U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

Thermodynamics

Teacher Guide

(Six Activities)

Grades: 5-8, 9-12

Topic: Energy Basics

Owner: NEED

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THERMODYNAMICS

Teacher Guide

Hands-on lab experiments to explore the principles of heat and movement.

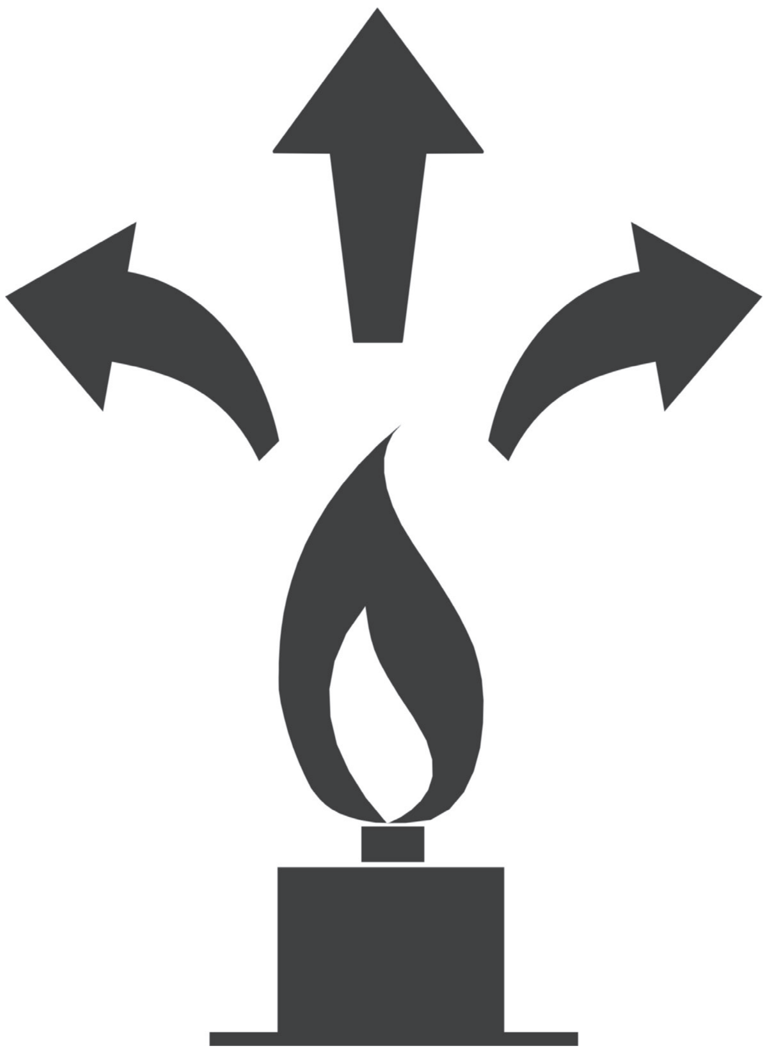
SCIENCE OF ENERGY

GRADE LEVEL

8–12

SUBJECT AREAS

Science
Math
Language Arts



NEED

2006-2007

Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 www.NEED.org

Teacher Advisory Board

NEED Mission Statement

The mission of the NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Vision Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Correlations to National Science Standards

UNIFYING CONCEPTS AND PROCESSES (FOR ALL GRADE LEVELS)

1. Systems, Order, and Organization

a. The goal of this standard is to think and analyze in terms of systems, which will help students keep track of mass, energy, objects, organisms, and events referred to in the content standards.

b. Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of order–or regularities–in systems, and by extension, the universe; then they can develop understanding of basic laws, theories, and models that explain the world.

c. Prediction is the use of knowledge to identify and explain observations, or changes, in advance. The use of mathematics, especially probability, allows for greater or lesser certainty of prediction.

d. Order—the behavior of units of matter, objects, organisms, or events in the universe—can be described statistically.

e. Probability is the relative certainty (or uncertainty) that individuals can assign to selected events happening (or not happening) in a specified time or space.

f. Types and levels of organization provide useful ways of thinking about the world.

2. Evidence, Models, and Explanation

a. Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.

b. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have an explanatory power. Models help scientists and engineers understand how things work.

c. Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. As students develop and as they understand more scientific concepts and processes, their explanations should become more sophisticated.

3. Change, Constancy, and Measurement

a. Although most things are in the process of change, some properties of objects and processes are characterized by constancy; for example, the speed of light, the charge of an electron, and the total mass plus energy of the universe.

b. Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same.

c. Changes can occur in the properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes in systems can be quantified and measured. Mathematics is essential for accurately measuring change.

d. Different systems of measurement are used for different purposes. An important part of measurement is knowing when to use which system.

