**Unit 1 Reading 3:**

**Representing Change using Energy Bar Charts**

**Why do we need to use Energy Bar Charts?**

This reading describes the third tool we use to help represent energy: Energy Bar Charts. The use of a “Bar Chart” will help us to more quantitatively represent energy storage and transfer. Together with a system schema and a state diagram, the Energy Bar Chart will help us represent how energy storage changes when energy is transferred within a system. Energy Bar Charts will also be very useful to help us represent changes when energy transfers into or out of the system, across the system boundary.

**What does an Energy Bar Chart look like?**

Here is an example of an Energy Bar Chart:

Initial

Energy

0

Final

Energy

0

**System/Flow**

**Important Features of an Energy Bar Chart:**

Before making an Energy Bar Chart, be sure to define your system and make a System Schema and State Diagrams if needed. Remember, the System Schema diagram identifies the objects that interact during a process or change. State Diagrams represent the positions or configurations of objects in your system at the instants that you choose to represent your system with Energy Bar Charts (at the very least you will represent initial and final states, but sometimes intermediate states as well). Next, an Energy Bar Chart will help us track changes in how the System stores and transfers energy during the process or change.

Each “bar” or “block” in the Initial graph or the Final graph of an Energy Bar Chart represents how the System is storing energy. The circle in the middle is used to represent the system. The circle in the middle is also used to show Energy Flow. We can use ‘quantified arrows’ (like the bars on the bar chart) that point into or out of the System circle to represent the amount of energy being transferred into or out of the system. If there are no transfers of energy into or out of the system, no arrow would point into or out of the system. This means the system was chosen to include all relevant objects, and the analysis is simplified: energy is conserved! In this instance, the initial and final bar graphs must have an equal number of “blocks” or “bars” distributed among the different modes of energy storage.

**Steps in constructing an Energy Bar Chart**

1. *Identify a system*.
2. *Draw the system schema.*
3. *Draw state diagrams for each state you will represent with an energy bar graph.*
4. *Identify the initial energy storage* *modes*, and represent them with bars that depict relative amounts of energy in each storage mode.
5. *Identify the resulting final energy storage modes* with final quantified bar graphs.
6. *Identify energy transfer(s).* If any energy transfer occurs across the system boundary, represent this transfer with arrows pointing into or out of the system schema to make the energy flow diagram.

In summary, you will use Energy Bar Charts to represent the initial and final energies, and the system schema and energy flow diagram to represent the intermediate processes. The difference in the initial and final energies is the system’s change in energy, ∆E, since ∆E = Ef - Ei.

Thus, the Energy Bar Chart, and Energy flow diagram help us represent the conservation of energy. Scientists call this concept of energy conservation the “First Law of Thermodynamics”: the energy of a system stays the same unless energy is transferred into or out of the system.

**Examples of Bar Graph/Energy Flow Diagram Usage:**

**Example 1:** A person pushes a box, that was initially at rest, across a floor; friction exists

person

surface

box

Earth field

**System** = person, Earth, box and surface

**System Schema diagram:**

The System Schema shows that energy cannot be transferred into or out of the system, since none of the object interactions cross the system boundary. Therefore, in the energy flow diagram no energy transfers in or out of the system. Energy is conserved.

**Corresponding Energy Bar Chart and Energy Flow Diagram:**

**Final**

**Initial**

**Energy Flow**

**Diagram**

**Ech**

**Eint**

**EK**

**Eg**

**EK**

**0**

**0**

**E initial = E final**

**Echem = Eint**

**Corresponding State Diagrams**

**Analysis**

1. The box has no initial stored energy but the person does (Ech).

2. Energy is transferred from the person’s stored Ech to other storage forms as the person pushes the box. Therefore, no transfer of energy occurs across the system boundaries, no energy is added to or removed from the system, and no arrow is shown in the Energy Flow Diagram.

3. At the final state, the energy is now stored partially as kinetic energy and partially as internal energy, since the box and surface have warmed during the process.

