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TITLE Vocational-Technical Physics Project. Thermometers: I. Temperature and Heat, II. Expansion Thermometers, III. Electrical Thermometers. Field Test Edition.

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ABSTRACT

This vocational physics individualized student instructional module on thermometers consists of the three units: Temperature and heat, expansion thermometers, and electrical thermometers. Designed with a laboratory orientation, experiments are included on linear expansion; making a bimetallic thermometer, a liquid-in-gas thermometer, and a gas thermometer; making, testing, and using thermocouples; comparing thermistors with ordinary materials, and calibrating a thermistor. Laboratory data sheets, illustrative drawings, review questions, student prerequisites, and objectives are also included in the module. (NJ)

Field Test Edition

THERMOMETERS

I. Temperature and Heat

II. Expansion Thermometers

III. Electrical Thermometers

Vocational-Technical Physics Project

Ralph Parsons, Project Director

Forsyth Technical Institute

Winston-Salem, North Carolina

sponsored by

the

Occupational Research Unit

State Department of Education

Raleigh, North Carolina

PRE-REQUISITES

The students should be able to read the scales of the following instruments.

1. metric rule
2. mercury-in-glass thermometer
3. Bourdon pressure gauge
4. millivolt meter
5. ohmmeter
6. milliammeter.

OBJECTIVES

After completing this module the student will be able to do the following.

A. Use molecular theory to describe the differences between

1. heat and temperature, and
2. solids, liquids, and gases.

Testing will be by multiple choice questions.

B. Describe the construction and operation of

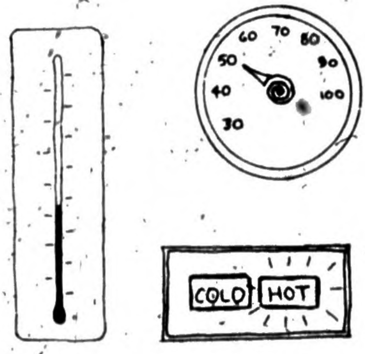
1. a bimetallic thermometer.
2. a liquid-in-glass thermometer,
3. a constant volume gas thermometer,
4. a constant pressure gas thermometer
5. a thermocouple thermometer, and
6. a thermistor thermometer.

Testing will be by discussion questions.

The system for assigning grades to levels of performance will be determined by the instructor.

UNIT I. TEMPERATURE AND HEAT

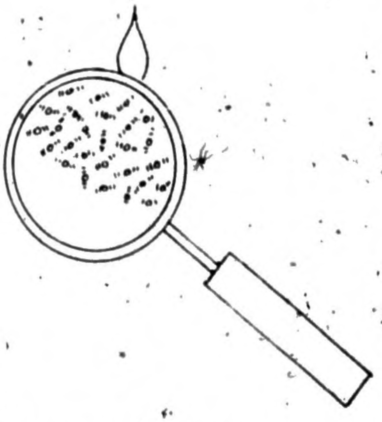
Thermometers are devices used to measure temperature. They can tell us how hot or how cold something is. Temperature is often confused with heat. In order to understand the difference between temperature and heat, we need to examine the definition of each.



THERMOMETERS MEASURE HOW HOT OR HOW COLD A BODY IS.

TEMPERATURE AND HEAT

Heat, also called thermal energy, is the energy a body has due to the random motion of its molecules. All materials that we come into contact with are made up of invisible little particles called molecules. They are so small that one drop of water contains about 1,670,000,000,000,000,000,000 water molecules. These molecules are in constant motion. They travel around at different speeds in unpredictable directions.

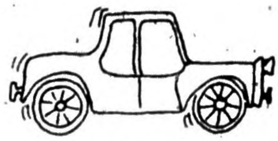


ACTUALLY, THE JIGGLING MOLECULES ARE MUCH TOO SMALL TO BE SEEN WITH A MAGNIFYING GLASS. THE IDEA THAT MATERIALS ARE MADE UP OF MOLECULES IS CALLED MOLECULAR THEORY.

MATERIALS ARE MADE UP OF MANY TINY MOLECULES THAT MOVE AROUND AT DIFFERENT SPEEDS IN DIFFERENT DIRECTIONS.

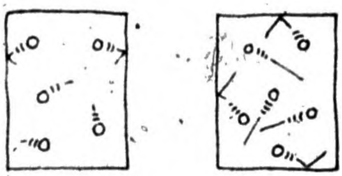
Any body that is in motion has energy. It is called kinetic energy. Just as a car traveling along a road has kinetic energy, a molecule moving about inside a material has kinetic energy. For any molecule, the faster it moves--the more energy it has. The heat that a body has is the TOTAL of the energies of each of its molecules. That means we can increase the amount of heat a body contains by:

1. adding more molecules, or
2. making its molecules move faster.



LOW ENERGY

HIGH ENERGY

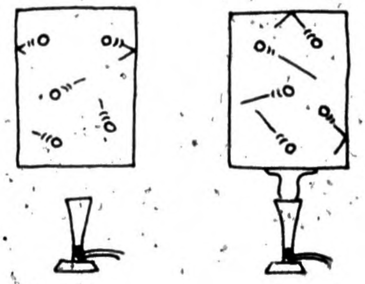


LOW ENERGY HIGH ENERGY

MOLECULES IN MOTION HAVE ENERGY. THE HEAT IN A BODY IS THE TOTAL OF THE ENERGIES OF ALL ITS MOLECULES.

The temperature of a body is a measure of the AVERAGE of the energies of its molecules. The molecules are moving about at different speeds.

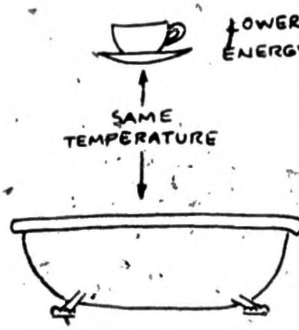
We increase the speed of some or all of the molecules in a body when we add heat to it. Increasing the speed of some molecules causes the average speed of all the molecules to increase. Since temperature depends on the average speed of the molecules, adding heat to a body causes its temperature to increase.



HEATING A MATERIAL INCREASES THE ENERGY OF ITS MOLECULES.

TEMPERATURE DEPENDS UPON THE <u>AVERAGE</u> ENERGY (OR SPEED) OF THE MOLECULES OF A BODY. ADDING HEAT TO A BODY CAUSES ITS TEMPERATURE TO INCREASE.

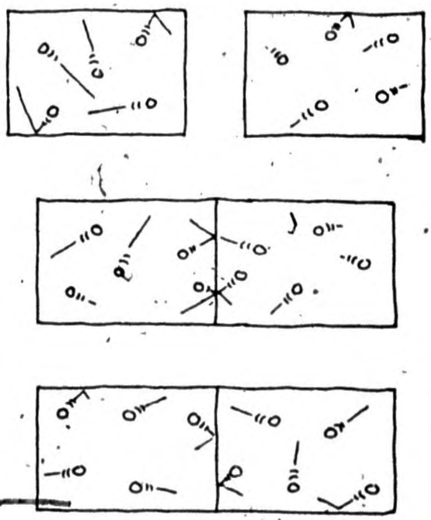
The difference between heat and temperature can be seen by considering two containers of water. A cup of water and a tub of water at the SAME TEMPERATURE have DIFFERENT AMOUNTS OF HEAT. Although the average speeds of the molecules in the two containers is the same, the body that contains the largest total molecular energy has the most heat.



