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ABSTRACT

This teacher's guide suggests activities that provide opportunities for children in grades 5 through 8 to explore, by direct experiment, the ways in which various materials behave when they are heated and cooled. Included within this guide are explanations for a set of Problem Cards which suggest experiments for students to try individually. (CS)

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Teacher's Guide for

Heating and Cooling

Elementary Science Study

WEBSTER DIVISION, McGRAW-HILL BOOK COMPANY
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The Heating and Cooling Unit

Teacher's Guide for Heating and Cooling
Problem Cards for Heating and Cooling
Kit for Heating and Cooling

Related Units

Gases and "Airs"
Ice Cubes

ISBN 07-017709-0

Preface

The Elementary Science Study is one of many curriculum development programs in the fields of science, social studies, and mathematics under preparation at Education Development Center, Inc. EDC (a private non-profit organization, incorporating the Institute for Educational Innovation and Educational Services Incorporated) began in 1958 to develop new ideas and methods for improving the content and process of education.

ESS has been supported primarily by grants from the National Science Foundation. Development of materials for teaching science from kindergarten through eighth grade started on a small scale in 1960. The work of the project has since involved more than a hundred educators in the conception and design of its units of study. Among the staff have been scientists, engineers, mathematicians, and teachers experienced in working with students of all ages, from kindergarten through college.

Equipment, films, and printed materials are produced with the help of staff specialists, as well as of the film and photography studios, the design laboratory, and the production shops of EDC. At every stage of development, ideas and materials are taken into actual classrooms, where children help shape the form and content of each unit before it is released to schools everywhere.

Acknowledgments

Many people have helped in the development of HEATING AND COOLING. Paul S. Lorris originated the unit and developed the activities and equipment with the help of H. Paul Jolly. After much classroom teaching, they prepared a trial teaching edition.

Revisions in the Teacher's Guide and Problem Cards were made in response to recommendations made by teachers in trial classes across the country. Norma Arnow prepared the commercial edition with technical guidance from Joe Griffith.

Adeline Naiman edited the manuscript and refined it to its present form. Nancy Weston handled its design and production.

Joan Hamblin and Major Morris took the photographs which appear throughout the manuscript. The cover photograph is by George Cope.

Doug Seager

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Introduction

Everything has a temperature. Few things stay at the same temperature, and we may be aware of the changes as they happen around us, some quickly, some almost imperceptibly. Children touch the sunny side of a brick building and it feels warm; where the wall is shaded, the building feels cool. As the sun moves down in the sky, the whole building feels cooler. We expect some things to feel warmer than other things: The surface of the chalkboard feels much cooler than its wooden frame; the metal legs of the desk feel cooler than the wooden top; a pair of scissors feels cooler than a pencil. Some things change their shape or condition when they are heated or cooled. In the kitchen, children notice that ice cubes start to melt as soon as they are taken from the freezer and that butter gets soft on a warm day and melts when heated. (The appearance of a cooking pot does not change noticeably no matter how hot it gets.) In summer, highway tar becomes soft and sticky, streams dry up, and sandy beaches may get too hot to walk on comfortably. In winter, moist hands freeze fast to outside doorknobs, automobile engines are hard to start, and the furnace goes off and on frequently (as a strip of metal inside its thermostat is heated or cooled throughout the day). All these are events with which children may already be familiar.

The equipment for HEATING AND COOLING has been selected to help children experience the ways in which various materials behave when they are heated and cooled. The *Kit* contains metal wires, rods, screens, and sheets. Copper and aluminum wires of various diameters are supplied, as well as screening of aluminum and copper and sheets of aluminum, lead, and copper. There are eight different kinds of rods, so that children can explore a variety of materials (copper, aluminum, brass, and glass), rods of different diameters, and hollow as well as solid rods.

The children soon see that materials conduct heat at different rates. They run heat "races" to see which material gets hot or cools off the fastest. Some of the materials take a long time to cool down; others cool very quickly, and the experimenters begin to see what kinds of things can be done to keep a substance from losing heat.

In the course of these comparisons, the children improve their technique and often find they must repeat some experiments to confirm their initial results.

A set of *Problem Cards** for students contains suggestions for experiments to try. (See page 2 for ways to use the *Problem Cards*.)

**Problem Cards for Heating and Cooling*, available from Webster Division, McGraw-Hill Book Company, Manchester Road, Manchester, Missouri 63011.

Ages and Scheduling

Children in fifth through eighth grades have worked with this unit successfully.

The time you will need to teach it will depend considerably on the kinds and numbers of problems your students find interesting. Most teachers allow 45 minutes to an hour for each session. HEATING AND COOLING will take a minimum of 20 class periods, though the unit can easily go on for several months, especially when students wish to set up carefully controlled experiments and test many different variables.

Starting the Unit

HEATING AND COOLING has been taught in several different ways, depending on the preferences of the teacher. You should choose whatever method you find most comfortable. Some teachers begin with a brief class discussion:

What things are hot?

What things are cool?

What things feel hot or cool to the touch?

Can two things have the same temperature, yet one feel colder than the other?

How do we make things hotter? . . . cooler?

The children's discussion will give you an idea of how much experience they have had in heating things and working with fire. Many children are used to lighting matches, working around stoves, and building campfires. Others may find this a new experience, and they are likely to be excited at first just by striking matches and watching the flames of the candles. Allow some time for these children to get used to working with fire. Discuss safety regulations you feel must be mentioned. (See page 6.)

Many children pursue their own investigations right from the start. One teacher commented, "Some children have an amazing reservoir of ideas, while others prefer to stick to the cards."

Problem Cards

The 22 *Problem Cards* are based on the kinds of experiments that children usually try on their own. The cards also suggest activities that may not have occurred to children. Most children use the cards after they have done quite a bit of their own experimenting. The *Problem Cards* may also serve as a starting point for those who [illegible] not used to working independently. Very few children choose to complete all the cards,

Materials

The materials contained in the *Kit*,* as described below, are adequate for 10 students. For a class of 30, it is suggested that three *Kits* be ordered.

Supplied in Kit

[14] 5 solid aluminum rods, [illegible]″ diameter
[13] 5 solid aluminum rods, ⅜″ diameter
[12] 2 solid aluminum rods, [illegible]″ diameter
[15] 5 hollow aluminum tubes, [illegible]″ diameter
[17] 5 hollow brass tubes, [illegible]″ diameter
[16] 5 solid brass rods, [illegible]″ diameter
[18] 5 solid copper rods, [illegible]″ diameter
[19] 5 Pyrex glass rods, [illegible]″ diameter
[23] 50 aluminum sheets, 4″ × 4″
[22] 50 lead sheets, 4″ × 4″
[21] 30 copper sheets, 4″ × 4″
[9] 20 copper screens, 4″ × 4″, 20 openings per square inch
[10] 20 copper screens, 4″ × 4″, 10 openings per square inch
[8] 5 aluminum screens, 4″ × 4″, 20 openings per square inch
[5] 25′ copper wire, #18 gauge
[6] 25′ copper wire, #22 gauge
[4] 10′ aluminum wire, #18 gauge
[20] 1 pair wire cutters
[3] 100 household candles
[1] 5 cardboard trays, 14″ × 18″
[11] 10 spring-type wooden clothespins
[7] 1 box aluminum foil
1 package soapless steel wool (for cleaning soot from rods and sheets) (Not shown in Fig.)
[2] 1 expansion frame

Note: The cardboard trays are used to protect desk tops from melted wax, spilled water, and hot objects. The clothespins make good tongs for holding hot objects.

*Available from Webster Division, McGraw-Hill Book Company, Manchester Road, Manchester, Missouri 63011.

You Will Need to Provide

shoe boxes
fire extinguisher
buckets or cans for water
"junk box" items
wooden safety matches (enough small boxes so that each child can have a box to strike on)
scissors for cutting sheets and screens

A Note on the Materials

Most teachers find it helpful to have each child bring a shoe box in which to store his own equipment. Empty

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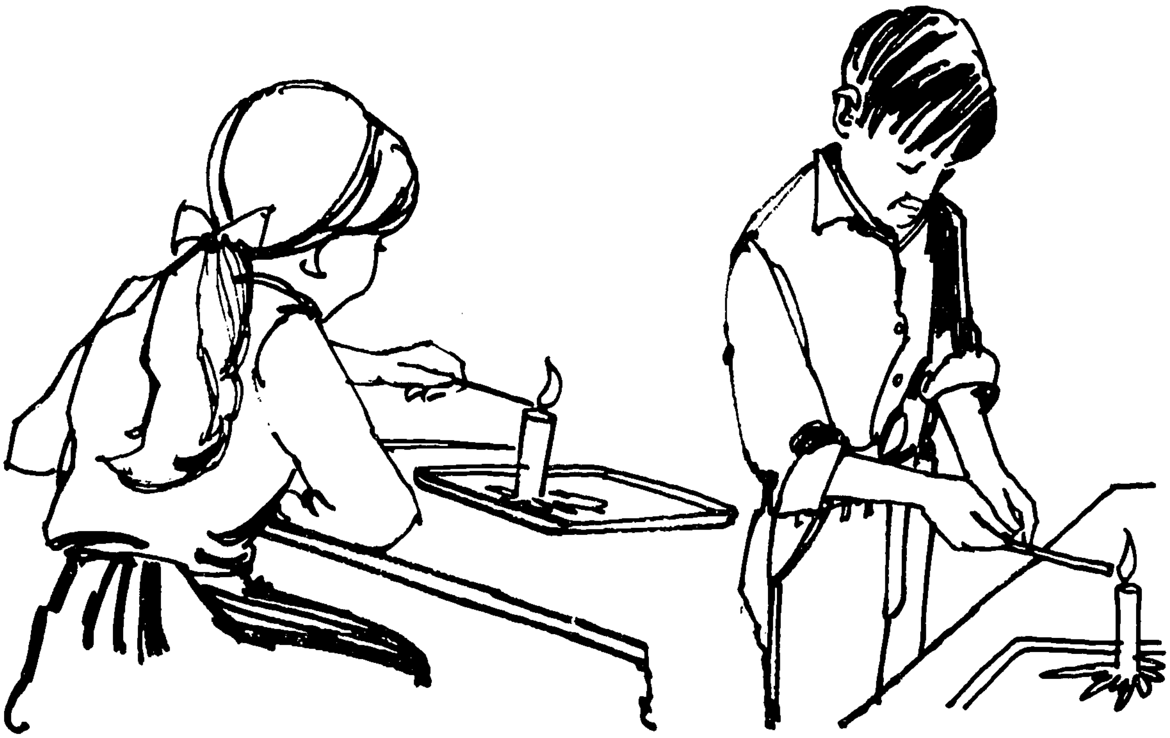


Safety Precautions

Children quickly learn to be careful and at ease around open candle flames. Only a few minor finger burns have occurred in trial classes. Still, it is wise to take simple precautions.

