Next Gen PET

UNIT EM

Developing Ideas

ACTIVITY 4: Warming and Cooling

Purpose

In the previous activity 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.

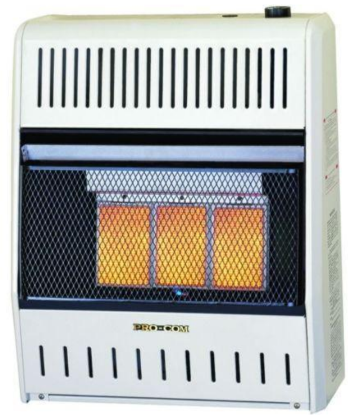
The purpose of this activity is to explore how we can incorporate these types of situations into our energy model by introducing another type of interaction.

ACT. ?

What other interactions can change the temperature of objects?

Collecting and Interpreting Evidence

Exploration #1: What happens when objects with different temperatures interact?



STEP 1: 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 switched-off heater while this was happening? What about the thermal energy of your legs, face, and hands? What evidence supports your answers?

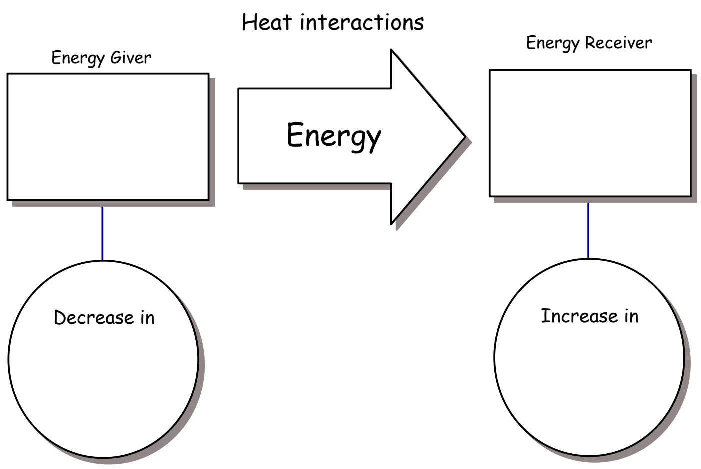
Do you think the switched-off heater was interacting with you? Why do you think so?

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.

STEP 2: 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 a **heat interaction.** Such an interaction takes place between two objects that have **different temperatures**, 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 other 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.

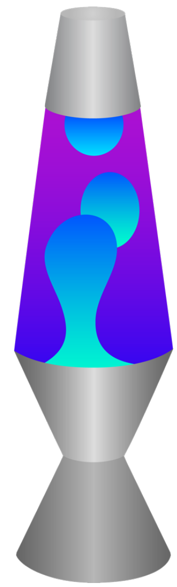


Three different mechanisms for heat interactions

In the situation you considered in Exploration #1, the heat interactions between the heater and your legs, face, and hands 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 chose to call them all simply *heat interactions*. You will learn more about these three different mechanisms in an extension activity but here is a brief description of them.

Heat conduction occurs when the warmer and cooler objects are actually in direct contact with each other, or when one part of an object is warmer than another. 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.

Convection occurs 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. 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.

Exploration #2: How do warm objects interact with their surroundings?

STEP 1. Imagine placing a hot cup of coffee on a table in a small room.

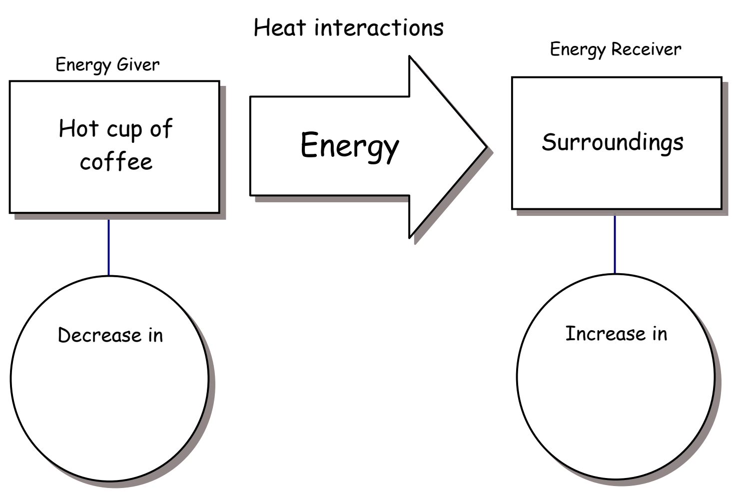
Suggest some objects in the room that the cup of coffee might be interacting with via heat interactions.

What effect would all of these heat interactions tend to have on the temperature of the cup of coffee?

What effect would all of these heat interactions tend to have on the temperature of the objects you identified?

Instead of identifying every single object in the room that the hot cup is interacting with via the different types of heat interactions, let us group them all together and simply call them the 'Surroundings'.

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.

