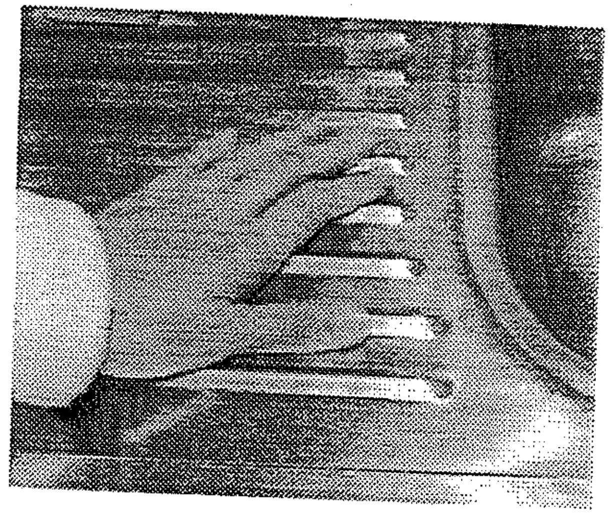
What materials are the coldest?

...an activity in temperature, heat transfer, and conduction.

Introduction:

In this lab you will use your hand as a thermometer to test what materials are colder than others. You will simply touch the different materials around the classroom at their ambient resting temperature and rank them from coldest to warmest. Be careful about warming them up with your hands though. Your body heat will warm the materials up as you touch them. Be careful about testing something right after someone else just warmed it up... When you are done with the questions you will continue to answer the questions and read the explanations in the sections that follow to understand the difference between temperature and heat transfer.



How do you feel when touching a metal surface?

Instructions:

1. Read the instructions for each step thoroughly before completing it.
2. From the list below, predict which materials will feel colder than others. Record your predictions by writing them into the data table with the coldest on top and the warmest on the bottom. You can add a couple materials that aren't on the list if you want.
3. Now walk around the room with your lab partner and each of you briefly touch one sample of each material and record how cold it feels. This is a subjective test but try to rank your results as accurately as you can from 1) really cold, 2) cold, 3) cool, 4) neutral, to 5) warm. (*If you don't know what subjective means, look it up in the dictionary.*) Be careful not to test something that has been artificially warmed up by someone's body heat, sunshine, or some other heat source. We want things to be at their ambient resting temperature. *(If you don't know what ambient means, look it up in the dictionary.*
4. Compare your predictions to the results from your "hand test." How did you do? Where there any surprises?
5. Now, the class will collectively measure the actual temperature of each type of material by placing a thermometer on the material. Wait until the reading on the thermometer equilibrates and then record those data in your data table. *(If you don't know what equilibrates means, look it up in the dictionary.)*
6. Hold the thermometer in your hand and record the temperature of your hand below the data table.
7. Hold the thermometer in the air and record the ambient air temperature below the data table as well.
8. Answer the post activity questions below.

Materials List:

a. Wood
b. Metal
c. Glass
d. Plastic
e. Cloth
f. Air
g. Water
h. ________
i. ________

Data Table

Materials Tested (Ordered according to your predictions: coldest on top, warmest on the bottom.)	**Hand Results:** (Really cold, cold, cool, neutral, or warm.)	**Measured Temperature** (°C)	**Coefficient of Conductivity** (W/m-°K)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

Hand temperature = ______ °C.
Room temperature at the time of the activity = ______ °C.

➢ **Post Activity Questions:** (Please answer on separate paper in complete sentences.)

1. Compare your hand's results to the thermometer's results. Were objects that "felt" colder actually colder?
2. How did the temperature of the objects compare to the ambient temperature. Are the objects in the room the same, colder, or warmer than then the ambient temperature?
3. Why do you think some objects "felt" colder than others if they are all the same temperature? It's ok if you don't know the answer. The following questions and explanations will help you figure out just what's going on.

Read the following passage on conduction of thermal energy gradients then continue to the next questions.

Microscopic interpretation of conduction

But what really happens in the process of conduction? Let's examine the process in the microscopic point of view. Recall that the internal thermal energy of an object is actually a measure of the average kinetic energy of its molecules. When one end of an object is heated, its temperature rises, the kinetic energies of the heated particles increase and the molecules vibrate more rapidly. Rapidly vibrating molecules push, pull, and generally knock around their more lethargic neighbors, causing them to vibrate faster too. This in turn affects other neighboring molecules, and energy is thus transferred from the hotter side to the colder side along the object. In this way, heat flows down the temperature gradient from hot to cold. It is as if the energy levels are trying to even out. The "cooler" molecules gain energy and speed up but only at the expense of the "hotter" molecules losing energy and slowing down. Left to itself, the energy flow will continue until all parts of the object have equal energy and the gradient essentially eliminates itself. The gradient can only be sustained if there is more energy being put into the system at one end, like in the picture above.

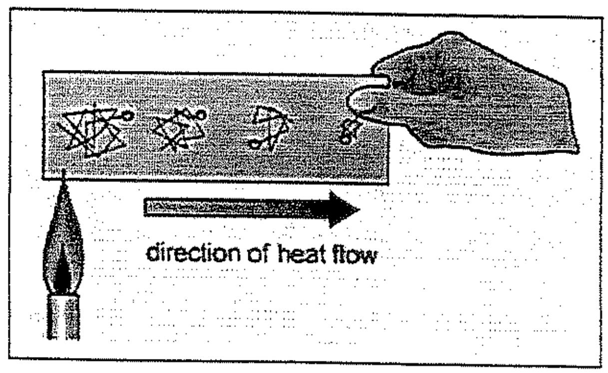


Fig. 1-3 Schematic illustration of heat conduction through a rod. Particles on the hot side vibrate more rapidly than that of the cold side.

