Litany For Energy Problems [©2012 RJ Bieniek]

1. A detailed sketch of the physical elements of the problem with all relevant positions clearly labeled for all states (e.g., initial and final). For example, in a gravitational problem involving two objects, the initial and final y **should** be shown for **each** particle with full subscripts uniquely identifying them: y_{1i}, y_{1f}, y_{2i}, y_{2f}, and the y=0 level (Note: "**should**"≈"**must**"). Some of these can be added as you solve the problem, but a diagram comes first even if it is initially incomplete.

2. **A fundamental equation must appear**, e.g., $E_f - E_i = (W_{other})_{i\to f}$.

3. Write a expression for mechanical energy where kinetic energies of all particles in the system and each of the potential energies due to conservatives forces are identified. For example, if gravity and a spring act on a single particle, one writes $E = K + U_g + U_s$ or $E = ½mv^2 + mgy + ½ks^2$. Include the work done by OTHER forces in W_{other}. If no other force acts except those already accounted for in potential energy, $(\cancel{W}_{other})_{i\to f}$ can be zeroed out. **But check and verify your decisions!**

4. If more than one potential acts (e.g., gravity and a spring), each potential **should** appear on **both** sides of the equation. Write out the explicit mathematical form for the potentials, with appropriate initial or final subscripts, e.g., mgy_i for the initial gravitational potential energy. **When you use such position-dependent formulae, you *must* clearly include the initial and final position symbols in your diagram (preferably with their value, e.g., $y_i = +H$ and $s_f = -d$), along with the location of the reference zero value, e.g., y=0**.

For example, consider the initial state of a particle at rest that is to be launched from a spring of compression *d* at a vertical distance *h* below the y=0 level in a gravitational field, the following steps **should** appear: $E_i = E_f$ because $(W_{other})_{i\to f} = 0$

$$K_i + (U_g)_i + (U_s)_i = \textit{analogous final-state expression}$$
$$½m\cancel{v}_i^2 + mgy_i + ½ks_i^2 = \textit{analogous final-state expression}$$
$$mg(-h) + ½k(-d)^2 = \textit{analogous final-state expression}$$

5. After they appear in your diagram, go ahead and substitute the algebraic values shown into your mathematics. Do not zero out a term unless your diagram supports it!

As an example, consider an Atwood machine with *M* > *m* and a massless pulley. Block *M* starts from rest and falls onto a spring (spring constant *k*), from an initial height *h* above it. When *M* is released, block *m* is pulled upward by an additional external force whose magnitude *P* equals half the block's weight magnitude. What is the spring's maximum compression *d*?

$$E_f - E_i = (W_{other})_{i\to f} \quad\Rightarrow\quad E_f = E_i + (W_P)_{i\to f}$$

$$½M\cancel{v}_f^2 + ½m\cancel{v}_f^2 + [MgY_f + mgy_f + ½ks_f^2]$$

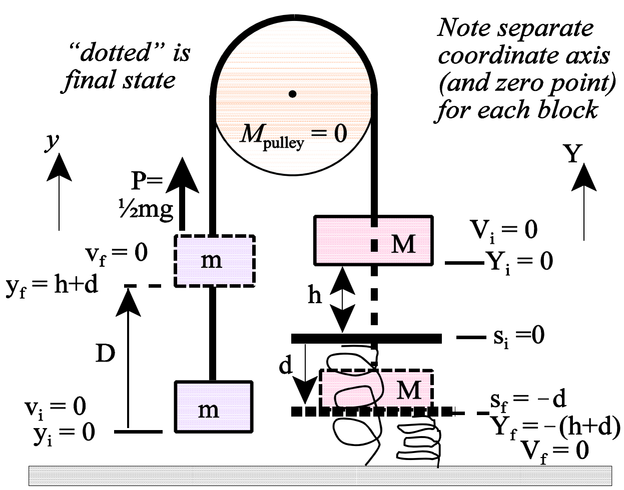
$$= ½M\cancel{V}_i^2 + ½m\cancel{v}_i^2 + [Mg\cancel{Y}_i + mg\cancel{y}_i + ½k\cancel{s}_i^2] + \vec{P}\bullet\vec{D}$$

$$Mg[-(h+d)] + mg[+(h+d)] + ½k(-d)^2 = +PD$$

$$-Mg(h+d) + mg(h+d) + ½kd^2 = (½mg)(h+d)$$

$$[½k]\,d^2 + (½m - M)\,g\,d + (½m - M)\,g\,h = 0$$

Solve this quadratic equation for *d* !



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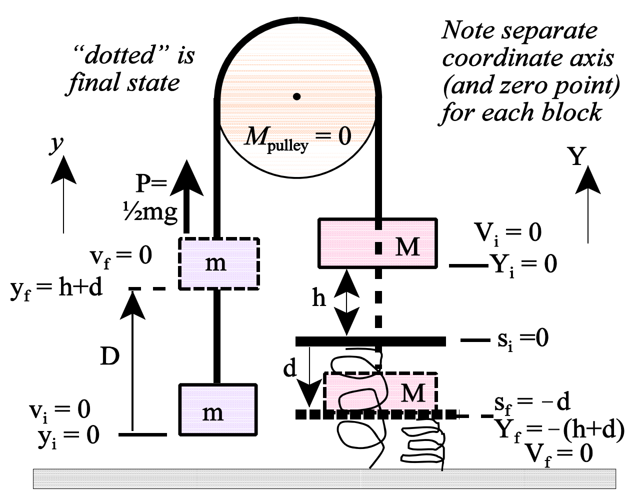

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