Heat and Energy

Energy is a part of everything we do and see.

Heat and light are energy.

Energy helps us move and grow.

Energy makes machines work.

There is energy in everything in the world—in the air, in our bodies, in every rock and plant.

We use heat, called **thermal energy**, every day. We can t see heat, but we can feel it. Our bodies make heat and our stoves and lights do, too. We heat our houses, our food, and our water.

Sometimes there is too much heat and we move it. Refrigerators take heat away from the food inside. Air conditioners take heat from inside the house and move it outside. Swimming pools take heat from our bodies.

Heat Is the Motion of Molecules

What is heat? Scientists say it is the **kinetic energy** in a substance. Kinetic energy is the energy of motion. Heat is the motion of the molecules in a substance, not the motion of the substance itself.

Everything is made of **atoms**. Atoms bond together to form molecules. **Molecules** are the building blocks of substances. Water is a substance. Have you ever heard water called H-2-O (H_2O)? That means a molecule of water has two hydrogen (H) atoms and one oxygen (O) atom.

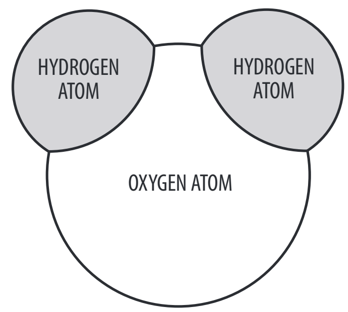
Even though we can t see them, the molecules in substances are never still. They are always moving. That motion is the kinetic energy called heat.

Molecules Vibrate, Spin, and Move

The molecules in solids—like rocks, wood, or ice—cannot move much at all. They are held in one position and cannot flow through the substance. They do move back and forth in their positions. They vibrate. The more heat they have, the faster they vibrate.

Liquids and **gases** are called **fluids**. The molecules in fluids move more freely than in **solids**. They flow through the fluids. The more heat fluids have, the faster their molecules move.

Water Molecule

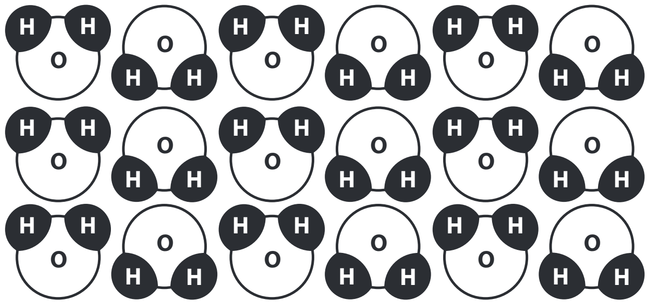


What happens when you heat an ice cube? Ice is a solid. A solid has a definite shape. Its molecules vibrate in one position. When you add heat, the molecules vibrate faster and faster. They push against each other with more force. They become a liquid—water. The molecules begin to move and spin. They are still bonded together, but not so tightly that they stay in one position.

A liquid flows to take the shape of its container. It has a definite volume, but can take any shape. **Volume** is the amount of space a fluid occupies.

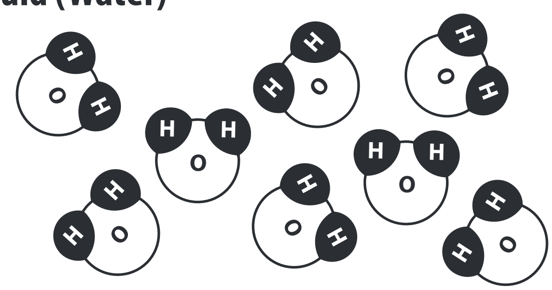
If you add more heat energy to the molecules, they move faster and faster. They crash into each other and move away. They become a gas—steam. A gas does not have a definite shape or volume. It spreads out and fills whatever space it is in.

Solid (Ice)



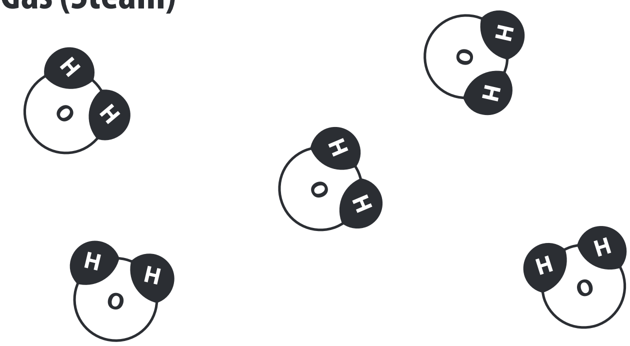
Molecules vibrate in one place.

Liquid (Water)



Molecules spin and move close together.

Gas (Steam)



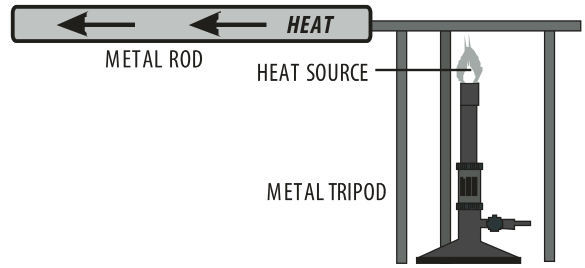
Molecules spin faster and move far away from each other.

Heat Seeks Balance

Everything in nature seeks balance. Heat seeks balance, too. Heat flows from hotter places to colder places and from hotter substances to colder substances. What happens if you pour hot water into a cold tub? The molecules of hot water have more energy. They are fast moving. They crash into the colder molecules and give them some of their energy.