TEMPERATURE DEPENDS ON THE <u>AVERAGE</u> ENERGY OF THE MOLECULES. AMOUNT OF HEAT DEPENDS ON THE <u>TOTAL ENERGY</u> OF THE MOLECULES.

HEAT TRANSFER

Whenever two bodies at different temperatures come into contact, heat flows from the hot body to the cold body. The fast-moving molecules of the hot body collide with the slow-moving molecules of the cold body. As a result, the fast molecules slow down and the slow molecules speed up. This causes the temperature of the hot body to decrease and the temperature of the cold body to increase. If the bodies remain in contact, the heat will continue to flow until both bodies are at the same temperature.



HEAT FLOWS FROM HOT BODIES TO COLD BODIES.

Heat transfer between two bodies that are touching is called CONDUCTION. Most thermometers rely upon conduction. To measure the temperature of a body, some part of a thermometer is brought into contact with the body. Conduction causes the temperature of the thermometer to rise or fall until it is the same as the temperature of the body.

THERMOMETERS RELY UPON CONDUCTION OF HEAT TO OR FROM THE THERMOMETER UNTIL IT IS THE SAME TEMPERATURE AS THE BODY BEING MEASURED.

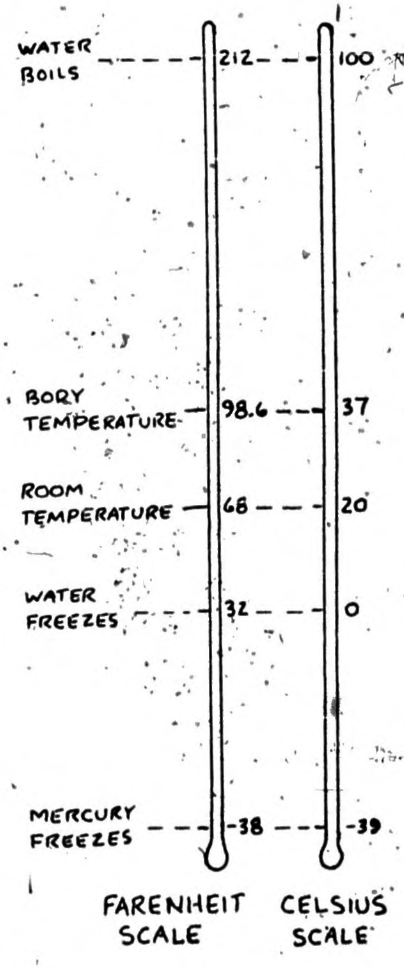
TEMPERATURE SCALES

As the temperature changes, a physical property (such as length) of the thermometer changes. The temperature is determined by measuring that change.

The change that a rising or falling temperature causes in a thermometer is measured in degrees. The degree is simply a unit of temperature change like the inch is a unit of distance.

Just as there are two systems for measuring distance (English and metric), there are two systems for measuring temperature--Fahrenheit and Celsius. The Fahrenheit scale is the one used most often in this country.

Instead of describing a body as being warm or hot or very hot, we can indicate its temperature in degrees. We can be exact.



THE PHYSICAL CHANGE THAT WE CAN OBSERVE IN A THERMOMETER IS MEASURED IN DEGREES. THERE ARE TWO SYSTEMS OF DEGREES (TEMPERATURE SCALES) CALLED FAHRENHEIT AND CELSIUS.

UNIT I. AUDIO-VISUAL MATERIALS

Use the audio-visual materials and then answer the questions below.

1. "Temperature and Heat", a sound/slide program.
2. "The States of Matter", a 16 mm film.
3. "Molecular Theory of Matter", a 16 mm film.
4. "Kinetic Molecular Theory", a filmstrip.

UNIT I. REVIEW QUESTIONS

1. What is a thermometer?
2. What is the difference between temperature and heat?
3. Is it possible for one material to have more heat or thermal energy than another but have a lower temperature? Why?
4. What happens to the molecules in a material as you add heat to it?
5. Under what conditions will heat flow from one body to another? When will that heat flow stop?
6. Since you can't see temperature, how can you measure it?
7. What units is temperature measured in? Describe the different systems of units.

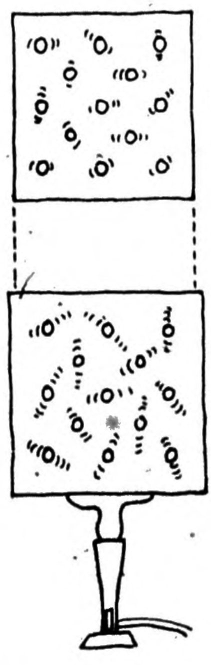
UNIT II. EXPANSION THERMOMETERS

When the temperature of a material rises, that material expands. It gets bigger in all directions. That fact is the basis for the operation of three types of thermometers. They use expanding solids, expanding liquids and expanding gases to indicate different temperatures.

SOLIDS, LIQUIDS, AND GASES EXPAND AS THEIR TEMPERATURE INCREASES.

SOLID EXPANSION

Adding heat to a material causes the molecules in that material to move faster. In solid materials the molecules are fixed in place and are free only to vibrate. As the energy of the molecules increases from the added heat, they vibrate faster and a little further in each direction. As the molecules vibrate further in each direction, the volume that each molecule fills becomes larger. As the volume for each molecule increases, the volume of the material increases. The material expands.



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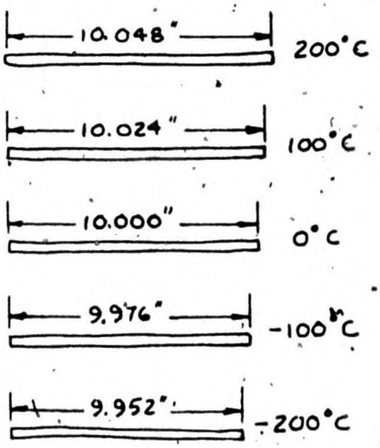
ADDING HEAT TO A SOLID CAUSES THE MOLECULES TO VIBRATE FURTHER IN ALL DIRECTIONS. WHEY THEY VIBRATE FURTHER, THEY OCCUPY A LARGER VOLUME AND THE SOLID EXPANDS.

As heat is added to a material, causing it to expand, the temperature of the material increases. Both the expansion and the increase in temperature are a result of the heat added. The size of the material and the temperature increase at the same rate. The amount of expansion can be measured to tell us how much the temperature has increased.

If heat is taken away from a solid, the molecules lose energy and slow down. Then they take up less volume, and the solid shrinks. As it shrinks, its temperature goes down.

The temperature change and the volume change both occur as the energy of the molecules is changed.



THE LENGTH OF AN ALUMINUM ROD INCREASES AS THE TEMPERATURE GOES UP AND DECREASES AS THE TEMPERATURE GOES DOWN.