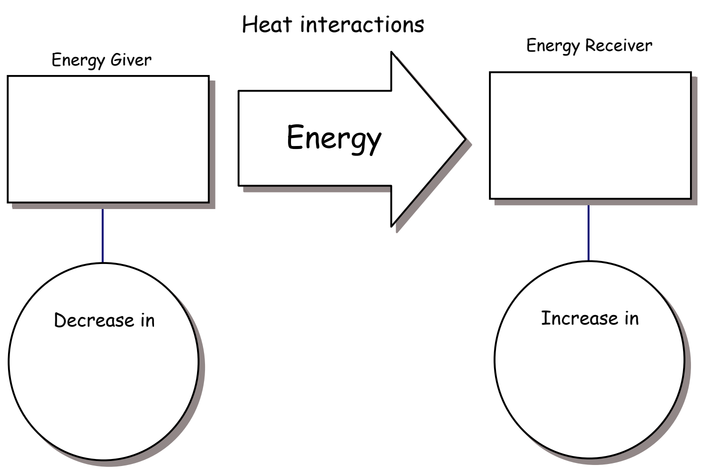
Decrease in ________________ *of* ____________________	=	*Increase in* ________________ *of* ____________________

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.

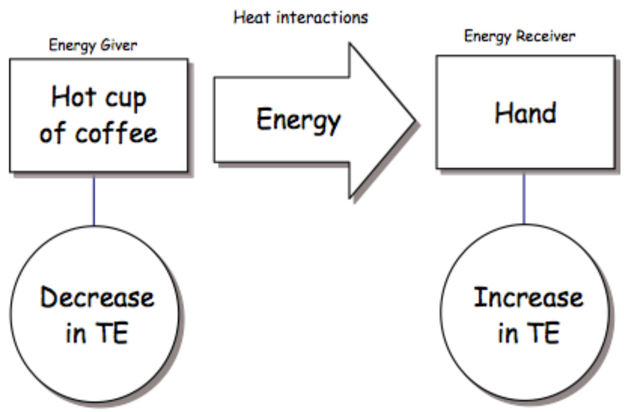


Decrease in ________________ *of* ____________________	=	*Increase in* ________________ *of* ____________________

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

STEP 2. Think about 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*

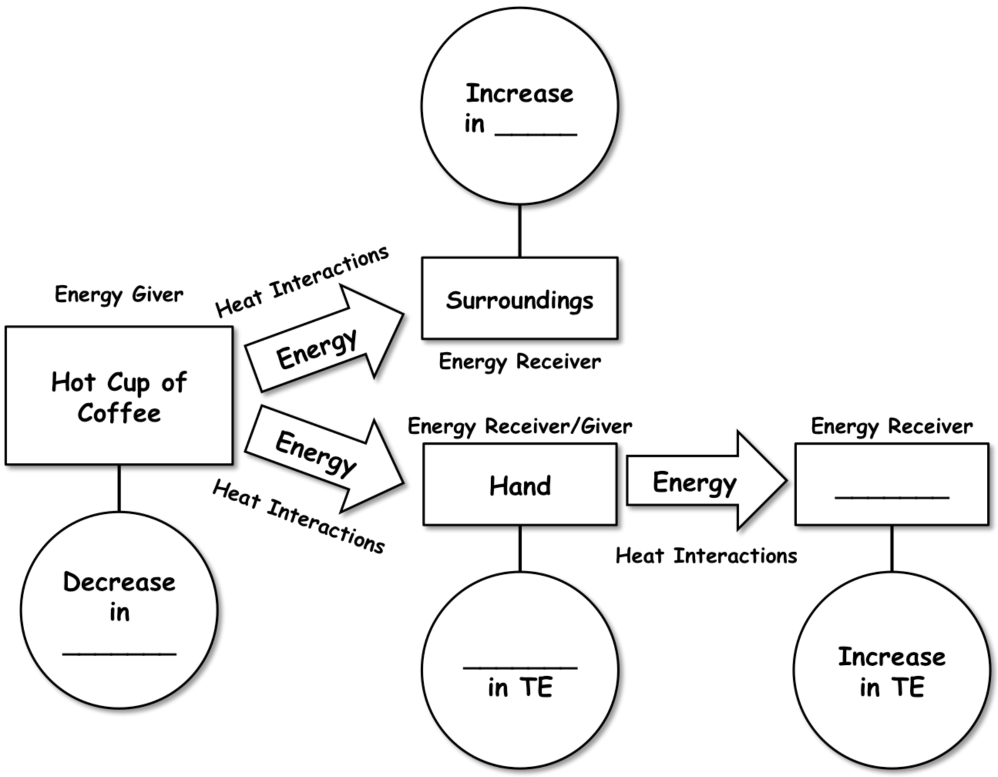
What is problematic, or at least misleading, about this statement of conservation of energy?

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 hand likely be interacting with via heat interactions? How could we refer to this group of objects collectively?

While we could simply 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.