The molecules of hot water slow down. The molecules of cold water move more quickly. The cold water gets warmer. The hot water gets cooler. Soon all the water is the same temperature. All the water molecules are moving at the same speed. The heat in the water is in balance.

Conduction in Solids



Heat Energy Moves

Heat energy is always on the move. It moves to seek balance. Heat can move in many ways. When a hot object touches a cold object, some of the heat energy flows to the cold object. This is called conduction. **Conduction** is the way heat energy moves in solids.

When we cook food in a pan on an electric stove, we use conduction. The heating element on the stove is hot. The pan is cold. Some of the heat from the heating element flows to the pan. The heat from the pan flows to the food inside. The heat moves by conduction.

Heat Moves by Conduction in Solids

How does the heat move? Let s think about it. All solids are made of molecules. The molecules in solids vibrate. The more energy they have, the faster they vibrate. In a hot object, the molecules vibrate fast. The molecules in a cold object vibrate more slowly.

Let s touch a hot object to a cold object. The fast-moving molecules in the hot object push against the slow-moving molecules in the cold object. The fast molecules give up some energy to the slower moving molecules. The vibration of the fast molecules slows down.

The molecules in the cold object gain some energy from the hot object. They vibrate faster. The cold object gets warmer. The hot object gets cooler. The energy in the molecules is seeking balance. When the energy is in balance, all the molecules vibrate at the same speed.

Look at the picture at the top of this page. The flame adds heat to the tripod. The tripod gets very hot because it is metal. The metal rod touches the tripod. The molecules in the tripod vibrate against the molecules in the end of the rod. The molecules in that end of the rod vibrate faster.

Now one end of the rod has more energy than the other end. What happens? The hotter molecules transfer some of their energy to the cooler molecules. The molecules in the rod conduct the heat from the hotter end to the cooler end. The heat moves from the tripod to the end of the rod touching it, then through the rod.

The energy flows from molecule to molecule as they vibrate against each other. Heat is moving by conduction.

Conductors and Insulators

In some materials, heat flows easily from molecule to molecule. These materials are called **conductors**. They conduct—or move—heat energy well.

Look back at the picture with the metal rod and the tripod. You would not hold the metal rod with your bare hand. You would get burned! The metal would conduct the heat to your hand. Metals are good conductors of heat.

If you touched a wooden pencil to the tripod, would it conduct heat as well as the metal rod? No—wood is not a good conductor of heat. Materials that don t conduct heat well are called **insulators**.

The molecules in good conductors are close together. There is very little space between them. When they vibrate, they push against the molecules near them. The energy flows between them easily.

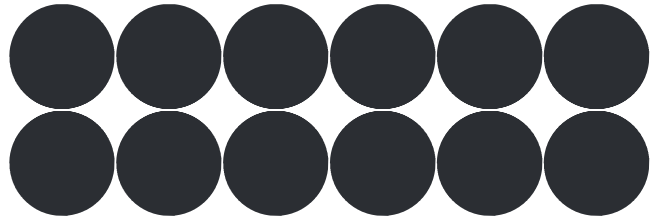
The molecules in insulators are not so close together. It is harder for energy to flow from one molecule to another in insulators.

Look at the objects to the right. The pot, the spoon, and the fork are made of metal. The pot and the spoon have plastic handles. The fork has a wooden handle. The dish is made of glass. The oven mitt is made of cotton fabric.

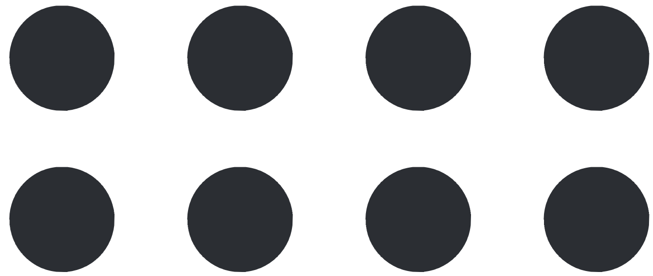
Which materials are the insulators? The insulators are the materials that don t move heat. They protect us from heat. Our experience tells us that wood, plastic, and cotton are all good insulators. Metals are good conductors. The metal part of the pan moves heat to the food inside to cook the food. The plastic handle protects our hands. The wooden handle and cotton glove protect our hands, too.

What about glass? It is not as good of a conductor or insulator as the other materials. It is used to conduct heat in pots and pans, and can also be used to insulate. It used to be used on power and telephone lines as an insulator.

Good Conductor



Good Insulator



Conductors and Insulators

Movement of Heat in Fluids

Fluids are liquids and gases. Heat also moves in fluids. Heat doesn't move by conduction. In fluids, the molecules are too far apart to conduct energy as they vibrate. The molecules in fluids are free to move and spin. As they move, they bounce against each other. The molecules with more energy give up some energy. The molecules with less energy gain some.

Heat energy in liquids and gases moves in currents by **convection**.

If we heat water on a stove, the water molecules begin to move and flow faster. The molecules near the flame have more energy. They push against each other and move farther apart.

The water at the top of the pan is cooler. Its molecules don t have as much energy. They are closer together than the molecules of hot water. They are denser.