Children should tie back long hair and loose clothing so that they will not fall into the flame. They should work on the trays, whether they use their desks or the floor as work surfaces. They should place the candles so that no one has to reach across a flame for materials.

Only wooden safety matches—the kind sold in packets of small individual boxes—should be used. Then each student can have a box on which to strike matches at his desk. Book matches are not recommended.

Some schools require children to wear safety goggles when working around open flames. All classrooms should have a fire extinguisher available, and the children ought to learn how to use it.

Warming Up

After the children have spent enough time lighting candles to be comfortable with them, you can suggest other activities. The following is a record of the first day's discussion in one trial classroom.

The children began with candles and $\frac{1}{4}$-inch aluminum rods. After a preliminary conversation about heat and cold and some talk about safety, the teacher asked:

What do you think will happen if you hold one of the rods in a flame?

"It will melt."

"The heat will attract to it."

"It would turn black."

"If you held it a long time, the heat would travel down the rod."

"It will swell."

"It might shrink."

"The bottom will get hot, and it will travel up."

"Hollow rods might bend and close at the end."

"Rods may stay the same and not do anything."

All right, try it. Be sure to work on the trays.

"I heated it at one end, and it traveled all the way to the other end."

How hot did it get?

"Just warm. I could still hold it."

"When I hold it straight up and down in the flame with a clothespin, it gets hot at the top because heat travels up."

Would it get as hot if you held the rod sideways and heated it that way?

"I don't know. I don't think so. I'll try it."

What do you think will happen to the rod if you leave it in the flame a long time?

Some children expected the rod to melt; a few expected it to shrink. One boy compared his rod with the clothespin holding it:

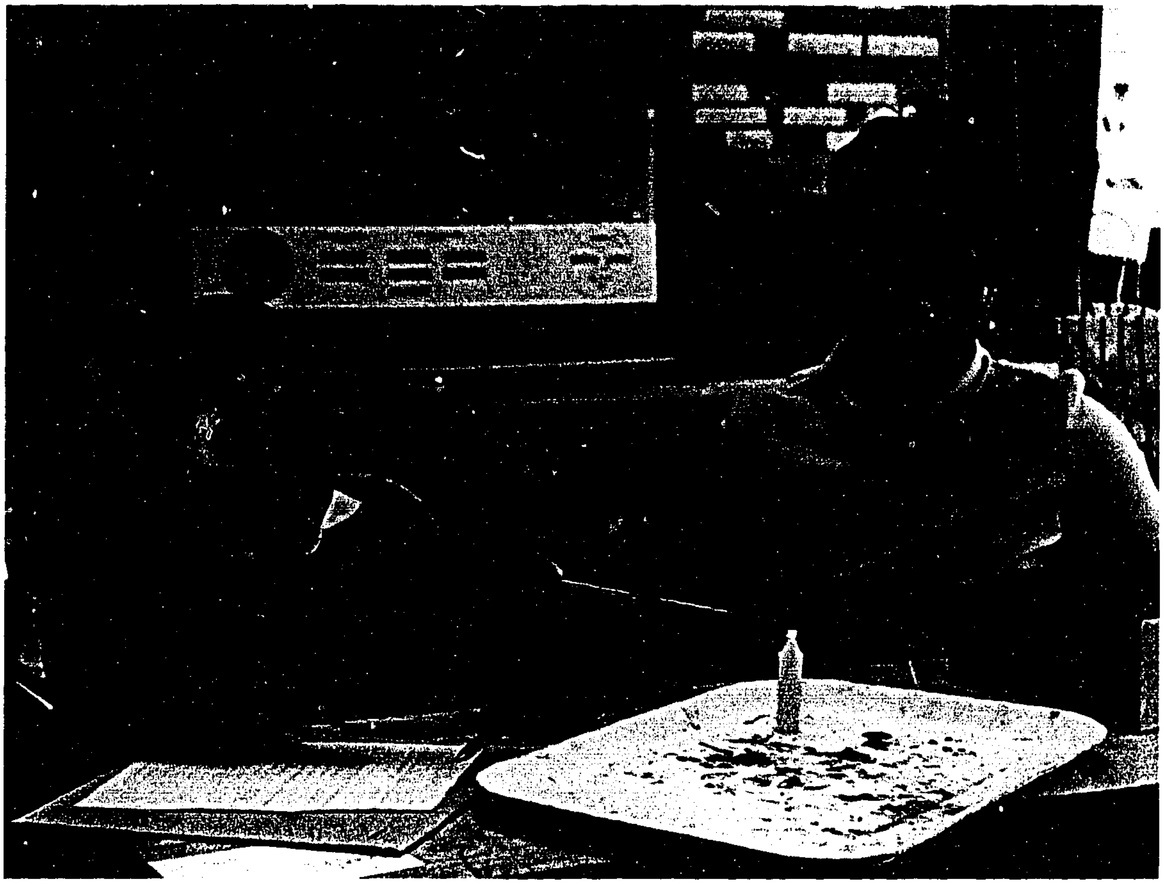
"I'm trying to see which keeps the heat in longer. The wood is just warm, and the steel is hot. The metal keeps the heat in longer."

One child had a rod that was sooty at one end. He held the ends and heated the center.

"The black end is hotter—I tried them both with my finger."

What would make the ends different?

"Maybe I used different fingers and one is more sensitive. Maybe the



black does something to one end. Maybe the candle isn't in the middle."

How do you tell when an object is hot? What does "hot" mean to you?

"When you touch it, your fingers sting. You can imagine that the temperature is very high."

"You could almost burn yourself."

Did it get too hot for all of you at the same time?

"No. Some people can stand more heat than others."

"I was cooking something in the oven, and I couldn't open the door—it was so hot. My mother had to do it."

"People have different feelings, and some can hold the hot bar longer than others. When you try not to think of how hot your hands are, you can hold it longer."

How long can you hold one end of a rod while you heat the other end?

"I dropped it in a minute."

"I held on for 4 minutes and 20 seconds."

Can you hold some rods in the flame longer than others if you use just your fingers? Which things heat up the fastest? . . . the slowest?

One child heated a thick, hollow aluminum tube and a thin, solid aluminum rod. He dropped one when it got too hot.

"The solid rod heats up faster because the air in the hole doesn't heat easily."

The fact that he was comparing rods of different diameters, as well as comparing a solid rod with a hollow tube, did not occur to him at this point. A boy said to him:

"You should have the same size rods, or you can't tell whether it's the air in the center of the rod or the metal that makes the difference."

Children are usually slow to see that they must consider only one difference at a time. It may help to suggest that they try different materials from the basic equipment and from the "junk box."

Can you think of a better test for "hot" than fingers?

"I made a rod of aluminum foil and put matches on top of it and waited for them to light."

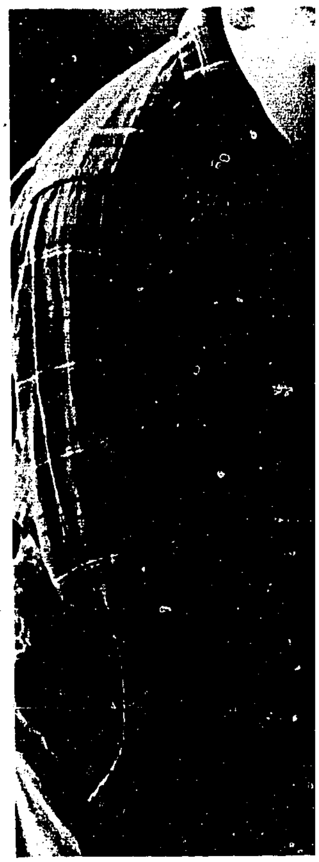
"Use a thermometer. Leave it on the rod."

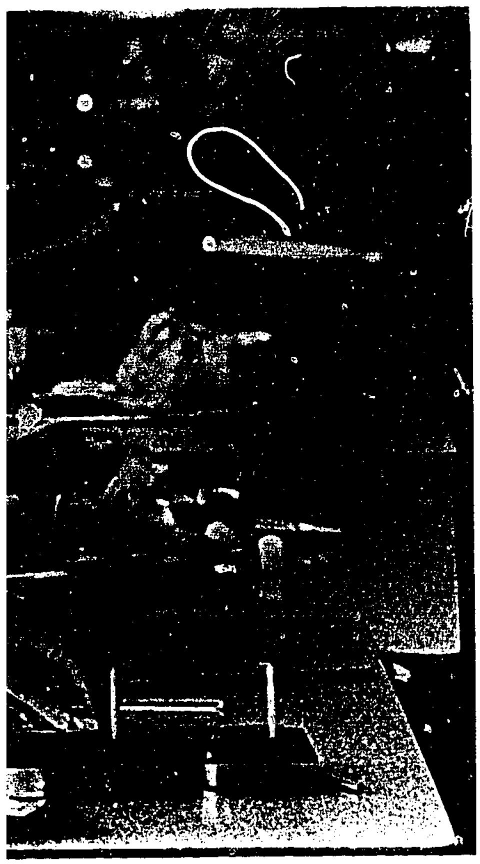
Such a small part of the thermometer touches the rod that very little heat will be transmitted. If the children put their thermometers directly in the flame, the instruments will break.

Several children suggested holding a candle against the rod until it melted.

One boy devised his own method for timing the heat flow down a rod. He inserted candles in a pegboard holder at intervals along the rod (see photograph).

"Timber! I have felled a mighty oak! The first candle took 5 minutes. Now the second one's beginning to melt faster . . . . The brass rod took 3 minutes to melt the first candle. It conducts heat faster than copper. Now I'm going to try the glass rod."





Some children noticed a liquid on the metal being heated.

"It's bubbling at the end. The metal is melting!"