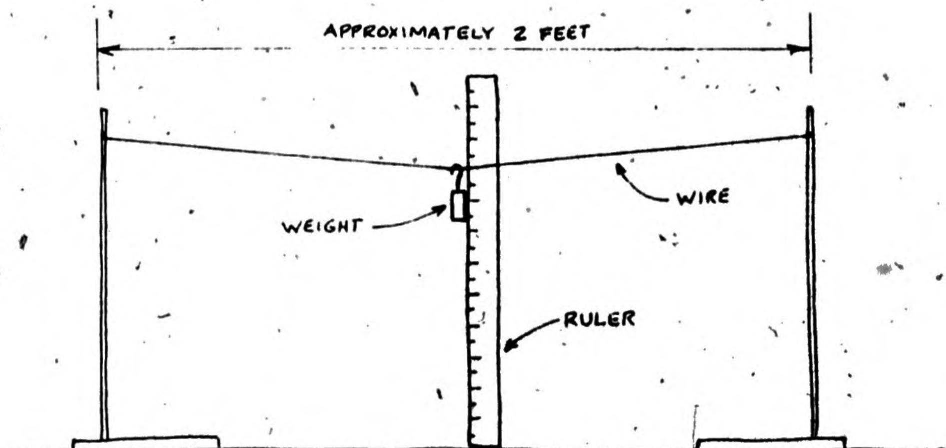
ADDING HEAT TO A SOLID CAUSES IT TO EXPAND. TAKING HEAT AWAY CAUSES IT TO SHRINK. THE TEMPERATURE CHANGE (WHICH WE CAN'T SEE) CAN BE FOUND FROM THE VOLUME CHANGE (WHICH WE CAN SEE).

EXPERIMENT NO. 1

AN OBSERVATION OF LINEAR EXPANSION

Volume expansion involves expansion of width, thickness, and length. Expansion in any one direction is called linear expansion.

Attach a piece of #18 gauge, or smaller, aluminum wire between two supports. Leave enough slack so that when a small weight is hung in the middle, it will cause the wire to sag about one inch. Support a ruler or meter stick behind the wire in the center so you can tell when the weight moves up or down.



EXPANSION VS. TEMPERATURE

Record the mark on the meter stick behind the bottom of the weight. Strike a match and slowly pass it back and forth under the wire on one side of the weight until the match burns down. Quickly record the mark at the bottom of the weight.

Watch the weight slowly rise as the wire cools off and shrinks back to its original position. Now do the same thing again except use a bunsen burner or propane torch to heat the wire. Apply the heat for about the same amount of time. Do not use the hottest part of the flame or heat the wire too much at any one place--it will melt. The gas flame was much hotter than the match. Which one caused the most expansion?

EXPANSION VS. ORIGINAL LENGTH

Repeat the experiment using the gas flame except this time only heat a two inch length of the wire. Compare the amount of expansion to that which occurred when you heated a longer length of wire. Which was more?

If everything went well you should have demonstrated that (1) linear expansion increases and (2) linear expansion increases as the length of heated material increases.

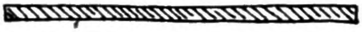
FILL OUT THE LABORATORY DATA SHEET

It would be difficult to measure temperature by measuring the amount that a solid expands. Although the solid does expand, that expansion is very small. This difficulty is overcome with the bimetallic strip.

Different materials expand different amounts for the same increase in temperature. The bimetallic strip uses this fact. Two strips of metal, such as iron and brass, bonded together will bend as the temperature changes. Since brass expands more than iron (for the same temperature change), an increasing temperature will cause the strip to bend with the brass on the outside, or long side.

The bimetallic strip converts a changing temperature into the motion of a strip of metal. This motion can be used to operate a pointer (as in a thermometer) or a switch (as in a thermostat).

IRON



BRASS

BIMETALLIC STRIP

INCREASING TEMPERATURE

DECREASING TEMPERATURE

SOLIDS EXPAND ONLY A SMALL AMOUNT AS THE TEMPERATURE CHANGES.

THERMOMETERS BASED ON SOLID EXPANSION USE A BIMETALLIC STRIP.

A BIMETALLIC STRIP BENDS AS THE TEMPERATURE CHANGES.

EXPERIMENT NO. 2

MAKING A BIMETALLIC THERMOMETER

Mount a bimetallic coil from a thermostat or automatic choke on a small metal plate or wooden block. Make sure the center cannot move.

Put the coil in ice water and when it stops moving, mark the location of the outer end of the strip as 0° C. Heat the water slowly and mark each 10° interval (0°, 10°, 20°, . . .) up to 100° C.

Now use your thermometer to measure room temperature.

FILL OUT THE LABORATORY DATA SHEET

1. BIMETALLIC COIL FROM AN AUTOMATIC CHOKE...

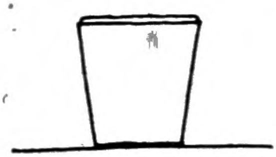
2. ... MOUNTED ON A WOODEN BLOCK...

3. ... BEING HEATED IN A CONTAINER OF WATER.

4. BIMETALLIC THERMOMETER

LIQUID EXPANSION

Liquids differ from solids because the molecules are not as strongly attached to one another. There is still an attraction between molecules but they are free enough to slide over one another. When heat is added to a liquid, the increase in the vibration of the molecules is generally more than in a solid. For the same increase in temperature, water will expand more as a liquid than as a solid.

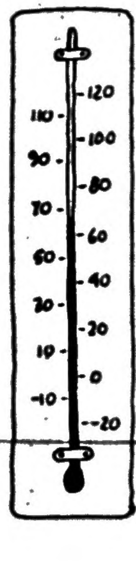


A GLASS COMPLETELY FULL OF COLD WATER...

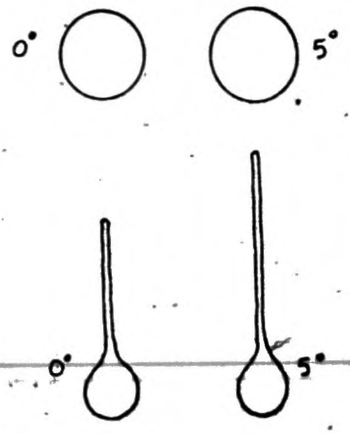
... OVERFLOWS AS IT WARMS UP.

MOLECULES IN A LIQUID HAVE MORE FREEDOM THAN MOLECULES IN A SOLID. ADDING HEAT TO A LIQUID CAUSES MORE MOLECULAR MOTION AND MORE EXPANSION THAN IN A SOLID.

The expansion of a liquid can be seen by watching the liquid rise in a small-diameter glass tube. This is the way that the most common thermometer works. It is called the liquid-in-glass thermometer.



This thermometer is made with a small bulb full of liquid attached to a small-diameter glass tube. As the temperature of the liquid increases, it expands. For a small temperature change, the volume change of the liquid is small. But a small volume change makes a noticeable change in the height of the liquid in the tube. This is true because the diameter of the tube is very small compared to the diameter of the bulb.



A SMALL CHANGE IN THE VOLUME OF A LIQUID IS EASIER TO SEE WHEN PART OF IT IS IN A SMALL TUBE.

THE COMMON LIQUID-IN-GLASS THERMOMETER WORKS BY THE RISE AND FALL OF A COLUMN OF LIQUID AS IT GETS HOT OR COOLS OFF.

The liquids most often used in the liquid-in-glass thermometer are mercury and alcohol. The alcohol has a red dye in it to make it easy to see. Almost any liquid could be used in making a thermometer. The ideal liquid would have a large coefficient of expansion*, a low freezing point and a high boiling point.

*The coefficient of expansion is simply a measure of how much a material expands as the temperature increases one degree. A large coefficient of expansion indicates a large amount of expansion.

Different liquids expand different amounts for the same change in temperature--just as solids do. The most important limitations are freezing point and boiling point. A mercury thermometer cannot be used to measure temperature below − 39°C (-38°F) because at that point it turns into a solid. (It will continue to shrink but at a rate so small that it would be difficult to see.) Mercury is good for measuring high temperatures because it does not boil (or turn into a gas) until 357°C (676°F.) Alcohol can be used in thermometers to measure temperature temperatures as low as -114°C (-173°F) but only as high as 78°C (172°F.)

