Next Gen PET LC

UNIT EM

LESSON 5: Warming and Cooling

Purpose and Key Question

In the previous lesson you saw that whenever objects rub together in a friction-type contact push/pull interaction, their temperatures increase so that they are warmer than their surroundings. To incorporate this observation into our energy model, we inferred that these increases in temperature were associated with increases in the **thermal energy** of both of them.

From your everyday experiences, you are probably aware of other situations in which the temperatures of objects increase, yet friction effects are not involved. For example, if you hold a hot cup of coffee, your hand becomes warmer. If you are outside on a sunny day, you may feel warmer than if you are inside an air-conditioned building. If it is chilly outside and you go inside and turn on a heater, you also eventually feel warmer. You also know that warm objects eventually cool back down. For example, your hands warmed up considerably while you were rubbing them together, but their temperature decreased again quickly after you stopped rubbing.

The purpose of this activity is to explore how we can incorporate these types of situations into our energy model by introducing another type of interaction.

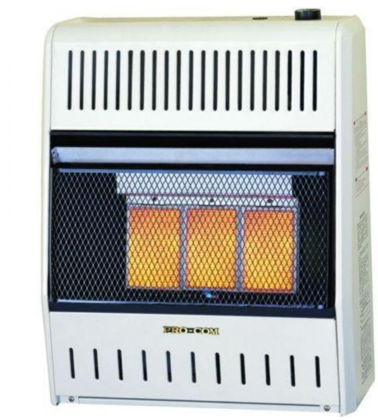
> LESSON
>
> ***What other interactions can change the temperature of objects?***

Predictions, Observations and Making Sense

Part 1. Heat Interactions

To begin, we consider what happens when objects with different temperatures interact.

On a winter's day you have an electric space heater operating in your house. When getting ready to go out, you walk to the heater and turn it off, placing your hands on top of its case as you do so.



As you stand in front of the now switched-off (but still glowing) heater, you feel your legs getting warmer, and when you look down at the heater, you feel warm air hitting your face. You also feel your hands getting warmer as they are touching the top of the heater.

What is happening to the thermal energy of the switched-off heater while this was happening? What about the thermal energy of your legs, face, and hands? What evidence supports your answers?

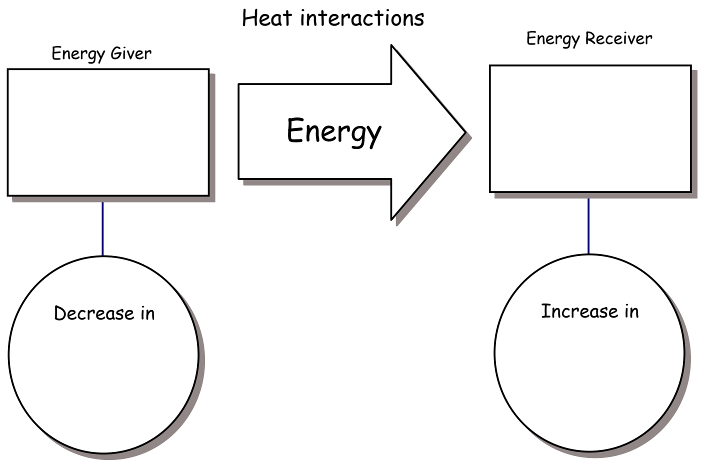
Do you think the switched-off heater was interacting with you? Why do you think so?

Do you think energy is being transferred between the switched-off heater and you? If so, what is the energy giver in this situation and what is the energy receiver? Briefly explain your reasoning.

The type of interaction occurring between the recently switched-off heater and your legs, face, and hands are particular examples of what we will call **heat interactions.** Such interactions take place between two objects that have **<u>different temperatures</u>**, and, as a result, energy is transferred from the warmer object to the cooler object. This transfer causes a decrease in the thermal energy of the energy giver (the warmer object), and an increase in thermal energy of the energy receiver (the cooler object).

As with the other interactions we have encountered, we can describe what happens using a G/R energy diagram.

Complete the G/R diagram below for the heat interactions between the recently switched-off heater and you.

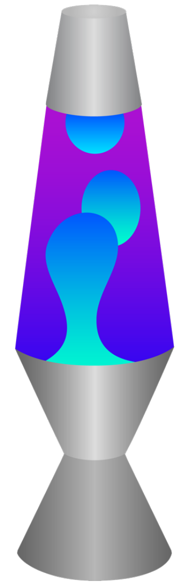


Three different mechanisms for heat interactions

For the space heater you considered earlier, the heat interactions between the heater and your hands, legs and face actually occurred via three different mechanisms. Scientists call these heat conduction, convection and infrared radiation. However, in most situations we encounter, all three of these mechanisms are responsible for the transfer of energy between objects that have different temperatures and so we choose to call them all simply *heat interactions*.

