# Energy Storage and Transfer Model
# Reading 1

**Energy**- a conserved, substance-like quantity with the capability to produce change.

The idea of energy is an invention that proves very useful. Energy is universal - it does not come in different "kinds" or exist in different "forms." To help us describe the interaction of energy and matter, we create various "accounts" in which energy can be stored in a given system, but the energy itself is unchanged. It can be transferred from one account to another as some aspect of the system undergoes a change. It can be transferred between system and surroundings via several mechanisms, although "working" (W) is the primary transfer mechanism used in this unit.

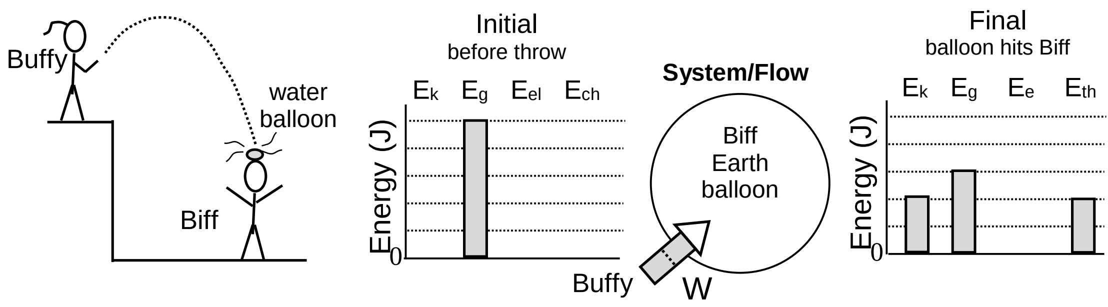
Energy always has a home; it is either stored in an object - which we label kinetic energy when the object is moving or elastic energy when it undergoes a restorable deformation - or it is stored by a field (gravitational, electric or magnetic), which we label potential energy. In this unit you will develop expressions that will enable you to determine the amount of energy stored in these various accounts. As energy is transferred from one account (or storage mode) to another, or between the system and the surroundings, the total amount of energy stays constant; we say that energy is conserved. The choice of which objects are in the system affects the way you calculate energy transfers. Generally, the smallest system that contains all the needed ways of storing energy is the easiest.

**Money analogy:** A useful analogy to help understand energy storage and transfer is to compare energy to money. We will define "the system" as the personal and institutional places where you keep your money. You can store your money in a number of ways: in a checking account, savings account, cash in a piggy bank, or a stock mutual fund. As you transfer money between your various accounts the amount of money stays the same (is conserved) even though some features of your resources may be different (e.g., using cash may be easier than a check in some transactions). Some transfers cost you money, such as using a debit card or getting a cash advance. In such cases, while the money is still there, you may no longer be able to transfer it to some other account. This is our analog to thermal energy.

**Diagrammatical representations for Energy:**
Energy is a scalar (amount only, no direction) so it can't be represented with the arrows we use for vectors. Instead, we use pie charts and bar graphs and energy flow diagrams.

Thus far you have used pie charts to show how energy is stored within a system and how energy moves from one storage mode to another as change occurs within the system. The size of the pie reflects the total energy of the system, and the size of each piece of the pie indicates how the energy is distributed among the various storage modes. Making the size of each slice represent the exact value of the energy in each mode is not an easy task in a pie chart model, so we tend to use pie charts for qualitative representations.

The next representational tools you will use are energy bar graphs and flow diagrams. They will help as you perform quantitative analysis of the energy flow during a change. The initial energy state of a system is represented with a bar graph showing the amount of energy stored in each account (or storage mode). To the right of the bar graph, an energy flow diagram indicates which items are inside and outside of the system and whether energy is transferred into or out of the system by working or heating. Finally, to the right of the energy flow diagram, another bar graph indicates the final distribution of energy stored within the system. To use the representation for quantitative analysis, a mathematical expression or energy value can be written below each bar and the energy flow diagram. The sum of the initial stored energy in the system plus or minus any energy flowing in or out of the system equals the sum of the final stored energy in the system. Consider the example below in which a water balloon tossed by Buffy lands and bursts on Biff's head.




$$E_g + W = E_k + E_g + E_{th}$$

The system contains Biff, the Earth and the water balloon. The zero reference position for the gravitational potential energy, $E_g$ , is the floor on which Biff stands. In the **Initial** state, the Earth-balloon system has some $E_g$ as the balloon rests in Buffy's hand. Buffy, an external agent, applies a force through some distance to the balloon, transferring additional energy to the system via the mechanism we call working (W). This is shown in the system/flow portion of the diagram. In the **Final** state, the moving balloon and water have some kinetic energy, $E_k$, and the Earth balloon system has some lower amount of gravitational energy (due to the decreased height of the balloon). In addition, some energy ends up in the thermal energy account due to the increase in the kinetic energy of the molecules of water, balloon scraps and Biff's head.

Had Buffy been included in the system, then a separate account for chemical energy, $E_{ch}$ would need to be shown on the energy bar charts with two more bars in the initial state than in the final state.