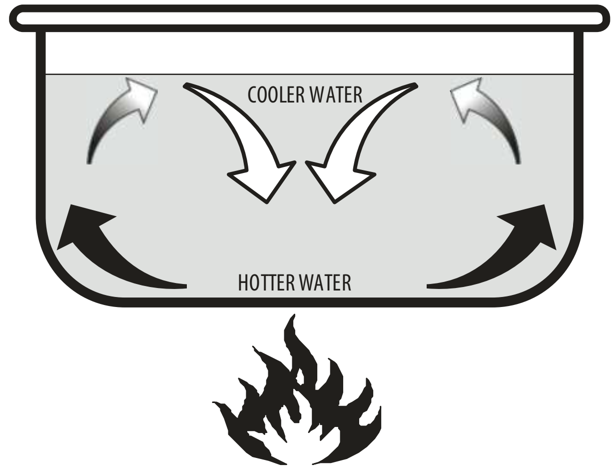
The cooler, denser molecules flow down. The warmer, less dense molecules rise up. They form currents of flowing molecules. During this motion, the hotter molecules transfer energy to the cooler molecules. This transfer of heat through the motion of currents is called convection.

Heat also moves by convection in gases. Air is the gas you know best. You may have noticed that the top floor of a building is warmer than the basement. The air near the ceiling is warmer than the air near the floor.

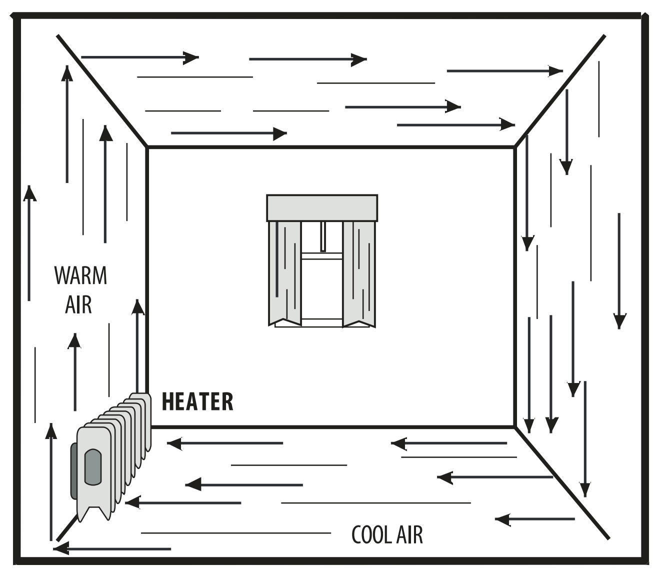
The molecules of gases are like molecules in liquids. The more energy they have, the farther apart they are. In a room, the cooler, denser air flows down. The warmer, lighter air rises. A current of flowing air is formed.

The warmer molecules give up energy as they bounce against cooler molecules. They give up some energy, become cooler, and flow down again. The heat is transferred by convection.

Convection in Liquids



Convection in Gases



Wind Is a Convection Current

Heat moves all the time—all over the world. Even the wind is energy in motion.

When the sun shines on the Earth, the land gets warmer than the oceans. Land can absorb more energy from the sun faster than water. It changes the radiant energy into heat.

This makes the air over the land warmer than the air over the ocean. The warm air rises. The cooler air over the ocean flows in to take its place. The air flows in currents. The heat in the air is transferred by convection. This moving air is the **wind**.

The ocean is a fluid similar to air. Ocean waters have currents, too. The water near the Equator is warmed by the sun. The water near the poles is cold. The warm water rises to the surface. The cold water flows in to take its place. Ocean currents are formed by convection.

Energy Moves by Radiation

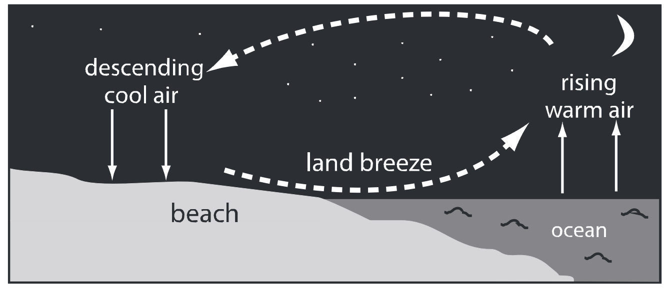
Most of the Earth s energy comes from the sun. Every day, the sun gives off a lot of energy. It comes from the sun in rays or waves. It is called **radiant energy**.

Energy does not travel from the sun as heat. Heat must move from molecule to molecule and there are no molecules in space. Solar energy travels in rays or waves as radiant energy.

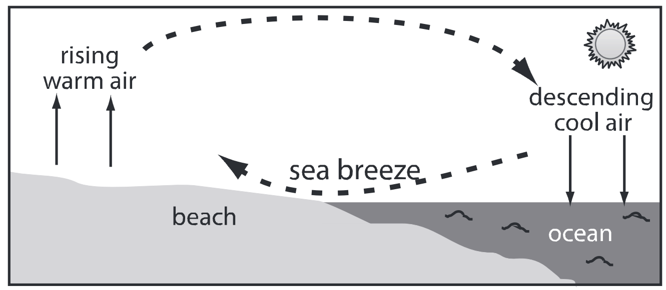
When the radiant energy reaches the Earth, it hits molecules in the air, in the ocean, and on land. It hits our bodies. The molecules turn some of the radiant energy into heat.

The energy from the sun that we can see is visible light. Other kinds of radiant energy are ultraviolet rays, infrared **radiation**, and microwaves. Infrared radiation produces most of the heat on the Earth.

