Choice of System and the Energy Equation

Bruce Sherwood
Ruth Chabay

Department of Physics
North Carolina State University

Review of potential energy

$$\Delta E_{\text{particles}} = W_{\text{ext}} + W_{\text{int}}$$

$$\Delta E_{\text{particles}} + (-W_{\text{int}}) = W_{\text{ext}}$$

$$\Delta E_{\text{sys}} = \Delta E_{\text{particles}} + \Delta U = W_{\text{ext}}$$

We'll consider situations where there is negligible Q (heat; microscopic work)

Interpretation: Potential energy is interaction energy of pairs of particles, the internal work done by all pairs of particles in a system on each other.
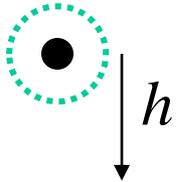
Pair-wise interaction energy

2 particles: 1 pair

3 particles: 3 pairs (12, 23, 13)

4 particles: 6 pairs (12, 23, 34, 13, 14, 24)

For example, in the Sun+Earth+Moon system there are 3 terms in the potential energy:

$$U_{\text{Sun,Earth}} + U_{\text{Sun,Moon}} + U_{\text{Earth,Moon}}$$
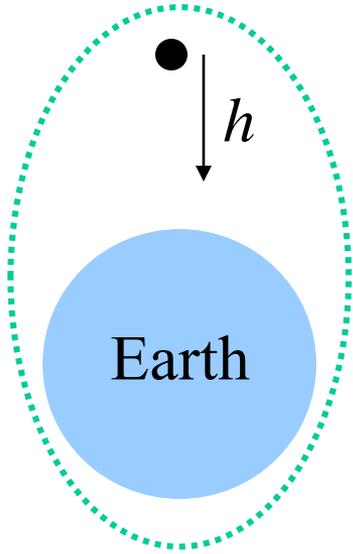
System: falling rock alone

$$\Delta E_{\text{sys}} = W_{\text{ext}}$$

$$\Delta K = +mgh$$

Interpretation: The Earth, which is external to the chosen system, does positive work on the system, increasing the kinetic energy of the rock.

System: Earth plus falling rock

$$\Delta E_{\text{sys}} = W_{\text{ext}}$$

$$\Delta K + \Delta U = 0$$

$$\Delta K + (-mgh) = 0$$

Interpretation: No external work is done on the Earth-rock system. The kinetic energy of the rock increases. The pair-wise interaction energy (potential energy) decreases.
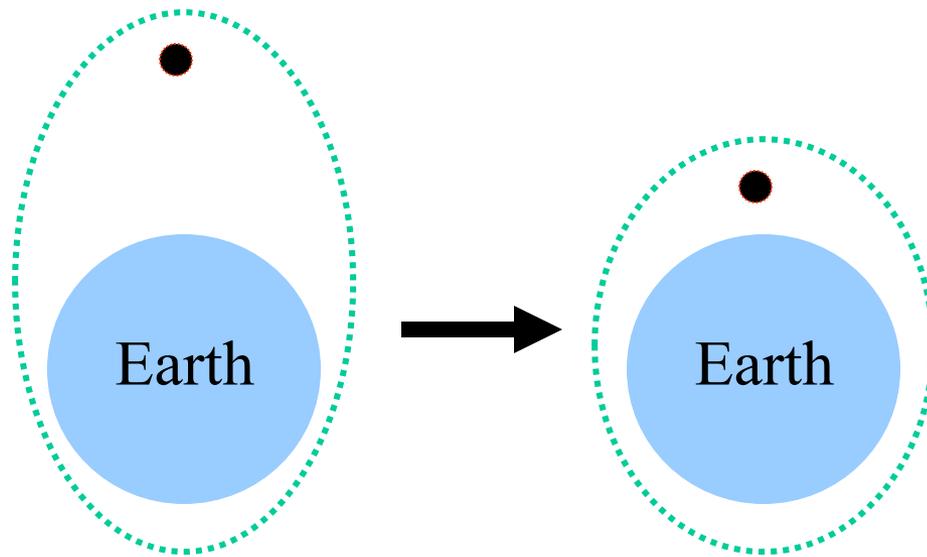
The *rock* has no potential energy

$$\Delta K + \Delta U = W_{\text{ext}}$$

$$\Delta K + (-mgh) = +mgh$$

(Mis)interpretation leads to double counting. Potential energy is associated with pair-wise interactions inside a system. The rock alone has no potential energy. Rather, external work is done on the rock by the Earth.

Change in potential energy is associated with change of shape

There is no change of shape of the rock alone.

