The Basics of Heat Transfer

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Summary:
In this lesson, students will learn the basic mechanisms governing the science of heat transfer, namely, conduction, convection and radiation. Students will know how to distinguish between the three in every-day life and will be able to conduct simple experiments showing each different mechanism at work with modern objects. This lesson incorporates lectures as well as demonstrations and activities to enforce the academic material.

Learning Objectives:
- Understand conduction, convection and radiation in theory
- Recognize heat transfer mechanisms used in everyday life
- Understand thermal conductivity

Lesson Plan:
The lesson plan is divided up into three sections. The first section is dedicated to the introduction of heat and heat transfer. The second section is dedicated to understanding heat transfer via conduction. The third and final section is dedicated to the understanding of convection and radiation. Each section will be paired with a demonstration or activity to give light to each concept. Any background or supporting information can be found in a physics textbook or a more advanced text on heat transfer. Adjustments may be made as desired. For further explanations on any of the material, please feel free to consult
http://www.physicsclassroom.com/class/thermalP/Lesson-1/Methods-of-Heat-Transfer,
http://www.explainthatstuff.com/heat.html

Session 1
Lecture: Basic introduction to heat transfer is desired here. In the lecture should be included such facts as what heat is (a form of energy), how it is transferred (conduction, convection, and radiation), how it is measured (temperature readings) and that the resulting science based off this knowledge is called heat transfer. Objects with a lot of heat also have a lot of energy.
object is hot or has a lot of heat energy, its molecules are moving about quite quickly. When an object has little heat energy or is deemed cold, its molecules are moving about slowly if at all. Explain how heat transfer always transitions from “cold” to “hot”. It may also be important to note that what is very special about heat transfer is the rate at which heat is conducted throughout a substance. Here begins the idea of thermal conductivity. Explain that conduction, takes place in substances as molecules of the substance absorb the heat energy and vibrate against each other, passing the heat energy from a hot area to a cold area. Metals such as copper are typically good heat conductors due to the presence of free electrons amidst their molecules.

Activity 1

Instructions: Have students stand in rows tightly packed together. Explain to them that each one of them represents a molecule. Have a student from one end of a row move through the entirety of the group to get to the other side. Once that is done, have each of the students hold hands. One row may commence to jump up and down or otherwise exert energy. Have the students next to them try their best not to move while the one row is jumping about. Explain to the students that jumping up and down can symbolize energy flow in molecules.

Constructive questions:
1. How did the student moving through the crowd affect those that they had to push past?
2. How did the one row of students jumping up and down affect nearby joined students?
3. How does this relate to energy, and heat energy specifically?

Demonstration 1
Materials: 5” long copper bar, 5” long nickel bar, and 5” long wood bar, stand to place all three on, Bunsen burner, matches, wax
Instructions: Align all of the three materials together such that the centers overlap but the ends do not touch. Place the combined materials on the stand above the Bunsen burner with wax on each end of each material. Light the Bunsen burner underneath the joining section of the three assembled bars. If done correctly, the wax should melt on the end of each bar according to each material’s thermal conductivity. Count the time it takes for the wax on each material to melt.

Constructive questions:
1. Which material’s wax melted first?
2. Why was this?
3. What explains the difference in thermal conductivity between copper and wood?

Session 2
Prerequisites: Session 1

Lecture: Explain convection, its overall part in heat transfer by fluids such as liquids and gases and how it is responsible for heat transferring from hot areas to cold ones in liquids and gases. A good example to use could be one of when hot air rises. The hot air molecules on the floor of a
room are in a place of higher density, and seeking an area of lower density, will rise to the ceiling, being replaced by cold air molecules in a rather cyclical event. This also can be seen occurring in the process of boiling water. When boiling water, bubbles come out of the top of the water. For explanation, they can learn that the same principle that occurs when hot air rises in a room is also governing the boiling water. Compare and contrast with conduction as methods of heat transfer between solids, liquids and gases. Give examples of convection other than hot air rising such as ocean air and water currents, occurrences of convection in the earth’s mantle, etc. To explain radiation, one can start by emphasizing that radiation occurs in a vacuum and does not involve molecules necessarily. Whereas conduction can be viewed as molecules vibrating against each other to pass heat energy, and convection can be seen as fluids moving and shifting to pass along heat, radiation is the heat transfer via a wave, or more specifically, an electromagnetic wave. There are various types of radiation such as seismic waves, radio waves, etc. Radiation is how the earth receives the necessary heat for life from the sun. Give examples of heat transfer by radiation such as sun tanning. It is also an emittance of energy; when heat radiates, it shoots out in all directions. Hot things expand while cold causes them to contract.

Demonstration 2
Materials: Rectangular glass container for water (a miniature aquarium is appropriate), divider which can split area in the container into halves, access to hot and cold water, food coloring

Instructions: Divide the container into halves using an appropriate divider. Fill one half of the container with cold water. Fill one half of the container with hot water and food coloring. Once the food coloring has set in completely, lift the divider. Note how the hot water can be traced as infiltrating the cold at random.

Activity 2
Materials: Tea bags, matches

Instructions: Give each student a tea bag. Have them empty the contents and remove everything except the paper bag material of the tea bag. Then, each student should set the bag upright so that it is a vertical paper cylinder. Light the entire top-most area of the bag on fire for them so as to prevent incident. Convection should cause each of the fiery bags to float to the ceiling.

Demonstration 3
Materials: Beaker filled with ice, heat lamp

Instructions: At the beginning of the lecture, set the beaker filled with ice beneath the heat lamp, and turn the heat lamp on. Towards the end of the lecture, there should be some melted water in the bottom of the beaker.

Constructive questions:
1. What are some examples of convection other than that just demonstrated?
2. How does radiation compare as a heat transfer method to conduction and convection?
3. What is the importance of the fact that radiation occurs in a vacuum?
Wisconsin Academic Standards covered in this lesson plan:

A.8.6 Use models and explanations to predict actions and events in the natural world
C.8.3 Design and safely conduct investigations* that provide reliable quantitative or qualitative data, as appropriate, to answer their questions
D.8.8 Describe and investigate the properties of light, heat, gravity, radio waves, magnetic fields, electrical fields, and sound waves as they interact with material objects in common situations
E.8.3 Using the science themes during the process of investigation, describe climate, weather, ocean currents, soil movements and changes in the forces acting on the earth