Heat Flow: Teacher Notes

Introduction

The focus of the investigation is the flow of heat between two objects. The Temperature probe enables students to investigate quantitatively and measure the effect of heat energy flowing into or out of an object. This investigation allows students to think critically and logically about relationships between temperature and heat energy based on evidence and explanations.

In addition, students will gain experience with inquiry skills, including:

- realizing that heat (energy) moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature;
- identifying variables that can affect the outcome of an experiment;
- understanding that energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways;
- knowing that scientific investigations involve asking and answering a question;
- planning and conducting simple investigations (e.g., formulating hypotheses, designing and executing investigations, interprets data, synthesizing evidence into explanations, proposing alternative explanations for observations, critiquing explanations and procedures);
- establishing relationships based on evidence and logical argument (e.g., provides causes for effects);
- knowing that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing experimental procedures, examining evidence, identifying faulty reasoning, identifying statements that go beyond the evidence, suggesting alternative explanations).

Discussion Guide

Using this Guide

This guide is designed to help you convert the investigations your students experience into solid learning. The "Overview" section mentions some of the learning issues raised by this content. These issues might come up in conversations with students anytime. The "Setting the Stage" section provides ideas for a discussion you might hold before beginning the investigations. This discussion is important to motivate and alert students to observations that might answer their questions. The "Wrap Up" section can be used after the investigations to help student reflect on what they have done. Taking time to reflect while the investigations are fresh in students' minds has been shown to substantially increase learning.

Overview

The point of this investigation is to introduce heat energy. It is natural for your students to confuse heat and temperature. Help them by insisting that they carefully distinguish between temperature and heat. It is also helpful to consistently use the term "heat energy" instead of simply "heat". The Temperature probe can help make this distinction. We can define temperature as what is measured by the Temperature probe. This provides a clean, simple operational definition of temperature.

Unfortunately, we have no comparable way of measuring heat energy directly. All we can do is measure the effect of heat energy flowing into or out of an object. We can define heat energy flowing into the heat cell as whatever causes it to warm up. We can measure how much heat energy flows into the heat cell by measuring how much it warms up. For every degree the heat cell warms, ten joules of heat energy must have flowed into it. Conversely, if the heat cell cools by a degree, ten joules of heat energy must have flowed out of it. Whenever there is a change in the temperature of the heat cell, we can infer that heat energy flowed in or out by observing the temperature rise or fall.

This still doesn't tell us the total amount of heat energy in an object. All this definition does is tell how much heat energy has been added or subtracted. We cannot do better. Heat energy is a relative thing. I can choose to say that there is no heat energy in the heat cell when it is at 0.0 C. Then if it is at 25 C, I would say it contained 250 joules of heat energy because it needed 250 joules of heat energy to get it that warm. But someone else might define zero heat energy at 20 C, so they would say that it contained only 50 Joules of heat energy at 25 C.

Because heat energy cannot be measured, it seems mysterious. It would be wonderful to have some sort of thin plastic sensor we could wrap around an object that would tell exactly how much heat energy the object contained. Unfortunately, this sensor is impossible to make. Students will have to make do with measuring the change in temperature of the heat cell and using that to infer changes in heat energy of an object.

Heat energy flows from hot to cold. In the process, the hot object cools and the cold object warms. Heat energy continues to flow until both are at the same temperature. When this happens, no further heat energy flows and the temperature stays constant. This is why everything in a room tends to reach the same temperature: "room temperature".

Setting the Stage

Start by focusing student attention on the difference between heat energy and temperature. Define heat as a form of energy and tell students that they must always say "heat energy" to help remember this. Also, ban the term "heat up," which means "increase the temperature". Probe students to find out what they already know about heat energy. Ask: [It usually gets warmer.] [Heat energy flows into it.] [The bathtub starts with more heat energy than the cup. Removing heat energy from the big bathtub to warm the rock only cools it slightly because it starts with so much.] [Heat energy flows quickly from the hot water to the cool air above it. Normally this warms the air to the water temperature and heat energy flow stops. When you blow away that warmed air and replace it with colder air, more heat energy can flow out of the hot chocolate. As the hot chocolate looses heat energy this way, it cools.] [Heat energy from the iron heats the cloth. Because the iron contains a lot of heat energy, it gets the cloth quite hot.] [Heat energy is flowing from the hot stove into the water, but the water isn't getting hotter. Instead the heat energy goes into converting the liquid water into steam, a gas. This is one case in which the addition of heat energy does not result in a temperature rise.]

As soon as feasible, draw attention to the temperature probe. It responds very quickly and is so small that it barely changes the temperature of anything it is measuring. Have students get used to it by measuring temperatures around the room. Hold the sensor near their nose and observe their breathing by recording temperature variations.

