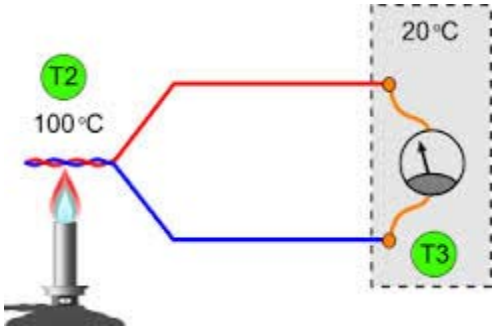
PHYS:1200 LECTURE 17 — THERMODYNAMICS (2)

In this lecture we will discuss a commonly used device for temperature measurement – the thermocouple, several thermal effects and their applications, and the mechanisms of heat transfer— convection, conduction, and radiation.

17-1. Practical Thermal Effects and Applications

(a) Thermocouples.—A **thermocouple** is a device which uses an electrical property of metals to measure temperature. Thermocouples are the basis for many commonly used digital thermometers, e.g., the probes that are used to measure the temperature of a turkey or to measure your own temperature.



A thermocouple consists of two wires made from **different metals** (indicated as red and blue wires in the figure) that are connected together at one end. The other ends are connected to an electronic circuit that measures current. When the connected ends are heated, a current flows through the circuit and the amount of current is proportional to the temperature. The circuit is then calibrated so that the current reading is the actual temperature. The advantage of a thermocouple thermometer compared to say a mercury thermometer is that the **thermocouple operates over a much wider range of temperatures.**

Thermocouples are also used as **safety devices** in gas heaters which use a pilot light to ignite the gas. A thermocouple is placed in the pilot flame. As long as the pilot light is on, the thermocouple circuit detects a certain amount of current flowing in it and allows the main gas

valve to open. If the pilot light goes out for some reason, the thermocouple circuit detects a lower current and prevents the main gas valve from opening. (**see slide 5**).

b. Thermal expansion.—**The length of a metal rod increases as the temperature of the rod increases.** In fact, not only metals, but nearly all materials increase in length when they are heated. The expansion of materials that make roads and bridges must be taken into account in their design, otherwise problems occur like buckling (**slide 11**). Metal bridges that must operate in cold winters and hot summers must have expansion gaps (**slides 9 and 10**) to deal with this effect. In fact, when an object is heated, all dimensions increase (**slides 12, 13**).

The fractional change in length of a rod = change in length/initial length is proportional to the change in temperature with a proportionality factor that depends on the material. The proportionality factors called the coefficient of linear expansion of various materials are listed on **slide 8**.

Thermal expansion of a liquid in a glass capsule is used to trigger fire sprinklers (**slide 15**).

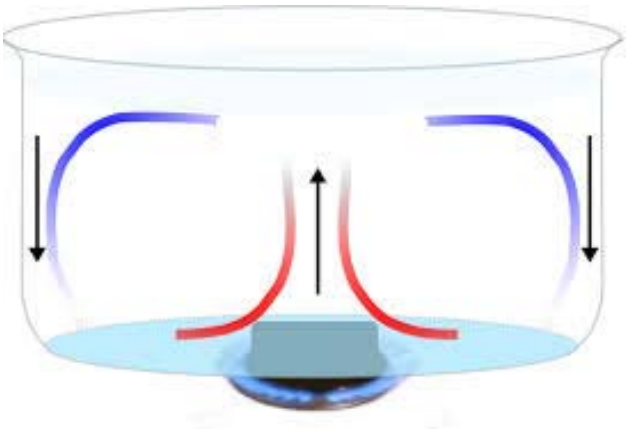
c. Bi-metal strips.—Thermal expansion is used purposefully in bi-metal strips. These are two thin strips of different metals that are bonded together. When heated, the metals expand at different rates, causing the strip to bend. This effect is used as a temperature sensor in coffee pots and hair dryers (**slides 17, 18**).