4. Evolution and Equilibrium

b. Equilibrium is a physical state in which forces and changes occur in opposite and offsetting directions.

c. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

5. Form and Function

a. Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world.

b. The form or shape of an object or system is frequently related to use, operation, or function.

c. Students should be able to explain function by referring to form and vice versa.

INTERMEDIATE (GRADE 5-8) CONTENT STANDARD–A: SCIENCE AS INQUIRY

1. Abilities Necessary to do Scientific Inquiry

a. Identify questions that can be answered through scientific inquiry

b. Design and conduct a scientific investigation

c. Use appropriate tools and techniques to gather, analyze, and interpret data

d. Develop descriptions, explanations, predictions, and models using evidence

e. Think critically and logically to make the relationships between evidence and explanations

f. Recognize and analyze alternative explanations and predictions

g. Communicate scientific procedures and explanations

h. Use mathematics in all aspects of scientific inquiry

2. Understandings about Scientific Inquiry

a. Different kinds of questions require different kinds of scientific investigations, including observing and describing, collecting, experimentation, research, discovery, and making models.

b. Current knowledge and understanding guide scientific investigations.

c. Mathematics is important in all aspects of scientific inquiry.

d. Technology enhances accuracy and allows scientists to analyze and quantify results.

e. Scientific explanations emphasize evidence, have logical arguments, and use scientific principles, models, and theories.

INTERMEDIATE STANDARD–B: PHYSICAL SCIENCE

1. Properties and Changes of Properties in Matter

a. A substance has characteristic properties, such as density, boiling point, and solubility, all of which are independent of the amount of the substance.

b. A mixture of substances can often be separated into the original substances using one or more of the characteristic properties.

c. Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved.

d. Substances are often put in categories or groups if they react in similar ways; metals, for example.

e. There are more than 100 known elements that combine in many ways to produce compounds, which account for the living and nonliving substances in the world.

f. These chemical elements do not break down during normal laboratory reactions involving heat, exposure to electric current, or reaction with acids.

3. Transfer of Energy

a. Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.

b. Energy is transferred in many ways.

c. Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

f. In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

Correlations to National Science Standards

SECONDARY (GRADES 9-12) CONTENT STANDARD–A: SCIENCE AS INQUIRY

1. Abilities Necessary to do Scientific Inquiry

a. Identify questions and concepts that guide scientific investigation.

b. Design and conduct scientific investigations.

c. Use technology and mathematics to improve investigations and communications.

d. Formulate and revise scientific explanations and models using logic and evidence.

e. Recognize and analyze alternative explanations and models.

f. Communicate and defend a scientific argument.

2. Understandings about Scientific Inquiry

a. Scientists usually inquire about how physical, living, or designed systems function.

b. Scientists conduct investigations for a wide variety of reasons.

c. Scientists rely on technology to enhance gathering and manipulation of data.

d. Mathematics is essential in scientific inquiry.

e. Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.

f. Results of scientific inquiry––new knowledge and methods—emerge from different types of investigations and public communication among scientists.

SECONDARY STANDARD–B: PHYSICAL SCIENCE

1. Structure of Atoms

a. Matter is made of minute particles called atoms, which are composed of even smaller components. These components have measurable properties, such as mass and electrical charge.

b. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.

c. The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called isotopes of the element.

2. Structure and Properties of Matter

a. Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.

b. An element is composed of a single type of atom.

c. A compound is formed when two or more kinds of atoms bind together chemically.

d. Solids, liquids, and gases differ in the distances and angles between molecules or atoms and, therefore, the energy that binds them together. In solids, the structure is nearly rigid; in liquids, molecules or atoms move around each other but do not move apart; in gases, molecules or atoms move almost independently of each other and are mostly far apart.

3. Chemical Reactions

a. Chemical reactions occur all around us.

b. Chemical reactions may release or consume energy. Some reactions, such as the burning of fossil fuels, release large amounts of energy by losing heat and by emitting light.

5. Conservation of Energy and the Increase in Disorder

a. The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

b. All energy can be considered to be either kinetic energy—the energy of motion; potential energy—which depends on relative position; or energy contained by a field, such as electromagnetic waves.

c. Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.

d. Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

6. Interactions of Energy and Matter

c. Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and, thus, can absorb and emit light only at wavelengths corresponding to these amounts.

d. In some materials, such as metal, electrons flow easily, whereas in insulating materials such as glass, they can hardly flow at all.

Teacher Guide

GOAL

To introduce students to the basic concepts of thermodynamics—atomic structure, atomic and molecular motion, states of matter, heat transfer, thermal expansion, specific heat, and heats of fusion and vaporization.

BACKGROUND

Thermo Dynamics is a hands-on laboratory unit that explores the concepts of heat. The activity encourages the development of cooperative learning, math, science, and critical thinking skills.