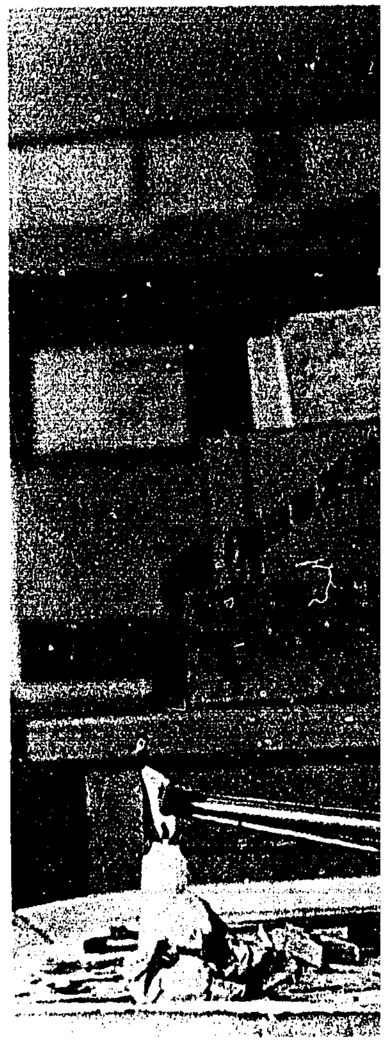
"Mine has grease!"

"It's gotten hot and also wet!"

It took them several days to discover that this liquid was wax and not melted aluminum rod.

Three girls dripped small drops of wax in a straight line from one end to the other of an aluminum and a glass rod. Then they lit a flame under the center of each rod, to find out which would heat up faster and whether heat would travel in both directions. Their results showed that wax drops were a helpful way of measuring temperature, and the method was soon adopted by the rest of the class.

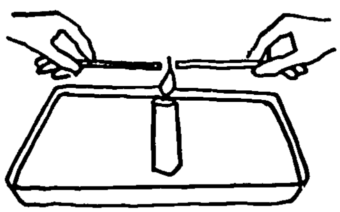
Eventually, in every trial class, children thought of using wax as a "thermometer." (The melting point of wax is between 126°F and 133°F—just a little bit too hot to touch.) This is a more consistent test of temperature than fingertips, although some children may still prefer other indicators. Several children have used tiny drops of water as indicators, watching them evaporate as the heat moved along the rod.



"Hot Rods"

Heat races come up naturally classrooms. They focus attentic way in which hollow tubes a rods of different materials and sizes conduct heat.

Heating and Cooling Problem Card 1



Heat an aluminum rod and a copper rod. Which one wins?
Try the same thing with a glass rod and any metal rod.

Although most children in trial classes used solid rods for the *Problem Card 1* comparison, some compared hollow tubes. One boy found that a hollow brass tube got hot faster than a hollow aluminum tube.

> "Copper rod gets the hottest, then aluminum, and then glass. I think that the heaviest rod gets hottest fastest, because the glass rod takes the longest and is the lightest and the copper is the heaviest and took the shortest time."

Many children brought in other kinds of metal to test. One boy used pieces of water pipe of different lengths. Others used odds and ends of metal from around the house, such as old faucets and fixtures.

> "This (copper) should do it because copper carries heat better than aluminum."

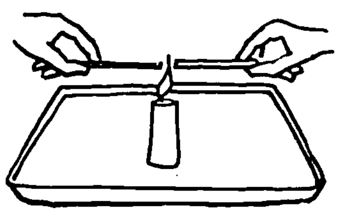
> "I had five candles together. The glass didn't break."

> "I'm going to try it again after the rods cool down to see if it happens the same way again."

Throughout their investigations, children find that their results vary when they repeat experiments. Often they get different results from those which their friends get.

In one class, students gathered at the end of the third session and made two lists—one of observations on which all agreed, the other of experiments to try over again either because there were several dissenting results or because the findings didn't make sense in the light of subsequent work.

Heating and Cooling Problem Card 2



Heat the end of a thick aluminum rod and the end of a thin aluminum rod. Which rod heats up faster?

Regarding *Problem Card 2*, a boy said:

> "These rods are the same. They're both aluminum, and they're both solid. They're just different sizes."

What do you think will happen when you heat them?

> "I think the thin one will win the race."

Later he said:

> "It's incredible, but the thin one never heated up. After 5 minutes, the thick rod was very hot, but after 12 minutes, the thin rod wasn't really hot. It doesn't make sense that it should take that long. I think I'll do it over."

Another boy said:

> "If rods are the same length, the thicker rod will take longer to heat because of the extra amount of material in it."

His partner argued that this wasn't true, that the thinner rod had more cooling surface.

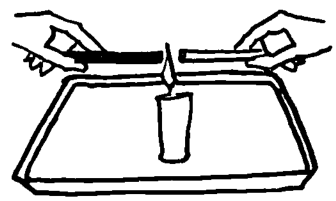
Another group of children decided to work together at the same candle, so that the race would be "fair."

When asked to predict whether wax at the end of a solid rod or a hollow tube would melt first, most children said, "Hollow."

One boy claimed that the solid brass rod and the hollow brass tube would "carry the same amount of heat" from one end to the other (that is, would heat in the same time). When this failed to happen, he undertook to repeat the *Problem Card* 3 experiment. The teacher asked if the rod and the tube were at the same temperature to begin with. This time the boy dunked both the rod and the tube in a bucket of water to make sure that they were cool to begin with.

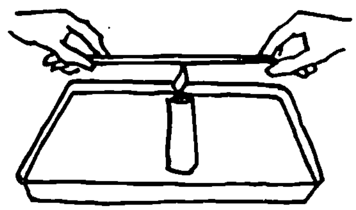
> "I put wax drops on both when they were cool—then I put them on the fire. The hollow tube was faster."

Heating and Cooling — Problem Card 3



Heat a solid aluminum rod and a hollow aluminum tube (same diameter) at the end. Which one heats up faster?

Heating and Cooling Problem Card 4



If you hold the middle of a rod over the flame, will one end heat up before the other?

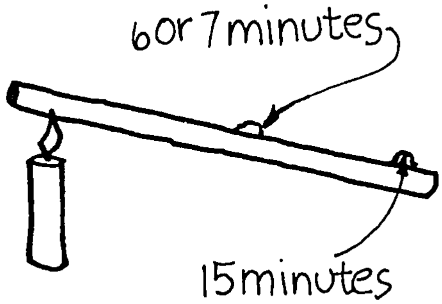
"If you heat the rod in the middle, both ends get hot at the same time, and this is faster than heating at one end."

"This is like two cars trying to go a mile. If they start at the middle and drive toward the ends, they will cover the distance fastest."

Several students in trial classes became convinced that heat flows faster in one direction along a rod than the other.

"Heat goes both ways, but one way faster."

They had to try the *Problem Card 4* experiment many times before they noticed that sometimes they had the flame off center, put different sizes of wax droplets on the ends of the rod, or left the candle in a draft so that the flame was blown in one direction more than in the other.

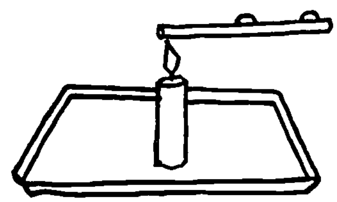


"It seems to go faster at first. Then it slows down."

Children often predict that it will tak[illegible] twice as long for the wax at the far end to melt. When their results don't [illegible] this out, they blame their techn[illegible]. Only after many repetitions, do [illegible] realize that heat doesn't travel at [illegible] same rate all of the time.

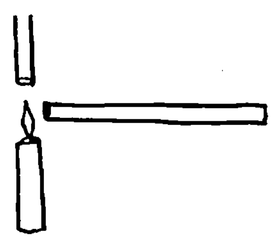
"Maybe the heat isn't going *through* the rod. Maybe the rod's being heated from the outside in."

Heating and Cooling — Problem Card 5



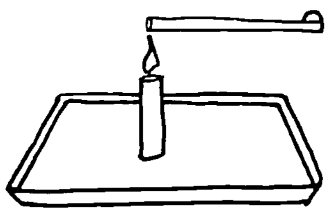
If you hold one end of a rod over the flame, will a drop of wax at the other end take twice as long to melt as a drop of wax in the middle?

Heating and Cooling — Problem Card 6



If you heat a horizontal rod and a vertical rod, which heats faster?

Heating and Cooling — Problem Card 7



Can you *prevent* a drop of wax from melting at one end of an aluminum rod when the rod is being heated at the other end?

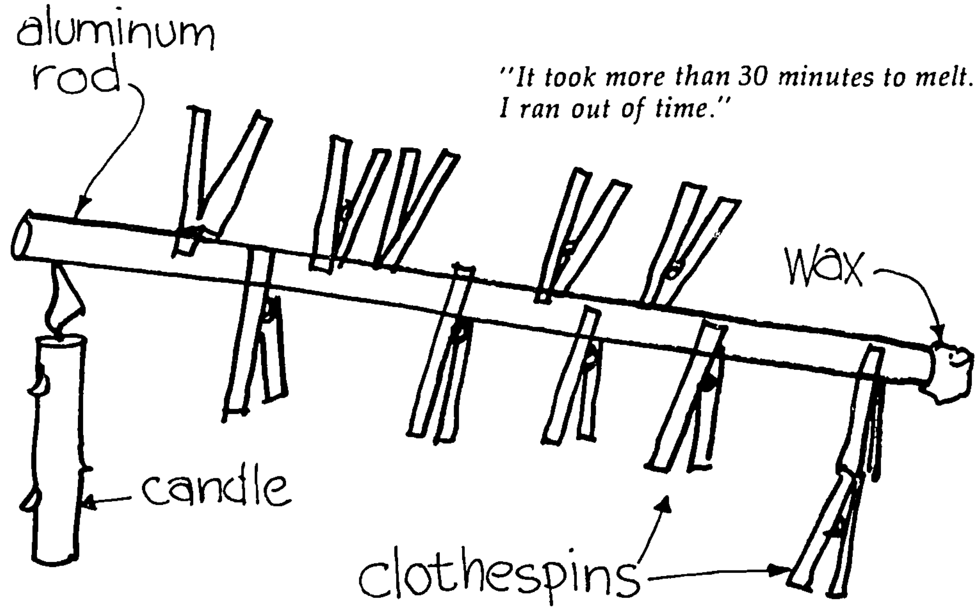
After they feel confident that they know something about the flow of heat through various materials, children enjoy "negative" heat races. They try *Kit* materials, "junk box" items—anything and everything—

. . . lead:

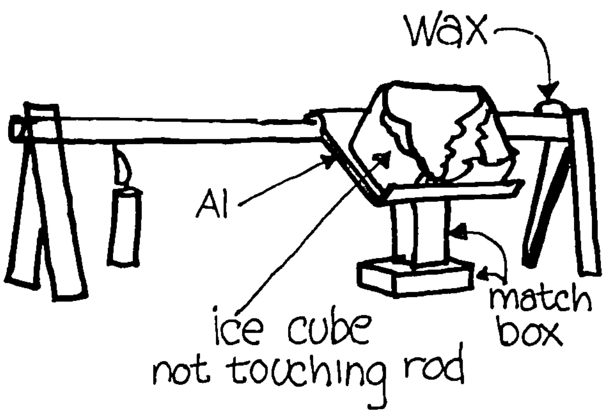
"We tried pouring lead in the hollow tube and putting lead sheets around it, because lead is the best insulator we found so far. But it didn't help much."

