ASHRAE

Cool Science Kit

Six Modules Containing 25 Demonstrations and Student Investigations

Developed by the National Foundation for Energy Education

Instructional Overview

The ASHRAE Thermal Science Demonstration Kit has been designed to assist ASHRAE members with classroom presentations to students in grades 3-12. The Teaching Kit contains most of the necessary hardware to conduct science demonstrations, and the modules include background to allow students to observe and participate in the demonstrations and scientific investigations. Each demonstration/investigation is accompanied by written and video taped instructions.

The twenty-five demonstrations/investigations are grouped together into six modules. The modules are numbered according to the best sequencing of science concepts and use of hardware. Conducting all six modules would take 90 minutes of class time. Some teachers may welcome a presentation of this length while others may be limited by the ring of the class-ending bell. To assist you with shorter presentations, a menu of three programs with selected activities from the modules is provided on page 4.

Instructions are included to allow you to tailor the presentation to the student's age, the level of understanding, and the time available for the program. Addressing all of the objectives listed at the beginning of each module is appropriate for older students. However, presenting demonstrations/investigations to older students may take more time as more background will be given.

When needed, background information is provided in the written and video instructions. However, background information is not provided for many of the demonstrations/investigations since the concepts may be quite familiar to ASHRAE members.

To further assist ASHRAE members, a draft letter has been included to help you communicate with educators about your willingness to present a program to students on internal and thermal energy.

Following your presentation, please take a few minutes to evaluate the overall effectiveness of the Teaching Kit as well as the hardware and instructions. An evaluation form can be found on page 22 to assist you with this important request. Your comments and suggestions will assist us with future revisions.

Thank you for investing your time to shape the engineers of tomorrow, and good luck with your presentation!

Draft Letter
To Science Educator

Dear _______________:

The study of internal and thermal energy is an important content component of state and national Science Education Standards. To assist teachers in meeting these standards, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has developed a Thermal Science Demonstration kit for its members to use in classroom presentations. This format has been extremely successful in clarifying scientific concepts using techniques that both engage and entertain.

I would like to offer my services in visiting your class to conduct several of the kit's internal and thermal energy demonstrations and student investigations. While working in teams, students actively participate in making predictions while observing, measuring and reporting the results of entertaining experiments.

By the end of the presentation, students will have concrete experience with the scientific principles of : *Temperature*, *Internal Energy*, *Thermal Energy*, *Methods of Heat Transfer* & *Phase Changes* and *Hidden Heat*. During my presentation, I will also discuss with students the technological importance and social effects of being able to regulate temperature and answer questions about careers in the Heating, Cooling and Refrigeration Industry.

Thank you for your consideration of my offer to make a presentation to your class. Please feel free to contact me if you would like to schedule a presentation or have any questions about this exciting program.

Sincerely,

Name, Title

Presentation Planning & Preparation

Presentation Opening

Introduce yourself and briefly discuss how ASHRAE and the industry has played a role in shaping the nation and the world over the past 100 years. Present examples of how people prior to the 21st century kept their homes warm during the winter. Discuss how refrigeration and air-conditioning affected everyone's life and changed society. **Please Note:** This segment alone can fill an entire class period; five minutes should be enough to give students an appreciation of the importance of heating, cooling, and refrigeration technologies.

Explain to students that they will assist you in conducting several demonstrations and experiments to learn about the scientific concepts that govern heating and cooling. When possible, try to include a 'real world' example in each module. **Please Note:** You may find that a stop-watch can be useful in keeping the presentation on track, as well as cue cards or an outline of the basic steps and questions to ask.

Presentation Options

Conducting each of the demonstrations/investigations from all six modules would require one and a half to two hours of class time. More time and depth of explanation will be required when presenting demonstrations/ investigations to older students.

Any combination of the twenty-five demonstrations and investigations found in the kit would make for an interesting and engaging program. To assist ASHRAE members plan a **45 minute** presentation, three grade level programs have been developed. Additional demonstrations/investigations can be added to these suggestions when making longer presentations.

