Physics Integration Lesson 14 – Where Did the Energy Go?

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Conservation of energy is a foundational concept that provides insight when answering questions about the physical world. We are familiar with the relationship between kinetic energy, potential energy and non-conservative work from first semester of physics. However, does this apply to electric fields, voltage and charge? Can we think of work in the same way or is it fundamentally different?

Well, you will be glad to know that energy and work have the same relationship in electricity and magnetism as they do in mechanics. The work-energy theorem, $W_{net} = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$, states that the total work done on an object is equal to its change in kinetic energy and, thereby, changes the magnitude of its velocity. If work is conservative, as with gravitational and electric fields, energy can be recovered from the field by changing its position. Defining potential energy change, ΔU, as the negative of work done by a conservative field, the work-energy theorem becomes $W_{non-cons} = \Delta K + \Delta U$. The $W_{non\text{-}cons}$ represents the work done by non-conservative forces such as friction and time-dependent electromagnetic fields.

When an electric circuit is in operation, work is done as charge moves through an electric field. Some components in the circuit store energy and can be treated as gaining potential energy. Other components dissipate energy from the circuit and, therefore, act like friction. In this lab, the resistor is doing non-conservative work to remove energy from the system while the power supply is doing non-conservative work to add energy to the system. Once current is flowing, the average electron moves at a constant speed and, therefore, does not change its kinetic energy. By the work-energy theorem, the positive work done by the power supply is cancelled by the negative work done by the resistor.

An article in *Wired* magazine, "Even Physics Textbooks Tend to Get Friction Slightly Wrong" (https://www.wired.com/story/even-physics-textbooks-tend-to-get-friction-slightly-wrong/) states that the work-energy theorem is slightly in error. This article points out that friction does work against a person pulling a block at constant speed. Therefore, the work done by the person is cancelled by the work done by friction. However, the surface over which the block moved got warmer, indicating that it gained energy. This is similar to our power supply and resistor example, where the resistor became warm and in turn heated our water. I disagree with the conclusion of the article's author because it implies that the work-energy theorem is only approximately true.

1. Last semester I derived the work-energy theorem using calculus (see chapter 7 of Openstax University Physics). Are there any assumptions made in the derivation that would make the conclusion only an approximation? Do you feel the work-energy theorem is approximately or exactly true? Why?
2. In the case of friction, as well as the resistor, conservation of energy cannot be violated. If it appears energy is appearing from nowhere, there is something being overlooked. When negative non-conservative work is being done, energy is converted into a form that is not directly recoverable mechanically. Where did the energy go? Is it ever possible to reclaim some of this lost energy? If so, how?