Representing Energy Storage & Transformations

How to Draw Energy Pie Graphs

What are the rules we learned about energy pie charts?

1. The size of the pie represents

2. More E_g in the system when the object is:

3. More E_k in the system when the object is:

4. More E_{el} in the system when the object is:

5. More $E_{thermal}$ in the system when the object is:

6. The total amount of energy in the system always:

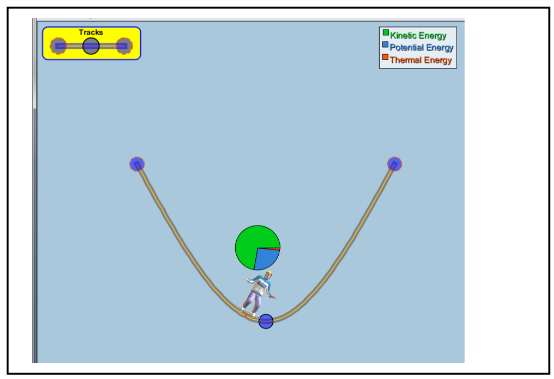
We know these things about energy:

a. Energy is stored within a system (one or more physical things)

b. When energy is put into a system, it can make things change

c. When the energy in a system changes from one storage type to another, something about the system changes

d. If no energy enters or leaves a system; meaning it is closed like Dennis the Menace's house, the total amount of energy stays the same.



Three Guiding Questions to Analyzing Energy in a System:

1. What is the System that stores the energy?
2. How is the energy stored in the system?
3. How does the energy change storage type?

What are Energy Pie Graphs Used For?

1. Energy pie graphs are used to show how energy changes from one storage type to another.

2. Since it would be very difficult to draw pies getting larger or smaller, pie graphs should not be used when energy enters or leaves a system.

3. In order to have pie graphs not change in size, the system must be made large enough to account for all possible energy storage types.

What about thermal, sound, & light energy? How will we show them in a pie chart?

1. When friction is present in a system, some of the energy stored will be converted into thermal energy. (the objects in the system get warmer)

2. In the real world, some energy is converted into sound or light.

3. Oftentimes, the energy converted into thermal, sound or light is not able to be converted back into other, more usable energy storage types (like E_g, or E_{el}). The ability to be converted back into more usable energy is called **Reversibility**.

4. We will consider any energy that is not reversible (able to be converted back to more usable forms) to **be dissipated energy**. Dissipated energy can be thought of as energy that has a very low density; it is spread out very far.

Any energy that is converted into thermal, sound, or light and is not able to be reversed back to other energy storage types will be labeled $E_{diss.}$

So, What is the Scientific Term for the Rules the Pie Charts Follow?

The pie charts follow the Laws of Thermodynamics. They are as follows:

Zeroth Law: If two objects are equal in temperature to a third object, they are also equal in temperature to each other.

1st Law: Energy cannot be created or destroyed. It can be transferred between systems by Heating, working or radiating. This is called the **Law of Conservation of Energy**. In other words, you can't win.

2nd Law: Whenever energy changes storage types, or moves from one system to another, some of it must be dissipated. (This means the Universe is always getting, on average more disordered; it is called entropy) In other words, you cannot break even.

3rd Law: The temperature of an object is proportional to the average kinetic energy (motion) of the particles that make up the object. It is impossible to get an object to reach absolute zero temperature (which would be zero energy). Even if you could get an object to zero, you would have to shine light on it to see it . .. and the light would impart some energy to the object! In other words, you cannot leave the game.

Why do we use E_{type}, instead of KE, PE, etc?

This E__ notation, as opposed to KE, or GPE, or EPE is used for two reasons:

1. It stresses the universal nature of energy - it's all energy. No one asks you how much penny or nickel money you have, they just ask you how much money you have!

2. In this energy unit, we will use E__ to indicate the mechanisms of energy storage involved in these various types of internal energy.

