Includes
Teacher's Notes
and
Typical
Experiment Results

Instruction Manual and Experiment Guide for the PASCO scientific Model TD-8561

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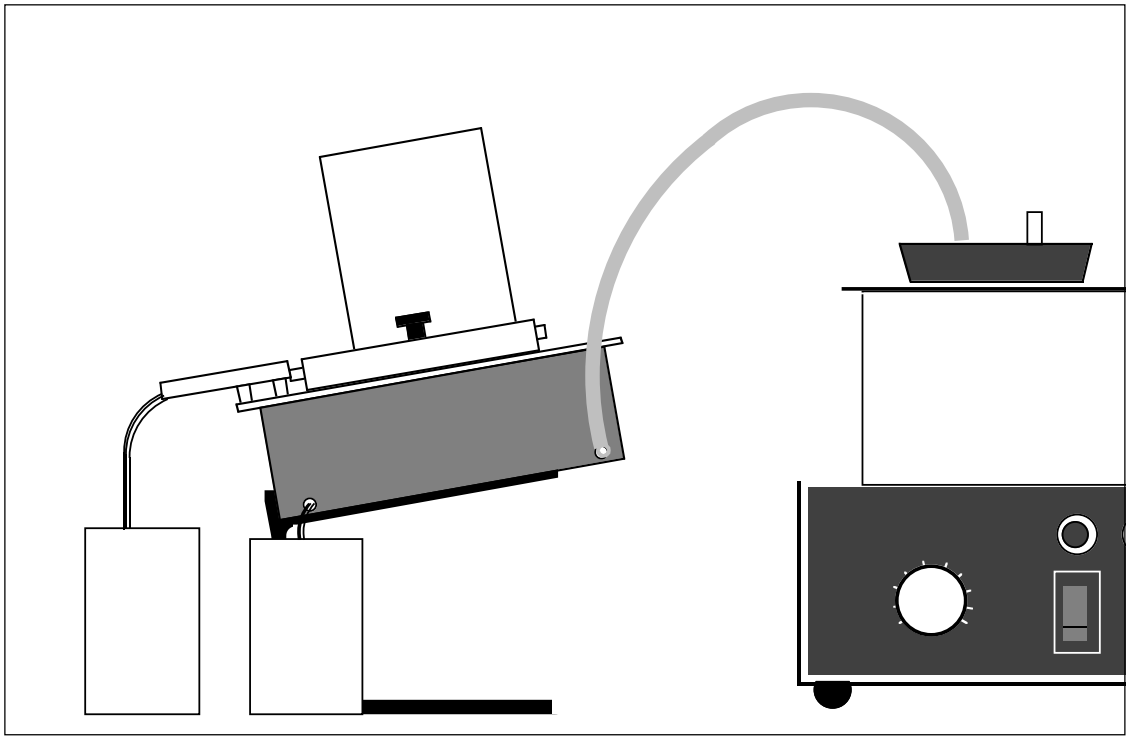
THERMAL CONDUCTIVITY APPARATUS



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Copyright, Warranty and Equipment Return

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When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

① The packing carton must be strong enough for the item shipped.

② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.

③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

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Introduction

Thermal Conductivity Apparatus

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. The TD-8561 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:

$$\Delta Q = k A \Delta T \Delta t / h.$$

In this equation, ΔQ is the total heat energy conducted, **A** is the area through which conduction takes place, ΔT is the temperature difference between the sides of the material, Δt 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 units for **k** depend upon the units used to measure the other quantities involved. Some sample conversions between different possible sets of units are shown in Table 1.

	$\frac{\text{Btu in.}}{\text{in.}^2 \text{ sec } ^\circ\text{R}}$	$\frac{\text{Btu in.}}{\text{in.}^2 \text{ hr } ^\circ\text{R}}$	$\frac{\text{Btu ft}}{\text{ft}^2 \text{ hr } ^\circ\text{R}}$	$\frac{\text{Btu in.}}{\text{ft}^2 \text{ hr } ^\circ\text{R}}$
$\frac{\text{Watt cm}}{\text{cm}^2 \ ^\circ\text{K}}$	1.338×10^{-2}	4.818	57.82	693.8
$\frac{\text{Watt m}}{\text{m}^2 \ ^\circ\text{K}}$	1.338×10^{-5}	4.818×10^{-2}	0.5782	6.938
$\frac{\text{Watt in.}}{\text{in.}^2 \ ^\circ\text{R}}$	9.485×10^{-4}	3.414	40.97	491.7
$\frac{\text{Cal cm}}{\text{cm}^2 \text{ sec } ^\circ\text{K}}$	5.600×10^{-3}	20.16	241.9	2.903×10^{3}

Table 1

The importance of **k** lies in whether one wishes to conduct heat well (good conductor) or poorly (good insulator). Therefore, the relative size of **k** is of importance to designers and builders, and should be of importance to home owners.

