MODULE

5

HEAT

In the previous modules, students learned about sound and light as forms of energy that travel in waves. This time, they will study about heat which is another form of energy that travels through moving particles or through radiation. In the first activity, they will determine the condition needed for heat to transfer from one place to another and the direction by which it transfers. Then they will observe and compare the different modes of heat transfer and identify some factors that affect the transfer of heat. They will specifically investigate how the color of the surface of the material affects it ability to absorb or emit heat. Lastly, they will apply what they learned in the module to describe how each part of the thermos bottle helps in keeping its content hot or cold for a longer period of time.

The lessons covered in Module 5 are relevant to life because they help explain some of our everyday experiences with heat. Also, some of the lessons covered in this module will be picked up in the next quarter when students learn about "weather and climate".

Key questions for this module

- How is heat transferred between objects or places?
- Do all objects equally conduct, absorb, or emit heat?

Heat and Thermal Energy

- At the start, students may be asked to give their own ideas about heat, based on what they learned in the lower grades or based on their everyday experiences with heat. Be aware of their misconceptions and take note of those which can be addressed by the module, like *cold is associated with lack of heat* or *heat is a substance that is in the object that makes the object warm.* Make sure to go back to them during the processing, wherever applicable.
- The difference between heat and thermal energy should be made clear to the students.

  Heat is a form of energy that refers to the thermal energy that is in the process of being transferred, say between objects due to the difference in their temperature. In other words, heat is energy "in transit". It transfers from an object of higher temperature to an object of lower temperature.

Activity 1 Warm me up, cool me down

- In this activity, students will analyze changes in the temperature of the water inside the containers to answer the following questions:
  a) What is the condition needed for heat transfer to occur between the containers?
  b) In which direction does heat transfer between them?
  c) Until when will heat transfer continue to occur?
- Since students will gather data using the thermometers, make sure that they know how to use the device properly and measure temperature accurately. If needed, give them a detailed review of how to use the thermometer and take data from it. Aside from the tips on how to measure temperature accurately, the following points may also be emphasized:
  a) Handle the thermometer with care to prevent breaking.
  b) Do not hold the thermometer by its *bulb* (the lower end of the tube)
  c) Do not 'shake down' the thermometer to reset it.
  d) Do not use the thermometer to stir the water inside the containers.
  e) Do not allow the thermometer to touch the bottom of the container.

- Each group should be provided with 4 thermometers – one for each container. If ever they have only one or two thermometers, they should be advised to consider one setup at a time.
- In the absence of a laboratory thermometer, students may use their 'sense of touch' to determine the relative hotness or coldness of the water inside the containers. Just make sure that if they do, they dip their fingers with care and use a different finger for each container. Students may be allowed to perform the activity provided in the module to show them how sense of touch may give different result in their activity.

Sample data:

Table 1

Container		Temperature (°C) of Water					
		0 (initial)	2 mins	4 mins	6 mins	8 mins	10 mins
Setup 1	**1** *(Tap water)*	23	23	23	23.5*		
	A *(Tap water)*	23	23	23	23		
Setup 2	**2** *(Tap water)*	23	39	42	43	44	44
	B *(Hot water)*	69	53	50	47	45	45

* This slight increase in temperature could be due to the warmer surrounding

Answers to the questions:

Q1. *Setup 2. Setup 1*

Q2. *Setup 2.*

Q3. *For heat transfer to take place, the objects must be of different temperature.*

Q4. *Container B. Its temperature decreases after 2 minutes.*

Q5. *Container 2. Its temperature increases after 2 minutes.*

Q6.
- *Heat is transferred from Container B to container 2.*
- *Heat is transferred from object of higher temperature to an object of lower temperature.*
- *Heat is transferred from a warmer object to a cooler object.*

Q7. *In container 2, the temperature of water continuously increases while the temperature of water in container B continuously decreases. Heat transfer is continuously taking place between the containers.*

Q8. *Heat transfer will continue to take place until both objects reach the same temperature (just like in Setup1)*

Q9. *The blue line shows that the temperature decreases as time increases. This represents Container B (with higher initial temperature).*

Q10. *The red line shows that the temperature increases as time increases. This represents Container 2 (with lower initial temperature)*

Q11. *The broken line shows that container 2 and container B have already the same temperature and their temperature is still decreasing as time continues. This time, heat transfer is taking place between the container and the surrounding.*

- At this point, it is important to emphasize that heat transfer will continue to occur as long as there is a temperature difference.