When warmer and cooler objects are actually in direct contact with each other, or when one part of a single object is warmer than another, it is called a *heat conduction interaction*. This was the case for the interaction between the heater and your hands when in contact with it. Other examples of heat conduction are a cold soda can warming up when held in someone's hand, or the handle on a pot becoming warm when the pot is on the stove.

When a gas or liquid is heated by being in contact with a warm object, and then this warm gas or liquid moves somewhere else (usually upward) and warms another cooler object by coming in contact with it, the interaction is called *convection*. This was the case for the interaction between the heater and your face, in which the heater warmed the air, which then rose upward and warmed your face. Another example of convection is found in the Earth's atmosphere. Unequal heating of the Earth by the Sun at the poles and the equator give rise to large movements of warm air toward the poles and cool air toward the equator, essentially transferring energy from the warm equatorial region to the cool polar caps. Lava lamps provide another example. In lava lamps, a lump of wax is heated in water; when heated sufficiently, it forms a semi-fluid blob that rise up through the water in the lamp. (View the image in color and a lava lamp YouTube video on the Student Resources website.)



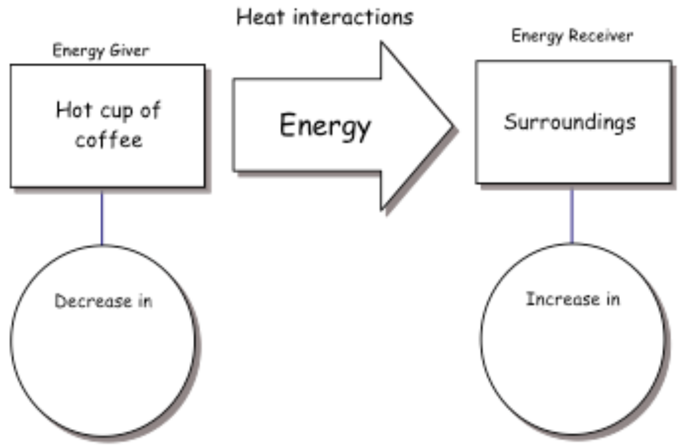
Infrared (IR) radiation is a non-visible form of radiation, emitted and absorbed by all objects, that was discussed in the previous activity. When two objects have different temperatures and there is a direct 'line of sight' between them, there is a net transfer of energy from the warmer object to the cooler one via the infrared radiation that can pass between them. This was the case for the interaction between the heater and your legs when standing directly in front of it. Since infrared radiation can pass through empty space, this is why you feel warm when you turn your face toward the Sun on a bright summer's day – there is an energy transfer across space from the Sun to you via IR.

You will learn more about these three different mechanisms in an extension activity.

Part 2. Considering interactions with the surroundings

As we consider scenarios involving interactions between two or more objects, there will always be cases where at least one of the objects warms up so that its temperature becomes greater than its 'surroundings '(including air and other objects, both touching and non-touching). In each such case, the object will become involved in heat interactions with, and transfer energy to, the surroundings. The object will then decrease in thermal energy and the surroundings will increase in thermal energy. For example, consider a hot cup of coffee that sits on a table in a small room.

Complete the G/R diagram below for the heat interactions between the hot cup of coffee and its ‘Surroundings’.



Assuming no other interactions are occurring at the same time, complete the statement of conservation of energy for the heat interactions between the hot cup of coffee and its surroundings.

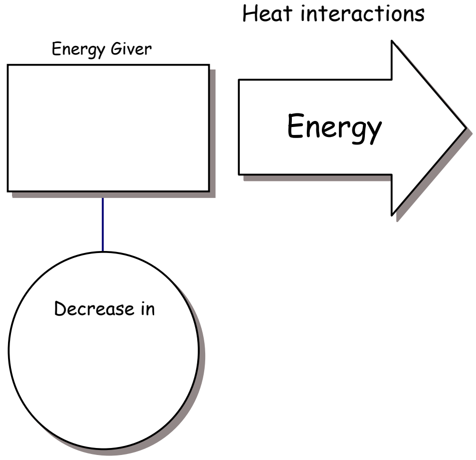
Decrease in ________________ *of* ______________________	=	*Increase in* ________________ *of* ______________________

Thus, whenever an object has a temperature that is different from other things around it, it will **always** be involved in heat interactions with them. When analyzing such situations with our energy model, we will therefore have to consider the ‘Surroundings’ as one of the objects involved.