. . . clothespins:

"It took more than 30 minutes to melt. I ran out of time."



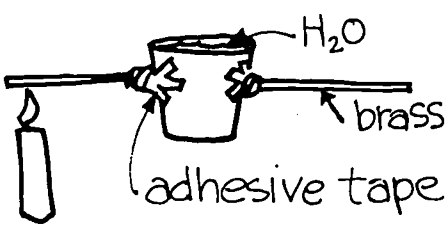
. . . ice:



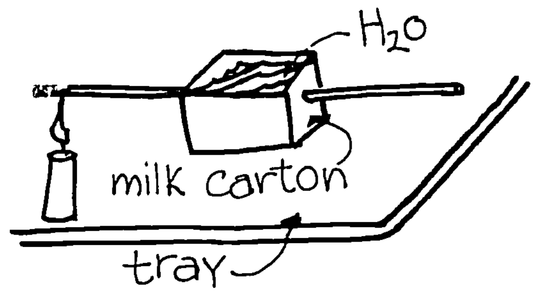
"Thi.; worked for a while."

"The heat traveled through the rod faster than the cold traveled through the aluminum sheet."

. . . water:

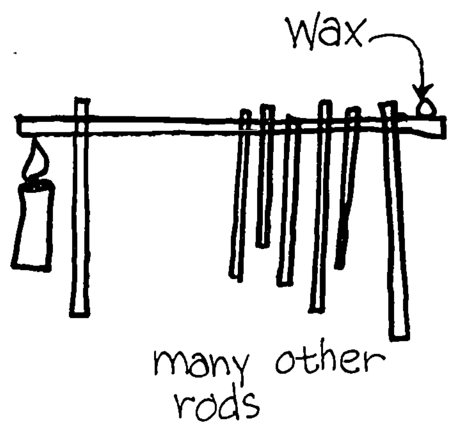


". . . but the adhesive melted, so we tried a milk carton."



"In a hot-rod race, the brass took 11 minutes, 36 seconds. With this water way, it's been cool for 35 minutes."

. . . rods:



". . . but the wax melted anyway."

Two boys reported:

"With copper coils—heat went through just as fast."

"With copper coils, lead sheet, and aluminum sheet—just as fast."

"Small copper mesh—stopped it some."

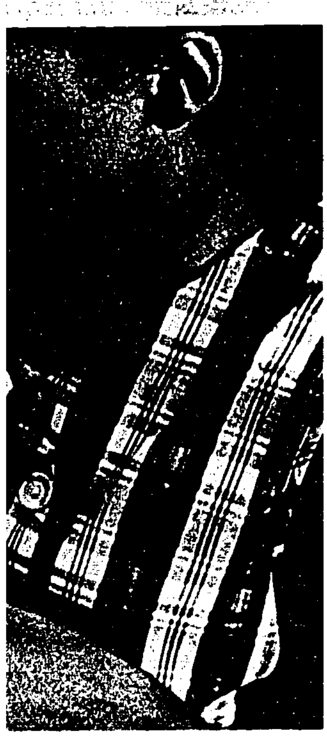
"Big copper mesh—better."

"Aluminum mesh—it got hot, but the mesh was loose."

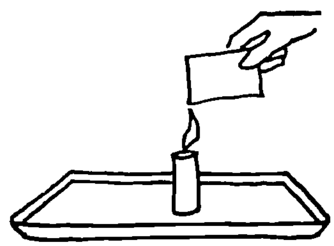
Most of the successful experimenters cooled the rods with water or used some combination of wires and screens that interrupted the heat at many points of contact.

Sheets

Use of metal sheets allows students to observe the patterns made when heat spreads out (rather than when it travels in a line as it does along the rod). Children cut the sheet metal into different shapes in an attempt to conduct heat faster from one point to another. They race shapes with one another.



Heating and Cooling Problem Card 8



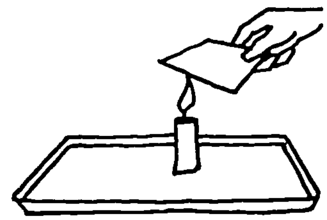
Where can you hold a 4" by 4" sheet of aluminum with your fingers the longest when you are heating one corner of the sheet?
Can you find a way to show what path the heat follows in this experiment?

"I took a flat piece of aluminum and put drops of wax on three corners and in the middle. And then I put a candle under the end without any wax. First, the wax melted on both corners nearest the flame. Then the wax on the opposite corner melted."

Children who have worked only with rods and tubes may hold the other corners, expecting them to heat up more slowly because "heat travels in a straight line and doesn't spread out."

Many children notice changes in the appearance of the metal as it becomes very hot, and they can "follow" the path that the heat takes across the aluminum sheet. Some children may try to figure out the path that heat takes along a sheet by dripping wax over the surfaces of the metal and then watching the order in which the droplets melt. Other children may wet the sheet or rub the side of a candle all over it before they heat it to see where the water evaporates or the film of wax melts.

Heating and Cooling Problem Card 9

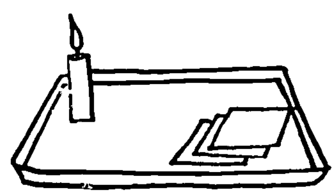


Where can you hold a 4" by 4" sheet of aluminum with your fingers the longest when you are heating the middle of one edge?
Can you find a way to show what path the heat follows in this experiment?

One boy heated metal sheets he had wrinkled.

"When it's wrinkled, the heat gets underneath the folds and heats it faster."

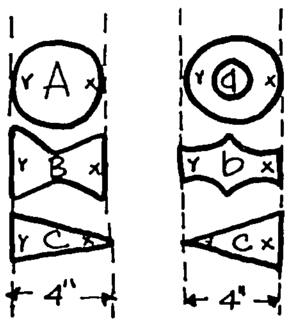
Heating and Cooling Problem Card 10



Is there any difference in the way heat passes through a 4" by 4" sheet of aluminum and the way it passes through a 4" by 4" sheet of another metal?
Does it matter where you heat the different sheets?

Heating and Cooling — Problem Card 11

Prediction — Winner

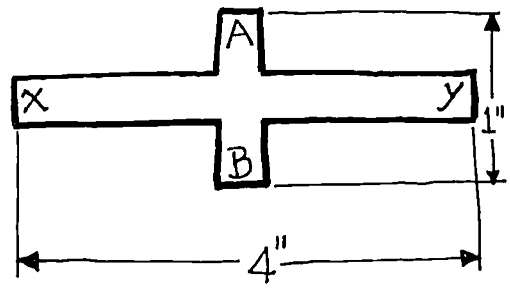


For each pair of shapes cut from aluminum sheets, which shape will conduct heat faster from point x to point y?

It is difficult for the children to cut the aluminum shapes without wasting sheets. If you wish to conserve supplies, you may cut these shapes before class, using ordinary scissors.

Unless students have placed the heat source at y instead of at x or have held the metal pieces at different angles to the flame (allowing more or less of the flame to pass along the bottom of the metal), all should find the same shapes winning. Their predictions will vary widely, however.

A boy cut the following shape:



"When I heat it at x or at y, the wax melts at the other end. But when I heat it at A or B, the heat never gets to the other side."

The teacher asked if he had an explanation for this.

"I think that when I heat it at A or B, the heat can spread out after it's gone just a little way."

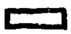
Another boy predicted:

"I think the dumbbell  will win because the heat can just go straight down it. With the other one  the heat will go and fill up both sides before it goes to the end."

After they have experimented for a bit with the shapes cut by the teacher, some of the children may find it fun to design and cut out shapes on their own. Trays from frozen TV dinners are good to use if supplies are running low.

One boy started with this shape:

 Then he cut the arms off

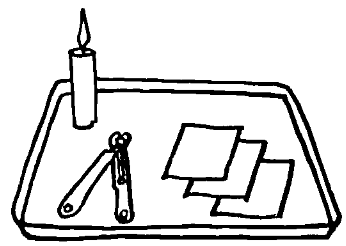
 and said it heated faster.

He went on to cut notches in the strip

 and found that heat traveled across the strip still faster.

"There's just as much heat, but there's less place for the heat to go."

Heating and Cooling Problem Card 12



What flat shape can you cut from a sheet of aluminum that will allow the fastest heat transfer from one point to another 4" away?

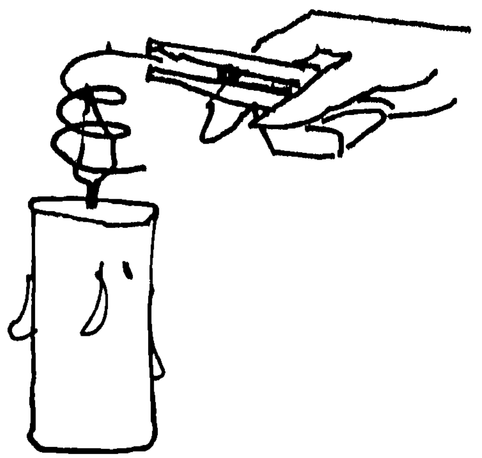
Cooling Off

When children see a flame go out, especially when it has been covered by something, they are likely to remark that the flame was "smothered." Often they are right, but there are other ways to put out a fire besides keeping air away from the flame.

To produce the heat and light we call "fire," there must indeed be air. There must also be fuel. Finally, there must be a temperature high enough (kindling temperature) to start a chemical reaction between the fuel and the air.

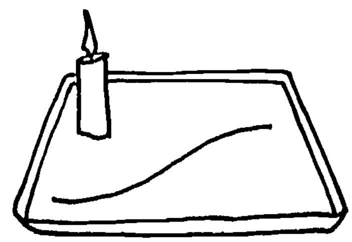
The removal of any one of the three necessities—fuel, air, or high temperature—can cause a fire to go out.

The next set of problems deals with putting out a flame by removing heat to lower the temperature of the flame.



"Yes! After one hour, I did it, with a copper coil."

