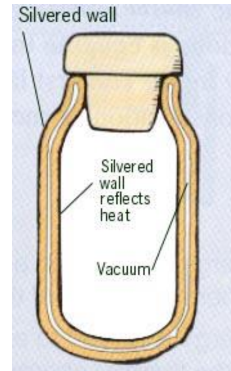
I. Objectives

1. Explain the differences among conduction, convection, and radiation.
2. Investigate thermal conductivity in common metals, convection in water, and radiation in a radiometer.

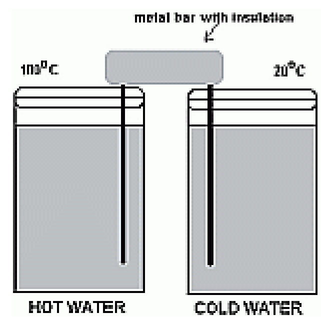
II. Introduction



This lab utilizes Bunsen burners and hot water. You must wear goggles when working with Bunsen burners and hot water.

Convection, conduction and radiation are the three ways in which heat is transferred. All three heat transfer methods, or any combination of the three, can occur simultaneously. A thermos bottle, for example, is designed to minimized all three forms of heat transfer. A vacuum reduces conduction, mirrored sides minimize radiation, and a tight lid minimizes cooling of the air above the liquid's surface by convection. (http://www.physlink.com/Education/AskExperts/ae601.cfm)

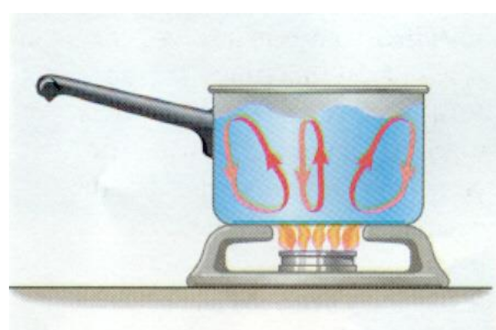
Part 1 Conduction



Conduction is the transfer of energy through matter from particle to particle, usually in solids. All atoms vibrate, but vibrate more when heated. Heat spreads by conduction when atoms increase their vibrations, and pass this energy on to nearby atoms.

In metals, free electrons carry the heat energy faster than the atomic vibrations and transfer it by colliding with other electrons and atoms, which makes them excellent conductors of heat energy.

Part 2 Convection



Convection is the transfer of heat by the circulation or movement of heated parts of a liquid or gas due to temperature variations, density differences, and the action of gravity. Convection functions because heated fluids, due to their lower density, rise and cooled fluids fall. A heated fluid will rise to the top of a column, radiate heat away and then fall to be re-heated, rise and so on. No convection occurs between or within solids.

Convection cells can be millimeters across or larger than Earth, but all work the same way. Towering vertical clouds, which can evolve in minutes, are a good example of convective processes. The tops of the clouds have a cauliflower appearance as warm moist air rises through the center of the cloud. The moisture in the cloud condenses as it cools. The air gives up some of its heat to the cold high altitude air and begins to fall.

Convection also occurs on the Sun. High resolution solar images reveal a pattern resembling rice grains, the result of very large convection cells. The bright center of each cell is the top of a rising column of hot gas. The dark edges of each grain are the cooled gas beginning its descent to be reheated. These granules are the size of Earth and larger. (http://www.solarviews.com/eng/edu/convect.htm)

Part 3 Radiation

Radiation is the transfer of energy by electromagnetic waves. This energy can take the form of infrared radiation or heat, visible light, radio waves, and x-rays, and unlike conduction and convection, radiation does not require a material medium.

A radiometer consists of a set of vanes, each shiny on one side and blackened on the other. When exposed to light, the vanes revolve. The first radiometer was constructed to settle the controversy regarding whether light exerts a force. It was believed that a reflecting surface would experience a greater force from the light than an absorbing one, however, the opposite effect was observed.

The blackened vane retreated from the light source because the black surface is warmer than the shiny one and gas molecules will recoil faster from the hot surface. The slight difference in molecule recoil is what causes the device to spin. Later experiments in a much better vacuum have confirmed that light does exert a very small pressure. (http://www.belljar.net/radio.htm)

III. Calculations

Part 1 Conduction

Conduction of heat through a material is determined using:

$$Q = \frac{kAt\Delta T}{L}$$

where k is the thermal conductivity constant of the material, A is the cross-sectional area, ΔT is the temperature difference between the hot and cold ends at temperatures, and L is the length of the bar.

Part 2 Convection

The calculations required to determine heat transport via convection are situation specific, and will not be dealt with in this lab.

Part 3 Radiation

Radiant energy is calculated using the Stephan-Boltzmann law:

$$Q = e\sigma T^4 At$$

where Q is the radiant energy, e is the emissivity, σ is the Stephan-Boltzmann constant, A is the surface area and t is the time.

IV. Equipment and Materials

Five prong thermal conductivity apparatus, wax, metal spatula, expansion ring and sphere, bunsen burner, 1,000 mL beaker, hot plate, food coloring, radiometer, flashlight, calculator

V. Procedure

Part 1 Conduction

1. Find the values of the thermal conductivities of aluminum, brass, copper, nickel, and steel.

2. Place a small ball of wax in each of the holes at the end of each of the prongs of the conduction apparatus.

3. Using the Bunsen burner, heat the thermal conductivity apparatus slowly and carefully by holding it above, but **not in**, the flame of the burner and record the order in which the wax melts, where 1 = melted first, and 5 = melted last.

4. Complete Table 1.

5. Heat the metal sphere. Try passing the sphere through the expansion ring, then heat the expansion ring and try it again. Record your observations.

Part 2 Convection

6. Place a large beaker of cold water on a hot plate and place a drop of food coloring in the middle of the beaker.

7. Record your observations of the food coloring as the water heats.

Part 3 Radiation

8. Place the radiometer under different lighting conditions and record your observations.

VI. Data

Table 1 Thermal Conductivities and Melt Order Data

A	B	C
Metal	Thermal conductivity	Melt order
Aluminum		
Brass		
Copper		
Nickel		
Steel		

VII. Discussion Questions

Part 1 Conduction

1. How is thermal conductivity related to the order in which the wax melted?

2. Under which conditions could you pass the sphere through the expansion ring? Why?

3. Why do metals on outside doors and railings feel cold to the touch on a winter day, even though they are the same temperature as the outside air?

Part 2 Convection

4. Explain your observations of the food coloring in the beaker.

Part 3 Radiation

5. Under which conditions did the radiometer rotate most rapidly and most slowly? Why?