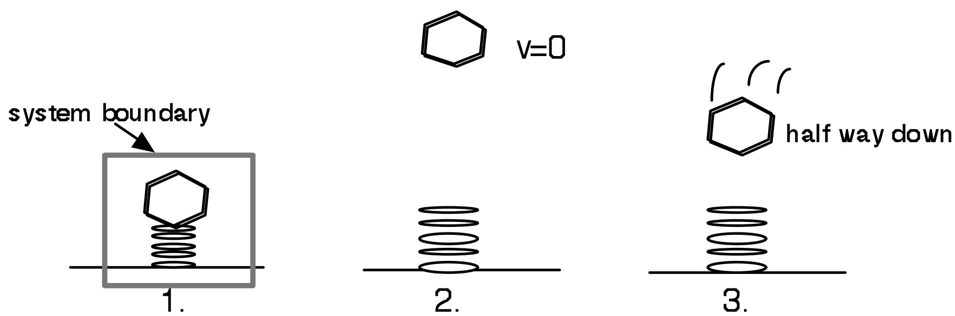
   Symbols of energy transfer (across the system boundary) will be Q (heating as energy transfer due to temperature difference, R (radiating), and W (working as energy transfer by an external force). These terms (Q, W, and R) will not be used with the pie charts, since the pie charts focus on energy storage and internal energy changes.

Why don't we every talk about potential energy?

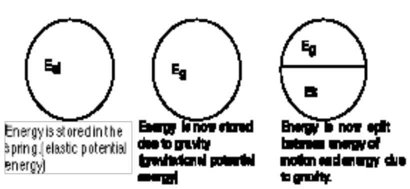
All energy storage types can be potential. For instance, your car has a heavy metal disc that spins even when the car is stopped. This is potential energy, but is stored as motion. Potential energy is often thought of as only E_g.

Example 1: a spring-launched toy which is propelled into the air

system: spring and toy object



Corresponding Pie Charts:

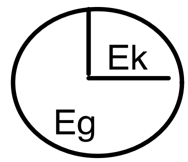


Analysis

1. It is critical to identify the system first. In this case, if the spring were NOT included in the system, the toy would initially have no energy, and the spring would then transfer energy to the toy by an external force across the system boundary (work).

2. Notice that the sizes of the circles are all the same. This is the implicit representation of the Conservation of Energy. If the toy were launched by a stronger spring, the circles would be larger.

3. The divisions in the pie show the relative amounts of the energies. For example, if point #3 had been when the toy was only 1/4 of the way down, then only 1/4 of the circle would be E_k, and 3/4 would be E_g.



Example 2: A ball rolling on the floor, coming to a stop due to friction

system: ball + floor

Analysis:

1. E_k includes both translational and rotational motion. It is the energy of motion.

2. E_{diss} = dissipated energy. It is a simple, qualitative way to account for the "loss" of energy of motion. It is shaded in to represent that the energy is no longer usable or accessible.

3. The system includes the table top in order to maintain the representation of conservation of energy. If the system were only the ball, the circles would have to get smaller as the energy of motion of the ball decreased and the dissipated energy left the system (the ball). Some of the dissipated energy does in fact go to the internal energy of the ball, but not all - some of it goes to the table top also. So if the table isn't included in the system, the circles would necessarily have to shrink as energy left the ball. This would be a confusing situation to reconcile with Conservation of Energy, and should be avoided!

Representing Energy Transfer

How to draw Energy Bar Graphs (LOL diagrams)

Energy Pie graphs were used to show how energy changed storage types within a system. But what happens when energy enters or leaves a system?

This is where using a bar graph makes a lot of sense. They are much easier than pie graphs to show energy entering or leaving a system.

Here are the guiding questions for constructing Energy Bar Graphs:

1. *What is the system?*
2. *Where does the energy come from?*
3. *Where does it go?*

Steps in constructing an energy bar graph:

1. *Identify the system*. Energy can now enter or leave your system, so it can be made more specific.
2. *Draw a pictorial representation* of the system inside the schema diagram.
3. *Identify the initial energy storage* (internal energies), and represent them with relative quantified bar graphs.
4. *Identify the resulting final internal energies* with final bar graphs.
5. *Identify the energy transfer(s)* that occur across the system boundary to cause the changes in the internal energies, and represent the transfer with quantified arrows pointing into or out of the system schema diagram.

Remember that energy can be transferred through three processes:

1. Heating (Q)
2. Radiating (R)
3. Working (W)

Thus the bar graphs and energy schema diagram represent the 1st Law of Thermodynamics:

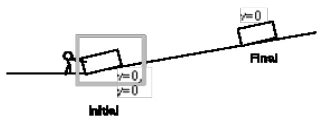
$W+Q+R = \Delta E$

So we all speak the same language:

1. Energy entering the system will be positive
2. Energy leaving the system will be negative

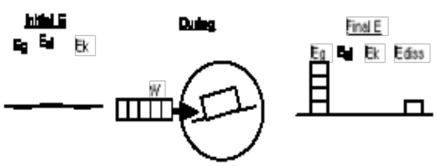
Examples of Bar Graph/Energy Flow Diagram Usage