Elementary Presentation (Grades 3-5)

Module # 1:	Part One & Optional Activity (molecular motion in solids) & Two (molecular motion in liquids)
Module # 2	Part One (heat flow-hot to cold) & Two
Module # 3	Part One, Two, Three & Four (conduction)
Module # 4	None
Module # 5	None
Module # 6	Brief explanation - (latent heat)

Middle School Presentation (Grades 6-8)

Module # 1	Part One (molecular motion in solids), Two (molecular motion in liquids) & Three (internal energy)
Module # 2	Part Two (thermal conductivity) & Three (temperature vs. internal energy)
Module # 4	Part One (thermal equilibrium and conductivity)
Module # 5	Part One (radiation and emission) & Two (convection)
Module # 3	**Part Five & Six (evaporation)** [sequencing change to enhance instruction]
Module # 6	Moderate explanation - (latent heat)

Junior/Senior High School Presentation (Grades 9-12)

Module # 1	Part Three (internal energy)
Module # 2	None
Module # 4	Part Two (conductivity)
Module # 5	Part One (radiation and emission), Two (convection) & Optional Activity (temperature stratification)
Module # 3	**Part Five & Six (evaporation)** [sequencing change to enhance instruction]
Module # 6	Full explanation - (latent heat)

Preparation

Each of the demonstrations/investigations are accompanied by detailed instructions that are provided in print and on video formats. The common requirement for conducting many of these activities is water - hot, warm, room temperature and cold water. Ask the teacher what source of water will be available to you during the presentation. Here are some hints on:

How to Make Water

Samples at Different Temperatures

Tap Water: Test your tap water first. See what temperatures the hot and cold water pipes deliver.

Room Temperature Water: Fill your room temperature water container with cool/warm tap water at least two hours before needed for experiments. Try to fill the container the night before.

Cold Water: Fill a large container with equal volumes of ice and water; wait five minutes. A two-quart juice pitcher with a strainer setting on its lid is a great dispenser of cold water (no ice). The cold water should range between 2-5 ☜C immediately after it has been poured from the container.

Warm Water: If the tap water isn't between 42-45 ☜C, you will have to add hot water to bring up its temperature. If a microwave oven is available, give your tap water a zap for a minute or two.

Hot Water: Mix approximately four parts boiling water with one part cool/warm tap water for water at 85 ☜C. A large coffee urn will provide you an easier and safer method of dispensing hot water. (It will cool slightly to 75-80 ☜C for the demonstrations.)

Containers: Plastic milk jugs (1-2 gallons) work great for room temperature and warm water. A kettle on a hot plate is good for boiling water. Hot water can be made in two-quart insulated drinking containers with a pouring spout in its lid by using a coffee urn.

Prior to the presentation, you may choose to notify the teacher of the number of student assistants you will require to conduct the demonstrations. If you are conducting student investigations you should inform the teacher in advance so he/she can organize teams. Science teachers can be very helpful in supplying you with all the resources required for your presentation *if you let them know what you'll need ahead of time.* They'll be glad to provide you with beakers, water, thermometers, heat sources, ice cubes and other items.

Closing Presentation Segment

During your closing remarks, discuss the wide variety of career opportunities in the heating, cooling and refrigeration industry. You may wish to spend more time on this segment in your presentations to older students.

Module # 1
Molecular Kinetic Energy & Temperature
(Three Parts - 15 minutes)

Suggested Grades: All grades with an emphasis on **6-12**.

Teaching Objective: To explain what is meant by the term temperature.

Upon completion of these activities students will understand the following concepts:

1. Increasing (decreasing) the motion of a substance's atoms/molecules increases (decreases) their kinetic energy.
2. The kinetic energy of an object's individual atoms/molecules varies greatly throughout the substance.
3. The average kinetic energy of all of a substance's atoms/molecules is known as its temperature.
4. Most of the atoms/molecules of a substance have kinetic energy near the average kinetic energy value.
5. Increasing (decreasing) the average kinetic energy of a substance's atoms/molecules will increase (decrease) its temperature.

Equipment & Supplies

Part One: Student Assistants - 1
- Metal Hanger
- Tennis Ball and Rubber Bands*
- (Optional Activity - Two containers of sand/salt/sugar; one hot, one cold)

Part Two: Student Teams - 6
- Clear Plastic Cups* - 12
- Warm (32 oz.) & Ice Water (32 oz.)
- Food Coloring* - 2 Bottles
- Insulating Mitt

Part Three: Student Assistants - 2
- Happy/Sad Balls*
- Super Ball*
- Hot Water
- Spoon

* Included in Kit.

Instructional Procedure

PART ONE (Grades 3 - 8): Clip or unwind a metal hanger so you are able to bend it easily. Have a student touch the bend in the metal hanger to test its temperature. **Ask about its temperature: is it hot, cold or body temperature?** Bend the hanger quickly 10 times and have a student test the temperature at the bend again. **Ask students if they can explain why the metal is heated at the bend.**

To understand why the temperature at the bend increases, explain the atomic structure of the hanger. The hanger is made up of countless iron atoms (trillions of trillions - 10^{24}). Atoms are the building blocks of matter, and they are extremely small.