THE MATERIALS IN THE LISTS BELOW ARE ARRANGED SO THAT THOSE THAT EXPAND MORE ARE NEARER THE TOP.

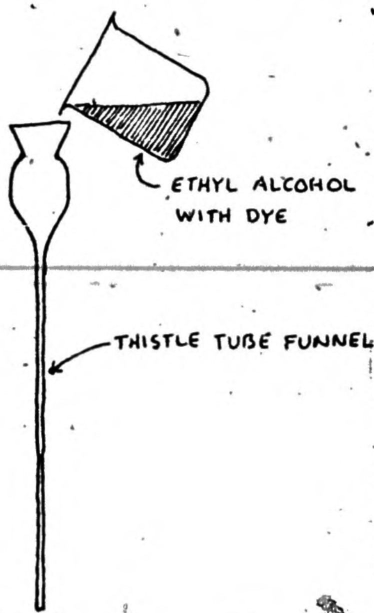
SOLIDS	LIQUIDS
LEAD	ALCOHOL
ALUMINUM	GLYCERINE
SILVER	WATER
BRASS	MERCURY
COPPER	
IRON	

THE LIQUIDS MOST OFTEN USED IN THERMOMETERS ARE MERCURY AND ALCOHOL. THE TEMPERATURE RANGE OVER WHICH A LIQUID THERMOMETER CAN BE USED DEPENDS UPON THE FREEZING AND BOILING POINTS OF THE LIQUID.

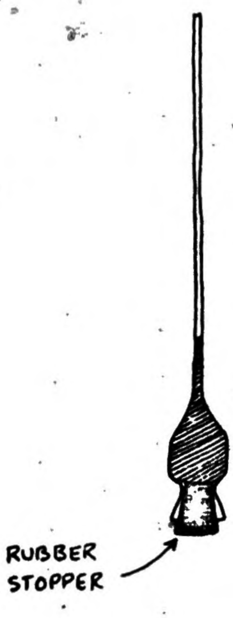
EXPERIMENT NO. 3

MAKING A LIQUID-IN-GLASS THERMOMETER

A liquid-in-glass thermometer is not difficult to make. Use alcohol (ethyl alcohol, also called ethanol) with a few drops of dye or food coloring to make it more visible. You also need a glass tube that has a bulb at one end that is large when compared to the inside diameter of the tube. One that works well is a piece of glassware used in a chemistry lab called a thistle tube funnel.



To make the thermometer, hold the thistle tube upright and, with your finger over the bottom, pour the colored alcohol into it until it is almost full. Put a rubber stopper or cork into the large hole. Now turn your thermometer so that the bulb is at the bottom. Add or take away alcohol until it fills the bulb and goes up in the tube about two inches.



To calibrate your thermometer use the following procedure.

1. Make a data table in which you will record the height of the alcohol above the bulb for several different temperatures.
2. Place your thermometer together with a regular mercury thermometer in a container of ice and water. After five minutes measure your alcohol level and record it as 0°C.
3. Replace the water in the container with tap water and begin to heat the water VERY SLOWLY.
4. Record the height of your alcohol at every 10°C interval (20°C, 30°C, 40°C,...).

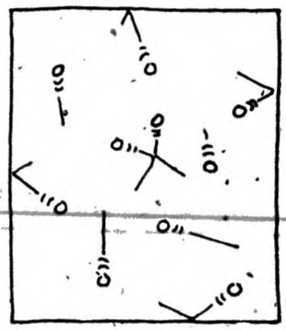
What is the highest temperature you can measure? Why?

Use your thermometer to measure your skin temperature.

FILL OUT THE LABORATORY DATA SHEET

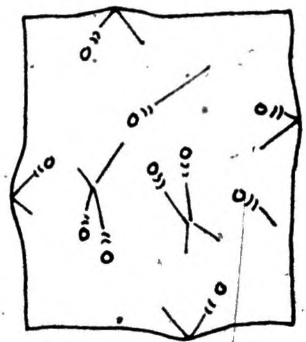
GAS EXPANSION

In a gas the molecules are free to move around without being attracted by other molecules. The molecules are so far apart and move so fast that they only meet occasionally in a collision. When they collide with one another or with the walls of their container, they bounce off and keep going.



THE MOLECULES OF A GAS HAVE MAXIMUM FREEDOM. THEY MOVE AROUND AT VARIOUS SPEEDS, BOUNCING OFF ONE ANOTHER AND THE WALLS OF THEIR CONTAINER.

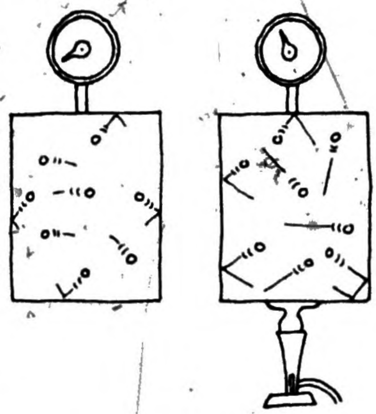
When heat is added to a gas, the molecules become more energetic and the temperature of the gas rises. The additional energy causes them to move faster, hitting the walls of their container harder. If the gas is in a container with moveable walls, the walls move back when they are hit harder. The volume that the gas occupies gets larger.



If heat is taken away from a gas, the energy of the molecules decreases. They slow down and hit the walls with less force. If the walls are moveable, the volume of the gas gets smaller.

ADDING HEAT TO A GAS CAUSES THE MOLECULES TO MOVE FASTER. THEY HIT THE WALLS OF THEIR CONTAINER HARDER AND, IF THE WALLS CAN BE MOVED, EXPAND INTO A LARGER VOLUME.

The force with which the molecules strike an area of the container walls is called pressure. If the walls can move, they will move until the pressure is the same on both sides of the wall. If the walls cannot move as the gas is heated, the pressure inside the container will increase.



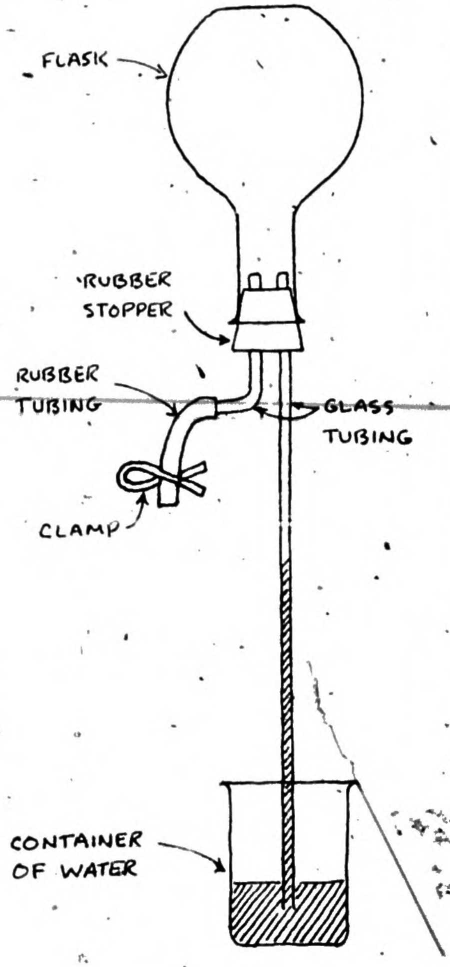
GASES EXERT A PRESSURE ON THE WALLS OF THEIR CONTAINER. IF THE WALLS CANNOT MOVE THE PRESSURE WILL INCREASE AS THE TEMPERATURE OF THE GAS GOES UP. THE PRESSURE WILL DECREASE AS THE TEMPERATURE OF THE GAS GOES DOWN.