Methods of Heat Transfer

Heat transfer by Conduction

Conduction takes place when the particles between objects or places that are in contact vibrate and collide at different speeds due to the difference in their temperature. The particles at a higher temperature are more energetic and thus vibrate faster than the particles at the lower temperature. When these particles collide, some of the energy from the more energetic particles is transferred to the less energetic particles, in the form of heat.

Heat transfer occurs not only in solids but also in fluids, but not all conduct heat equally. Some materials conduct heat easily; other materials conduct heat poorly. Objects that conduct heat poorly, like wood are particularly called *insulators*. There is no particular name for those materials which conduct heat easily.

One basis for determining the use of materials is by their ability to conduct heat, known as their **conductivity**. Higher conductivity means that the material is a good conductor of heat. As shown in the table below, most

metals have higher conductivities; they are good conductors of heat. That's why they are generally used for products that require better heat conductivity like cooking utensils.

Table 2: List of thermal conductivities of common materials

Material	***Conductivity *W/(m·K)***	***Material***	***Conductivity *W/(m·K)***
Silver	429	Concrete	1.1
Copper	401	Water at 20 C	0.6
Gold	318	Rubber	0.16
Aluminum	237	Polypropylene plastic	0.25
Ice	2	Wood	0.04 - 0.4
Glass, ordinary	1.7	Air at 0 C	0.025

* Watt (W) is the unit of power where 1 watt is equal to 1 joule per second. 1 joule is equal to 0.24 calories.

Activity 2

Which feels colder?

* This activity is adapted from the book of Harry Sootin, entitled "Experiments with Heat"

- Motivate the students by asking them to touch or feel some objects found inside the classroom, like the metal bars or grills, the curtains, glass windows, the floor, the wooden chairs. Then ask some volunteers to share their observations to the class. Let them also try to explain their observations. Be aware of the misconceptions that students may give, such as the following:
  a) The objects have different temperatures.
  b) Some objects contain greater amount of heat than others.
  c) Some objects are naturally cooler than others.

  If ever, make sure to go back to these during the post activity discussion for clarifications.
- The first part of the activity must be done at home or in school one day ahead. In case there is no available refrigerator, students may just bring cooler with ice cubes inside the classroom where they can place their thermometer and samples before the day ends.
- For the second part of the activity, make sure that the students read the temperature from the thermometer or touch their sample objects while these are still inside the freezer (cooler). Bringing them out may affect

the result of their experiment, especially if the materials are already out for long. Also, make sure that the students feel each sample with a different finger. Lastly, make sure that each student will touch all the samples to determine their relative coldness. (Do not compare the coldness of an object with another object that is examined by another student) They can just compare their conclusions and answers to the questions with the other members of the group once they are done examining all their samples.

- During the discussion, emphasize that different objects or materials conduct heat differently. And this explains why even if they are of the same temperature, they do not feel (cold) equally. Materials with higher conductivities feel cooler than those with lower conductivities because they allow more energy to be transferred from the (warmer) finger than those with lower conductivities.

Answers to the questions:

Q1. *Answer will depend on their reading from the thermometer.*

Q2. *The temperature of the objects inside the freezer must all be the same because they are just exposed to the same condition. Their temperature must also be equal to the temperature that was read from the thermometer.*

Q3. *Yes. When my finger got in contact with the object, heat was trasferred from my finger to it.*

Q4. *Yes. Because my finger loses some amount of thermal energy (heat), so that makes me feel the object cold.*

Q5. *No, the objects did not feel equally cold. This means that the objects conduct heat differently. Some objects conduct heat more easily than the others.*

Q6. *Answers depend on the objects or materials used.*

Q7. *Answers depend on the objects or materials used. The coolest should be the best conductor.*

Heat Transfer by Convection

Heat transfer by conduction can take place in solids and in fluids. **Convection**, on the other hand, takes place only in fluids because it involves the movement of particles themselves from one place to another.

In the module, heat from the bottom part of the water is transferred to the upper part through convection. As the water gets warmer, it expands and become lighter and so it rises at the top of the cooler water. This will then be replaced by the cooler water that goes down from above, which will in turn become warmer and also will rise to the top.