GRADE LEVEL/TIME

This unit is designed for upper middle and high school students (Grades 7-12) and will take eight to ten 45-60 minute class periods, plus homework.

PREPARATION

- Familiarize yourself with the **Teacher Guide** and **Student Lab Guide**.
- Decide if you wish to conduct the **Exploration** exercise and the **Teacher Demonstrations**.
- Obtain the equipment needed for the **Exploration, Teacher Demonstrations**, and **Student Labs** (see **Equipment List** on page 10).
- Set up the equipment at six laboratory stations (see the **Student Lab Guide**). Place the steam generator for Lab Six where you can directly supervise its use.
- Fill two 36 ml test tubes with screw caps about one-third full of corn syrup and seal. (Lab One)
- Fill two 50 ml volumetric flasks—one with 40 ml of glycerin at room temperature and one with 40 ml of water at room temperature—and seal. (Lab Four)
- Fill two 250 ml graduated cylinders with 200 ml of isopropyl alcohol and seal with stoppers. (Lab Four)
- Place small balloon over the end of the expansion tube. (Lab Four)
- Make one copy of the **Unit Exam** for each student or group, as you choose (see page 18).
- Divide your students into six groups.

PROCEDURE

DAY 1: Introduction

- Introduce the unit to the class, explaining that the students will work in small groups to investigate the concepts of heat, conducting different experiments each day for the next six days. You may want to discuss rules for working in groups. Explain that each group should assign tasks to members of the group—recording data, timing, etc. Encourage the students to assign group members to different tasks each day.
- For younger students who are not familiar with the basic concepts and terminology, allot an extra class period to introduce the unit.

- Place students into groups, assign one lab station to each group, and distribute **Student Lab Guides**. Go over the **Student Guide** with the students, giving instructions for using the guides.
- Review the **Metric Measurements and Conversions** with the class (see page 6 of **Student Guide**).
- Review the **Lab Safety Procedures** (see page 7 of **Student Guide**), as well as any additional safety rules that you require.
- Review the **Scientific Concepts** (page 5 of **Student Guide**).
- Review the *Learn About It* sections of the student guide for all six stations, using the **Teacher Demonstrations** (page 13 of **Teacher's Guide**) for each lab, if desired. Have students complete the **Recording** and **Calculating** sections of Lab One for that demonstration. *(The labs are written as separate units and are not dependent on the previous labs. The concepts, however, build on each other.)*
- *Optional––One Day: Have students conduct the **Exploration** exercise (page 14 of Teacher Guide), calibrating thermometers in their lab groups as an additional introduction to the unit. Evaluate the exercise with the class.*
- Instruct student groups to preview the lab stations to which they have been assigned. Instruct the students to complete the ***Think About It*** questions for their labs as homework. *(Lab Answer Key* is on page 15 of **Teacher Guide***)*

DAYS 2–7: Student Labs

- Rotate the groups through the lab stations. Remind the students at the beginning of each day about the lab safety rules. *It is recommended that the teacher operate the steam generator (Lab 6) and directly supervise its use by students.*
- Assign the ***Think About It*** questions for the next day's lab for homework.

DAY 8: Evaluation

- As a class, discuss the labs, the results, and the questions and problems included in the **Student Lab Guide**. Note: the questions in the ***Make Sure You Understand It*** sections are designed to be progressively difficult. For younger students, you may wish to assign only the first one or two questions.
- Have the students take the **Unit Exam** in groups or individually.

Equipment Needed

BY STATION

DEMO-1

1—Marbles
1—Beads

2—250 ml graduated cylinders
1—Triple Beam Balance

DEMO-2

1—Heat Transfer Set
Water—hot and cold

DEMO-3

1—Gas Convection Apparatus
1—Touch Paper
1—Candle

DEMO-4

1—Ball & Ring Set
1—Bunsen burner or alcohol lamp

DEMO-5

1—Specific Heat Demonstrator
1—600 ml Beaker
1—Bunsen burner or alcohol lamp
1—Ring stand or tripod
Water

DEMO-6

1—Palm Glass

EXPLORATION

6—Ungraduated thermometers
6—100 ml beakers

LAB 1

2—250 ml graduated cylinders
2—36 ml test tubes w/screw caps
1—100 ml graduated cylinder
1—25 ml graduated cylinder
140 ml Ethyl Alcohol
10 ml Table salt
1—Triple Beam Balance
Ice
Water
Corn Syrup
Waxed paper

LAB 2

1—Steel crucible
1—Steel crucible lid
1—Porcelain crucible with lid
1—Thermometer
1—Conductometer
1—Paraffin
1—Shallow pan
1—Polystyrene foam cup with lid
1—Ring stand with clamp or tripod
1—Timer or clock with second hand
1—Candle or alcohol lamp
1—Large safety pin
Ice
Water

