Measurement of Thermal Conductivity

Aim: To determine thermal conductivity of a bad conductor.

Apparatus: The Thermal Conductivity Apparatus includes the following equipment:

- Base, Weighing balance
- Steam chamber with hardware for mounting sample
- Ice mold with cover
- Materials to test: glass (This experiment can be done with other materials such as wood, lexan, masonite, and sheet rock and the wood, masonite, and sheet rock are to be covered water leak proof.)

Theory: Heat can be transferred from one point to another by three common methods: conduction, convection and radiation. Each method can be analyzed and each yields its own specific mathematical relationship. Thermal Conductivity Apparatus allows one to investigate the rate of thermal conduction through five common materials used in building construction.

The equation giving the amount of heat conducted through a material is:

Q = kATt/h.

In this equation, **Q** is the total heat energy conducted, **A** is the area through which conduction takes place, **T** is the temperature difference between the sides of the material, t is the time during which the conduction occurred and h is the thickness of the material. The remaining term, **k**, is the thermal conductivity of a given material.

The importance of **k** lies in whether one wishes to conduct heat well (good conductor) or poorly (good insulator).

The equation for determining k is:

k = Qh/ATt

The technique for measuring thermal conductivity is straightforward. A slab of the material to be tested is clamped between a steam chamber, which maintains a constant temperature of 100 °C, and a block of ice, which maintains a constant temperature of 0°C. A fixed temperature differential of 100 °C is thereby established between the surfaces of the material. The heat transferred is measured by collecting the water from the melting ice. The ice melts at a rate of 1 gram per 80 calories of heat flow (the latent heat of melting for ice).

The thermal conductivity, k, is therefore measured using the following equation:

$$k\left(\frac{cal.}{cm\ \sec K}\right) = \frac{(mass\ of melted\ ice).\left(80\frac{cal}{gm}\right).(thickness\ of material)}{(area\ of ice).(time\ during\ which\ ice\ melted).(temp.differential)}$$

where distances are measured in centimeters, masses in grams, and time in seconds.

Procedure:

1. Measure and record **h**, the thickness of the sample material.
2. Mount the sample material onto the steam chamber as shown in Figure 1. **NOTE: Take care that the sample material is flush against the water channel, so water will not leak, then tighten the thumbscrews. A bit of grease between the channel and the sample will help create a good seal.**
3. Measure the diameter of the ice block at 4 or 5 different heights. Record these value as $\mathbf{d_1}$. Place the ice on top of the sample as shown in Figure 1. Do not remove the ice but make sure that the ice can move freely in the mold. Just place the open end of the mold against the sample, and let the ice slide out as the experiment proceeds.
4. Let the ice sit for several minutes so it begins to melt and comes in full contact with the sample. (Don't begin taking data before the ice begins to melt, because it may be at a lower temperature than 0 °C.)
5. Obtain data for determining the ambient melting rate of the ice, as follows:
   i. Determine the mass of a small container used for collecting the melted ice and record it.
   ii. Collect the melting ice in the container for a measured time $\mathbf{t_a}$ (approximately 10 minutes).
   iii. Determine the mass of the container plus water and record it.
   iv. Subtract your first measured mass from your second to determine $\mathbf{m_{wa}}$, the mass of the melted ice.
6. Run steam into the steam chamber. Let the steam run for several minutes until temperatures stabilize so that the heat flow is steady. (Place a container under the drain spout of the steam chamber to collect the water that escapes from the chamber.)
7. Empty the cup used for collecting the melted ice. Repeat step 5, but this time with the steam running into the steam chamber. As before, measure and record $\mathbf{m_w}$, the mass of the melted ice, and **t**, the time during which the ice melted (5-10 minutes).
8. Finally, measure the diameter of the ice block at different heights and record these values as $\mathbf{d_2}$.

