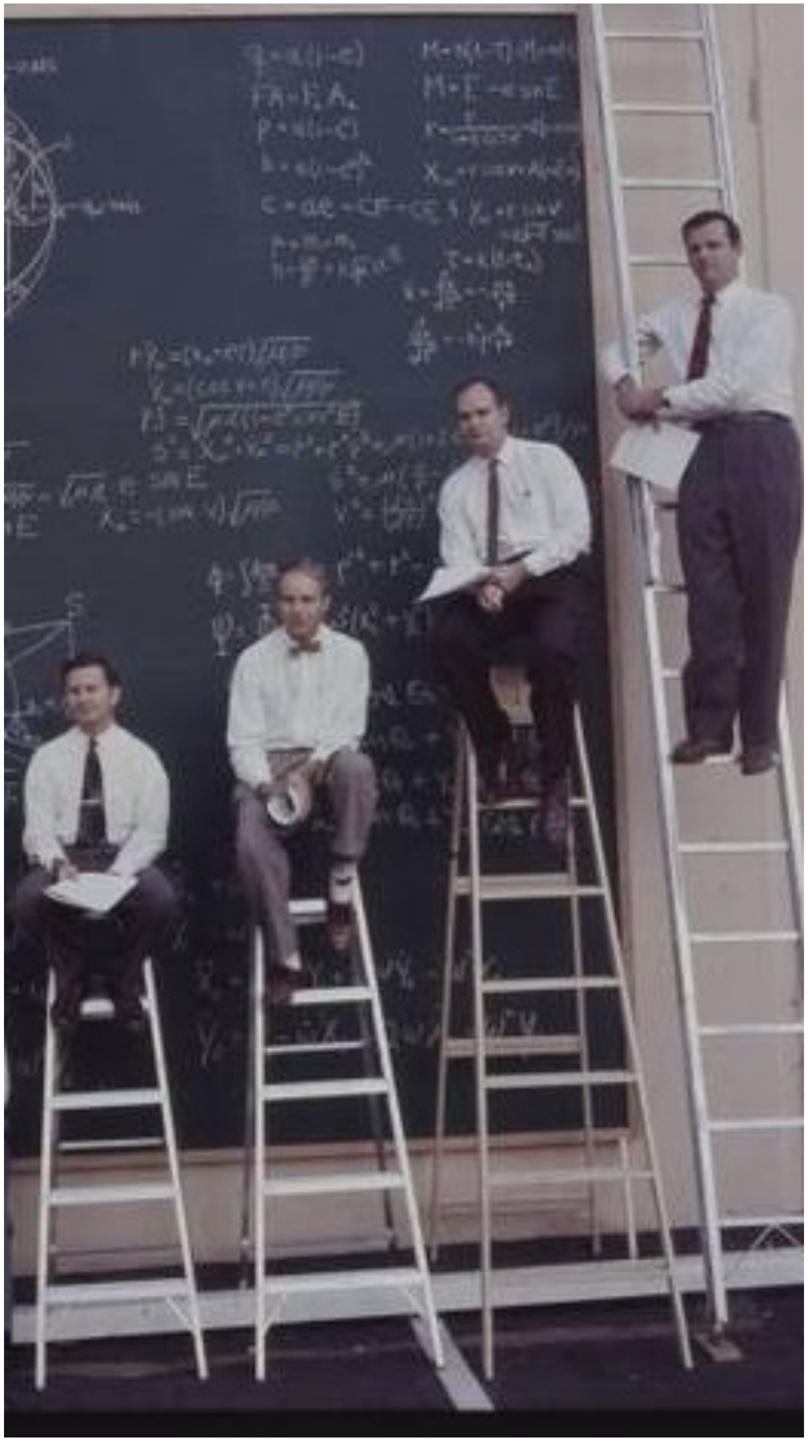
January 29, 2016 Physics 132 Prof. E. F. Redish

- **<u>Theme Music:</u> Blondie**
  Atomic
- **<u>Cartoon:</u> Bill Amend**
  FoxTrot





The Equation of the Day

Potential energy and force

$$F = -\frac{dU}{dx}$$

Work energy theorem

$$\Delta\left(\tfrac{1}{2}mv^2\right) = \int \vec{F}\cdot d\vec{r}$$

Foothold ideas: Conservation of Mechanical Energy

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

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

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

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)

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

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

Just add up all pairs!