\*Notice that Ek and Eint add up to 4 blocks which is equal to the initial 4 blocks of Ech in agreement with the Conservation of Energy.

**Example 2:** A person pushes a box from a 0 position up a ramp to a stop.

Initial

Final

v=0

y=0

v=0

**System Schema diagram:**

person

Earth field

box

surface

**System** = box + surface of ramp + Earth

The System Schema shows that energy could be

transferred into the system by the person or even out

of the system to the person.

**Corresponding Energy Bar Chart and Energy Flow Diagram:**

**Energy Flow**

**Diagram**

**0**

**EK**

**Initial**

**Eg**

**0**

**Final**

**EK**

**Eg**

**Eint**

**W**

**Ech**

**E initial < E final**

**Win = Eg + Eint**

**Corresponding State Diagrams**

**Analysis**

1. Assuming the box starts at a 0 (“zero”) reference point, it has no initial energy.

2. Energy is transferred to the system via the push provided by the person who is outside the system. We call this energy transferred by pushing “Working” and give it the symbol “W”. If the person transfers 5 blocks worth of their Ech into the system by pushing, then the ‘Working’ energy flow arrow is 5 blocks long.

3. In the final state, the energy transferred into the system by Working has been stored in the energy of the gravitational field, Eg, and some has been dissipated due to friction, Eint.

\*\*Note that Eg and Eint add up to 5 blocks, in agreement with the Conservation of Energy (the total energy in the universe did not change even though the initial and final bar graphs do not match, the total number of blocks does). 5 blocks (Win) = 4 blocks (Eg) + 1 block (Eint).

**Example 3:** A person lowers a box to the ground.

**System Schema diagram:**

Person

box

surface

Earth field

Initial

v=0

Final

v=0

0

y

**System** = box + Earth

The system schema shows that energy can be transferred into the system by the person or the surface. Energy can also be transferred out of the system to the person or the surface.

**Corresponding Bar Graphs and energy flow Diagram**

**Energy Flow**

**Diagram**

**0**

**EK**

**Eel**

**Initial**

**Eg**

**0**

**Final**

**EK**

**Eg**

**Eel**

**Eint**

**W**

**Ech**

**E initial > E final**

**Eg = Wout**

**Analysis:**

1. Initially, the box only has gravitational energy, Eg, due to its position above the ground, which has been defined as the point where y = 0.

2. Afterwards, the box system has no energy! The box lies motionless on the ground!

It might be tempting to say that the energy Eg was “lost” to Eint. However, it’s difficult to imagine the temperature of the box or its internal structure undergoing significant change in this process. Friction is minimal as the box is lowered, and we assume it was lowered gently so it doesn't slam into the ground. Therefore, the energy had to be transferred out of the system by the interaction of the box with the person who lowered the box to the ground (by ‘pulling’ or ‘working’)! This is a case where the analysis is actually more complicated if the person is included in the system (that situation would be beyond the scope of this course).

**Example 4:** A person pushes a box that was initially at rest across a floor; friction exists

**System** = box + surface

person

Earth field

box

surface

**System Schema diagram:**

The System Schema shows that energy can be transferred into the system by the person or the Earth or even out of the system to the person or the Earth.

**Corresponding Energy Bar Chart and Energy Flow Diagram:**

**Energy Flow**

**Diagram**

**0**

**EK**

**Initial**

**Eg**

**0**

**Final**

**EK**

**Eg**

**Eint**

**W**

**Ech**

**E initial < E final**

**Win = Ek + Eint**

**Analysis**

1. The box has no initial energy.

2. Energy is transferred to the system (Ech) via the external pushing provided by the person. The ‘Working’ arrow is 4 blocks long.

3. At the final state, the energy transferred to the system is stored partially as kinetic energy and partially as dissipated internal energy, since the box and surface has warmed during the process.

\*\*Notice that Ek and Eint add up to 4 blocks in agreement with the Conservation of Energy.