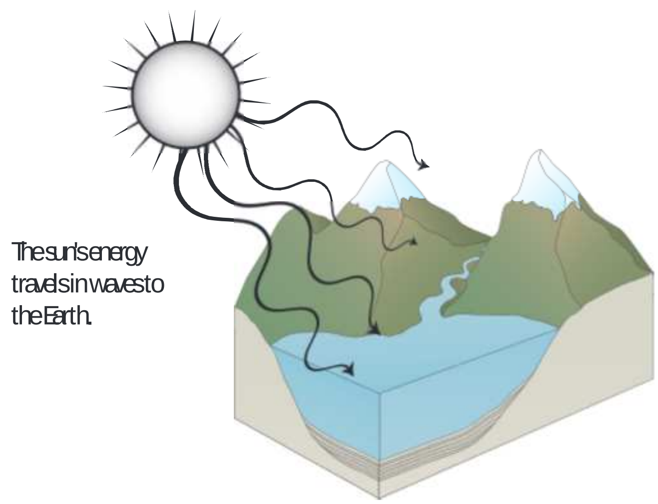
Land Breeze



Sea Breeze



Radiation



Heat and Temperature

Heat and **temperature** are different things. Two cups of boiling water would have twice as much heat as one cup of boiling water, but the water would be at the same temperature.

A giant iceberg would have more heat energy than a cup of boiling water, even though its temperature is lower. It would have more heat energy because it is so big.

Heat is the total amount of kinetic energy in a substance. Temperature is a measure of the average kinetic energy of the molecules in a substance. Temperature is also described as a measure of the hotness or coldness of a substance.

Think about a pan in a hot oven. The pan and the air in the oven are the same temperature. You can put your hand into the oven without getting burned. You can t touch the pan. The pan has more heat energy than the air, even though it is the same temperature. The pan can transfer heat at a faster rate to your hand. The air is a better insulator than the pan.

We Can Measure Temperature

We use thermometers to measure temperature. Thermometers can measure temperature using different scales. In the United States, we usually use the Fahrenheit (F) scale in our daily lives. Scientists usually use the Celsius (C) scale, as do people in most other countries.

On the Fahrenheit scale, the **boiling point** of water is 212 degrees. The **freezing point** of water is 32 degrees. On the Celsius scale, the boiling point of water is 100 degrees. The freezing point of water is 0 degrees.

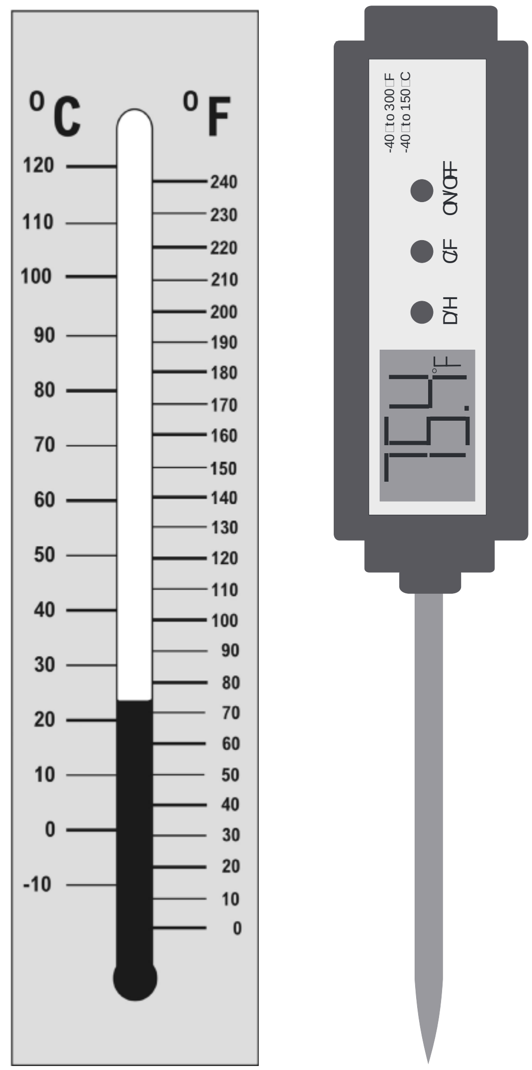
Thermometers

There are many kinds of thermometers. Some have only one scale. Others have both Celsius and Fahrenheit scales.

In the diagram on the right, the thermometer on the left shows both scales. It is a long glass tube filled with colored alcohol. The alcohol expands—gets bigger—when it has more heat energy. It contracts—gets smaller—when it has less heat energy.

The thermometer on the right is digital. It does not have alcohol in it. It has a tiny computer chip and a battery. By pushing a button, it can measure the temperature on either the Fahrenheit or Celsius scale.

Thermometers



Expansion and Contraction

Why does the alcohol in a thermometer **expand** and **contract**? The alcohol is a liquid. Its molecules move and spin. When heat energy is added, its molecules move faster. They push apart from each other. The space between the molecules gets bigger. The alcohol in the tube expands.

The molecules don t get bigger, the space between them does. When heat energy is taken away, the molecules slow down. They move closer together. The alcohol contracts. The molecules don't get smaller—the space between them does.

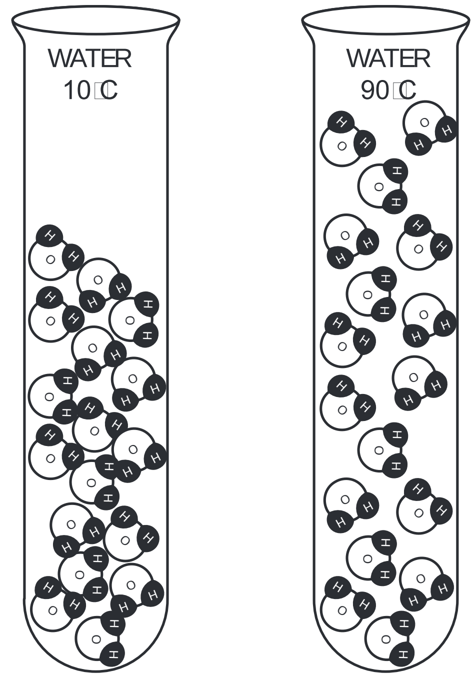
Solids, Liquids, and Gases

All substances expand when they are heated. Some expand a little; some expand a lot. They all expand at different rates.