Activity 3

Move me up

- Refer the students back to the conductivity table. Then ask them this question: *Is water a good conductor of heat*? When they say no, ask them again: *Then why is it that when we heat the bottom of the pan containing water, the entire water evenly gets hot so quickly?* Allow students to give their answers/opinions. Be aware of their misconceptions and make sure to go back to these during the post activity discussion. These may include be the following:

  a) The particles of the water travel faster than the particles of the solids.
  b) Heat is distributed so fast throughout the water (without mentioning how).

- Prepare the hot water prior to the activity. If available, better use an electric thermal pot for convenience. Remind the students to take extra care when pouring hot water into their containers.
- In the absence of liquid food coloring, students can use the 'water color' that they use for their arts activities. Make sure that the colored water is much cooler than the tap water.
- Remind the students not to bump the table nor shake the containers while doing the activity.
- The third and fourth steps are very crucial. Make sure that students follow them accordingly and very carefully.

- During the discussion, emphasize that following

  - This module considers convection in water only. Convection does not only take place in liquids. It also takes place in gases, like air. This will be discussed when they study about weather and climate in Earth Science.

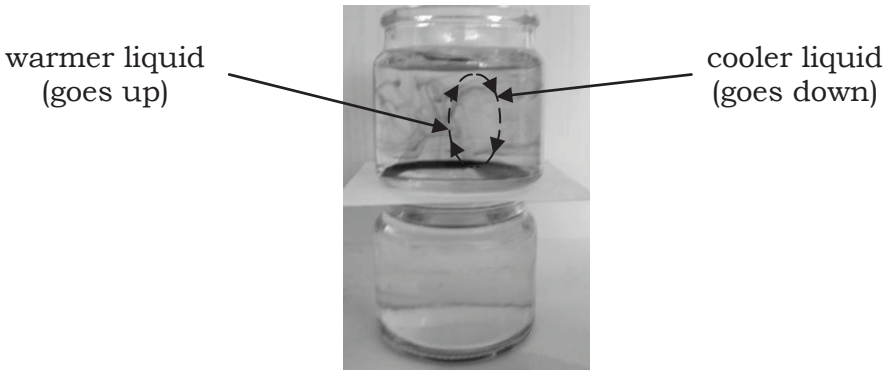
Sample answers to the questions:

Q1. *Most of the colored liquid stayed at the bottom (a small amount mixed immediately with the water).*

Q2. *When the container was placed on top of the other container with hot water, the liquid (water and food coloring) at the bottom rises slowly to the top.*

Q3. *Yes. Heat is transferred by the heated liquid that moved from the bottom to the top.*

- You can extend the discussion by asking the students to describe what happens to the cooler liquid on top.
- You can use the illustration below to discuss about **convection current**.



Q4. *Yes. The food coloring itself goes up.*

Q5. *Convection is a method by which heat is transferred through the liquid (or gas) by the movement of its particles.*

Q6. *(Students can be asked to try out this part).*

Heat Transfer by Radiation

Radiation refers to the emission of electromagnetic waves which carry energy away from the surface of the emitting body or object. In this process, no particles are involved, unlike in the processes of conduction and convection. This is why radiation can take place even in vacuum.

All objects emit and absorb radiation, known as thermal or infrared radiation. The amount of radiation emitted depends on the temperature of the emitting object. The hotter an object is, the more infrared radiation it emits.

Heat transfer by radiation takes place between objects of different temperatures, when the hotter object emits more energy than it absorbs from the cooler object and the cooler object receives more energy than it emits.

Activity 4 — Keep it cold

- This is an unstructured type of activity wherein will be the one to design their own experiment based on the given situation. They will construct their own problem, write their own procedure, and gather and analyze their data to arrive at an answer to the problem.
- Not all surfaces absorb or reflect radiation equally. Some surfaces reflect or absorb radiation better than others. The aim of this activity is to enable the students to compare the abilities of the two different surfaces to absorb or reflect radiation from the Sun or from a lighted electric bulb.
- To motivate the students, ask them of their favourite cold drinks. Then ask them how they usually make their drinks inside the container stay cold longer.

Prediction

At this point, there is no need yet to check whether their predictions are right or wrong. They should find out themselves later when they do their investigation.

