Laws of Thermodynamics

"Moreover You led them by day with a cloudy pillar, And by night with a pillar of fire,
To give them light on the road Which they should travel." Nehemiah 9:12

Scenario #1

Consider a very hot mug of coffee on the countertop of your kitchen. For discussion purposes, we will say that the cup of coffee has a temperature of 80°C and that the surroundings has a temperature of 26°C. What do you suppose will happen in this situation?

--> The cup of coffee will gradually cool down over time.

--> And if you resist the temptation to drink the coffee (not likely), it will eventually reach room temperature.

Energy

- The coffee and the mug are transferring heat to the surroundings. This transfer of heat occurs from the hot coffee and hot mug to the surrounding air.
- The fact that the coffee lowers its temperature is a sign that the average kinetic energy of its particles is decreasing. The coffee is losing energy. The mug is also lowering its temperature; the average kinetic energy of its particles is also decreasing. The mug is also losing energy.
- The energy that is lost by the coffee and the mug is being transferred to the colder surroundings. We refer to this transfer of energy from the coffee and the mug to the surrounding air and countertop as heat.
- **Heat** is simply the transfer of energy from a hot object to a colder object.

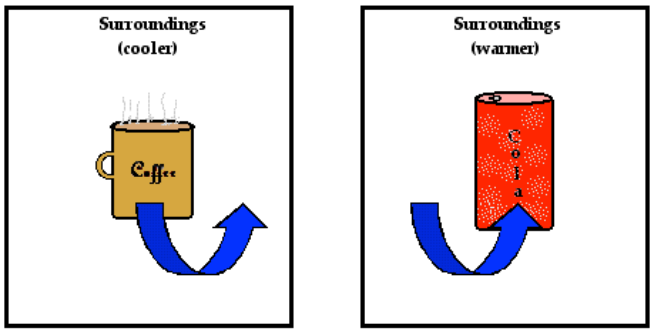
Scenario #2

Now let's consider a different scenario - that of a cold can of pop placed on the same kitchen counter. For discussion purposes, we will say that the pop and the can which contains it has a temperature of 5°C and that the surroundings has a temperature of 26°C. What will happen to the cold can of pop over the course of time?

-->The cold soda and the container will both warm up to room temperature.

-->There is a heat transfer.

- Over time, the soda and the container increase their temperature. The temperature rises from 5°C to nearly 26°C.
- This increase in temperature is a sign that the average kinetic energy of the particles within the pop and the container is increasing.
- In order for the particles within the pop and the container to increase their kinetic energy, they must be gaining energy from somewhere. But from where? Energy is being transferred from the surroundings in the form of heat.
- Energy is being transferred from the higher temperature objects to the lower temperature object. Once more, this is known as **heat** - the transfer of energy from the higher temperature object to a lower temperature object.



Heat is the flow of energy from a high temperature location to a low temperature location.

Another Definition of Temperature

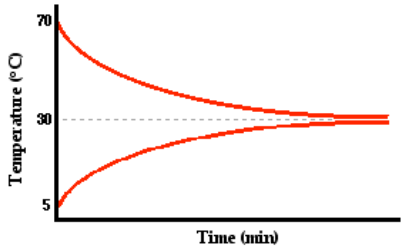
- An object decreases its temperature by releasing energy in the form of heat to its surroundings.
- An object increases its temperature by gaining energy in the form of heat from its surroundings.
- Both the *warming up* and the *cooling down* of objects works in the same way - by heat transfer from the higher temperature object to the lower temperature object.
- **Temperature is a measure of the ability of a substance to transfer heat energy to another physical system**. The higher the temperature of an object is, the greater the tendency of that object to transfer heat. The lower the temperature of an object is, the greater the tendency of that object to be on the receiving end of the heat transfer.

Thermal Equilibrium

Scenario #3

Suppose that a small metal cup of hot water is placed inside of a larger Styrofoam cup of cold water. Let's suppose that the temperature of the hot water is initially 70°C and that the temperature of the cold water in the outer cup is initially 5°C. And let's suppose that both cups are equipped with thermometers (or temperature probes) that measure the temperature of the water in each cup over the course of time. What do you suppose will happen?

Fortunately, this is an experiment that can be done and in fact has been done on many occasions. The graph below is a typical representation of the results.



- As you can see from the graph, the hot water cooled down to approximately 30°C and the cold water warmed up to approximately the same temperature. Heat is transferred from the high temperature object (inner can of hot water) to the low temperature object (outer can of

cold water). If we designate the inner cup of hot water as *the system*, then we can say that there is a flow of heat from *the system* to the *surroundings*.

- As long as there is a temperature difference between the system and the surroundings, there is a heat flow between them.
- The heat flow is more rapid at first as depicted by the steeper slopes of the lines. Over time, the temperature difference between system and surroundings decreases and the rate of heat transfer decreases.
- Eventually, the system and the surroundings reach the same temperature and the heat transfer ceases. It is at this point, that the two objects are said to have reached **thermal equilibrium**.