Solids expand a little when they are heated. The molecules in solids have strong bonds. They are held tightly in one position. They cannot move around—they can only vibrate. When heat energy is added, they vibrate faster. They push against each other with more energy. The space between them gets a little bigger. But they are still held in position.

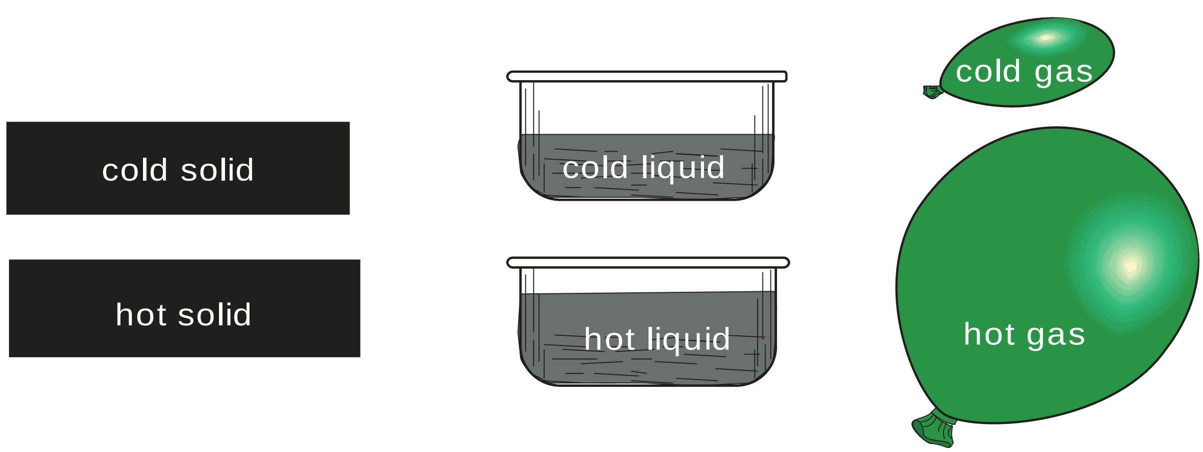
Have you ever seen doors that are hard to open in the summer? They have expanded because of the heat. Sidewalks are made with cracks so that the concrete can expand in the summer heat. Without the cracks, the sidewalks would swell and break. Bridges have spaces, too.

Molecular Expansion



The same molecules of water take up more space when they are hotter.

Expansion with Heat Energy



Key Words—Heat

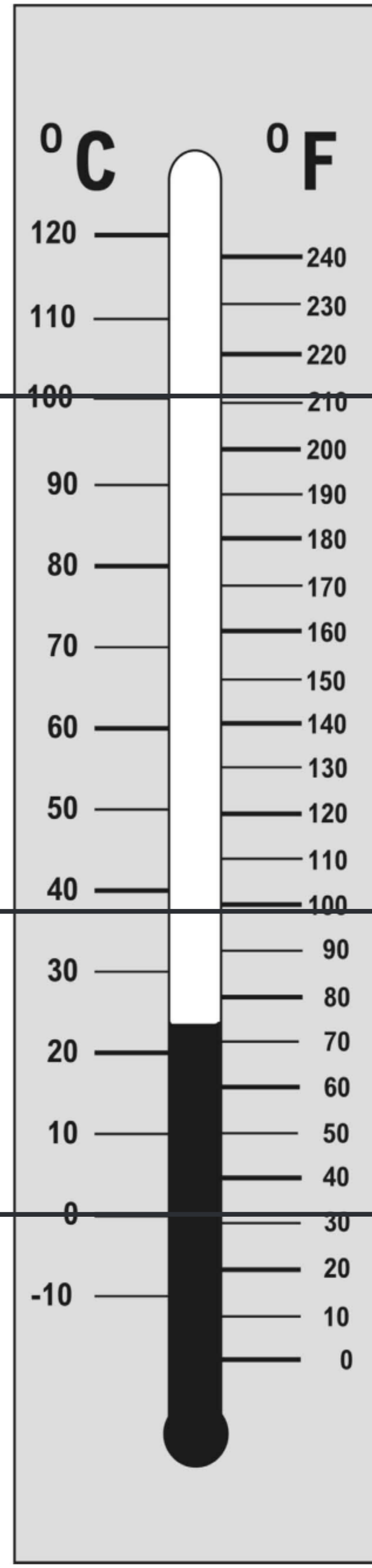
Directions: Use each key word in one of the sentences below.

boiling point	**contracts**	**freezing point**	**kinetic energy**	**radiation**
conduction	**convection**	**gas**	**liquid**	**solid**
conductor	**expand**	**insulator**	**molecules**	**temperature**

1. ______________________________ is the energy of motion.
2. Heat energy moving in currents is called ____________________________ .
3. The molecules move fast and far apart in a(n) ___________________________ .
4. The temperature at which a liquid turns into a gas is called its ________________________ .
5. Adding heat to a substance makes it get bigger or ____________________________ .
6. _________________________ is the average kinetic energy of the molecules in a substance.
7. Energy from the sun moving in waves or rays is called ___________________________ .
8. The molecules of a(n) _________________________ vibrate in one position. They can t spin.
9. A substance that doesn t conduct heat well is called a(n) ________________________ .
10. Heat energy moving between two touching objects is called ______________________ .
11. The temperature at which a liquid turns into a solid is called its ________________________ .
12. The building blocks of substances are called _______________________ .
13. When a substance gets smaller as it loses heat energy, it __________________________ .
14. A substance that moves heat energy well is called a(n) ____________________________ .
15. The molecules flow and vibrate close together in a(n) _____________________________ .