Heating and Cooling Problem Card 13

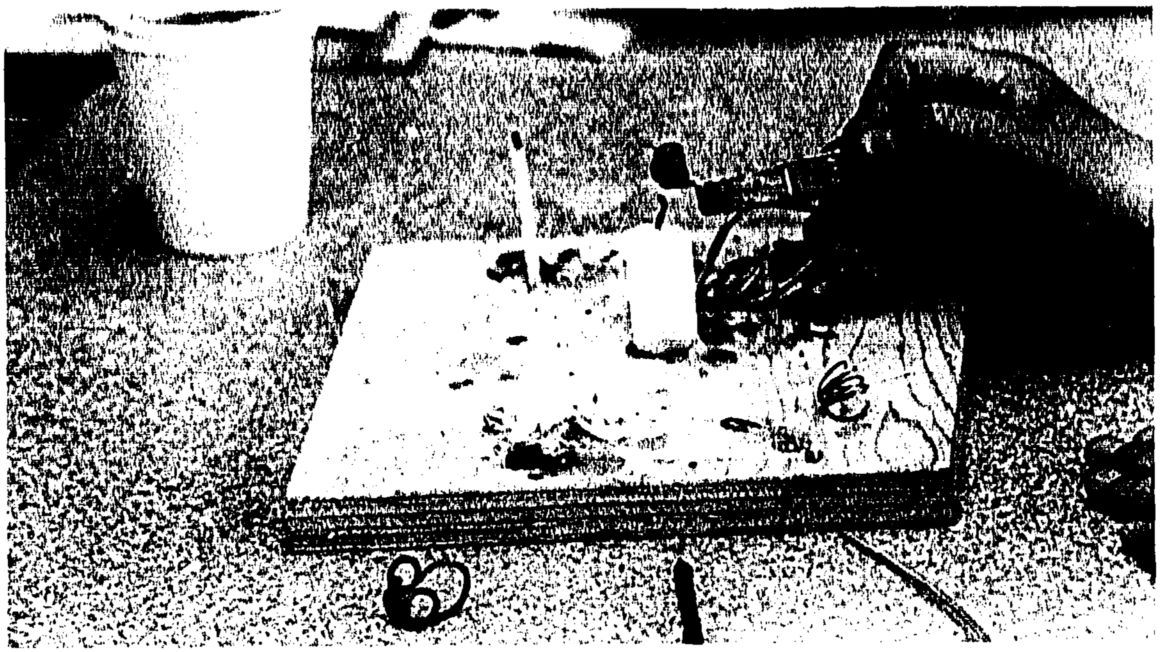


Without blowing on the flame or touching the wick, can you put out the flame by using a single piece of copper wire?

Children often start fanning the flame with their wires—to no avail. Eventually they either wad up the wire or make a coil of it to place around the flame.

One boy made a tightly wound candle snuffer out of wire. It worked. The children decided that it kept the air away from the flame, so that the candle couldn't burn. The teacher asked if the snuffer would still work if the loops were separated. The child reported:

> "Hey! The loose coil put the flame out just as well, even though the air can get through. But the coil won't work if it's *wide* open."



After several children were able to make the flame go out with a wire, the teacher asked:

How many times in a row can you put out the flame in this way?

This led to a new difficulty. After the wire had been used several times, the children found it harder to put out the flame. After much discussion and experimenting, they decided that the coil of wire gradually heated up to the point at which it was too *hot* to cool down the flame. After more experimentation, they reached a number of conclusions:

"To put out the flame, the coil must be *cool*."

"I guess when the wire's cool, all the heat goes out of the flame into the metal."

"The metal takes the heat. The more metal there is around the flame, the more heat it takes, so the flame gets too cool to burn. But when the wire is hot, it can't take any more heat, so the flame stays on."

"I had two wires—one thick, the other thin. The thick one put it out faster."

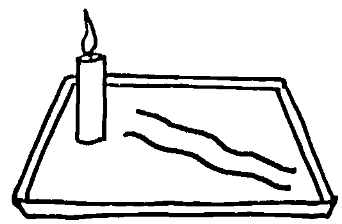
"The thick one puts it out faster. Each time I put the coil over the flame, it just goes out."

"But if you coil the thin wire tightly, it's as fast as a loose coil of thick wire."

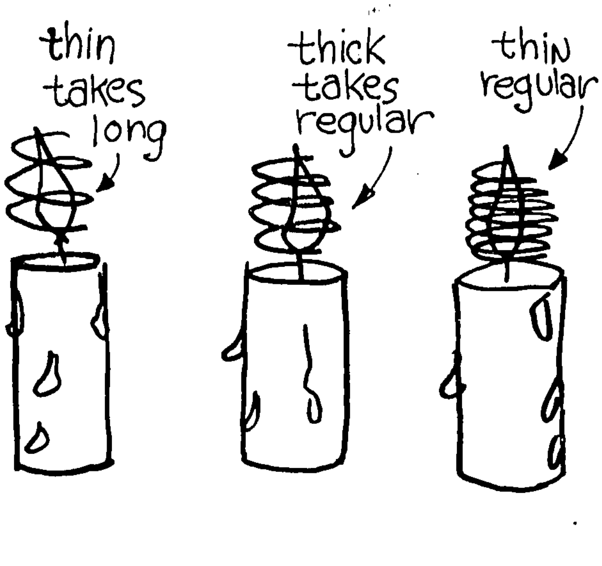
After much experimenting, children are ready to talk about the conditions that allow heat to be carried away.

"We predicted that the thick wire would put out the flame first. This proved true. So we tried to find the best shape for putting it out. A loosely wound cone works best."

Heating and Cooling — Problem Card 14



Is there any difference in the ability of a *copper wire* and an *aluminum wire* to put out a flame without touching the wick? Is there any difference in the ability of a *thick copper wire* and a *thin copper wire* to put out a flame without touching the wick?



Spoon R

The idea t
and that it
areas to c
inside mat
way in on

heat goes *into* materials
be transferred from hot
areas, and even stored
ls, came up in a special
ss.

A girl put water in a plastic spoon and held it over the flame to see if it would boil. The water did not boil, but the spoon melted. The girl tried this a second time and timed the experiment. It took 49 seconds for the spoon to start melting.

The teacher asked:

What would happen if the spoon were empty?

The girl held the same kind of plastic spoon in the flame. In 14 seconds the empty spoon started to melt.*

The teacher asked:

Why did it take longer with the water?

"Because the heat had to go into the water *and* the spoon, so the spoon didn't get hot right away."

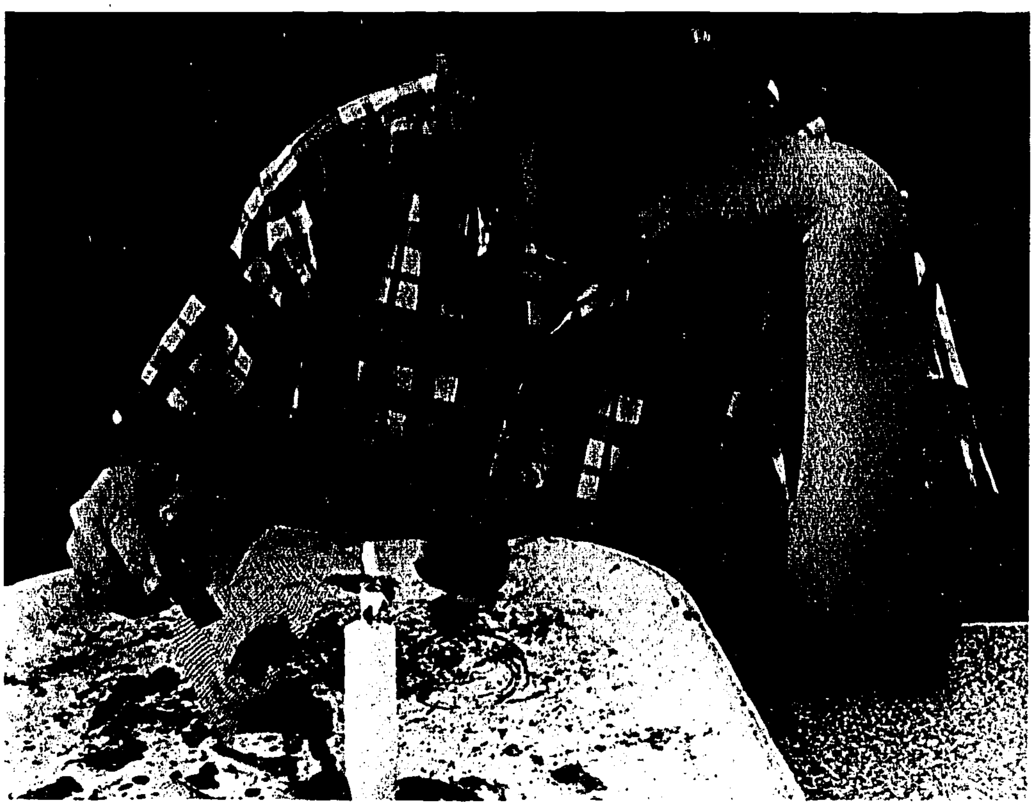
Would anything else work, besides water?

The girl filled a plastic spoon with melted wax, let it cool, and then put it in the flame. It took 35 seconds for the spoon to melt.

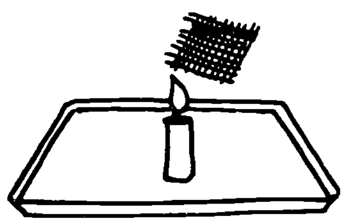
*If your students do this kind of experiment, they should hold the spoon over a tray to catch any hot drops of plastic. Warn them to avoid inhaling any fumes if the plastic burns.

Screens

When children start to compare metal sheets and screens, there may be some discussion about whether air and metal conduct heat equally. Since the screens consist mainly of air spaces, they will conduct heat differently than the solid sheets will. Children should be encouraged to test their hypotheses by bringing in screens of different mesh sizes. They can also snip wires within the screen to make larger openings with the same thickness of wire. (The sheets and the screens can be cut with ordinary scissors.)



Heating and Cooling   Problem Card 15



How will the heat travel when you heat a 4" by 4" piece of screen at one corner?

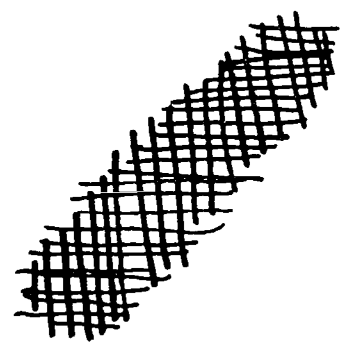
"It goes around on the outside. It will get hot at the far corner before it gets hot in the middle."