Foothold ideas: Forces from PE

- For conservative forces, PE can be defined by

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

- If you know U, the force can be gotten from it via

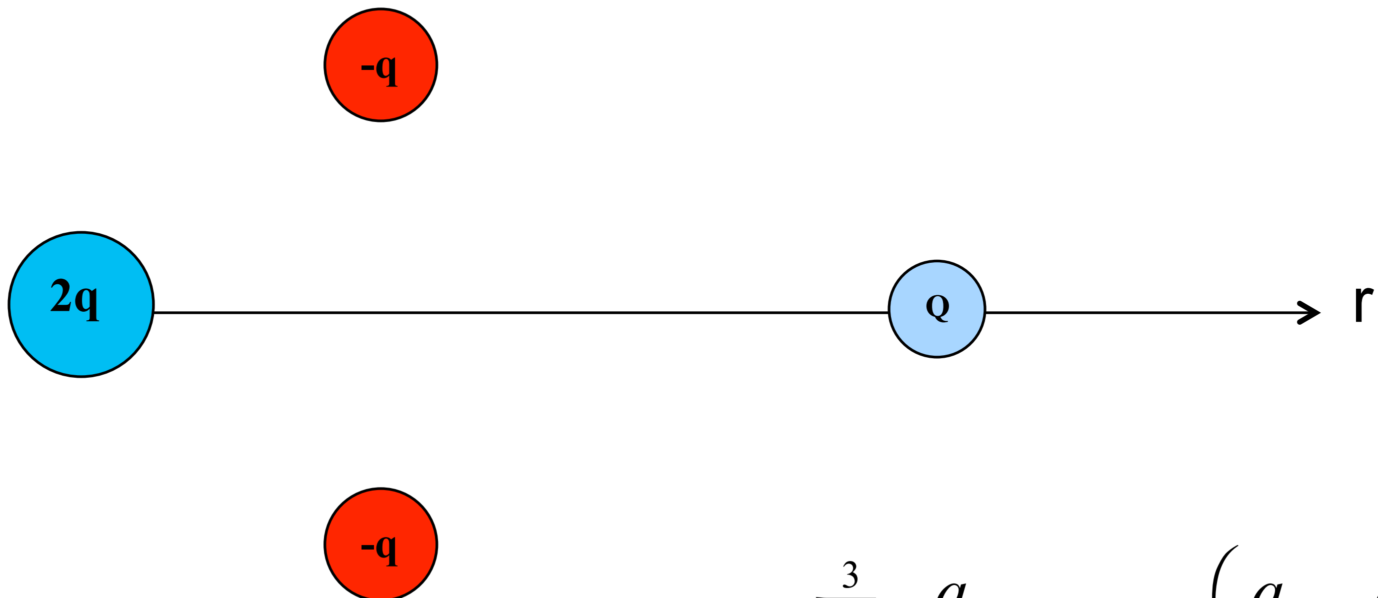
$$F_{\parallel}^{type} = -\frac{\Delta U_{type}}{\Delta r} = -\frac{dU_{type}}{dr}$$

