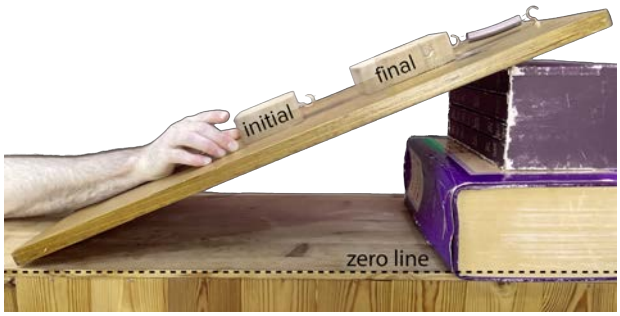
Flipping Physics Lecture Notes:

Energy Systems Clarified
http://www.flippingphysics.com/energy-systems.html

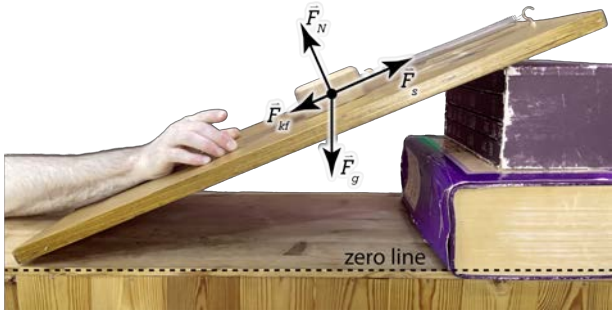
The objects which are a part of the system determine how work and energy are related. Let's start with an example to show how this works.

Example: A block attached to a spring slides up an incline.



Let's define:

- The initial point after the block has started moving
- The final point before the block has stopped moving and before the block gets to the spring's equilibrium position.
- The horizontal zero line at the bottom of the incline. The block is always above the zero line.



We need to draw a free body diagram of all the forces acting on the block. Notice the force of gravity, the force of kinetic friction, and the spring force all do work on the bock, however, the force normal does not do work on the block because it is perpendicular to the direction of the motion of the block.

In order to discuss work and energy of a system, let's start with the most basic equation relating work and energy: $\Delta E_{system} = \sum T$

This equation states that the change in energy of the system equals the net energy transferred into or out of the system. Let's rearrange the equation to make it easier to work with in this situation.

$$\Delta E_{system} = \sum T \Rightarrow E_{system\,f} - E_{system\,i} = \sum T \Rightarrow E_{system\,f} = E_{system\,i} + \sum T \Rightarrow E_{system\,i} + \sum T = E_{system\,f}$$

Remember, energy is transferred into or out of the system via work done on the system by forces external to the system.

If we choose ***the block*** as the system:

- All the forces which act on the block are external to the block.
- The block starts and ends with kinetic energy
- The block does not have gravitational potential energy because gravitational potential energy is caused by the interaction of two masses and the block is just one mass.
- The block does not have elastic potential energy because the spring is not a part of the system.

The equation relating work and energy for the block system looks like this:

$$KE_i + W_s + W_g + W_{F_{kf}} = KE_f \Rightarrow KE_i + W_{net} = KE_f \Rightarrow W_{net} = KE_f - KE_i \Rightarrow W_{net} = \Delta KE$$

Notice this ends up being the Work Energy Theorem
(or the Net Work equals Change in Kinetic Energy Theorem)

If we choose ***the block and the Earth*** as the system:

- The force of gravity is now internal to the system.
- Instead of work done by the force of gravity on the system, we can now look at it in terms of the initial and final gravitational potential energy of the system.

The equation relating work and energy for the block and Earth system looks like this:

$$KE_i + W_s + U_{gi} + W_{F_{kf}} = KE_f + U_{gf}$$

If we choose ***the block, the Earth, and the spring*** as the system:

- The spring force is now internal to the system.
- Instead of work done by the spring force on the system, the system now has initial and final elastic potential energy.

The equation relating work and energy for the block, Earth, and spring system looks like this:

$$KE_i + U_{ei} + U_{gi} + W_{F_{kf}} = KE_f + U_{ef} + U_{gf} \Rightarrow W_{F_{kf}} = \Delta KE + \Delta U_e + \Delta U_g \Rightarrow W_{NC} = \Delta ME$$

And … let's do one more:

If we choose ***the block, the Earth, the spring, and the incline*** as the system:

- The force of friction is now internal to the system.
- Instead of work done by the force of friction on the system, the system now has initial and final internal energy.

The equation relating work and energy for the block, Earth, spring, and incline system looks like this:

$$KE_i + U_{ei} + U_{gi} + U_{Ii} = KE_f + U_{ef} + U_{gf} + U_{If} \Rightarrow 0 = \Delta KE + \Delta U_e + \Delta U_g + \Delta U_I$$

Notice this means energy is conserved. When you include everything in your system, you get conservation of energy because energy is neither created nor destroyed, it just changes forms.

This is just a restatement of $\Delta E_{system} = \sum T$ But, there is no energy transferred into or out of the system because the system contains everything.

Remember that work done by the force of friction goes into the system as internal energy: $W_{F_{kf}} = -\Delta U_I$

And the work done by a conservative force equals the negative of the change in potential energy associated with that force:

$$W_{conservative\ force} = -\Delta U$$

And because the force of gravity and the spring force are both conservative forces:

$$W_g = -\Delta U_g \ \& \ W_s = -\Delta U_e$$

Therefore, if we take the equation we ended with, move the changes in potential and internal energy to the left-hand side, and replace all the negative changes in energy with work, we return to our original Net Work equals Change in Mechanical Energy equation and we are back to just having **the block as the only object in our system**.

$$\Rightarrow -\Delta U_e - \Delta U_g - \Delta U_I = \Delta KE \Rightarrow W_s + W_g + W_{F_{kf}} = \Delta KE \Rightarrow W_{net} = \Delta KE$$