Now consider another situation involving the surroundings of an object. Suppose you take a cold bottle of water out of the refrigerator, leave it on the kitchen table, and leave the room. When you come back sometime later, you find that the water bottle has warmed up to 'room temperature'.

Was the water bottle involved in any heat interactions while you were out of the room? If so, what do you think was the energy source and the energy receiver, and how do you know?

Complete this G/R diagram and statement of conservation of energy for the heat interactions that warmed the cold bottle of water.

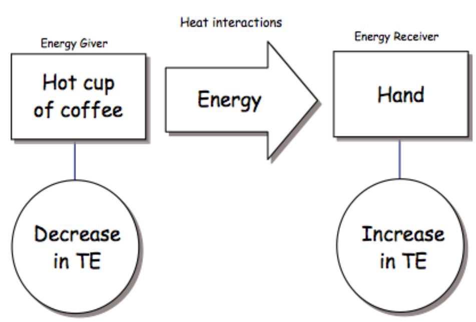


Decrease in ________________ *of* ____________________	=	*Increase in* ________________ *of* ____________________

In both of the situations above, **all** the other objects the hot coffee cup and cold water bottle were interacting with were considered part of the surroundings. However, if we are interested in how a particular object in the surroundings is behaving, we will consider it explicitly, and use 'Surroundings' to indicate all other objects that are not of particular interest, but must be taken into account. The situation considered next will illustrate this.

Consider holding a hot cup of coffee. Assume that while you are doing so, your hand is increasing in temperature.

When considering such a situation, some students drew this G/R energy diagram and then wrote the statement of conservation of energy below. (TE = thermal energy)



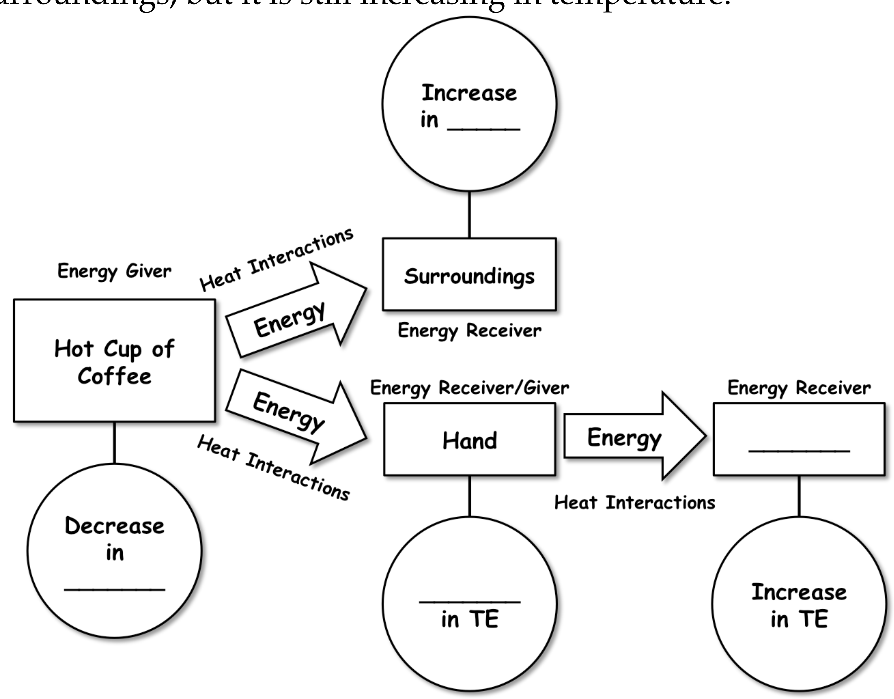
Decrease in TE of hot cup of coffee	=	*Increase in TE of hand*

What is problematic, or at least misleading, about this statement of conservation of energy?

What other objects, apart from the hand, would the **hot cup of coffee** likely be interacting with via heat interactions? How could we refer to this group of objects collectively?

Assuming the hand has warmed up somewhat, what other objects (apart from the hot cup of coffee) would the **warmed hand** likely be interacting with via heat interactions? How could we refer to this group of objects collectively?

Complete the following G/R energy diagram for all the heat interactions involved in this situation. Assume your hand is already warmer than the surroundings, but it is still increasing in temperature.



Use the completed energy diagram to help you complete this statement of conservation of energy for the heat interactions between the hot cup of coffee, the hand, and the surroundings while the hand is warming up. (Hint: You should have the same thing happening to the surroundings in two places in your diagram. For convenience you can group this together into one entry in the conservation of energy statement.)