Complete this G/R energy diagram for all the heat interactions involved in this situation. (Note that the hand is included as a separate object.) Assume your hand is already warmer than its surroundings, but it is still increasing in temperature.



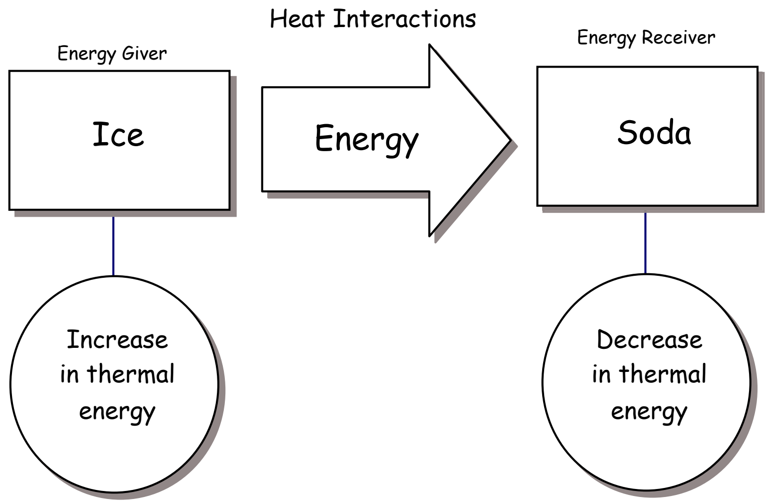
Use the completed energy diagram to help you complete this statement of conservation of energy for the heat interactions between the hot cup of coffee, the hand, and the surroundings while the hand is warming up. (Hint: You should have the same thing happening to the surroundings in two places in your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

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

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.)



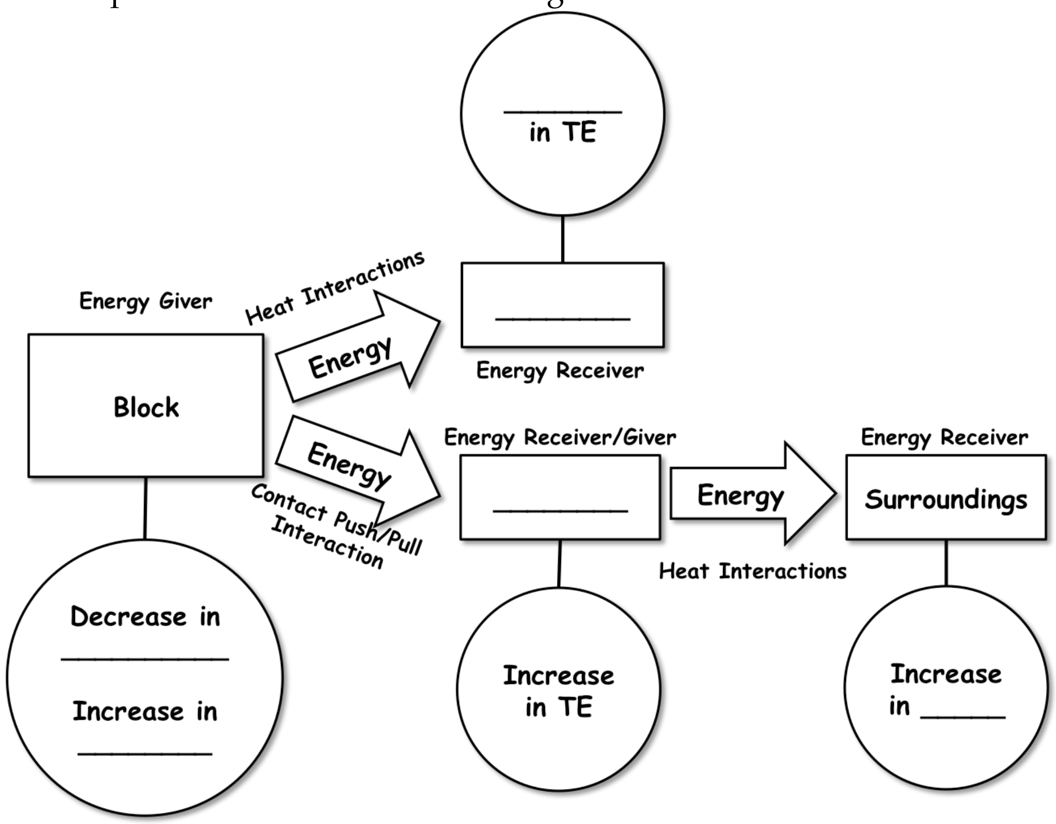
Write the narrative:

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.

Do you think this explanation (including the diagram) is 'good' or 'problematic'? Give your reasons and, if 'problematic', make any corrections you think necessary.

S2. Recall that in an earlier activity, 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 temperature 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 temperature 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 the statement of conservation of energy for this situation (next page).

Decrease in_____ of ____________	=	Increase in ______ of ____________	+	Increase in ______ of ____________
			+	Increase in ______ of ____________