Ask students which phase of matter the atoms of the hanger are in.

In the solid phase. The atoms in solids are in fixed positions, vibrating in countless directions**.** Use the tennis ball with the rubber bands to demonstrate this motion in a fixed position. Using the tennis ball explain how some atoms have a great amount of kinetic energy and some have little. Most atoms have energy values around or at, the average kinetic energy.

While bending the hanger explain that these atoms are being pushed and pulled by the bending. This makes the metal's atoms vibrate with more motion. The greater the motion of atoms, the greater the molecular kinetic energy, and the higher the temperature.

Ask another student to test the temperature at the bend.

Explain that this student is touching trillions of atoms at one time. The **average** value of those atoms is what he/she senses-its temperature.

Optional Activity: To reinforce the relationship between **average kinetic energy and temperature**, have a student test the temperature of two containers (or ziplock bags) of sand/salt/sugar. Ten minutes in advance heat the granular material in one container using a heat lamp, hot water bath, or hot plate on low. Cool the other container's grains by placing the container in the freezer or a bath of ice water. **Ask a student to test the temperature of the grains in each container and report their findings to the class.**

Now combine the grains from each container and give them a quick stir or shake. **Ask the same student to test the temperature of the grains now. Ask them if they can identify which grains were from the hot and cold containers.** They can't, they are too small. Atoms are even smaller. In fact there are trillions of trillions of atoms in one grain of sand.

PART TWO (Grades 3 - 8): Conduct this student investigation as a demonstration to save five minutes of presentation time.

To demonstrate visually the relationship between molecule motion and temperature, use a liquid instead of a solid. Explain to students that in solids the atoms are in fixed positions, and in liquids, molecules are free to move throughout the container. The hotter the liquid, the faster this molecular motion is inside the liquid. Have student assistants provide each of the six teams with a plastic cup of cold water (no ice) and a cup of warm water (45-60 ☜C). Fill cups about 2/3 full, and have assistants use an insulating mitt to carry the warm cup. You or the teacher should then place ONE drop of food coloring into each team's cup. Place the dropper as close as you can to the surface of the water before gently releasing the drop.

Ask students to observe how quickly the food coloring dispersed throughout the liquid in each cup.

This student investigation demonstrates the fact that molecules in liquids are free to move and this movement is greater when the temperature of the liquid is greater.

<u>PART THREE</u> <u>(Grades 6 - 12):</u> Drop the happy ball (with bounce) from a height of one meter four times. **Ask students to approximate the average height of its rebound.** A rebound of 60 cm would indicate that 60% of the potential energy has been restored.

Ask students what happened to the other 40% and why the happy ball didn't return to a height of 100 cm.

The happy ball didn't return to a height of 100cm because some of the energy was transformed into internal energy in the ball and table. Air molecules were struck and gained energy as the ball fell and rose. Finally, the rest of the energy was transformed into sound caused by the vibrating table.

Remind students that energy is still being conserved, the loss in kinetic energy on a large visual scale is now taking place on a molecular level.

Carefully switch balls without the class observing and be prepared to drop the sad ball from the greatest height you or the tallest student can attain.

Ask a student assistant to estimate where it will rebound to and place his/her finger at that point before you drop the sad ball.

Drop the sad ball. No bounce. Try it several times and then admit that you switched balls.

Approximately 95% of the kinetic energy has been transformed into internal energy and sound. Compare the sounds of the balls when they strike the table. The sad ball produces more sound. Place the sad ball into a cup of hot water.

The sad ball's (neoprene) rubber transforms almost all the kinetic energy of the collision into the movement of its molecules. When the happy ball's molecules (norbereen) are compressed, the forces of repulsion between the molecules produce a bounce. The structure of the sad ball's rubber molecules allow the molecules to slide by each other instead of at each other. This sliding produces small repulsive forces and little bounce. However, the back and forth sliding motion will continue and this motion will increase the internal energy of the sad ball.

Have a student squeeze the happy ball and the super-ball with his/her fingers and ask which was hardest to squeeze. Which one will bounce higher? Drop both at the same time from the same height.

After one minute remove the sad ball from the cup with a spoon. Drop the sad ball from the height of a meter. It should produce a bounce of 25 cm.

Ask the class why the sad ball has become happier.

The ball now has more internal energy when it strikes the table. The molecules are vibrating with great energy and can absorb only some of the kinetic energy from the collision. The sad ball bounces and energy is conserved. As the ball cools, it absorbs energy from colliding with the table so it bounces less and less.

For further background information and demonstrations, refer to the information card included in the envelope containing the balls.