- In more than 1D need to use the *gradient*

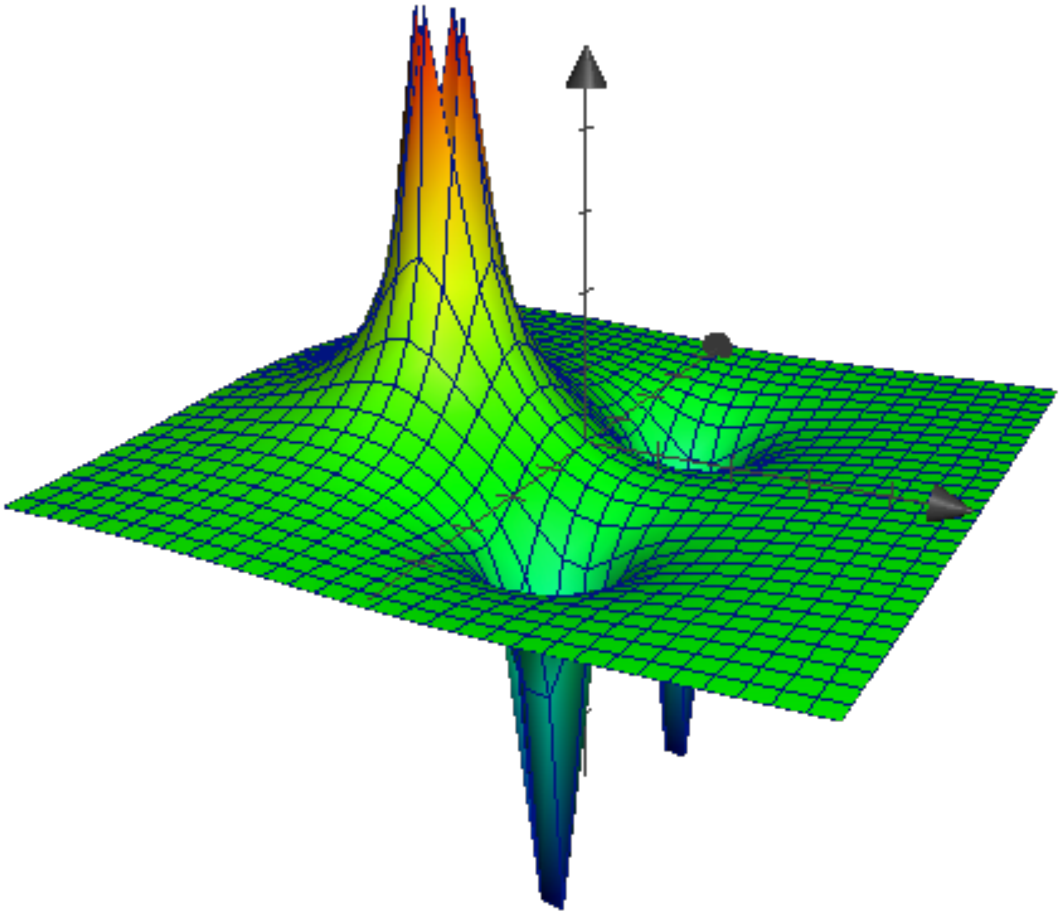
$$\vec{F}^{type} = -\left(\frac{\partial U_{type}}{\partial x}\hat{i} + \frac{\partial U_{type}}{\partial y}\hat{j} + \frac{\partial U_{type}}{\partial z}\hat{k} \right) = -\vec{\nabla} U_{type}$$

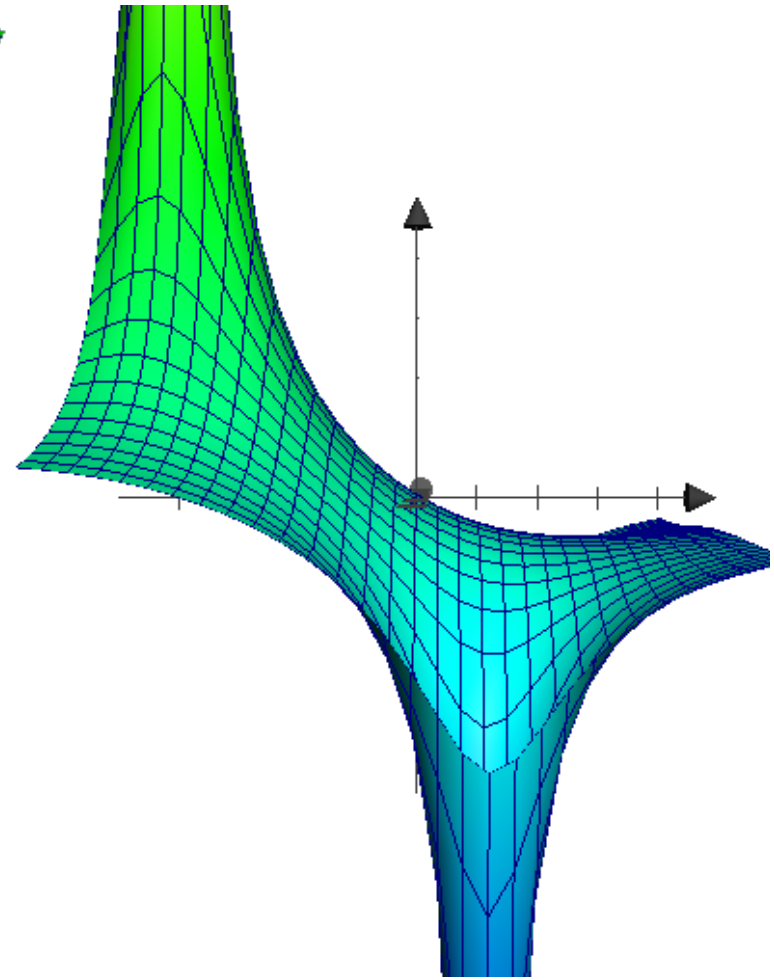
- The force always points <u>down</u> the PE hill.