Example 1 A person pushes a box from a 0 position up a ramp to a stop.



system = box + surface of ramp

Corresponding Bar Graphs and Energy Schema Diagram

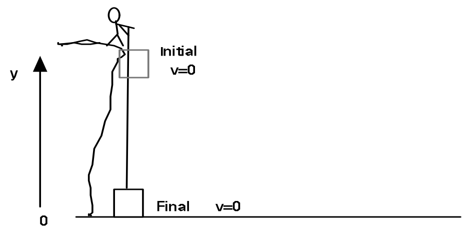


Analysis

1. Assuming the box starts at a 0 reference point, it has no initial energies.
2. Energy is transferred to the system via the external force provided by the person. This is defined as working. The work arrow is 5 blocks long.
3. At the final point, the energy transferred by working done has been stored as the energy of gravity, E_g, and some has been dissipated due to friction, E_{diss}.

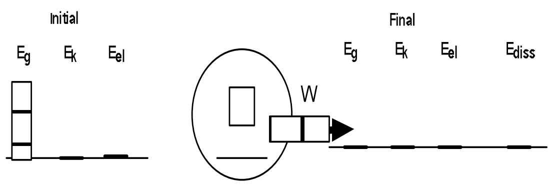
Notice that E_g and E_{diss} add up to 5 blocks also, in agreement with the Conservation of Energy.

Example 2: A person lowers a box to the ground.



system = box + earth

Corresponding Bar Graphs and Energy Schema Diagram



Analysis:

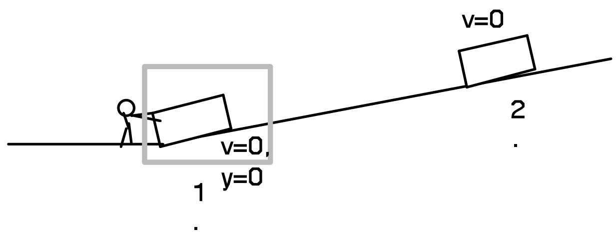
1. Initially, the box only has gravitational potential energy, $E_{g,}$ due to its position above the reference point where y=0.

2. Afterwards, the box system has no energy - it is on the ground, not moving.

   It might be tempting to say that the energy E_g was lost to $E_{diss.}$ However, what would it have been dissipated by? Friction is minimal, and we assume it was lowered gently so it doesn't slam into the ground. There is nothing internal to the system that would account for E_{diss}. Therefore, the energy was removed from the system by the external force of the rope acting on the box, which lowered the box to the ground. There was working done by the rope, and since the internal energy of the system decreased ($-\Delta E_g$) the working arrow must point OUT of the system, showing that $-\Delta E_g = -W$, since energy was transferred out of the system.

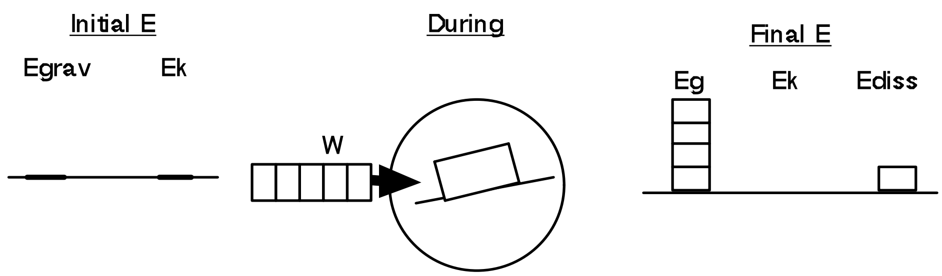
   *Some students will probably want to account for E_{chem} of the person. They just need to be reminded that the person is not in the system. If he *was*, in the system, then yes, there would be a decrease in E_{chem}, as well as E_g and could be accounted for by an increase in E_{diss}, the person's metabolism.

Example 3 A person pushes a box from a 0 position up a ramp to a stop.



system = box + surface of ramp

Corresponding Bar Graphs and Energy Flow Diagram



Analysis

1. Assuming the box starts at a 0 reference point, it has no initial energies at point 1.

2. Energy is transferred to the system via the external force provided by the person. This is defined as work (work done on the system.) The work arrow is 5 blocks long.

3. At point #2, the energy from the work done has been transferred to the energy of gravity, E_g, and some has been dissipated due to friction, E_{diss}.

Notice that E_g and E_{diss} add up to 5 blocks also, in agreement with the Conservation of Energy.