A more complicated example
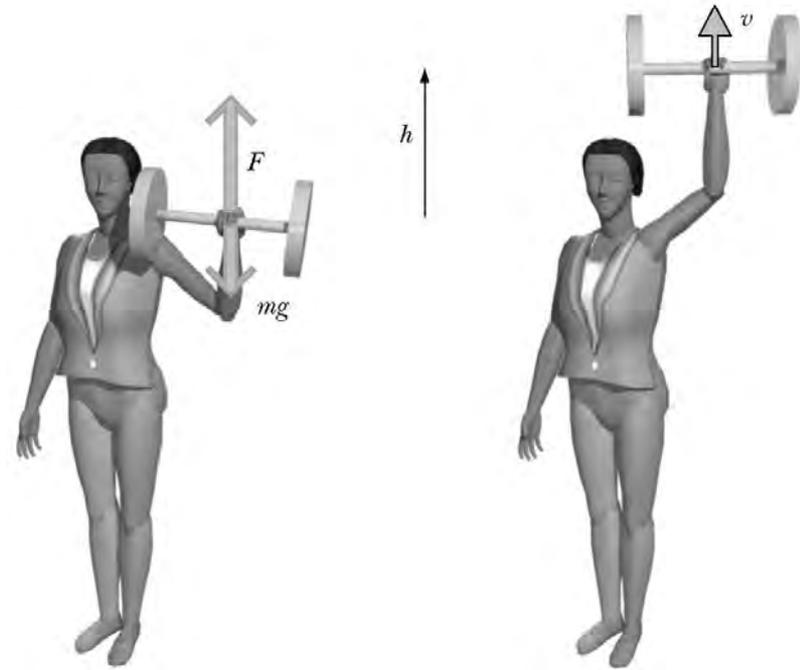
Barbell alone: $\Delta K = Fh - mgh$
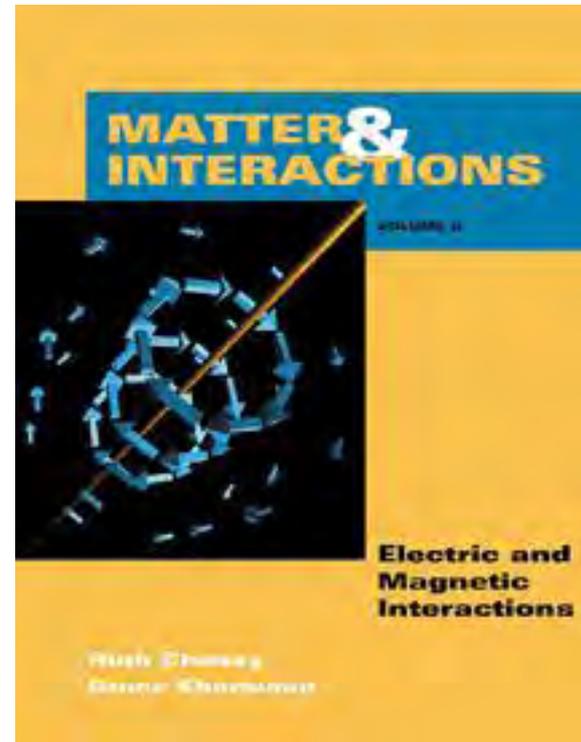
Barbell + Earth: $\Delta K + \Delta U = Fh$
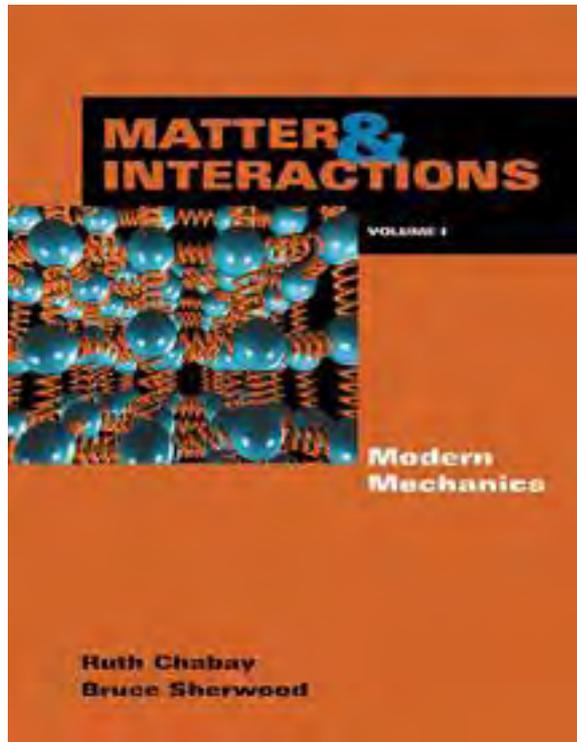
Barbell + Earth + woman:
$$\Delta K + \Delta U + \Delta E_{\text{int}} = 0$$

Matter & Interactions

Ruth Chabay & Bruce Sherwood

John Wiley & Sons, 2002
http://www4.ncsu.edu/~rwchabay/mi