The extra potential energy from adding Q as a function of position r of charge Q



$$\Delta U = k_C Q \sum_{i=1}^{3} \frac{q_i}{r_{Q \to q_i}} = k_C Q \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} \right)$$





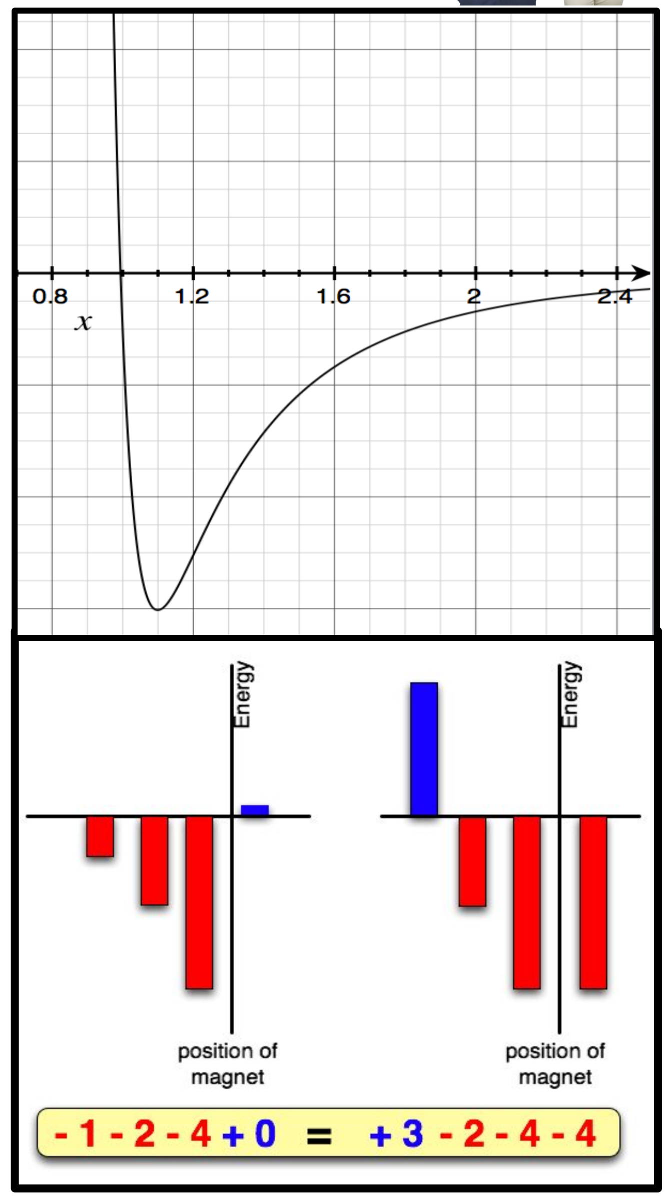
Foothold ideas: Bound states

- When two objects attract, they may form a *bound state* – that is, they may stick together.
- If you have to do positive work to pull them apart in order to get to a separated state with KE = 0, then the original state was in a state with negative energy.

The Gauss Gun: A classical analog of an exothermic reaction

Sketch

1. What the potential energy curve must look like between the magnet and a metal sphere as a function of distance.
(Hint: think about the WEΘ)
2. Energy bar graphs that show the initial and final energies of each of the 4 spheres (when the moving one is far from the magnet)



Energy conservation with chemical reactions: 1

- Consider the collision of two molecules in isolation   A + B → A + B

$$K_A + K_B + U_{AB} = \text{ constant}$$

- If the initial and final states both have the two molecules far apart, $U_{\mathrm{AB}} \sim 0$.

$$K_A + K_B = \text{ constant}$$

Energy conservation with chemical reactions: 2

- Consider the reaction of two molecules in isolation $\quad A + B \rightarrow C + D$

$$\left(K_A + E_A\right) + \left(K_B + E_B\right) + U_{AB} = \left(K_C + E_C\right) + \left(K_D + E_D\right) + U_{CD}$$

- If the initial and final states both have the two molecules far apart, $U_{\mathrm{AB}} \sim U_{\mathrm{CD}} \sim 0$.

$$\left(K_A + E_A\right) + \left(K_B + E_B\right) = \left(K_C + E_C\right) + \left(K_D + E_D\right)$$

Note: The "E"s here are **molecular internal energies** and are negative since the molecules are bound. The (positive) **bond energies** from chemistry are given by $\boldsymbol{\mathcal{E}} = -E > 0$.