*Decrease in*_____ *of* ___________	=	*Increase in* ______ *of* ___________	+	*Increase in* ______ *of* ___________

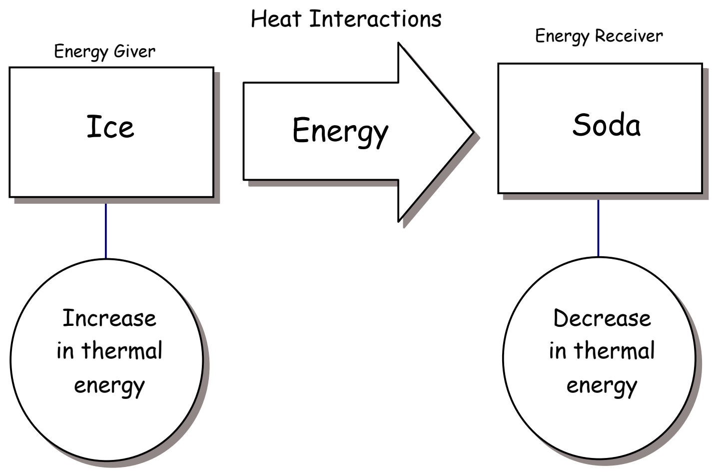
(Note that while we could consider the hand to be part of the 'Surroundings', if we want to explicitly analyze what is happening to the hand, we should treat it separately.)

Note that in the above case there are two competing processes occurring with the hand. The hand receives energy from the hot cup of coffee (via heat interactions) and also transfers energy out to the surroundings (via heat interactions). The energy transferred to the hand causes it to warm up, increasing its thermal energy. At the same time, the energy transferred from the hand to the surroundings would, by itself, cause the hand to cool down, decreasing its thermal energy. In other words, the hand is simultaneously both an *energy giver* and an *energy receiver*. In this case, however, because the hand is still warming up, the increase in thermal energy exceeds the decrease in thermal energy, so there is a net increase, which is what appears in the oval beneath the hand's box.

Summarizing Questions

S1. When you go on a picnic, a good way to cool down warm sodas is to put them in a cooler with some ice. A student used the energy model to write the following explanation for why a can of soda cools down when it is in such a cooler.

Describe the model using a diagram: (Draw a G/R energy diagram for the interactions responsible for cooling the soda.)



Write the narrative:

Since the ice and the soda are at different temperatures, there are heat interactions between them. During these interactions, energy is transferred from the ice to the soda, so the thermal energy of the soda decreases. This decrease means the temperature of the soda goes down.

CQ 5-1. Evaluate this explanation (both diagram and narrative) for accuracy.

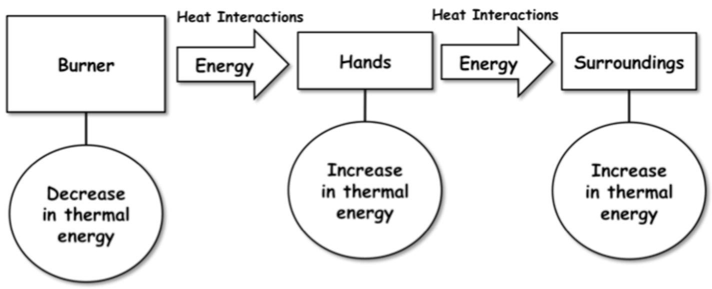
A. The diagram is accurate, but the narrative is not.
B. The narrative is accurate, but the diagram is not.
C. Both the diagram and narrative are accurate.
D. Neither the diagram nor the narrative is accurate.

If you chose A, B or D, what is specifically wrong with the explanation?

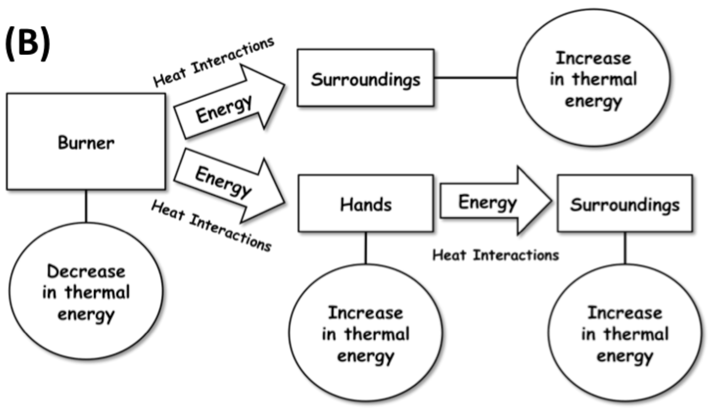
S2. Suppose you turn up the electric burner on a stovetop until the coils are warm, but not glowing. If you then turn off the burner, and then put your hands above the burner, they still feel warm for quite some time.