Thermometer

A thermometer measures temperature. This thermometer measures temperature on both the Celsius and Fahrenheit scales.



Water Boils ______ C ______ F

Human Body ______ C ______ F

Water Freezes ______ C ______ F

We drew lines across the thermometer to show three temperature readings. Read both scales of the thermometer and write the temperature in the blank spaces on the lines.

Now, draw lines across the thermometer that show what you think the temperature is in the classroom, the temperature outside, and the temperature of the water in the drinking fountain. How can you check your predictions? Try it!

Exploring Heat Transfer 1

HEAT MODULE ONE

Question

In liquids, does heat move in predictable ways?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

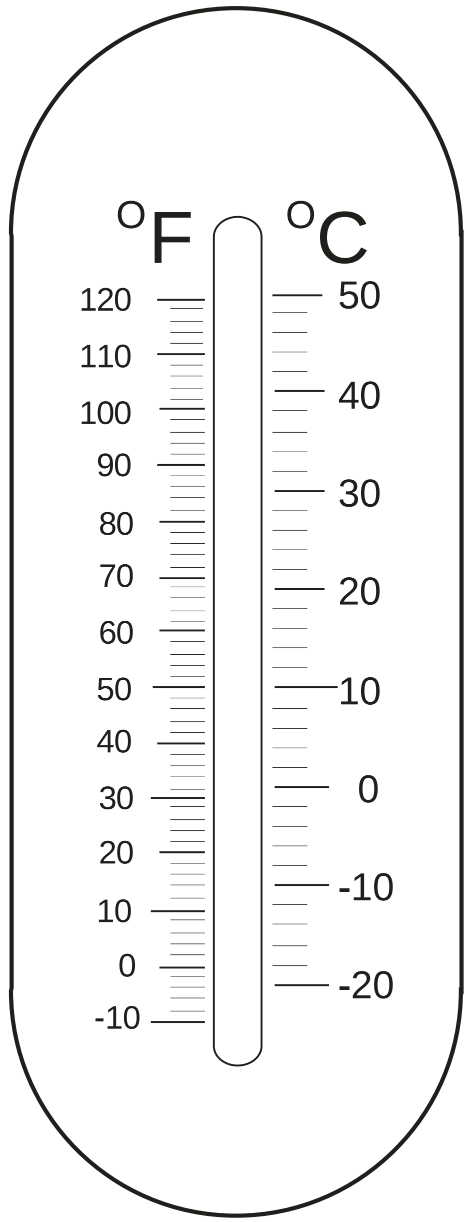
NOTE
When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)

Materials

- 1-1,000 mL Pitcher
- 2-500 mL Pitchers
- 1 Thermometer
- Colored pencils
- Cold and warm water, 250 mL each

✔Procedure

1. Fill one 500 mL pitcher with 250 mL cold water and record the temperature in Celsius and Fahrenheit in your science notebook.
2. Use a blue pencil to record the temperature of the cold water by drawing a line on the picture of the thermometer.
3. Fill one 500 mL pitcher with 250 mL warm water and record the temperature in Celsius and Fahrenheit in your science notebook.
4. Use a red pencil to record the temperature of the warm water on the picture.
5. Pour the warm water and the cold water into the 1,000 mL pitcher.
6. Estimate the temperature of the mixture by drawing a black line on the picture.
7. Measure the temperature of the mixture in Celsius and Fahrenheit and record it in your science notebook.
8. Record the temperature on the picture with a purple pencil. Was your estimate correct?



Observations and Data

Record observations and data in your science notebook.

Conclusion

1. Did the amount of heat lost by the warm water equal the amount of heat gained by the cold water? How can you tell? Find the average of the two temperatures to find out.
2. Did the heat move in predictable ways?

Exploring Heat Transfer 2

HEAT MODULE ONE

Question

In liquids, does heat move in predictable ways?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

Materials

- 2-1,000 mL Pitchers
- 1-500 mL Pitcher
- 1 Thermometer
- Colored pencils
- 500 mL Cold and 250 mL warm water

✔ Procedure

1. Put 500 mL of cold water in one 1,000 mL pitcher and record the temperature in Celsius and Fahrenheit in your science notebook.
2. Use a blue pencil to record the temperature of the cold water by drawing a line on the picture of the thermometer.
3. Fill a 500 mL pitcher with 250 mL warm water and record the temperature in Celsius and Fahrenheit in your science notebook.
4. Use a red pencil to record the temperature of the warm water on the picture.
5. Mix the 500 mL of cold water and 250 mL of warm water in the other 1,000 mL pitcher.
6. Estimate the temperature of the mixture by drawing a black line on the picture.
7. Measure the temperature of the mixture and record the temperature in Celsius and Fahrenheit in your science notebook.
8. Record the temperature on the picture with a purple pencil. Was your estimation correct?