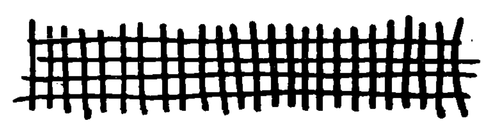
"It goes in a zigzag. It goes down the edges and then in toward the middle."

One boy decided to see if the heat would go along a diagonal strip of screening. He cut two pieces that looked like the following drawings.

He said that the heat didn't go down either one very well.

The children find that when they rub a candle across the screen they can see the pattern that the heat makes.





Most children were surprised to discover that they could hold their fingers over a piece of screen that was being heated and not feel much heat.

"Maybe all the heat goes into the screen. When I hold a candle over the screen it doesn't melt."

Someone said he was able to hold a finger over the screen for 2 minutes.

How many layers of screening did you use?

"Two."

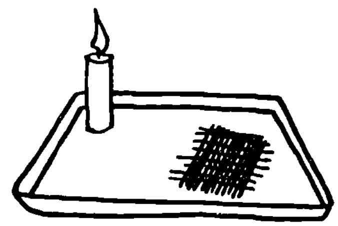
Ronald cut up a screen and found that the flame went through the little pieces every time he held them in the fire with a clothespin. Quite by happenstance, he cut one piece on the bias and discovered that pulling at the edges of the screen opened and closed the mesh. The flame shot up through the open mesh at once. When he tried the closed mesh, the flame took longer to come through.

"The holes are smaller."

"When it's closed there's much more metal near the flame. I think the extra metal takes the heat away better."

Next Ronald tried putting a very small piece of screen in the flame. The flame went through immediately, and soon the screen crumpled and broke in half.

Heating and Cooling — Problem Card 16



Does a screen prevent the *flame* from going through? Does it prevent *heat* from going through?

Children begin to notice that a cool screen prevents the heat from going through longer than a hot screen does.

"When the screen is hot, the flame is bigger on top, but it's not as hot on top as when the screen isn't there."

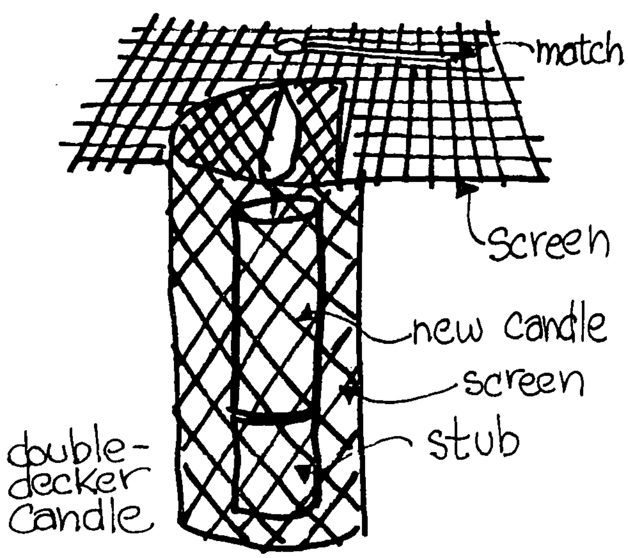
"Maybe if it got the screen hot all around, the flame would go through fast."

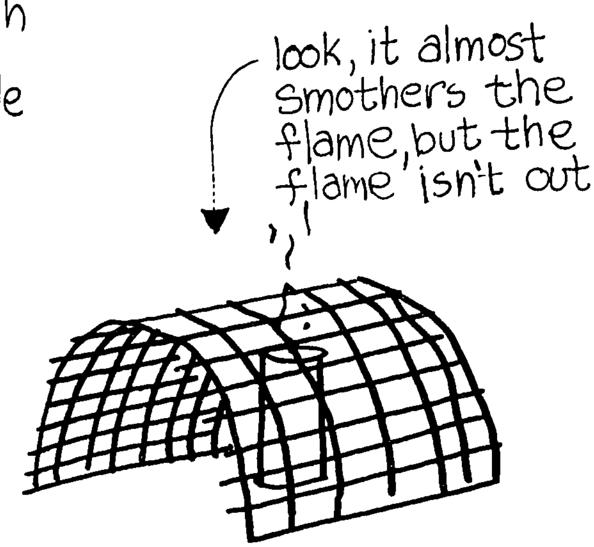
One girl held a piece of hot screen and then a piece of cold screen in the candle flame.

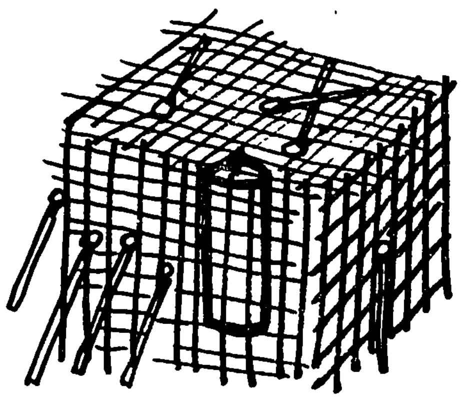
"I'm trying to see if the flame will go through both. The first two times the flame did not go through either one at all."

Two boys made a setup as illustrated and waited until the match ignited. Then they repeated the experiment.

"It goes through faster the second time because the screen's hotter."







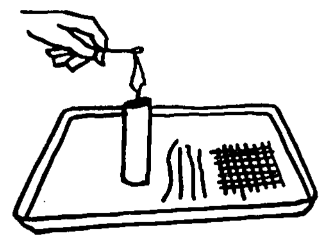
"I made a screen cage and put some matches on the top and leaned other matches against the sides. The one on top lit first. The side matches took a long time."

An unlit match head in an open flame usually catches fire immediately, since the temperature is high enough. In order to hold a match in a flame without its catching fire, you must keep the *heat* of the flame from reaching the head.

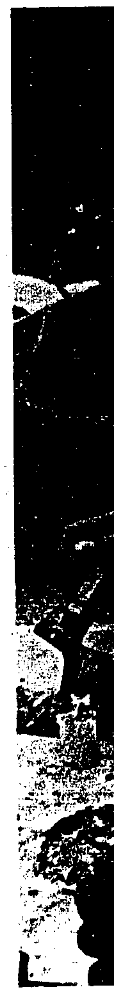
"I prevented the match from bursting into flame for about 15 seconds by wrapping the wire around the match head."

"You can do it by putting four screens on top of the flame. The match just smoked, but it didn't light."

Heating and Cooling — Problem Card 17



Can you hold the head of an unlit match in the tip of a flame and prevent it from bursting into flame for 15 seconds? . . . 30 seconds?
Try this again, using any wires and screens you wish.



Several children in trial classes held the match head inside a wire coil in the middle of the flame. It took several seconds to light this way. Others tried placing their matches on top of a piece of screen and holding the screen in the flame.

One boy placed the match head between two layers of screening and held the "sandwich" in the flame. After 25 seconds the match head caught fire, and the boy noticed that the candle flame went down but did not go out.

Another boy rolled a match inside a piece of copper screen. He held this in the flame for 40 seconds before the match head burst into flame.

A girl put a match on top of four screens. It took 40 seconds for the match head to light.

Soon a contest developed to see who could hold a match head in the flame, without the match catching fire, for the longest time. Children wrote their times on a chart drawn on the chalkboard. The times ranged from 25 to 250 seconds.

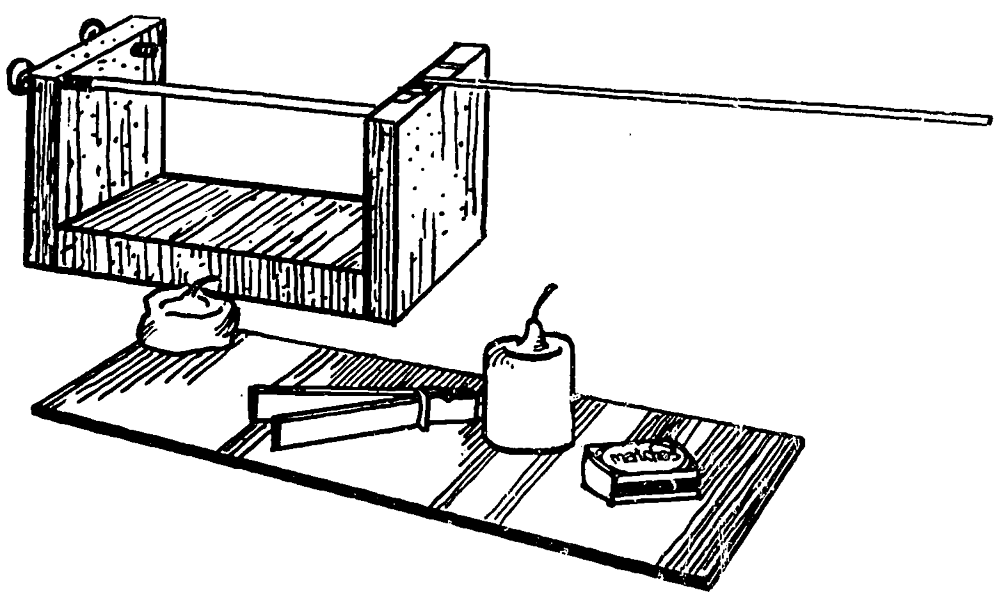
One girl managed to double her time by folding two layers of screening in half and in half again and placing the match on top of the screening.

Expansion

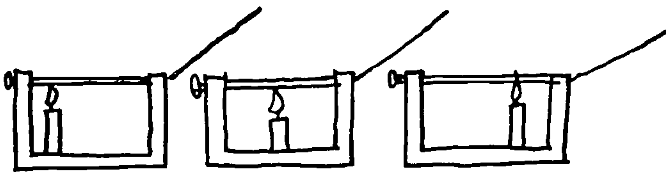
Some changes that occur when an object is heated are so slight that they cannot be seen. Rods and wires expand in diameter as well as in length when heated, and they return to their original size when cooled. An expansion frame is included in the HEATING AND COOLING *Kit* for students who wish to investigate the amount and the rate of change in the length of different rods.

The expansion in diameter is too small for children to measure with any accuracy. Children find it hard to see the small changes in the length of a rod, much less to compare the change in two rods of different metals or diameters. The expansion frame is designed to "magnify" the effect. As a rod expands, the pointer is pushed up by a correspondingly larger amount. Two rods can be compared at a time. These may be of different materials (aluminum, copper, brass, glass) or they may be of different diameters (the aluminum rods are supplied in three diameters).

Students should have time to examine the expansion frame thoroughly, to insert a rod, and to move the rod back and forth so that they may see the relationship between the movement of the rod and the motion of the pointer. When they begin to heat the rods, they will need to use partly burned candles or to trim new ones to fit in the frame.