Module # 2
Detecting Thermal Energy Flow
(Three Parts - 10 minutes)

Suggested Grades: All grades with an emphasis on **3-8**.

Teaching Objective: To demonstrate the flow of thermal energy from hot to cold.

Objectives:

1. Heat or thermal energy always travels from the substance with the higher temperature to the substance with the lower temperature.

2. The mass of an object will affect the amount of thermal energy which can flow into or out of that object.

Equipment & Supplies

Part One: Student Assistants - 2
Foam Cup* with Ice Water
Foam Cup* with Warm Water (42-45 ☜C)
Two Foam cups* with Room Temperature Water
Thermometers* - 2
Paper Towels

Part Two: Student Assistants -1
32oz Foam Container* with Room Temperature Water
Empty 32 oz Foam Container*
Thermometers* - 2

Part Three: Student Assistants -1
Copper Shot* and Bare Cooper Wire* in Hot Water (65-70 ☜C)
Spoon
Thermometer* - 1

* Included in Kit.

Instructional Procedure

PART ONE (Grades 3 - 5): Ask one student assistant to place two fingers from one hand in a cup of warm water (42-45 ☜C). **(TEST the WATER TEMPERATURE FIRST!)**

At the same time the assistant should place two fingers from the other hand in a beaker of ice water. Keep the fingers submerged for 15 seconds. During this time have the other student assistant report the temperature reading for both cups.

Have the assistant remove his/her fingers from the cups, and have the other assistant quickly (2 seconds) dry both sets of fingers with a towel. Immediately place fingers in two separate cups of room temperature water; don't tell the students that both of these cups are at room temperature.

Quickly ask the student assistant which cup of water is warmer. Inform the class that both water samples were at the same temperature - room temperature.

Ask students why the room temperature felt warm to one set of fingers and cold to the other.

Explain how the same room temperature water can appear cold to one set of fingers while the other set senses the water to be warm. Explain how our 37 ☜C fingers sense warm, hot, cold and no temperature.

<u>PART TWO (Grades 3 - 8):</u> Have a student assistant place one fist in an empty foam container, and the other fist in a foam container a third full of room temperature water. Ask the students if the temperature of the contents of both containers is the same or different. They will say the water is colder. Measure the temperature of the air in the container and the water. They should both be at room temperature. Why does the water feel colder?

Over 500 times more molecules are present in the container of water than in the container of air. More molecules means more matter to absorb energy from the more energetic molecules in the student's hand. More matter also means more **internal energy**. Placing your hand in front of a stream of hot air from a hair dryer may make your hand feel uncomfortable. A stream of hot water at the same temperature in contact with the skin for the same time would cause injury; **more molecules means more internal energy**.

<u>PART THREE (Grades 6 - 8):</u> Have one student assistant tell the class the temperature of the hot water (60-65 ☜C) which has a single piece of copper shot and section of bare copper wire. Inform students that the copper shot and wire are also at this temperature. Remove the copper shot from the hot water with the spoon and place it on a paper towel. Ask a student assistant to quickly pick up the shot and put it between his/her index finger and thumb. Ask how hot the shot is. It may feel hot for the first few seconds, but its temperature will drop quickly. Next remove the copper wire from the water and have the same student try to hold it as they did the shot. With many times more mass than the shot, the wire will be too hot to hold comfortably. Let them know this in advance and allow them to quickly release the wire if needed.

Once again mass matters when it comes to internal energy. The shot was hot, but its mass was small compared to the student's fingers. Only a small amount of thermal energy was transferred to the fingers. Mass and temperature affect the internal energy of an object, and the amount of thermal energy flow.

<u>PART FOUR:</u> If time permits also place the copper shot and wire into the cup with the ice water and repeat the process described above.

Module # 3
Conduction & Evaporation
(Six Parts - 15 minutes)

Suggested Grades: All grades with an emphasis on **3-8**.

Teaching Objectives: To explain how thermal energy is transferred by conduction.
To demonstrate that evaporation is a cooling process.

Objectives:

1. Thermal energy can be transferred by direct contact, by conduction.
2. Conduction transfers kinetic energy through the collisions of atoms/molecules with neighboring atoms/molecules.
3. Heat (thermal energy) always travels from the substance with the higher temperature to the substance with the lower temperature.
4. Evaporation occurs when the atoms/molecules at the liquid surface receive sufficient energy to escape the forces of attraction of neighboring atoms/molecules and are transformed into the gaseous or vapor phase.
5. Evaporation is a cooling process resulting from the most energetic atoms/molecules escaping the liquid, lowering the average kinetic energy (temperature) of the remaining atoms/molecules.