This means that gas thermometers can be made that indicate temperature by changing volume or by changing pressure.

EXPERIMENT NO. 4

MAKING TWO GAS THERMOMETERS

Make a gas thermometer with a small section of moveable wall as follows. Use a small flask equipped with a two-hole stopper, two glass tubes, a section of rubber tube and a clamp. Support the flask upside down over a container of water. Suck some air out, through the rubber tube until the water rises halfway up the long tube. Put the clamp on the rubber tube.



Now observe the change in the volume of air (as seen by the level of water) as you warm the air with your hand or cool it with an ice cube. How do you think you could reduce the volume of air to nothing?

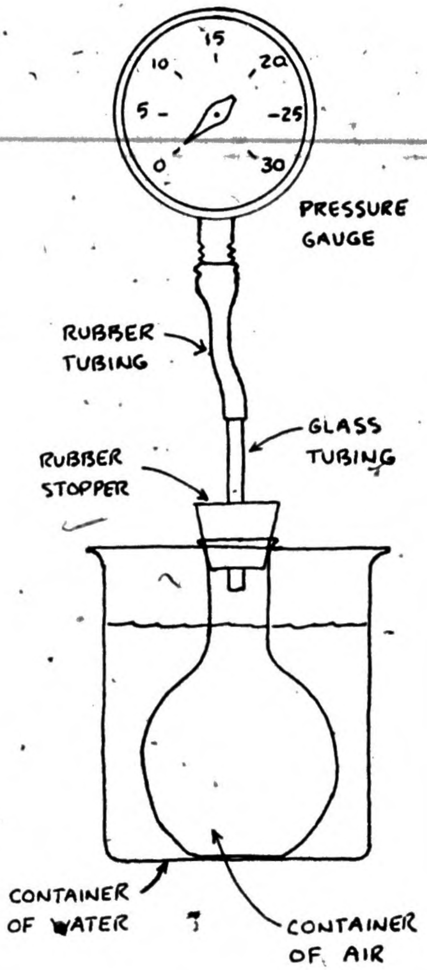
The increase of pressure with temperature is the basis for many automobile engine temperature gauges. This type thermometer consists of a pressure gauge (on the instrument panel), a small container of gas (in the engine) and a connecting tube. The volume of the gas remains essentially the same so as the engine warms up the pressure of the gas goes up.

Make another gas thermometer using a pressure gauge, a small flask with a one-hole stopper, some glass tubing, and rubber tubing. Put the flask in ice water and leave it ten minutes before inserting the stopper. This will make sure the gas (air) in the thermometer is at 0°C when the pressure gauge reads 0.

Now remove the ice water and fill the container with water at room temperature. Heat the water until it boils and record the temperature and pressure. Let the water cool and continue to record the temperature and pressure at 20°C intervals until the water is at 40°C. Tap the side of the pressure gauge occasionally.

Does the pressure change at the same rate as the temperature? How could you reduce the pressure of the gas so that the gauge reading was below zero?

FILL OUT THE LABORATORY DATA SHEET



UNIT II. LABORATORY DATA SHEET

EXPERIMENTS NO. 1,2,3, AND 4

EXPERIMENT No. 1 AN OBSERVATION OF LINEAR EXPANSION

	Heating with Match	Heating with Gas Flame	Heating Short Section with Gas Flame
Starting Position of Weight			
Position After Heating			
Difference in Position			

EXPERIMENT NO. 2 MAKING A BIMETALLIC THERMOMETER

Room Temperature (from bimetallic thermometer) = ______________

EXPERIMENT NO. 3 MAKING A LIQUID-IN-GLASS THERMOMETER

Height of Alcohol	Temperature (°C)

What is the highest temperature you can measure with an alcohol thermometer?

____

Why is it the highest? ______________

____

____

Skin temperature (from alcohol-in-glass thermometer) = ______________

UNIT II. LABORATORY DATA SHEET

EXPERIMENT NO. 4 MAKING TWO GAS THERMOMETERS

How does the volume of the gas change as you heat it with your hand and cool it with an ice cube?____________________

____

Temperature of Gas (°C)	Pressure of Gas (psi)
0	
100	
80	
60	
40	

Does the pressure change at the same rate as the temperature?

____

How could you reduce the pressure of the gas so that the gauge reading was below zero?____________________

____

UNIT II. AUDIO-VISUAL MATERIALS

Use the audio-visual materials and answer the questions below.

1. "Expansion Thermometers", a sound/slide program.
2. "Heat Expands Metals", an 8 mm film loop.
3. "Heat Expands Liquids", an 8 mm film loop.
4. "Heat Expands Gases", an 8 mm film loop.

UNIT II. REVIEW QUESTIONS

1. Why do materials expand as their temperature rises?
2. What determines how much a material will expand when heated?
3. How does the bimetallic thermometer work?
4. Why do liquids expand more than solids?
5. How does the liquid-in-glass thermometer work?
6. What determines the best liquid to use in a thermometer?
7. Describe the action of the molecules in a gas.
8. What two things can happen when a gas is heated?

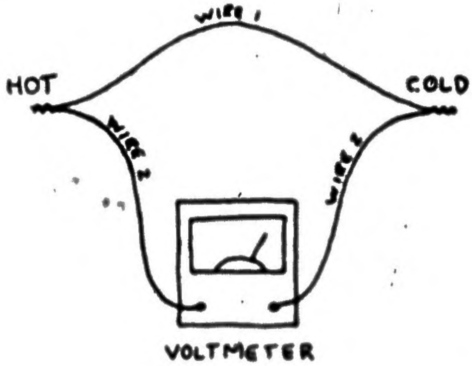
UNIT III. ELECTRICAL THERMOMETERS

Sometimes it is necessary to measure the temperature at one point and read it at another point. This is called remote temperature sensing. It can be done by measuring the pressure created by an expanding liquid or gas. More often, remote sensing is done electrically. Electrical thermometers rely upon the effects of changing temperatures on the electrical properties of certain materials.

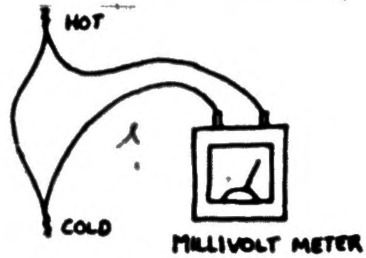
REMOTE TEMPERATURE SENSING IS USUALLY DONE WITH ELECTRICAL THERMOMETERS. THEY WORK BECAUSE THE ELECTRICAL PROPERTIES OF SOME MATERIALS DEPEND ON TEMPERATURE.

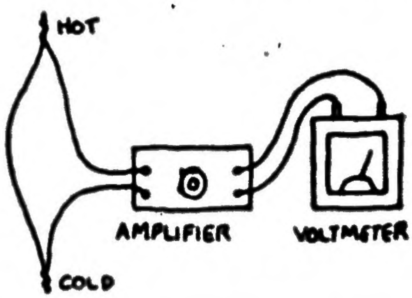
THERMOCOUPLES

If two different types of wire are joined at their ends to form a loop, and if the two junctions are at different temperatures, a voltage will be generated in the loop.