17-2. Heat Transfer Mechanisms

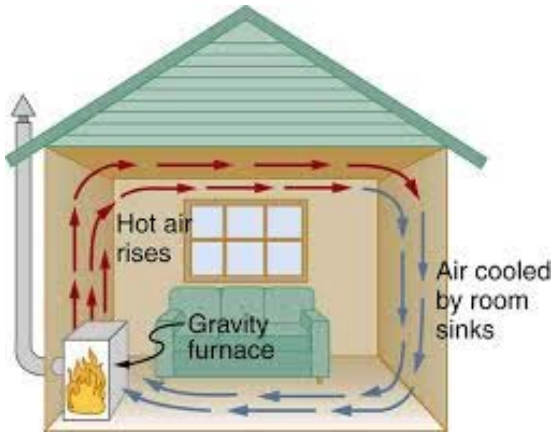
Heat is energy transferred from one body to another when they are at different temperatures and are placed in contact. The heat flow stops one they come to a common temperature. There are three mechanisms by which heat is transferred.

a. Convection.—Heat transfer by convection occurs in liquids and gases but not in solids. **Convection is the transfer of heat from one location to another by the bulk movement of fluids.** For example: when water is heated in a pot, the hot water on the bottom of the pot flows upward and mixes with cold water at the top (Figure A below). Convection in a liquid can be observed as the vigorous motion of boiling water. Another example is in a heated room (Figure B below). Air, heated in the furnace, is blown into the room from vents on the floor. The heated air rises and

mixes with the cooler air in the upper part of the room. Convection of air plays a large role in the earth's atmosphere.

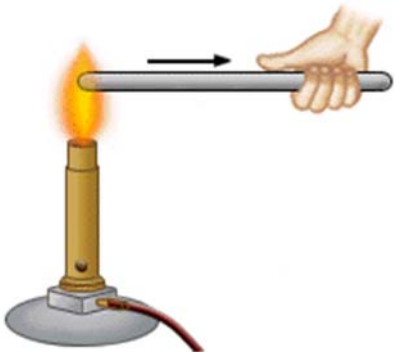


A. Convection in a liquid



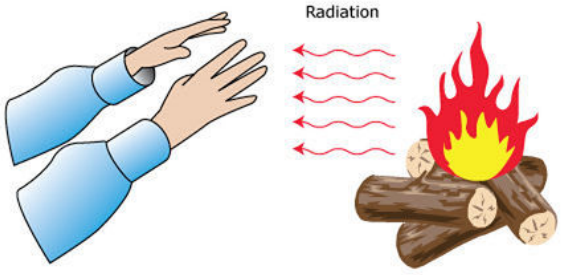
B. Convection in a gas

b. Conduction.—Conduction can occur in solids, liquids and gases, but it is the major form of heat transfer in solids. **Conduction is the transfer of heat energy directly through a material, but with no bulk movement of the material itself.** It is important in solids because the molecules of a solid are not free to move about as in liquids or gases. Conduction is illustrated in a situation where one end of a metal rod is placed in a flame. Eventually the heat is *conducted* to the other end of the rod --- it gets hot! Conduction depends on the properties of the material and is characterized by a parameter called the thermal conductivity. A table of the thermal conductivities of some common materials is given on **slide 21.** Materials that have a high thermal conductivity are referred to as "good heat conductors." Metals are good heat conductors. Materials that have low thermal conductivities are called poor thermal conductors or thermal insulators. Wood and glass as examples of poor thermal conductors or thermal insulators. The ability of an object to conduct heat depends on its thermal conductivity value, and on its geometry. The heat flow is proportional to the cross-sectional area of the rod, A, and inversely on its length, L. In terms of insulating materials, such as insulation in



the walls of a house, the length corresponds to the amount of insulation between the outside and inside walls. More insulation placed between the inside and outside walls provides better thermal insulation. The insulating material keeps the heat in the winter and out in the summer.

c. Radiation.—**This is heat transfer by the emission or absorption of electromagnetic waves from an object.** All objects that are not at zero degrees absolute temperature radiate (emit) invisible electromagnetic waves. The warmth you feel on a cold but sunny day in the winter is due to the Sun's thermal radiation. The heat you feel emanating from a fireplace is also thermal radiation. Even if an object is not in contact with another material, it can lose heat by radiation. Objects that are in outer space, far from the sun, gradually cool off due to the emission of radiation. A more detailed discussion of radiation will be given in the next lecture.



The figure below illustrates a situation in which all three forms of heat flow are occurring.