Equipment & Supplies

Parts One, Two, Three, and Four: Student Teams - 8
Liquid Crystals* - 8
Ice Cubes in Plastic Bags* - 8

Parts Five and Six**:** Student Teams - 8 / Student Assistants - 3
Liquid Crystals* - 8
Moist Cotton Swabs* - 8
Thermometers* - 3
Room Temperature Water & Isopropyl Alcohol

* Included in Kit.

Background

The liquid crystals are attached to the surface of the plastic film and are given additional kinetic energy by the atoms and molecules in the students' finger tips. The crystal acts like a prism or a diffraction gradient and separates the white light.

The temperature of the liquid crystal causes it to flex its spiral structure. The spacing between the crystal layers making up the spiral is affected by temperature. This spacing causes the white light to be separated into all seven colors of the spectrum (ROY G BIV). Using this type of crystal, you and the students may not see the violet as it is obscured by the blue. The crystals also emit infrared and ultraviolet. The crystals in this kit appear red at 25 ☜C and blue-violet at 30 ☜C.

Instructional Procedure

<u>PART ONE (Grades 3 - 5):</u> Provide a thermal crystal to each student team (2-4 students per team). Ask one student from each team to place his/her thumb firmly in the middle of the crystal for 45 seconds. While you are waiting, explain to students that the liquid crystal is sensitive to heat, and will separate visible light into different colors according to the temperature of the crystal. Clear is the coolest color; it may appear black because of the black background.

Have students remove their thumbs from the crystal. Ask them to observe the changes in the color of light which the crystal emits over the next 20-45 seconds. The temperature of the classroom will determine the time students should observe the crystal before it turns to clear, allowing the black background to appear. In a warmer classroom, it will turn clear in 45 seconds. If the classroom is above 25 ☜C, the crystal may start to turn red-orange without being touched.

During the 20-45 second waiting time, ask the students to observe the crystal and answer the following questions.

1. How many different colors do you see?
2. What color was a result of the warmest temperature, and why?
3. Rank the colors, warmest to coolest.

<u>Answers</u>

1. Five - Blue, Green, Yellow, Orange & Red.
2. Blue represents the warmest area because that was the area in direct contact with the thumb. The surrounding area's colors were not directly touched by the thumb but were produced as a result of the thumb's internal energy and conduction through the crystal.
3. Warmest = Blue, Green, Yellow, Orange, & Red = Coolest.

<u>PART TWO</u> <u>(Grades 3 - 5):</u> Have one student from each team place his/her thumb on the crystal to start. Ten seconds later have him/her place the other thumb on the crystal so the thumbs are about three centimeters apart. Five seconds later (in a warm room this time may only be three seconds), lift both thumbs and observe the size and color change of the effected area. Ask students to describe and explain the difference between the color patterns produced by each thumb.

The 15 second thumb print will look and behave like the image from **Part One**. The 5 second thumb print will have very little to no blue color because it did not receive as much heat energy from the thumb. Immediately after your 5 second thumb is raised the image looks like the thumb print image from **Part One** after 15 seconds of heat transfer. The 5 second print will also fade back to clear faster.

PART THREE (Grades 3 - 5): Have a student team member place his/her thumbs **a half a centimeter** (pencil thickness) apart on the crystal for 15 seconds and observe what happens to the area between the thumbs prints. Ask students to explain the color change even though neither thumb was touching this area.

Students should find that the area between the thumbs is red-orange. This is a result of the area receiving thermal energy from both sides. Have them repeat this procedure, but this time have the thumbs **three centimeters** apart. **Ask why they don't see the red-orange color between the thumb prints this time.**

PART FOUR (Grades 3 - 5): Have another team member place one thumb on the ice cube (while it is in the plastic bag) for 15 seconds. Quickly dry this thumb and place both thumbs **three centimeters** apart on the thermal crystal for 15 seconds. Lift both thumbs and record your observations. **Ask students why they think the iced thumb produced no color pattern.**

The thermal energy flow is now from the crystal into the thumb.

PART FIVE (Grades 6 - 12): Provide each team with a moist (not wet) cotton swab. Have a student from the team place the crystal on his/her forehead until almost the entire crystal turns blue. Now have a student make a Z on the crystal with the moist side of the swab. What color does the Z change to and why? Explain to students that the thermal energy in the crystal is being transferred to the water, allowing this water to evaporate. Evaporation is a cooling process, and the line made by the swab shows cooler colors.