Explanation: What is a gradient?

A gradient is anything that goes from high to low and things always flow down gradients. There are many different kinds of gradients in nature and they work a lot like the slope of a hill. You already know this because you already know that water always flows downhill. In nature you can find pressure gradients, slope gradients, electric gradients, concentration gradients, and many more. The way to find a gradient is to identify something that is flowing like air, electricity, heat, or water. Wherever there is a flow, there is a gradient causing it. At the most basic level, all gradients are caused by differences in energy levels and things inevitably want to go from high energy to low energy.

➢ **More Questions to answer:**

4. Which is higher, your body temperature or the ambient room temperature?
5. When you touch an object that is colder than your hand, which direction does the temperature gradient go: from your hand to the object or from the object to your hand? In other words, which is the "uphill" side of the temperature gradient and which is the downhill side? (The direction of gradients is always from high to low.)
6. So then, when you touch a cold object, which direction does heat flow?
7. OK, heat is kinetic energy of vibrating molecules. On the molecular level then, how does the "heat" get transferred down the temperature gradient from more active molecules to their less active neighbors?
8. What happens to the molecules in your hand once they pass come kinetic energy to the object?
9. Good. Now put it all together and describe in your own words, what is conduction? Your explanation should include temperature gradient, thermal energy, kinetic energy, molecules, and transfer.

Explanation: What is "cold"?

OK, we've thought about thermal energy, and heat conduction. Now let's think about the flip side: cold. After you touch a cold object like metal or glass, your hand gets colder. Thermal energy flows out of the molecules of your hand into the molecules of the colder object leaving your hand…colder. So you see, cold is, in essence simply the absence of heat energy. In fact when you get down to it, there's really no such thing as cold; there is only more or less heat energy. So cold does not flow, only heat does. It's like getting into bed when your covers are cold. The heat energy flows from your body into the covers and mattress until they warm up. Until you generate more body heat to replace the energy you've put into the blankets, you are left a little cold yourself. It is the energy flowing out of your body into the covers that leaves you cold. Cold did not flow from the bed into you. Luckily you are a mammal and generate a lot of body heat so you warm back up and have a cozy night's sleep.

➢ **More questions to answer:**

10. Explain why it doesn't make sense to say that cold flows from a cold object into your hand.
11. Explain why it is technically incorrect to say that a cold object "sucks" the heat out of your hand. In other words, is the energy transfer a "push" or a "pull." (Remember, there's no suck in science. Also, nature never sucks.)

Explanation: Good conductors feel colder.

OK, now we can begin to understand why some objects "feel" colder than others when in reality they have the same temperature. As you know now, what makes your hand cold is that heat is conducted out of it into the object that you are touching. The faster heat leaves your hand, the colder it feels. The key here is that not all materials conduct heat equally well. Good conductors easily transfer kinetic energy from one molecule to another. The way their molecules are packed and bonded together in good conductors, vibrating molecules easily get their neighbors vibrating. In bad conductors, also know as insulators, vibrations are not easily passed to neighboring molecules. Heat tends to stay where it is.

➢ **More questions to answer:**

12. Find the Coefficients of Conduction table at the back of your thermos activity handout. Look up the coefficients of conduction for the materials you tested in this lab and record them in the data table above. If the exact material isn't listed, use the coefficient for a similar type material. High coefficients mean that a material is a good conductor.
13. Compare the coefficients to how the materials felt. Is there a pattern that you can see? What is it?
14. Why do materials that are good heat conductors "feel" colder than materials that are bad heat conductors even though they are at the same temperature?
15. Why is a nice, puffy jacket good at keeping you warm?
16. In the outdoors, many people each year die of hypothermia when their core body temperature gets so low that their organs and cells stop functioning properly. One myth about hypothermia is that it must be very, very cold outside before there is a serious risk of it being a problem. In reality, the key risk factor for hypothermia is if a person gets wet. Many, many people get hypothermia in merely cool weather after accidentally getting caught out in the rain or falling in a stream. Looking at the coefficients of conductivity for water vs. felt, why does just getting wet make such a big difference in increasing the rate of heat loss from someone's body? Felt is a fluffy cotton material that has a similar coefficient of conductivity as dry clothing. In answering this question, it is not enough to simply say that water is a better conductor than felt. How much better is it? How many <u>times</u> better is water than felt at conducting heat?

Wrap up: <u>Temperature</u> vs. <u>Heat Transfer</u>

** The key to understanding the difference between what your hand was "feeling" and what the thermometer was measuring is to understand the difference between *<u>temperature</u>* and *<u>heat transfer</u>*.

➢ **<u>Thermometers read temperature:</u>** *Temperature* is proportional to how much thermal energy an object has. On the molecular level, that means the kinetic energy of the object's molecules.

➢ **<u>Your hand's sensation was dependent on Heat Transfer:</u>** *Heat transfer* is when thermal energy is moved to another place or object. *Conduction* is the most basic heat transfer process. A hot object can feel cool if it doesn't conduct heat very well. A cold object might not feel very cold if it doesn't conduct heat very well.

➢ **No more questions to answer.** ☺ ☺ ☺ ☺

Biology note: Most animals have special nerve cells called thermoreceptors which sense changes in temperature. Thermoreceptors send messages to your brain that tell you if their temperature is changing. Once they get used to a certain temperature they stop sending the message. That's why the shower feels really hot at first until you get used to it and why you have to keep turning the hot water up for it to continue to feel really hot.