This arrangement of two different types of wires is called a thermo-couple. The voltage generated in the loop is very small. It is measured in thousandths of a volt--called milli-volts (mv). The measurement of this voltage requires a very sensitive voltmeter (a millivolt meter). Another method is to amplify the voltage and use a regular voltmeter.





A LOOP MADE OF TWO DIFFERENT KINDS OF WIRE JOINED AT THEIR ENDS CAN BE USED AS A THERMOCOUPLE. IF THE TWO JUNCTIONS ARE AT DIFFERENT TEMPERATURES, A SMALL VOLTAGE WILL BE GENERATED IN THE LOOP.

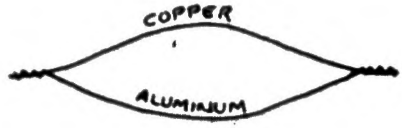
EXPERIMENT NO. 5

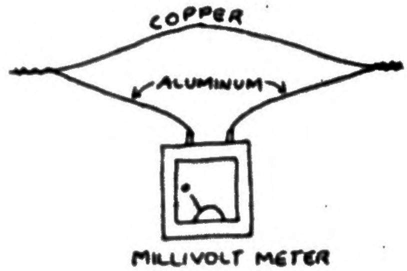
MAKING AND TESTING SOME THERMOCOUPLES

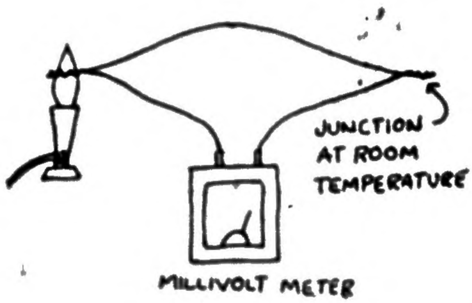
Any two different metals can be used to make a thermocouple. In the following experiment you will make several thermocouples and see how the voltage generated is related to the temperature difference.

WEAR SAFETY GLASSES DURING THIS EXPERIMENT

Make a COPPER-ALUMINUM thermocouple using regular aluminum wire and enameled copper wire, each about #22 AWG*. Cut a piece of each type wire about three feet long. Scrape the enamel from the ends of the copper wire and twist the wires together to form a loop. Cut the aluminum wire in the middle and connect the ends to a millivolt meter. The meter should read zero. Use a bunsen burner or propane torch to slowly heat one end of your thermocouple. (If the needle on the meter starts to move in the wrong direction, switch the leads on the meter.) Continue heating the junction until the aluminum melts and the junction comes apart. Record the highest meter reading.



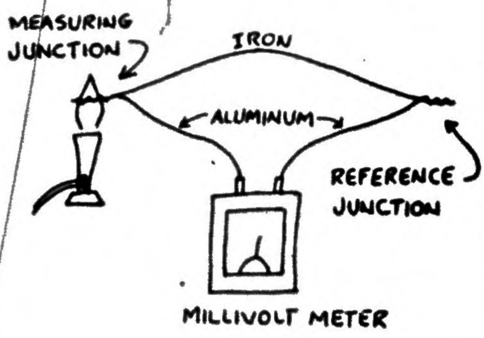




*AWG means American wire gauge. The gauge of a wire depends upon its diameter. The larger the gauge-the smaller the diameter.

A THERMOCOUPLE MEASURES THE DIFFERENCE BETWEEN THE TEMPERATURES OF TWO JUNCTIONS. IN THE SITUATION HERE, THE MEASURING JUNCTION IS PLACED IN THE FLAME AND THE REFERENCE JUNCTION IS AT ROOM TEMPERTURE.

Make an IRON-ALUMINUM thermocouple in the same manner as you did before. Test it with a bunsen burner to find the voltage generated for the temperature at which aluminum melts. Record that voltage.



For both thermocouples you made, how does the voltage produce change as the temperature rises? Which type thermocouple generated the highest voltage for the same temperature (the melting point of aluminum)?

ALUMINUM MELTS AT 660°C.

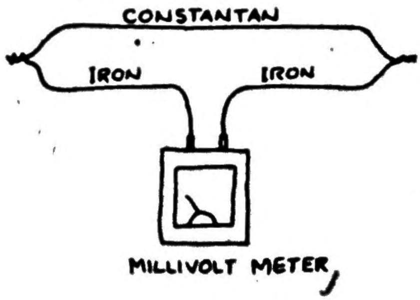
You have demonstrated that the voltage produced depends on:

1. the temperature difference between the junctions, and
2. the type of metals used.

FILL OUT THE LABORATORY DATA SHEET

EXPERIMENT NO. 6

MAKING AND USING A REAL THERMOCOUPLE



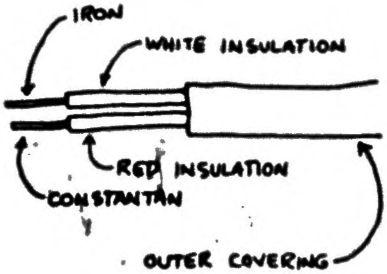
One of the most commonly used thermocouples in industry is made of iron and constantan (an alloy of copper and nickel). It can be used to measure temperatures between -190°C (310°F) and about 870°C (1600°F). The exact range depends on such factors as the gauge of the wire and the type of atmosphere around it.

THE IRON-CONSTANTAN THERMOCOUPLE IS KNOWN AS TYPE J. SOME OTHER COMMONLY USED METALS ARE:
COPPER-CONSTANTAN - TYPE T
CHROMEL-CONSTANTAN - TYPE E
CHROMEL-ALUMEL - TYPE K

In this experiment you will make an iron-constantan thermocouple and use it to measure the temperatures in different parts of a candle flame.

WEAR SAFETY GLASSES DURING THIS EXPERIMENT

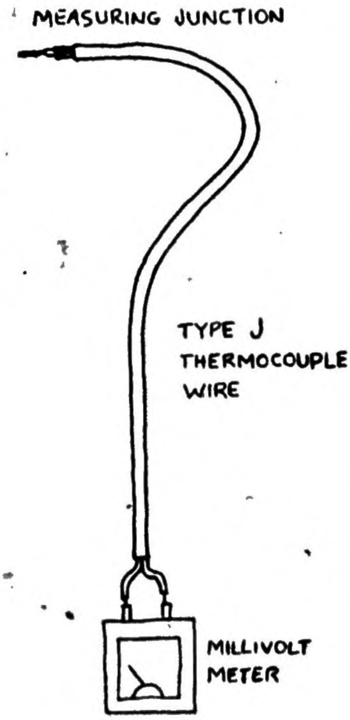
Begin with a two-foot length of iron-constantan thermocouple wire. It is made with the two wires laying side-by-side but insulated from one another. There is an outer covering over the pair.



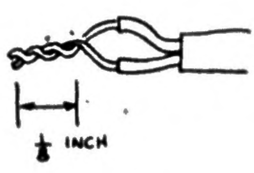
Remove two inches of outer covering from both ends. Then remove the insulation from one inch of each wire on both ends. Make the measuring junction by twisting the iron and constantan tightly together (use pliers). Connect the loose ends of the wires to a voltmeter (connect the iron to the positive terminal) with a range of at least 0-50 millivolts.

Insert the measuring junction in a candle flame and record the voltages produced by three parts of the flame; the area at the wick, the middle of the flame, and just above the top of the flame. Read the graph on the following page to convert the voltage to temperatures.