PART SIX (Grades 6 - 12): To reinforce the concept that evaporation is a cooling process, conduct the following evaporation demonstration. Have one student place their thermometer into the isopropyl alcohol bottle and the next student place their thermometer in a sample of water. Both liquids should be at room temperature. The third student's thermometer is the control and will keep their bulb dry.

Remove the two thermometers from the liquids. In less than ten seconds students should see temperature drops for the wet thermometers. The liquid is evaporating, changing from a liquid to a gas.

The energy needed to change those liquid molecules into gaseous molecules is being provided by the internal energy of the thermometer; the temperature of the thermometer drops. Evaporation is a cooling process. Discuss examples of this evaporative cooling process (stepping out of a shower, hosing down a hot sidewalk or perspiring).

Module # 4
Conductors & Insulators
(Two Parts - 15 minutes)

Suggested Grades: All grades with an emphasis on **6-12**.

Teaching Objective: To demonstrate that materials differ in their ability to transfer thermal energy by conduction.

Objectives:

1. Conductors transfer thermal energy well because the transfer of kinetic energy between neighboring atoms/molecules is fast.
2. Insulators are poor conductors of thermal energy because the transfer of kinetic energy between neighboring atoms/molecules is slow.
3. Objects at the same temperature may feel like different temperatures because of each object's ability to transfer energy between atoms.

Equipment & Supplies

Part One: Student Assistants - 2
Jars* with Tile, Rug and Air
Thermometers* - 3
Rug & Tile Samples* - 6 sets

Part Two: Student Teams - 6 / Student Assistants - 2
Steel Cans* - 6
Clear Plastic Cups* - 6
Foam Polystyrene Cups* - 6
Ice Water - one gallon

* Included in Kit.

Instructional Procedure

PART ONE (Grades 6 - 12): Inform students of the room temperature and ask them to estimate the temperature of the substances in the three plastic jars (rug fibers, crushed tiles and air). Have a student assistant measure the temperature of the substances in each jar. Explain to students the concept of thermal equilibrium. Give students the analogy of water in a partitioned fish tank, with the water level higher on one side of the tank. If a cork at the bottom of the tank (in the partition wall) is removed, what would happen to the water levels on each side? They would balance out; one water level rising, the other falling. The same is true for thermal equilibrium, one substance will gain thermal energy while the other loses thermal energy until equilibrium is reached.

Now pass out a tile and rug sample to each student. Have them place the tile and rug sample on opposite cheeks of their faces and **ask them which is colder, the tile or the rug.** Most students will say the tile is colder. Remind them of the demonstration just completed, where it was found that both the rug and tile were at the same temperature; room temperature.

Why does the tile feel cooler? Because the tile is a better conductor of thermal energy. The tile absorbs the thermal energy from your face faster than from the rug, so your skin senses greater heat loss. The rug is a poor conductor of thermal energy and appears neither warm nor cold; it's a good insulator. Ask why the first student in the team using the rug and tile might have felt the biggest difference in temperature.

PART TWO **(Grades 9 - 12):** . Have two student assistants pour cold water (no ice) into the six clear plastic cups, six foam polystyrene cups and six steel cans. Fill all 18 containers about half way with cold water and give one of each type to six student teams. **Ask students to observe the condensation forming on the cups**. You should inform students that millions and millions of water vapor molecules are in a cubic centimeter of air. Slow them down by cooling them, and they will join together to form water drops or condensation.

The best conductor of thermal energy is the steel can as it has condensation above the water line. Explain how thermal energy is being transferred (conducted) from the can above the water line, leaving it cold enough to condense water. The plastic cup has condensation to the water line, not above. This shows that plastic is not a good conductor of thermal energy. Students can use their fingers to feel moistness below but not above the water line. Finally, the foam polystyrene is an outstanding insulator, so much so that no condensation forms on the outside of the container.

If the humidity level in the room is low, have the students hold the containers above and below the water level to detect the temperature differences.

Module # 5
Radiation & Convection Observations
(Two Parts - 12 minutes)

Suggested Grades: All grades with an emphasis on **6-12**.

Teaching Objective: To demonstrate how thermal energy is transferred through convection and radiation.

Objectives:

1. Matter is not always needed to transfer thermal energy, radiant energy can travel through a vacuum.
2. All objects emit and absorb radiant energy; good (poor) emitters are also good (poor) absorbers of radiant energy.
3. In liquids and gases thermal energy is transferred by convection, the movement of its atoms/molecules throughout the sample.
4. Increasing the kinetic energy (temperature) of atoms/molecules in liquids and gases will result in greater distances between the atoms/molecules and lower fluid densities. (Hot air expands).
5. The more energetic atoms/molecules in a liquid or gas will rise to the top and the less energetic will fall to the bottom. (Hot air rises).