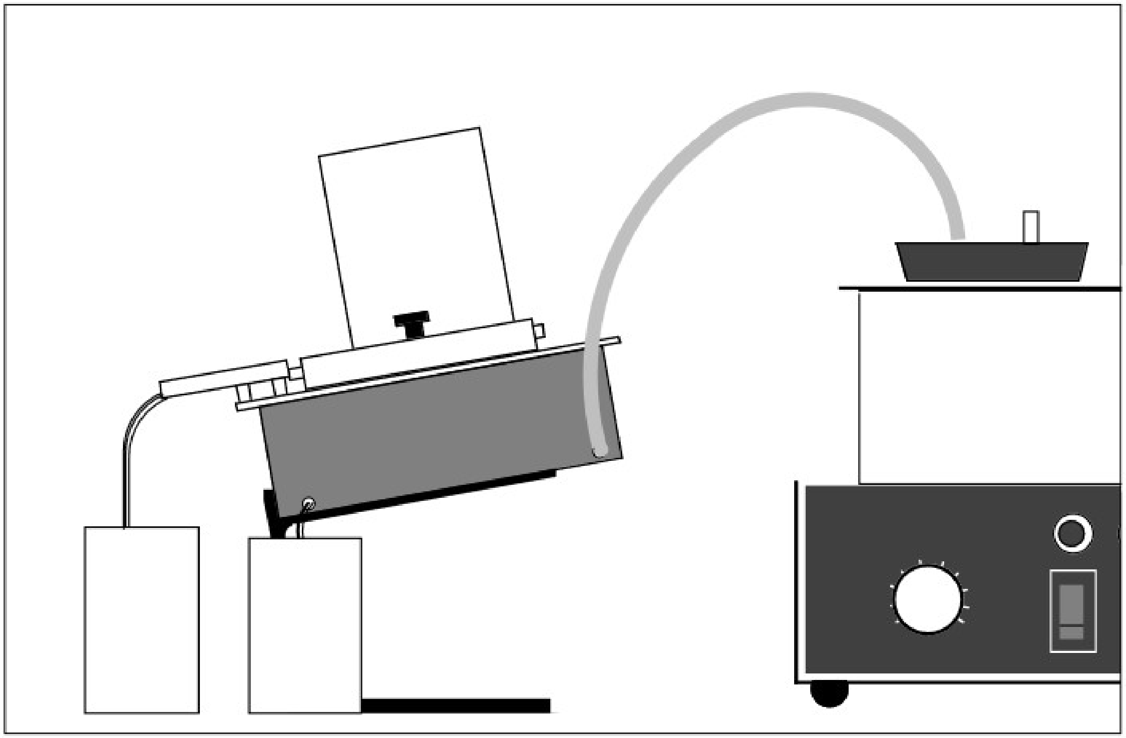

Figure 1: Thermal Conductivity experiment setup

DATA AND CALCULATIONS

1. Take the average of $\mathbf{d_1}$ and $\mathbf{d_2}$ to determine $\mathbf{d_{avg}}$, the average diameter of the ice during the experiment.
2. Use your value of $\mathbf{d_{avg}}$ to determine **A**, the area over which the heat flow between the ice and the steam chamber took place. (Assume that **A** is just the area of the ice in contact with the sample material.)
3. Divide $\mathbf{m_{wa}}$ by $\mathbf{t_a}$ and $\mathbf{m_w}$ by **t** to determine $\mathbf{R_a}$ and **R**, the rates at which the ice melted before and after the steam was turned on.
4. Subtract $\mathbf{R_a}$ from **R** to determine $\mathbf{R_0}$, the rate at which the ice melted due to heat flow through the bad conductor.
5. Calculate **k**, the thermal conductivity of the sample and estimate the error in **k**.

Data and Calculation Tables

Table – 1: Table for diameter (d_1)

Sl. No.	M.S.R.	V.C.	V.S.R.	Total
			Average d_1	

Table – 2: Table for diameter (d_2)

Sl. No.	M.S.R.	V.C.	V.S.R.	Total
			Average d_2	

Table-3: Table for all measured data

Sl. No.	h	d_1	d_2	t_a	m_{wa}	t	m_w	d_{avg}	A	R_a	R	R_0