Observations and Data

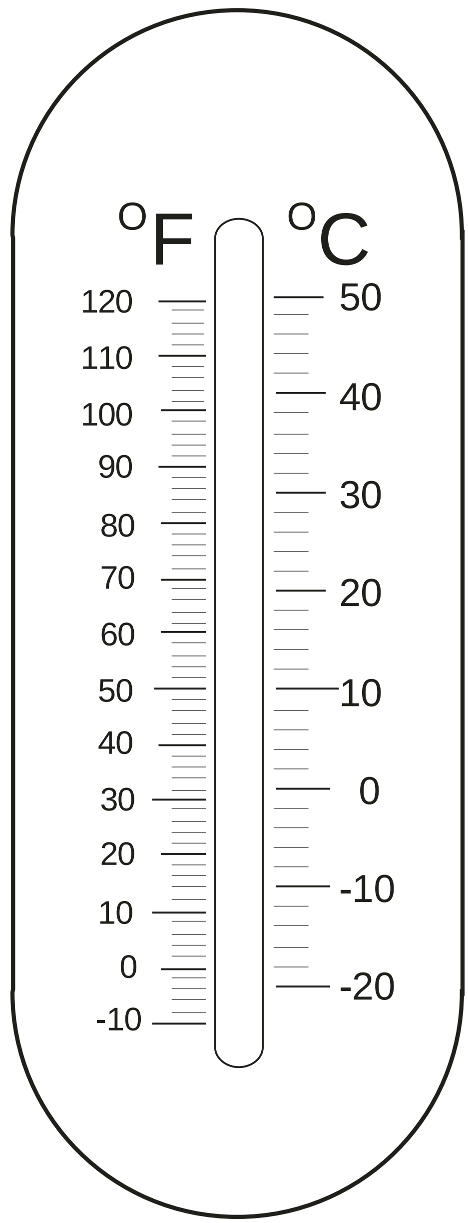
Record observations and data in your science notebook.

Conclusion

1. Did the amount of heat energy lost by the warm water equal the amount of heat energy gained by the cold water?
2. What do you think the temperature of the mixture would be if you mixed 500 mL of warm water with 250 mL of cold water?

NOTE

When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)



Exploring Heat Transfer 3

HEAT MODULE ONE

Question

In liquids, does heat move in predictable ways?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

NOTE
When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)

Materials

- 1 Wallpaper pan
- 2 Thermometers
- 2-500 mL Pitchers
- 500 mL Cold water
- 500 mL Warm water
- Room temperature water
- Metric ruler

✔Procedure

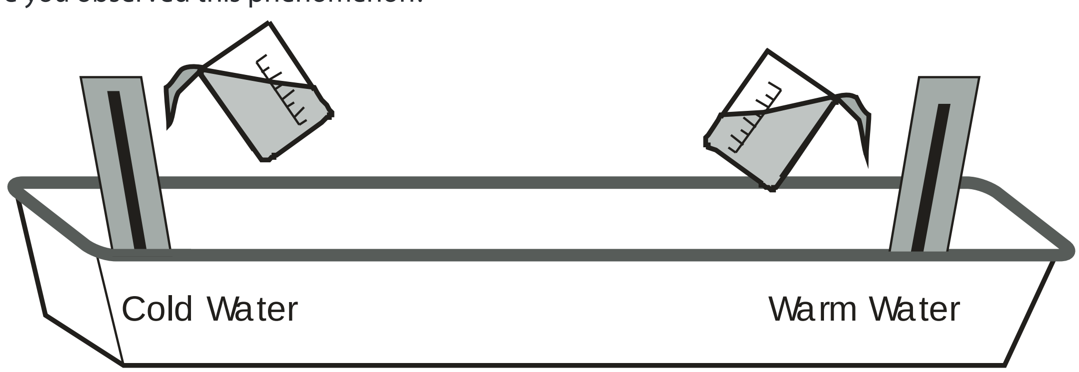
1. Fill the wallpaper pan to a depth of 2 cm with room temperature water. Place a thermometer at each end of the pan and record the temperature in Celsius and Fahrenheit in your science notebook.
2. Fill one pitcher with 500 mL warm water and one pitcher with 500 mL cold water. Measure and record the temperatures of the cold water and the warm water in Celsius and Fahrenheit in your science notebook.
3. Pour 500 mL of cold water into one end of the pan and 500 mL of warm water into the other end. Immediately record the temperatures at both ends in Celsius and Fahrenheit in your science notebook.
4. Wait two minutes and record the temperature again at both ends of the pan. Record the temperatures in Celsius and Fahrenheit in your science notebook.

Observations and Data

Record observations and data in your science notebook.

Conclusion

1. Explain the evidence you have that supports heat from the warm water flowed to the cooler end.
2. Where have you observed this phenomenon?



Conductors and Insulators

HEAT MODULE TWO

Question

How does the material a cup is made of affect the transfer of heat?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

NOTE
When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)

Materials

- 1 Plastic cup
- 1 Foam cup
- 1 Metal cup
- 1 Paper cup
- 4 Digital thermometers
- 4 Rubber bands
- Plastic wrap
- Stopwatch or clock with second hand
- Ice water
- Hot water

✔ Procedure

1. Create the table below in your science notebook once for the ice water, once for the hot water.
2. Using a rubber band, attach a thermometer to the outside of each cup.
3. Fill each cup with the same amount of ice water.
4. Cover each cup with plastic wrap.
5. In 30 second intervals, record the temperature of each cup for a total of three minutes.
6. Calculate the change in temperature (ΔT) for each type of cup.
7. Repeat steps 2-6 with hot water.