Equipment & Supplies

Part One: Student Assistants - 2
Heat Lamp or Flood Light
2 Black & 2 Silver Cans*
Thermometers* -2
Liquid Thermal Crystals* - 2
Hot Water

Part Two: Student Assistant - 1
Hot (10 oz.) & Cold Water (10 oz.)
Clear Plastic Cups* - 2
Food Coloring - 2 Bottles*

Optional Activity: Student Assistant - 1
Digital Thermometer
Large Foam Containers & Lids - 2
Hot Water (20 oz.) & Ice Water (20 oz.) Chair/Ladder

* Included in Kit.

Instructional Procedure

<u>PART ONE</u> <u>(Grades 9 - 12)</u>: Most students know that black objects are better absorbers of radiant energy than light or shiny objects. If you have a heat lamp, or a lamp with a fixture that directs light, you can prove this. To do so, fill two cans (one black and one silver) with room temperature water and place
them at equal distances from the lamp. Set this up before or at the start of your presentation. In approximately 10-15 minutes you will find the black can's water temperature is higher. If you do not have a light source, explain this portion of the demonstration. Then proceed with the radiant emission demonstration.
Will the black can radiate its energy slower or faster? **Ask students to make a hypothesis about cooling by radiation**.

Fill one black can and one silver can with hot water and record their temperatures; they should both be the same temperature to start (75-80 ☜C). We will give some time for them to settle and then measure their temperatures. While you are waiting three minutes, conduct the following demonstration.

Have one student assistant hold a liquid thermal crystal about 10 cm to the side of the silver can while the other assistant holds another crystal the same distance from the side of the black can. The can radiating more energy, will produce a large colored area as well as more colors at the blue end of the spectrum rather than at the red. Explain to students that radiant energy does not require matter for energy to be transferred. Explain how the vacuum in a Thermos bottle prevents heat transfer by radiation. Also, discuss how the sun's radiant energy travels 93 million miles through a vacuum to earth.

After approximately three minutes, measure the water temperatures in the two cans. The black can should be cooler due to more radiant heat loss. Both demonstrations will show that black objects are also good emitters of radiant energy. If black objects were not good emitters, they would never result in thermal equilibrium.

PART TWO **(Grades 6 - 12):** Another method of thermal energy transfer is by convection. Convection occurs in liquids and gases. In order to demonstrate that cold, less energetic molecules in a liquid fall while the more energetic molecules rise, conduct the following demonstration. (If time permits you may wish to have students observe cups at their own desk/lab table.)

Fill one plastic cup with hot water (75-80 ☜C) and one with cold water (5-10 ☜C). Place a bottle of food coloring in both cups for about three minutes.

Optional Activity (Grades 9 - 12): If you have access to a digital thermometer, show students the stratification of temperature in a large foam container (with lid) of hot water. You should see about a three degree Celsius difference from the top to the bottom (about 10 cm difference). With the help of a chair or ladder, you can also show the difference in temperature from the floor to the ceiling of the room.

If time permits, try the same experiment with ice water (1/3 ice and 2/3 water)**.** This time the colder water (1-2 ☜C) will be at the top of the foam container and the warmer water (3-4 ☜C) will be at the bottom. At 4 ☜C, water expands when heated just like other substances. When its temperature drops below 4 ☜C, the molecules slow down, the forces of attraction increase, and the randomly arranged molecules form a hexagonal crystal expanding to take up 9% more space. If water didn't have this unique property, bodies of water would freeze from the bottom up, and some bodies of water would remain frozen year round.

Take out both bottles of food coloring from their baths. Place a drop of hot coloring into the cold water and observe. (Place the dropper as close as you can to the water level before gently releasing the drop.) Next, have a student assistant carefully observe the water in the plastic cups. The molecules in the hotter and less dense food coloring float on the top of the water. Repeat this process, using the cold food coloring and the hot cup of water and noting that the molecules in the denser and colder food coloring sink.

Module # 6
Hidden Heat & Phase Changes
(Three Parts - 5 minutes)

Suggested Grades: All grades with an emphasis on **8-12**.

Teaching Objective: To demonstrate how internal energy effects the phase of a substance.

Objectives:

1. Liquids contain hidden (latent) heat as a result of their phase; this heat is revealed when it changes into the solid phase.

Equipment & Supplies

Part One: Student Teams - 4
Heat Packs* - 4

* Included in Kit.