Note further that choosing a material with a small value for **k** does not guarantee a well-insulated structure. The amount of heat conducted out in winter (and therefore needing to be replaced) depends also upon three other factors: area, thickness and temperature difference. The same holds true for heat conducted in during the summer.

The equation for determining k is:

$$k = \Delta Q \, h / A \Delta T \Delta t = _____$$

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:

$$k = (\text{cal cm/cm}^2 \text{ sec}) = \frac{(\text{mass of melted ice})(80 \text{ cal/gm})(\text{thickness of material})}{(\text{area of ice})(\text{time during which ice melted})(\text{temp. differential})}$$

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

The Thermal Conductivity Apparatus includes the following equipment (see Figure 1):

- Base
- Steam chamber with hardware for mounting sample
- Ice mold with cover (Part # 648-03427)
- Materials to test: Glass, wood, lexan, masonite, and sheet rock (The wood, masonite, and sheet rock are covered with aluminum foil for waterproofing.)

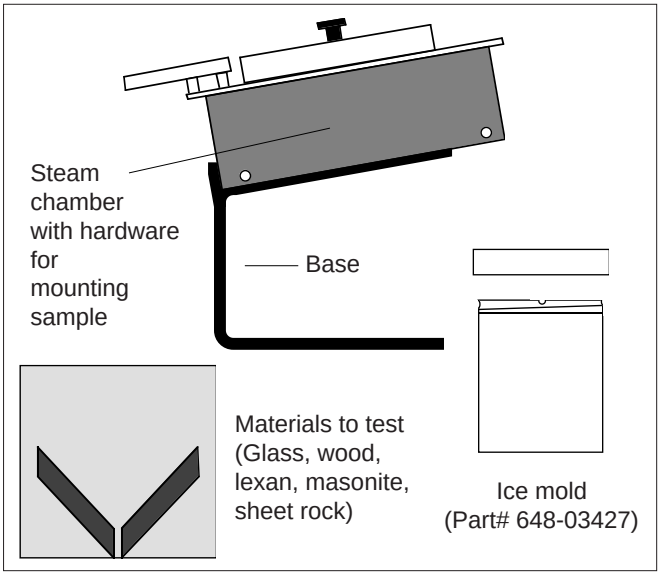

Figure 1 Equipment Included with the Thermal Conductivity Apparatus

Notes

Experiment: Measuring Thermal Conductivity

EQUIPMENT NEEDED:

- — Steam generator that will deliver approximately 10 grams/minute (e.g., PASCO's Model TD-8556 Steam Generator)
- — Freezer
- — Container to collect melted ice (a paper cup is fine)
- — Gram balance to weigh collected water (you could collect the water in a graduated flask, but your results will be less accurate)
- — Container to collect condensed steam
- — Grease such as petroleum jelly ("Vaseline")

Measuring Thermal Conductivity

① Fill the ice mold with water and freeze it. Do not freeze water with lid on jar. (A few drops of a non-sudsing detergent in the water before freezing will help the water to flow more freely as it melts and will not significantly effect the results.)

② Run jar under warm water to loosen the ice in the mold.

➤ **NOTE:** Do not attempt to "pry" the ice out of the mold.

③ Measure and record **h**, the thickness of the sample material.

④ Mount the sample material onto the steam chamber as shown in Figure 2.

➤ **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.

⑤ Measure the diameter of the ice block. Record this value as $\mathbf{d_1}$. Place the ice on top of the sample as shown in Figure 2. 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.