Heating and Cooling Problem Card 18



When you put a rod in the expansion frame, does it matter where you put the flame?
Will one of the pointers shown rise higher than the others?

"When the candle is in the middle, the heat travels in both directions at once, so the ends get hotter faster and the rod expands more in a shorter time."

If the heat has to travel the length of the rod instead of just half the length, will anything happen to the heat?

"Maybe the rod would cool because some of the heat can escape, as it has to go a longer distance."

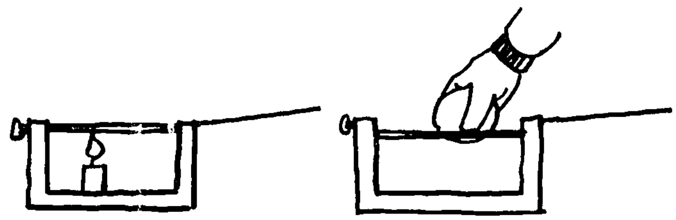
Most children feel that the rods expand only at the ends. In fact, expansion occurs all along the rods, with the hottest part of the rods expanding the most. This is hard to determine when using simple equipment.

It is important that children have a chance to work on as many different problems as possible, using their own equipment and making their own observations.

In the *Problem Card 18* experiment, children are surprised to see that the flame position does not affect either the amount or the speed of expansion.

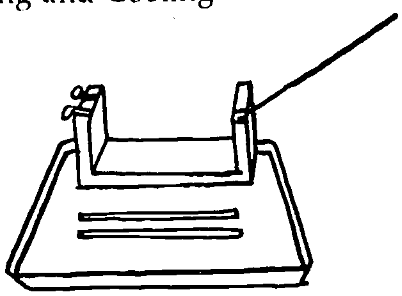
Children try many ways to make the pointer move faster—using more candles or different heat sources or placing the flame at different locations under the rod. They also try blowing, fanning, and rubbing with ice cubes as cooling methods.

Heating and Cooling — Problem Card 19



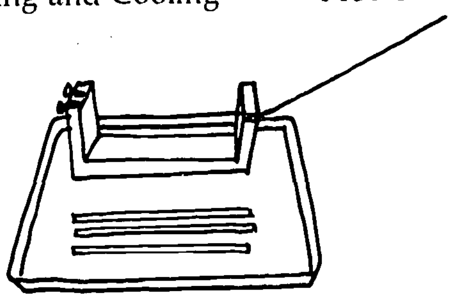
Put a rod in the expansion frame and heat it. What happens to the pointer?
Put a rod in the expansion frame and cool it with ice or snow. What happens to the pointer?

Heating and Cooling Problem Card 20



Which will produce a greater change in the pointer—heating a thick aluminum rod or a thin one?

Heating and Cooling Problem Card 21



Which of the ¼" rods will produce the greatest change in the pointer when heated—aluminum, copper, brass, or glass?

To keep a record of the movement of the pointer, children tape a sheet of lined paper on the cylinder and place it near the end of the pointer. Then they choose an interval—15 seconds, 30 seconds, or 1 minute—after which to mark the position of the pointer with a dot. After each selected interval, they turn the cylinder one space and mark another dot. The result is a simple graph of the motions of the pointer during heating as well as during cooling.

You may want to place several of the children's graphs on the wall or show them on an overhead projector to serve as the basis for a discussion. The irregular pattern formed by the dots on many of the graphs will be obvious. Why do the dots occur irregularly? Why do students using the same kind of rod get different graphs?

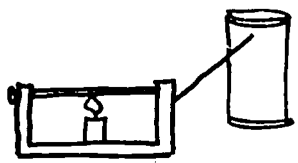
"Different people kept records."

"Some people used different time intervals for marking."

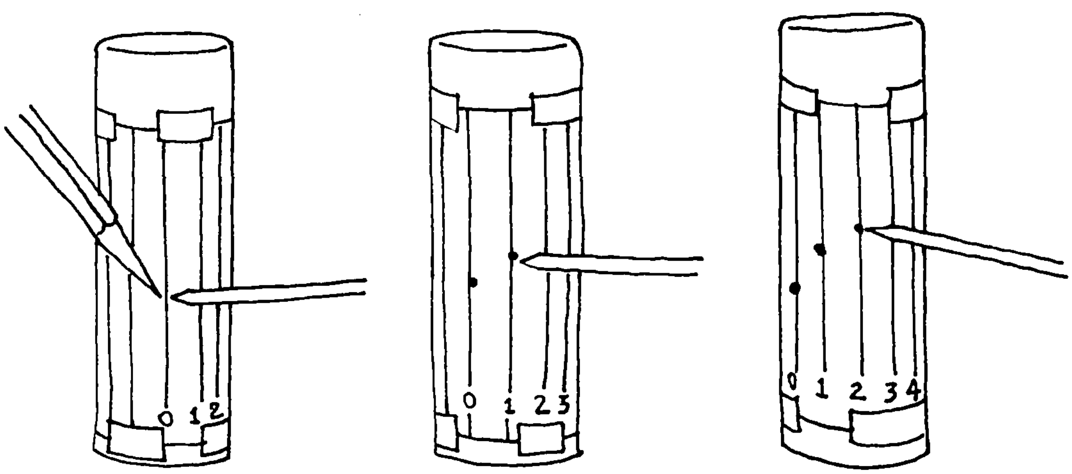
"The dots weren't placed carefully."

"The flames all flickered differently."

Heating and Cooling   Problem Card 22



How many inches does the pointer rise in 1 minute as you heat a rod?
How many inches in 2 minutes? . . . in 3 minutes?
How many inches does the pointer fall in 1 minute when you stop heating a rod?
How many inches in 2 minutes? . . . in 3 minutes?



Children's Own Questions

Wherever HEATING AND COOLING has been taught, children have become interested in projects that were not thought of when the unit was being developed. For some of these projects, the materials in the *Kit* were used; for others, items were scrounged from the classroom or brought from home.

The following ideas and questions were thought up by teachers and children in trial classrooms. They give some idea of the range of investigations that can arise from the materials and procedures of HEATING AND COOLING when a child starts on a project of his own or when a teacher poses a question to a group of children.

Can you make popcorn, using the candle flame?

"I can get a piece of popcorn to pop without burning if I wrap a coil of wire around it."

What makes the best popping pan—metal screens or metal sheets? Which metal?

How about an aluminum foil bag?

Which is better, a closed popper or an open one?

Does it make a difference if you add oil before heating the corn? If you add water?

Does the corn weigh the same after it's popped?

Some children were amazed at the weight loss. When they used a covered container, they noticed droplets on the lid.

"Wax?"

"No, water!"

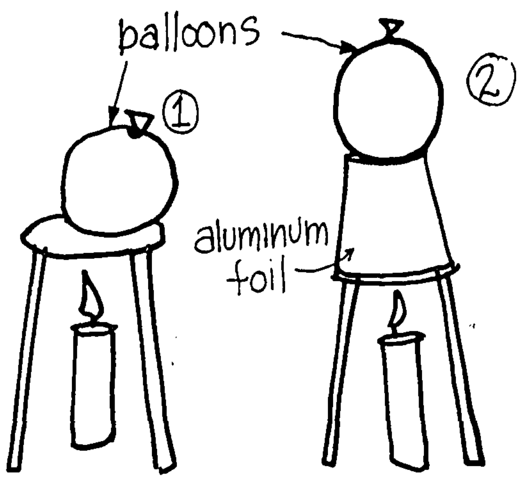
A great many uses were found for balloons in trial classrooms.

What happens if you put a balloon on the end of a hollow aluminum rod?

Wrap a balloon around the middle of a hollow aluminum rod with a rubber band, and see if heat will pass through the hollow tube.

Some children made their own "balloons" from foil or paper bags. Very elaborate arrangements were designed.

Will hot air make a bag rise?



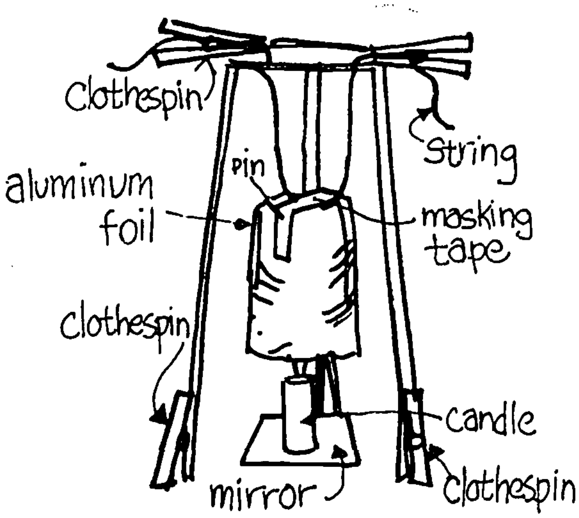
1. *"The balloon got larger and then popped."*

2. *"The same thing happened."*

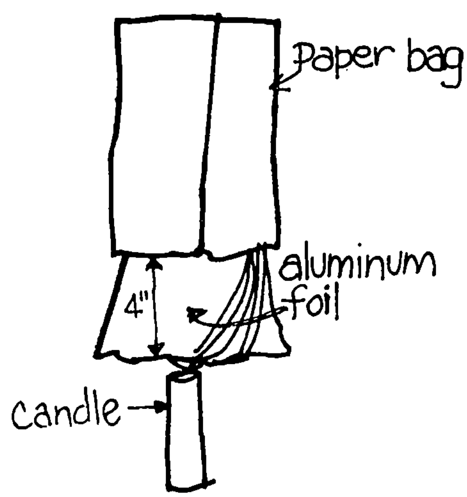
3. *"Same arrangement as #2 but balloon was not blown up all the way. It rocked back and forth and looked as if it started to rise, then popped."*

"Will heat make a balloon rise?"

First attempt, no motion.



Second attempt, no result.



The bag went up in flames. "It was too close to the flame. I need a bigger aluminum cone."

54

Some of the things that the children heated were:

. . . buttons:

"Does the weight change while they're burning?"

. . . sinkers:

"It's lead. Tomorrow we'll try to melt the stuff that dropped off it."

"It gets shiny after it hardens in the pool of wax. It's hard to bend now, but before it was very soft."