Instructional Procedure

PART ONE (Grades 9 - 12) : Provide teams (4-8 students) with a Heat Pack and have them feel the pack to determine its relative temperature. The pack should be at room temperature and will feel slightly cool to the touch. Explain to students that the liquid inside the pack is a supersaturated solution of sodium acetate. In a supersaturated solution, the concentration of solute is more than its solubility.

Explain to students that the solution is like the Roadrunner and the Coyote from cartoons. The Coyote is chasing the Roadrunner near a cliff. Just before the Roadrunner approaches the edge of the cliff, he steps to the side. As expected, the coyote runs off the edge of the cliff. The Coyote continues to run on air until he realizes that he is running on air; the shock causes him to fall.

The same is true for the supersaturated sodium acetate solution. At room temperature this concentration of sodium acetate should be a solid. **Ask the students to shock the solution by clicking the metal disk inside the pack.** The clicking will produce some thermal energy and cause the sodium acetate molecules around the disk to crystallize. In turn, neighboring molecules will be shocked by the heat given off as the liquid turn into a solid. The students will feel heat coming from the pack. They are feeling the hidden heat found in liquids.

In solids, the force attraction between molecules is greater than when in its liquid phase. This force of attraction requires energy to keep atoms/molecules in their fixed positions. In the liquid phase, molecules contain enough energy to overcome this attractive force that would keep them in fixed positions. When the free moving atoms/molecules in liquid become solid they emit this excess energy, and we experience the hidden heat stored in the liquids' molecules.

Have students read the **"To Reuse"** instructions on the heat pack. Heat must be added to the solid to return it to a liquid. This heat is used to overcome the forces of attraction between molecules and will become hidden heat.

Providing this hidden heat through a phase change explains why a little bit of ice can cool a drink of water. Energy from the water is being consumed to break the forces of attraction (melt) between ice crystals and not to raise the temperature of the ice.

ASHRAE Class Presentation Kit
Hardware

Hardware Item	Number	Modules Required
Thermal Liquid Crystals	8	3 & 5
Heat Packs	4	6
Steel Cans	6 shiny & 2 black	4 & 5
Thermometers	3	2, 3, 4, & 5
Food Coloring & Dropper	2	1 & 5
Tile & Rug	6 Sets	4
Plastic Jars with Samples	3	4
Clear Plastic Cups	15	1, 4, & 5
Foam Cups	15	1, 2, & 4
Foam Containers	4	2
Isopropyl Alcohol	1	3
Plastic Bags	8	3
Copper Shot	4	2
Copper Wire	2	2
Tennis Ball With Rubber Bands	1	1
Happy / Sad / Super Balls	1	1

News Release

Demonstrating the flow of thermal energy from hot to cold and introducing the relationship between kinetic energy and temperature were just two demonstrations conducted today for science students at (Name of School) by (Name & Affiliation). The demonstrations and student investigations were all directed at helping students understand the scientific concepts behind internal and thermal energy.

"Members of the heating, cooling and refrigeration industries are interested in assisting teachers with instruction which helps their students meet state and national science education standards, said (Name & Affiliation) about the objective of his/her presentation. Industry engineers can also explain the practical applications of these concepts when it comes to designing and operating a refrigerator, air-conditioner or numerous other everyday equipment."

Following the program, science teacher Mr./Ms. (Name) remarked, "Students are required to understand concepts like temperature, methods of heat flow, phase changes, and hidden heat. The demonstrations and hands-on student investigations conducted by (NAME) thoroughly engaged students during the one-hour program and were helpful in reinforcing required science concepts."

The students enjoyed observing crystals that changed color from the warmth of their touch while having the opportunity to assist with demonstrations. (Name) opened the program by explaining how the ability to regulate temperature has changed how and where we live and work over the past 100 years. At the end of the program, students were also given a glimpse into the heating, cooling and refrigeration industry as well as its many career opportunities.

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Presentation Evaluation

The development of effective teaching materials takes years of revision based on field testing and evaluation. In order to assist in this process, please respond to the questions below.

- Are you an ASHRAE Member, Educator or both? ____
- How many students attended the presentation? ____
- What was the class grade presented to? ____
- Did you find the kit useful? Yes/No ____
- Please rate the modules based on a +/0/- scale. ____

1. How helpful were the written and video taped instructions in preparing and conducting your presentation?

2. Was the hardware provided in the kit effective and reliable when making your presentation?

3. Did the demonstrations and investigations interest and engage students?

4. How successful were you at helping the teacher introduce or reinforce science concepts?

5. What suggestions would you offer to make this kit more effective?

[ ] I have provided additional comments on reverse side of this form or on an additional page.

RETURN FORM TO: ASHRAE Education Coordinator
1791 Tullie Circle, NE
Atlanta, GA 30329