Sample Design

- Testable Question: *Which container will keep the temperature of the cold milk tea longer?*
- Independent variable: *The surface of the container (dull and black surface or bright and shiny surface).*
- Controlled Variables: *The amount of the liquid, the amount of light entering the container (degree of exposure)*
- Dependent variables: *The temperature of the liquid inside the container at equal intervals of time*

Sample Answers to the Questions

Q1. *Dull black container*

Q2. *Dull black container*

Q3. *Bright shiny container*

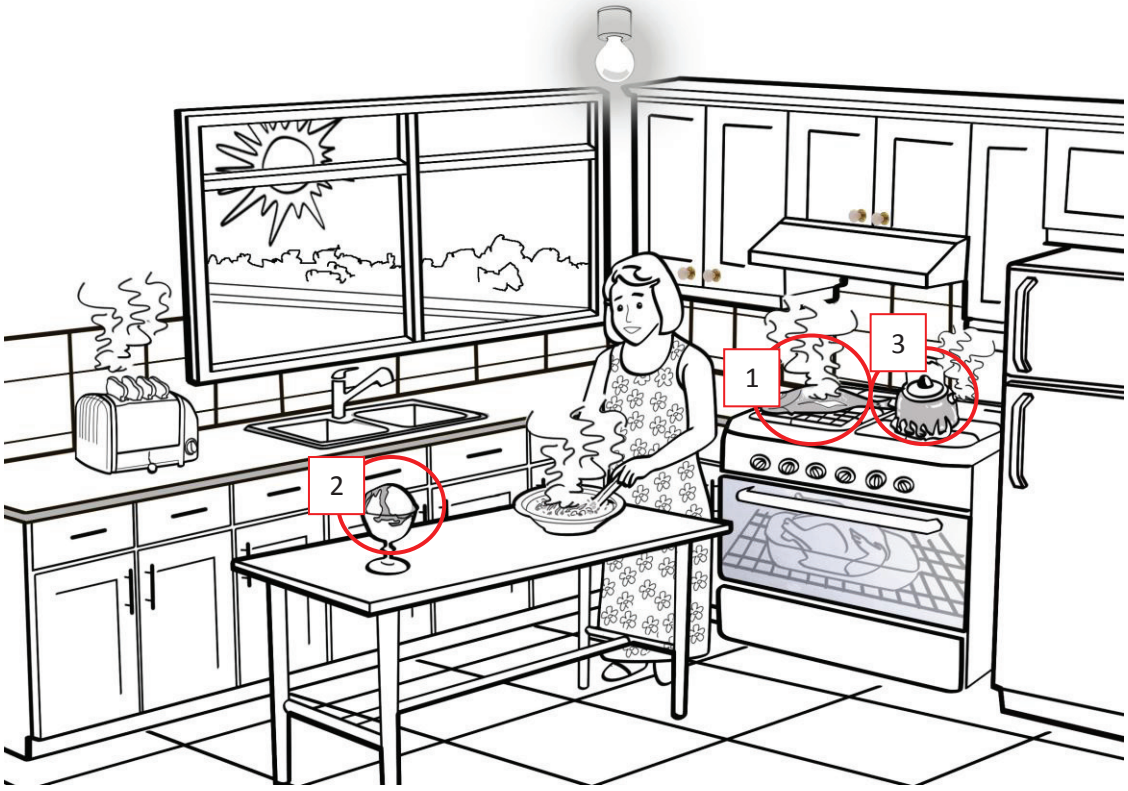
Q4. *No.*

Activity 5

All at once
(How much do you know)

These last two tasks are applications of what the students learned so far from this module.

Task 1: *What's For Dinner?*



Sample answers

	Description	***Which object gives off heat?***	***Which object receives heat?***	***What is the method of heat transfer?***
1	broiling fish	flame	fish	conduction/ convection
2	melting ice cream	sun	Ice cream	radiation
3	steam coming out of the kettle (with boiling water)	boiling water	Air above	convection

Task 2

(Adapted from: http://1e1science.files.wordpress.com/2009/08/13.pdf)

Below is a diagram showing the basic parts of the thermos bottle. Examine the parts and the different materials used. Explain how these help to keep the liquid inside either hot or cold for a longer period of time. Explain also how the methods of heat transfer are affected by each material.