<u>CQ 5-2</u>: Which of the following three G/R energy diagrams best describes all the interaction(s) between the burner, your hands, and the surroundings as your hands are warming up and the burner is still warm (but cooling down)?

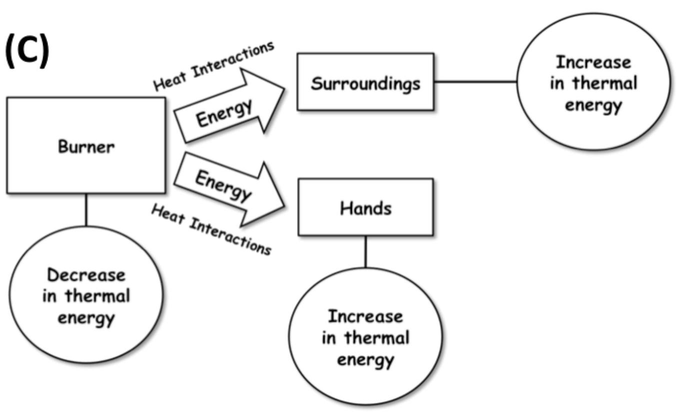
(A)



(B)



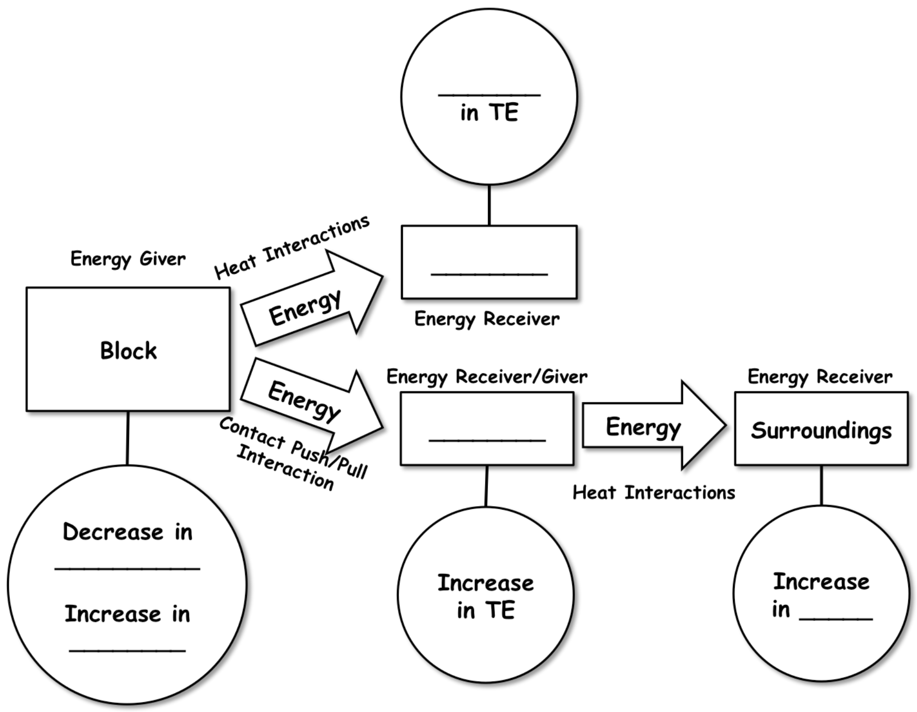
(C)



Write down a statement of conservation of energy for this situation. On the left side, the statement should include all energy decreases in the giver and/or receiver. On the right side, the statement should include all energy increases.

S3. Recall that in an earlier lesson you considered a block decreasing in speed as it slides across a table (**after** being given a quick shove). In this situation, you know that the block and the table are interacting with each other via a friction-type contact push/pull interaction, during which the block decreases in speed. This also causes the temperatures of both the block and the table to increase, which you now know will result in heat interactions between them and their surroundings.

Complete the G/R energy diagram for this situation below. Assume that the speed of the block is decreasing, but the temperatures of both the block and the table are increasing, with both already being at a higher temperature than their surroundings.



Use your completed diagram to help you complete this statement of conservation of energy for this situation.

Decrease in_____ of ___________	=	*Increase in _____ of ___________*	+	*Increase in _____ of ___________*
			+	*Increase in _____ of ___________*