FILL OUT THE LABORATORY DATA SHEET



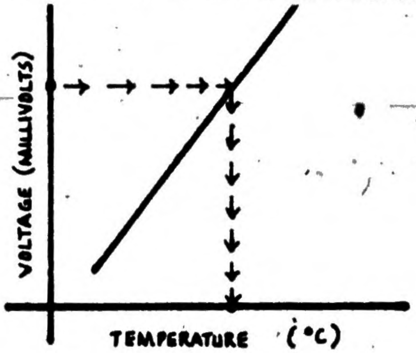
WHEN THE REFERENCE JUNCTION IS GOING TO BE AT ROOM TEMPERATURE, THE CONNECTION AT THE METER CAN SERVE AS A JUNCTION.

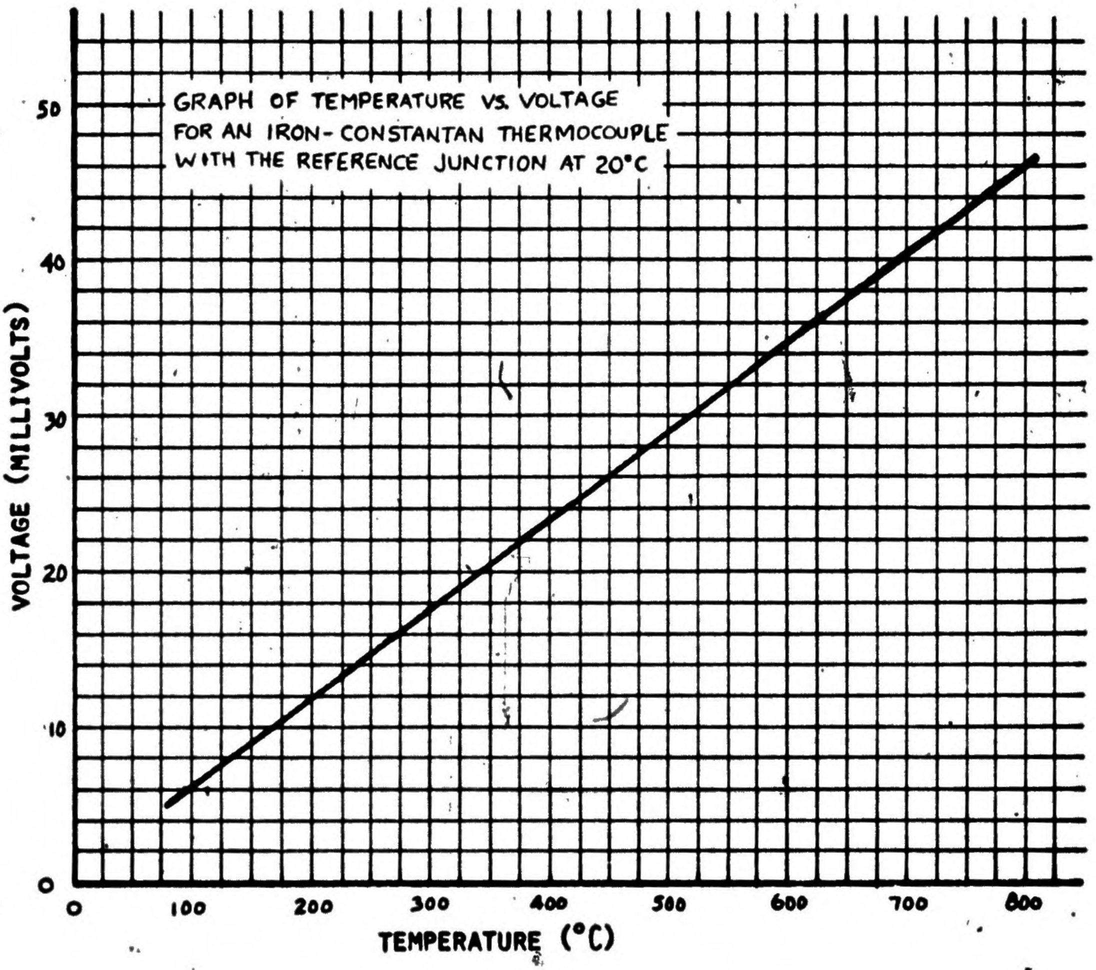


THE MEASURING JUNCTION

To use the graph below:

1. find the voltage on the vertical line,
2. move straight across the page to the dark curve, and
3. move straight down and read the temperature.

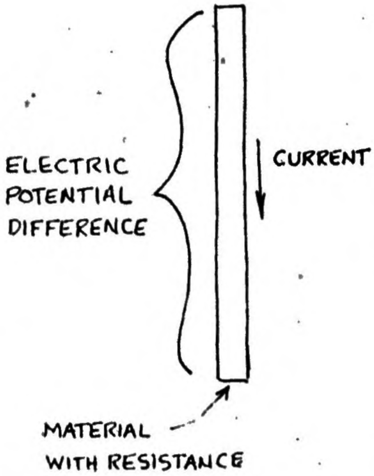




THERMISTORS

A thermistor is a thermal resistor- a device whose electrical resistance changes as the temperature changes. The electrical resistance of a material is a measure of how well that material resists an electrical current.

If an electric potential difference- a voltage- exists between two points in a solid material, there will be a current between those points. If the resistance between the points is high, the current will be small. If the resistance decreases, the current will increase.



A THERMISTOR IS A DEVICE IN WHICH A CHANGING TEMPERATURE CAUSES A CHANGING ELECTRICAL RESISTANCE. FOR A CONSTANT VOLTAGE BETWEEN TWO POINTS IN A MATERIAL, THE RESISTANCE CONTROLS THE AMOUNT OF CURRENT.

All materials have resistance and the resistance of all materials changes as the temperature changes.

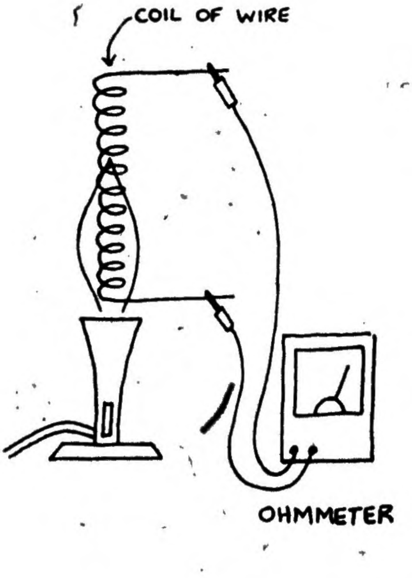
Thermistors are ceramic materials made from a mixture of metal oxides. The resistance-temperature characteristics of thermistors differ from ordinary materials in two important ways--as you will see in the following experiment.

EXPERIMENT NO. 7

A COMPARISON OF THERMISTORS WITH ORDINARY MATERIALS

Using a piece of #22 AWG iron wire about three feet long, make a coil by winding it around a pencil. Leave about six inches straight at each end. Connect an ohmmeter* to the coil and record its resistance.

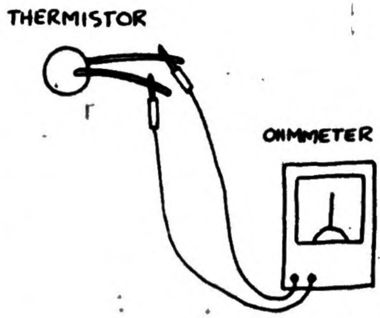
Place the coil in the flame of a bunsen burner and record its resistance after five seconds. Pour water on the coil. How does the resistance of the wire change as the temperature changes?