Observations and Data

Material	0 sec	30 sec	60 sec	90 sec	120 sec	150 sec	180 sec	Δ T (ºC)
Plastic cup								
Foam cup								
Metal cup								
Paper cup								

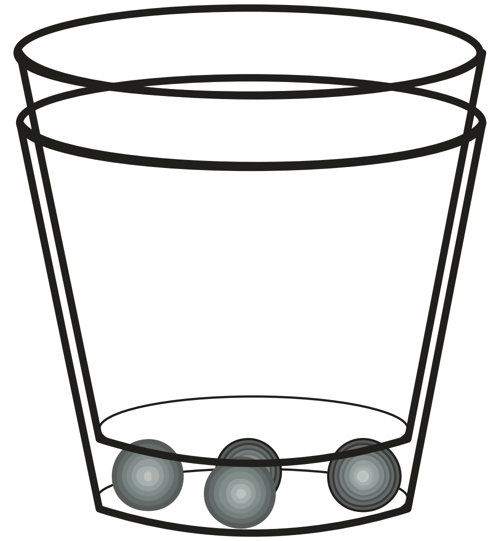
1. Use the data from the table to create a graph in your science notebook or use the graph paper on the following page.

Conclusion

1. Which material had the greatest change in temperature? Is it a conductor or insulator?
2. Which cup would be the best for hot chocolate? Which would keep a drink cold the longest? Use data to support your answer.
3. What variables might have affected the results of your experiment?

Exploring Heat in Solids, Liquids, and Gases 1

HEAT MODULE THREE



Question

How does heat move through fluids?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

Materials

- 2 Clear plastic cups
- 4 Marbles
- Hot water
- Ice water
- Food coloring

✔ Procedure

1. Place the marbles in the bottom of one cup so they are evenly spaced around the cups edge. Pour hot water in the cup until the water just covers the marbles.
2. Place the second cup inside the first one, resting on the marbles. The hot water in the first cup should touch the bottom of the second cup.
3. Fill the second cup almost to the top with ice water.
4. **Wait 15 seconds.** Carefully put one small drop of food coloring on top of the water.

NOTE

When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)

Observations and Data

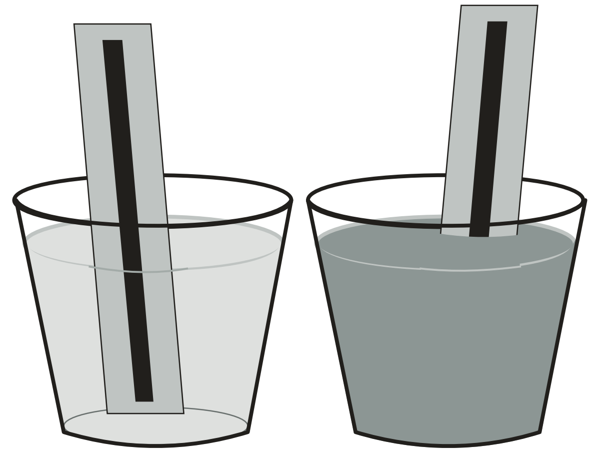
Record your observations in your science notebook. Draw a diagram of the food coloring in the water. Use arrows to show the direction of movement.

Conclusion

1. Look at your diagram. What did your investigation demonstrate?
2. Refer to your reading. Where else do we see heat move in this way?

Exploring Heat in Solids, Liquids, and Gases 2

HEAT MODULE THREE



Question

How does sunlight affect sand and water?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an"If... then... because..." format.

Materials

- 2 Clear plastic cups
- 2 Thermometers
- Room temperature sand
- Room temperature water
- Sunny day or bright lamp

✔ Procedure

1. Create the table below in your science notebook.
2. Fill one cup with sand and place a thermometer in it. Record the starting temperature.
3. Fill the other cup with room temperature water and place a thermometer in it. Record the starting temperature.
4. Place the cups in the light source. Wait 10 minutes and record the temperatures of the water and sand. Wait another 10 minutes and record the temperatures again.
5. Let the cups stand away from the light for 10 minutes. Record the temperatures of the water and the sand on the chart.

Observations and Data

Materials	Starting Temperature	10 Minutes	20 Minutes	Temperature After Removed From Light
Sand				
Water				

Conclusion

1. Which material had a greater increase in temperature? Why do you think this is?
2. From your reading of the text, how does this investigation show how wind is made?

Exploring Heat in Solids, Liquids, and Gases 3

HEAT MODULE THREE

Question

How does temperature affect air?

Hypothesis

Read the procedure and record your hypothesis in your science notebook using an "If... then... because..." format.

Materials

- 1 Bowl of ice water
- 1 Bowl of hot water
- 1 Round balloon
- 1 Measuring tape
- 1 Thermometer

NOTE
When the procedure calls for:
cold water, use water between 7-13°C or 45-55°F
ice water should be even lower of a temperature.
warm water, use water between 43-49°C or 110-120°F
hot water, use water just under boiling (the teacher should handle the container for hot water)

✔ Procedure

1. Create the table below in your science notebook.
2. Blow up the balloon about as big as a baseball and tie it. Let the balloon sit for a minute so that the air in the balloon is the temperature of the air in the room.
3. Using the measuring tape, measure the circumference of the balloon at its largest point. Circumference is the distance around an object. Measure the temperature of the room. Record the measurements in a table in your science notebook.
4. Put the balloon in the ice water for one minute. Measure the circumference of the balloon and the temperature of the water. Record the measurements.
5. Put the balloon in the hot water for one minute. Measure the circumference of the balloon and the temperature of the hot water. Record the measurements.

Observations and Data

Air Temp.	Balloon Circumference	Ice Water Temp.	Balloon Circumference	Hot Water Temp.	Balloon Circumference

1. Use the data from the table to create a graph in your science notebook or use the graph paper on the following page.

Conclusion

1. How did temperature affect the balloon? Use data to support your reasoning.
2. Draw a line through the points on your line graph, then extend the line as far as you can. Estimate the circumference of your balloon at 40°C and at 80°C.