Wrap Up

After the trials, return again to the distinction between heat energy and temperature. This may seem like overkill, but research shows that many middle school students fail to make this distinction, even when taught very well. Encourage students to reflect on their explorations. Ask: [A total of 120 joules of heat energy left the heat cell and warmed the water.] [An insulator slows down the flow of heat energy. The slower heat energy escapes a hot object, it longer it will stay hot.] [Yes. Keeping something cold requires blocking heat energy flow in. An insulator that blocks heat energy flow out works just as well at blocking heat energy flow in.]

Additional Teacher Background

When two equal volumes of water at different temperatures are mixed, the temperature is halfway between the two because the quantity of heat energy that flows between them cools one the same amount as it heats the other. Water also mixes quite quickly.

A solid, such as a ball of clay behaves differently. It doesn't mix physically with the surrounding water. The surface of the clay quickly reaches the water temperature. Then it takes some time for the heat of the clay to flow to the surrounding water (or the other way round, depending on which, is warmer). It may take several minutes for the water and clay to reach the same temperature. This new temperature will be somewhere between the two starting temperatures, but it depends on the quantity of each and their relative heat capacities or, in other words, how much heat energy each material gives up when it changes one degree Celsius. Water has a very high heat capacity compared to most common materials, including clay. So if equal weights of water and clay at different temperatures are mixed, the resulting temperature will be closer to the initial water temperature than that of the clay.

This brings up an important distinction between heat flow in fluids, such as water and air, and heat flow in solids. In fluids, the flow is often done by mixing - hot or cold substances traveling from one place to another. This is also called convection. It is usually driven by the fact that hot fluids are generally less dense and more buoyant than cold fluids, so they rise and circulate. Heating water on a stove, or hot air rising from the land on a sunny day, are good examples of conduction.

By contrast, the molecules in solids stay put. They can wiggle, but they cannot travel from one place to another. So energetic molecules transmit the heat energy in solids. They bump into their less energetic neighbors and pass the energy along. Electrons moving around also play a role. This is called heat conduction. Metals generally conduct extremely well. Materials like plastic foam, that trap air, are not as good conductors. Other materials, called insulators, are materials that slow down the flow of heat energy. Suppose the clay ball is hotter than room temperature. A temperature graph resulting from a Temperature probe in the center of the clay ball will drop quickly at first, then more slowly as it comes closer to room temperature. This is evidence that the rate of heat flow decreases as the difference between the two temperatures decrease. This smooth curve, that becomes less steep as it approaches the final temperature, is called a cooling curve.

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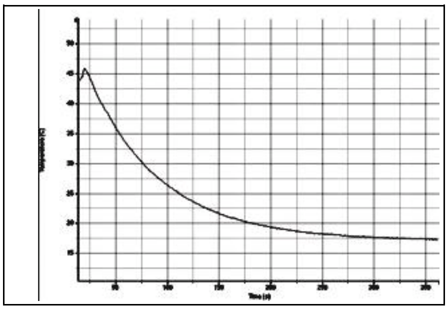
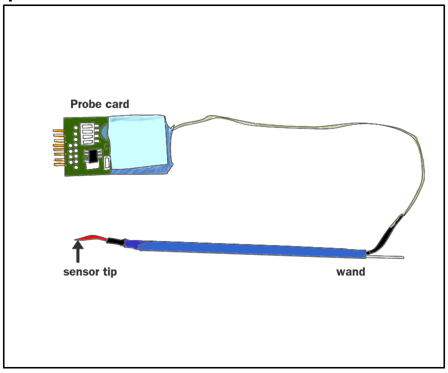


The Fast Response Temperature Probe uses a thermocouple to measure temperature. A thermocouple a made from two special wires, each of a different metal, with their ends twisted together or welded. When the temperature of that joint is different from the temperature of the other ends of the wires, a slight but highly predictable voltage is created. It comes from the way the two metals interact. Thermocouples are useful because they can work at very high temperatures. The CC Temperature probe can be put in a candle flame without damage.



The only sensitive part is the tip where two special bare wires are twisted together. The wires produce a voltage depending on the temperature, and the program converts this to degrees (C or F). The response is very fast, because the two wires are small and easily heated or cooled by whatever they touch.

Suggested Timeline

The amount of time you spend on introductory discussions, data collection, and analysis, will determine your overall timeline. The following represents a possible timeline.

One class period - "Setting Up" discussion

One class period - Trial I: Mixing the bath water just right

One class period - Trial II: Reaching equilibrium in temperature

One class period - Trial III: Using insulation to prevent heat flow

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