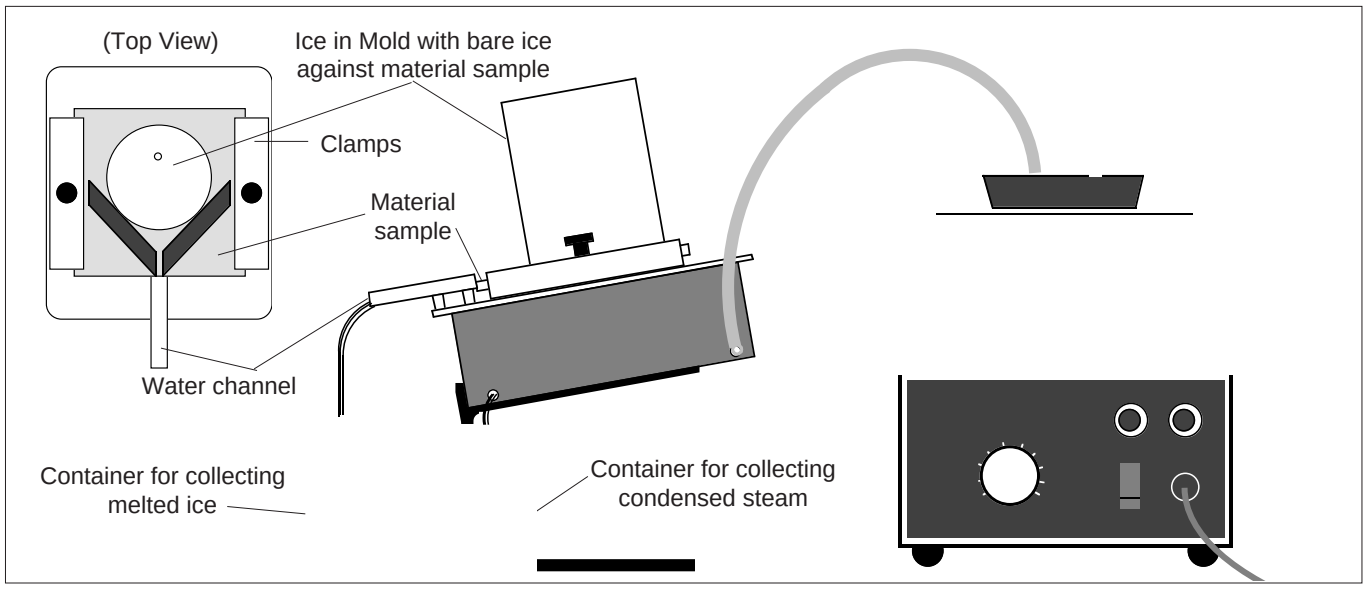

Figure 2 Experimental Setup

⑥ 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.)

⑦ Obtain data for determining the ambient melting rate of the ice, as follows:

a. Determine the mass of a small container used for collecting the melted ice and record it.

b. Collect the melting ice in the container for a measured time $\mathbf{t_a}$ (approximately 10 minutes).

c. Determine the mass of the container plus water and record it.

d. Subtract your first measured mass from your second to determine $\mathbf{m_{wa}}$, the mass of the melted ice.

⑧ Run steam into the steam chamber. Let the steam run for several minutes until temperatures stablize 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.)

⑨ Empty the cup used for collecting the melted ice. Repeat step 7, 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).

⑩ Remeasure the diameter of the ice block and record the value as $\mathbf{d_2}$.

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 the temperature differential only.

⑤ Calculate **k**, the conductivity of the sample:

k (cal cm/cm^2 sec) = _____

$\Delta\mathbf{T}$ = Boiling point of water (100 °C at sea level) - 0°C.

Data and Calculations Table

h	d_1	d_2	t_a	m_{wa}	t	m_w	d_{avg}	A	R_a	R	R_0

$$\frac{(R_0)\ (80\ \text{cal/gm})\ (h)}{(A)\ (\Delta T);}$$ _____

Teacher's Guide

Experiment: Thermal Conductivity Apparatus

Notes on Procedure

① Expect 10-15% error under normal (student laboratory) operating conditions.

② Keep the ice as isolated from the surroundings as possible. Our best results were obtained using a PASCO styrofoam calorimeter cup as an ice mold; however, this has the disadvantage of splitting the cup when the water freezes. (Medium-sized styrofoam cups also work very nicely.) Whatever mold you use, leave it on the ice during the experiment.

③ Apply a dab of grease to the joint between the plate and the water trough to prevent leakage. Vaseline® works well; it melts, but still seals the gap.

④ A note about the aluminum covers on some samples: This was found experimentally to have no measurable effect on the conductivity of the samples. We tested this using a glass plate which we measured both with and without an aluminum cover, and there was no statistically significant difference between multiple readings in both states.

Accepted Values

Substance	**cal•cm/cm^2•sec•°C**	**watt•m/m^2•K**
Masonite	1.13 x 10-^{4}	0.047
Wood (Pine)	206 - 3.3 x 10-^{4}	0.11 - 0.14
Lexan	4.6 x 10-^{4}	0.19
Sheet Rock	10.3 x 10-^{4}	0.43
Glass	17.2 - 20.6 x 10-^{4}	0.72 - 0.86

Note

Values (with the exception of Lexan) from the *Handbook of Chemistry and Physics, 46th Edition*, published by The Chemical Rubber Company. Value for Lexan is from a specifications sheet provided by the manufacturer. Values for Masonite and for Sheet Rock will vary considerably.

Notes

Technical Support

Feed-Back

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feed-back. Your input helps us evaluate and improve our product.

To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

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- If your problem is computer/software related, note:

  Title and Revision Date of software.

  Type of Computer (Make, Model, Speed).

  Type of external Cables/Peripherals.

- If your problem is with the PASCO apparatus, note:

  Title and Model number (usually listed on the label).

  Approximate age of apparatus.

  A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

  If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

- If your problem relates to the instruction manual, note:

  Part number and Revision (listed by month and year on the front cover).

  Have the manual at hand to discuss your questions.