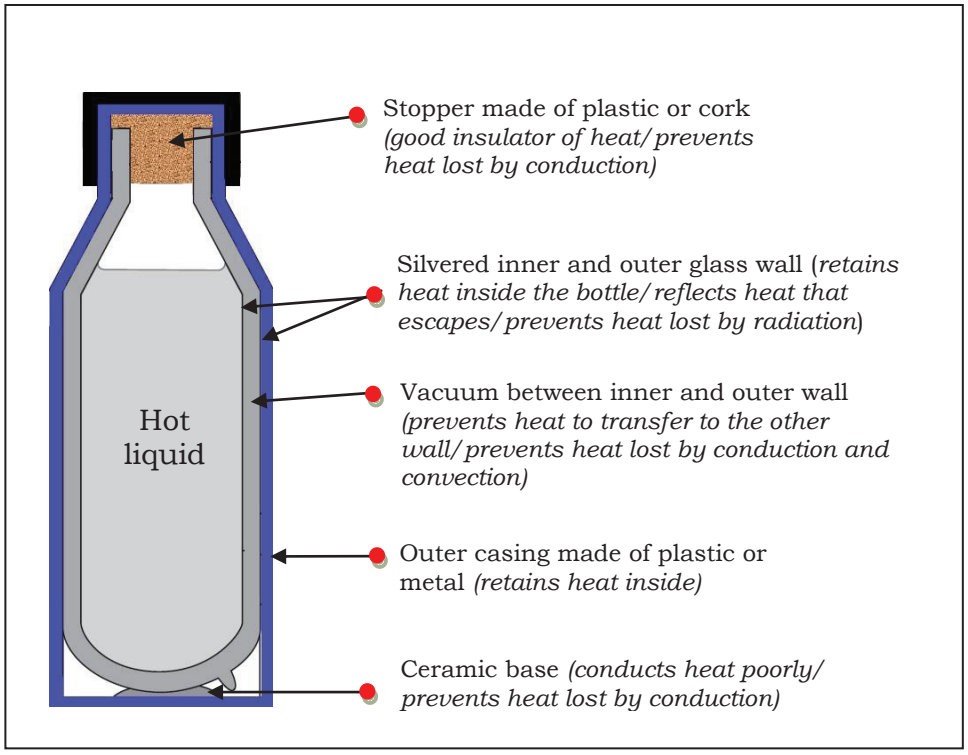


Figure 7: Parts of a thermos bottle

Summary

Below is a list of concepts or ideas developed in this module.

- Heat is a thermal energy that is in transit.
- Heat transfer takes place between objects of different temperature.
- When the object becomes warmer, it means that it gained energy. When it becomes cooler, it means that it lost energy.

- Heat energy always transfers from object of higher temperature to object of lower temperature.
- Heat can be transferred in three ways: conduction, convection, and radiation.
- Conduction takes place due to the vibrating and colliding particles of objects that are in contact. It can take place in solids, liquids, and gases but it takes place best in solids.
- Conductivity refers to the ability of the material to conduct heat. The higher the conductivity of the object, the better it conducts heat.
- Metals are mostly good conductors of heat.
- Convection takes place in fluids because their particles can move around. In convection, the heat is transferred by the particles themselves.
- During convection, warmer liquid or gas expands and goes up while cooler liquid or gas moves down.
- Heat transfer by radiation does not need particles or a medium to take place.
- Different surfaces emit or absorb heat differently. Dull and black surfaces absorb heat better than bright and shiny surfaces.

PRE/POST TEST

The illustration on the right shows a lady making a noodle soup using a pan made of metal. Use this illustration to answer the questions below:

1. How does heat travel through the pan?
   A. by radiation
   B. by convection
   C. by dispersion
   D. by conduction

2. How does heat travel through the soup?
   A. by radiation
   B. by convection
   C. by dispersion
   D. by conduction

3. In what direction does heat travel through the soup?
   A. from top to bottom
   B. from bottom to top
   C. both A and B
   D. neither A nor B

4. Which of the following explains why the lady is able to hold the handle of the pan with her bare hands?

   I. The handle is made of good insulator of heat.
   II. The handle has low thermal conductivity.
   III. The handle has high thermal expansion.

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II, and III

5. Which of the following methods of heat transfer is NOT taking place in the given situation?

   A. Conduction
   B. Convection
   C. Radiation
   D. None of them

Answer Key

1. D
2. B
3. B
4. A
5. D

Links and References

Classroom Clipart. "Marine Life." [Online image] 23 October 2003. http://classroomclipart.com/cgi-bin/kids/imageFolio.cgi?direct=Animals/Marine_Life

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/transfer.html