*An ohmmeter is a device used to measure resistance.

Now you will find out how the resistance of a thermistor changes with temperature.

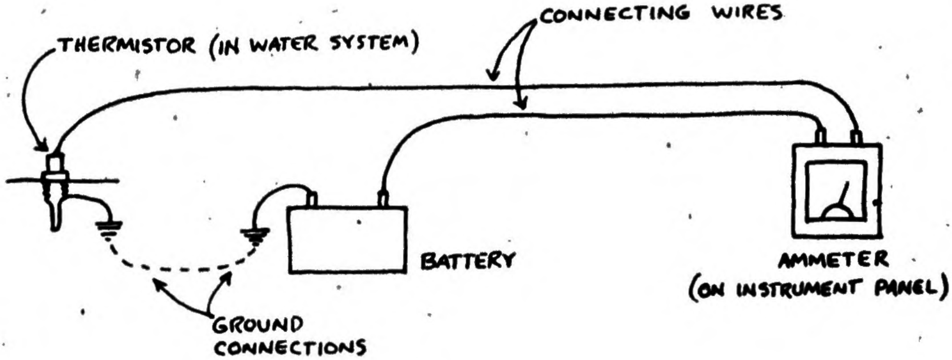
Record the resistance of a thermistor at room temperature. Now hold the thermistor with your fingers and notice how the temperature changes.



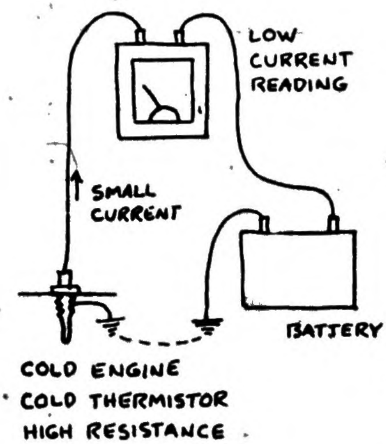
How does the resistance vary as the temperature changes? Which is more sensitive, the iron wire or the thermistor.

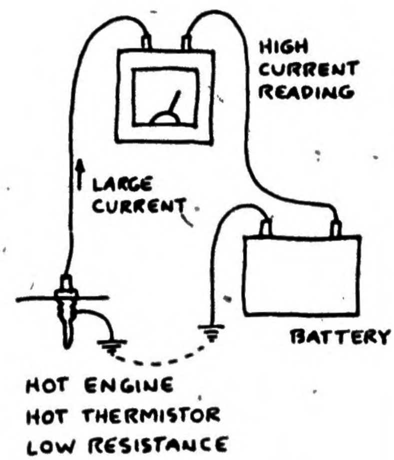
EXPERIMENT NO. 8
CALIBRATING A THERMISTOR

Thermistors are often used in a system that indicates the temperature of the water in an automobile engine. Such a system includes a thermistor, a battery, and an ammeter all connected in series.



In a series connection the voltage of the battery causes the same amount of electrical current to be in the thermistor, the ammeter, and the battery. The amount of current is limited by the resistance of the thermistor and the resistance of the meter. The resistance of the meter stays the same but the resistance of the thermistor changes. As the engine gets hot, the thermistor gets hot and its resistance goes down. As its resistance goes down, more current is allowed to flow and the ammeter needle moves up the scale. The ammeter can be calibrated to read the temperature of the thermistor.





Make a table of values of current for known temperatures of the thermistor. To do this suspend the thermistor in a container of ice water along with a regular mercury thermometer. Connect the thermistor into a series circuit with a 12-volt battery, (or power supply), an ammeter* and a resistor.

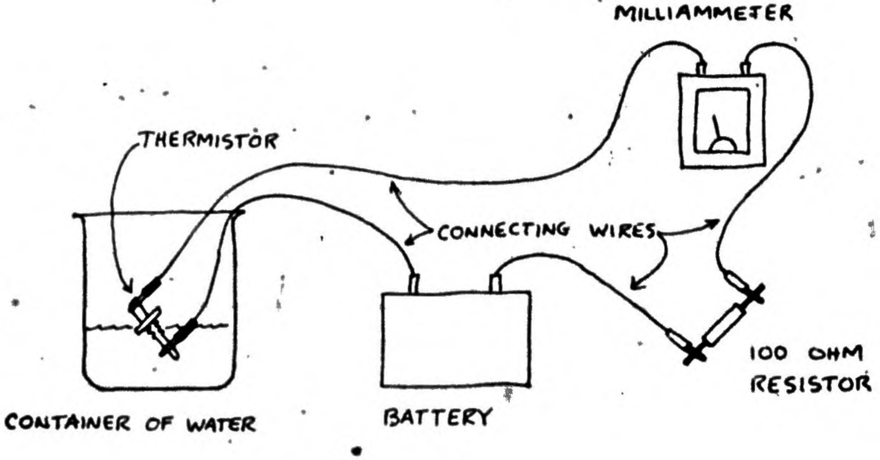
*The current will be measured in thousandths of an ampere-called milliamps.

The ammeter should read from 0 to 0.100 amperes (0-100 milliamperes). The resistor is in the circuit to reduce the amount of current that flows. Too much current through the thermistor can damage it.

Slowly heat the water and record the current for temperatures of 0°, 10°, 20°, 30°, and so forth until the water boils or the ammeter reaches its maximum reading.

Now hold the thermistor in your hand and determine what your skin temperature is.

FILL OUT THE LABORATORY DATA SHEET



UNIT III. LABORATORY DATA SHEET Sheet 1

EXPERIMENTS NO. 5,6,7, AND 8 Name________________

EXPERIMENT NO. 5 Date________________

MAKING AND TESTING SOME THERMOCOUPLES

Highest voltage from copper-aluminum thermocouple = ____________mv

Highest voltage from iron-aluminum thermocouple = ____________mv

How does the voltage change as the temperature rises?__________

____

Which thermocouple pair produced the highest voltage for the same temperature?____

EXPERIMENT NO. 6

MAKING AND USING A REAL THERMOCOUPLE

Temperature of candle flame: at the wick, ______________ C

in the middle ______________ C

at the top, ______________ C

EXPERIMENT NO. 7

A COMPARISON OF THERMISTORS WITH ORDINARY MATERIALS

Resistance of iron wire at room temperature = ____________Ohms

Resistance of hot iron wire = ________________Ohms

How does the resistance of iron wire change as the temperature changes?____

UNIT III. LABORATORY DATA SHEET Sheet 2

EXPERIMENT NO. 7 (continued)

Resistance of thermistor at room temperature = __________ Ohms

Resistance of warm thermistor = ______________ Ohms

How does the resistance of a thermistor change as the temperature changes? ____

Which is more sensitive, iron wire or the thermistor? __________

EXPERIMENT NO. 8 CALIBRATING A THERMISTOR

Temperature (°C)	Current (Milliamps)
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Skin temperature (measured by thermistor) = ______________ C

UNIT III. AUDIO-VISUAL MATERIALS

Use the audio-visual materials and then answer the questions below.

1. "Electrical Thermometers", a sound/slide program.

UNIT III. REVIEW QUESTIONS

1. What is "remote temperature sensing"?
2. Describe a thermocouple.
3. What determines the voltage generated in a thermocouple?
4. What limits the maximum temperature a thermocouple can measure?
5. What is a thermistor?
6. How does temperature affect the resistance of a metal (like iron)?

   How does it affect the resistance of a thermistor?
7. Describe how a thermistor can be used to measure temperature.