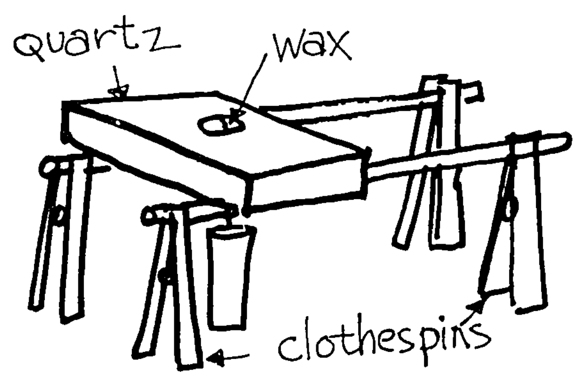
. . . iron filings:

"I tried to make a 'sparkler' with candle wax sprinkled with iron filings on a copper sheet . . . no luck. The best results came by blowing the filings from a sheet of metal onto a flame."

. . . magnets:

"In 2 minutes, it lost its magnetic power. After 5 minutes 50 seconds, it came apart."

. . . quartz:



"Can you melt wax on a rock?"

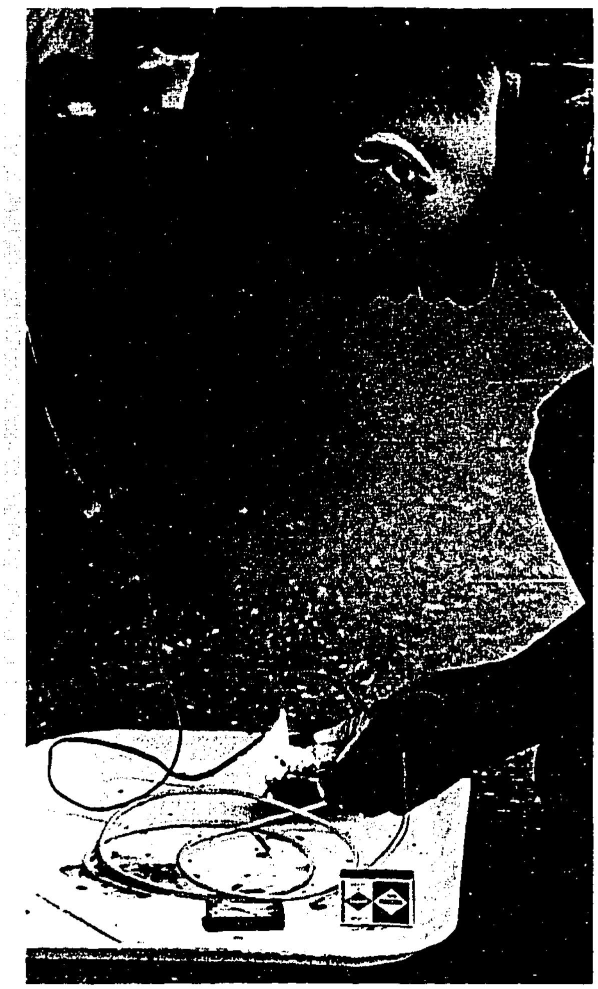
enough

Children asked many kinds of questions:

"Can you take the temperature of a rod with a thermometer?"

"How can you make a hotter flame, using candles?"

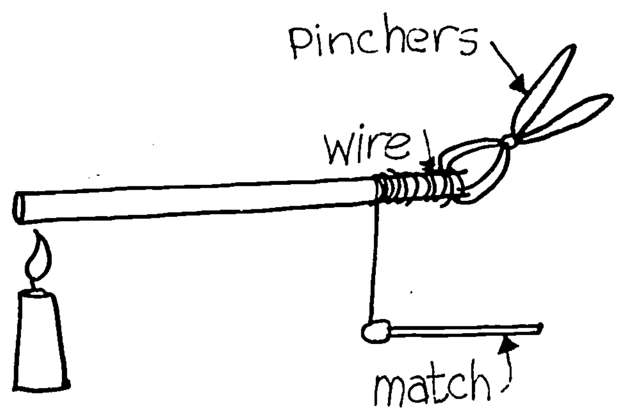
One boy made a "blowtorch," using candles, aluminum foil, and an aquarium air pump. Then he put foil over the blowtorch to see if the flame would get even hotter in that it had to go through a smaller hole.



"Will heat travel through wire to a rod and melt a wax drop?"

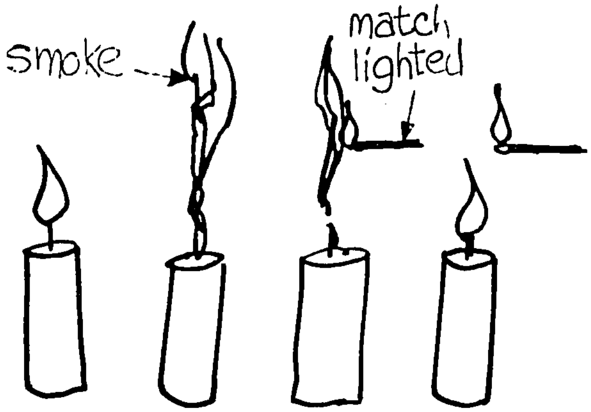
Does wire expand?

"I heated a coil of copper wire. It expands and unbends. I think if I heated aluminum wire, it would spread out more, because in the expansion frames aluminum expands more than copper."

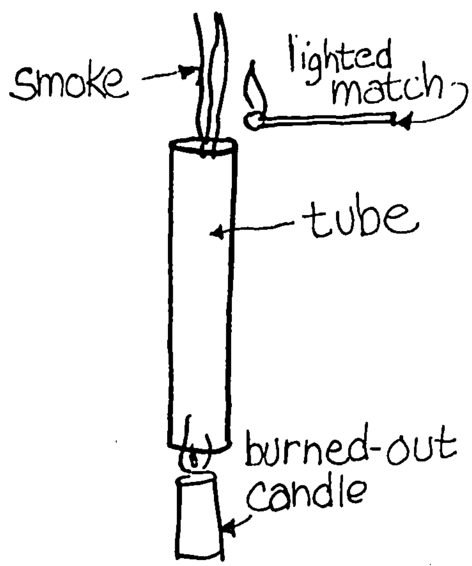


"Will heat travel through a rod and through a wire to light a match?"

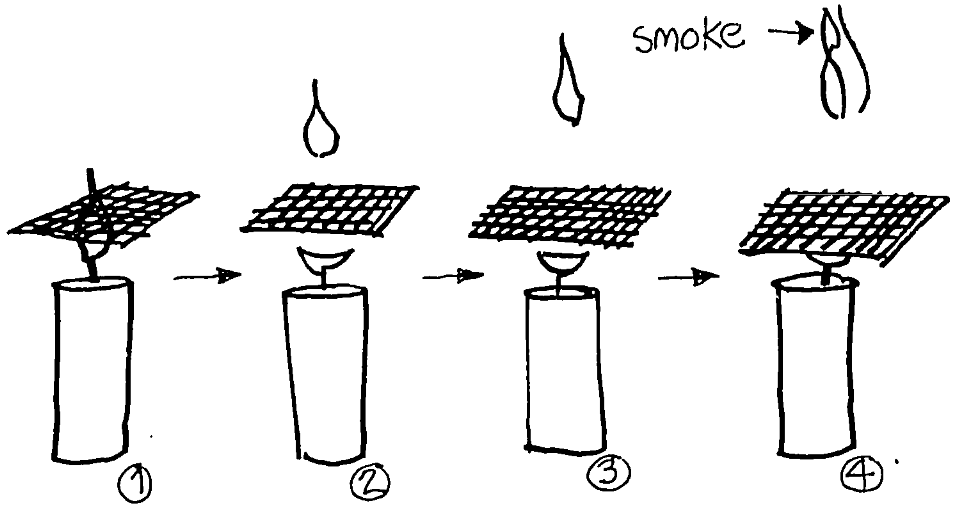
Can you get a candle to relight, after you've blown it out?



"If you blow out a candle and hold the lighted match in the smoke above the candle, the flame travels down the smoke, and the candle lights again. Will it work through a long tube?"



"Trying to light the smoke, it sparked almost every time," said Chris.



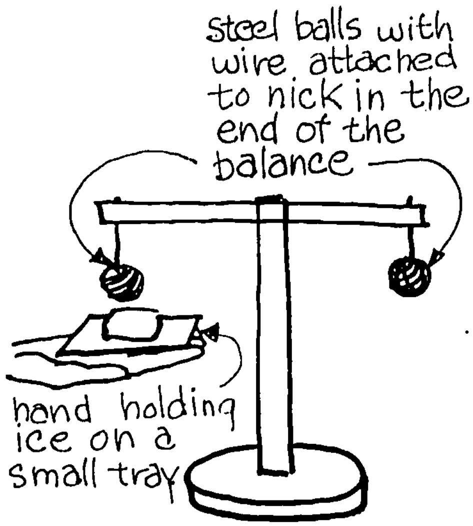
"If you hold the edge of the screen in a flame, the flame seems to be going through the screen, and then the top part of the flame appears to become detached, float in air, and disappear into smoke."

Can you keep a flame going in a closed container?

One boy who tried to do this by pumping oxygen into the container said that he failed because he couldn't keep the oxygen coming fast enough.

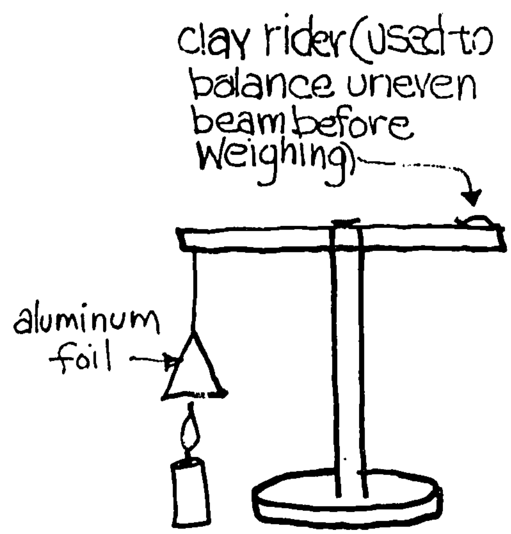
Does heating things change their weight? Does cooling them change their weight?

"Does a steel ball weigh more when hot or cold?"



1. *Balanced*
2. *Hold ice against it—no change in weight*
3. *Heat ball with candle—no change in weight*

What happens when you heat aluminum foil on a balance?



"Heat makes the balance beam rock back and forth."

Can you make new candles out of left-over wax?

Some children get involved in candle making, and they try molding candles as well as dipping them. One boy made a candle at home. It was huge, made of a pound of paraffin and five string wicks. It produced quite a blaze.

"Can you get heat to go down a really long rod?"

These boys found a piece of pipe at the dump. They heated it for half an hour and were surprised that the heat went only a little way down it.