BY STATION

LAB 3

1—Radiation kit
1—Thermoconductivity strip
1—U-tube
2 —Thermometers
1—Food coloring
1—Index card
1—Timer or clock with second hand
1—Candle or alcohol lamp
1—Ring stand with clamp or tripod
Tape
Water
Matches

LAB 4

1—Compound bi-metal bar
3—100 ml Beakers
4—1000 ml beakers
4—250 ml graduated cylinders
2—Stoppers
2—50 ml Volumetric Flasks
4—Thermometers
1—Expansion tube
40 ml Glycerin
400 ml Isopropyl Alcohol
1—Candle or alcohol lamp
1—Small balloon
Water
Ice

LAB 5

1—Specific Heat Specimen Set
5—Thermometers
1—600 ml beaker
1—100 ml graduated cylinder
1—Safety tongs
1—Triple beam balance
5—Foam cups with lids
1—Marker
1—Bunsen burner or alcohol lamp
1—Ring stand or tripod
Water

LAB 6

1—Steam generator with hose
2—250 ml graduated cylinders
2—Thermometers
2—Large foam cups with lids
1—Bunsen burner or hot plate
1—Ring stand
Water
Ice cubes

To Obtain Equipment

SOURCE	QUANTITY	CATALOG #	EQUIPMENT
SARGENT WELCH	1	WLA1610-20	Marbles
	1	WL6823-03	Beads
	3 sets	WLS80290-10	Ungraduated Thermometers
	1	WL6819R	Heat Transfer Set
	1	WL1653-10	Conductometer
	1	WLC3256T	Bee's Wax
	1	WL1728	Touch Paper
	1	WL68185	Radiation Kit
	1	WL1665	Palm Glass
	1	WLC3736F	Ethyl Alcohol (anhydrous)
	1	WLC3841E	Glycerol (Glycerin)
	1	WLC3985E	Isopropyl Alcohol
	1	WLC4642T	Sodium Chloride (Table Salt)
	10	WLS4678HE	Beakers (100 ml)
	1	WLS24638-17C	Graduated Cylinder (25 ml)
	2	WLS24638-17E	Graduated Cylinder (100 ml)
	10	WLS24638-17G	Graduated Cylinder (250 ml)
	1	CP77300-00	Gas Air Thermometer Tube (with Small Balloon)
	2	WL534810-F	50 ml Volumetric Flask with Cap
	2	WL5681	Package of 15 Dual Thermometers
	14	WLS-80036	Student Lab Thermometers
	1	WLC3799&	Food Coloring
	6	WLS65723-A	Permanent Markers
	2	WLS-79645-C	Test Tubes with Caps
	1	WL1729	Liquid Convection Apparatus
	1	WLS73326-30	Package of Stoppers
	1	WLS4678ME	600 ml Beaker
	4	WLS4678PE	1000 ml Beakers
	1	WLS-82270	Safety Tongs
	1	WLS-23835-C	50 ml Steel Crucible
	1	WLS-23836-C	50 ml Steel Crucible Cover
	1	WLS-23687-J	50 ml PorcelainCrucible with Cover
NASCO	1	SA05698M	Steam Generator
	1	S00185M	Convection Apparatus
	1	SB07985M	Ball & Ring
	1	SA05697M	Specific Heat Specimens
	1	S00188M	Compound Bar
FREY	1	15584391	Tyndall's Apparatus (Specific Heat Demonstrator)
	1	15590778	Fickle Foam

SARGENT WELCH	**800-727-4368**	**www.sargentwelch.com**
NASCO	**800-558-9595**	**www.eNASCO.com**
FREY	**800-225-3739**	**www.freyscientific.com**

Teacher Demonstrations

LAB ONE DEMO––MARBLES & BEADS REPRESENT ATOMS AND MOLECULES.

2—250 ml graduated cylinders **Marbles** **Beads** **Triple Beam Balance**

1. Record the mass of one empty cylinder. Fill the cylinder with 100 ml marbles and record the mass.
2. Record the mass of second cylinder. Fill the cylinder with 100 ml of beads and record the mass.
3. Carefully pour the beads into the cylinder of marbles. Gently tap the cylinder several times to settle the beads into the cylinder. Record the volume and mass of the cylinder.

LAB TWO DEMO—HEAT TRANSFERS FROM ONE CUP TO ANOTHER THROUGH ALUMINUM ROD.

Heat Transfer Set **Hot and cold water**

1. Fill one cup with hot water and the other with an equal volume of cold water. Note temperatures.
2. Observe as the aluminum rod conducts thermal energy from the hot water to the cold water and the temperatures equalize. For further explorations, use different materials as the conductor.

LAB THREE DEMO—GAS CONVECTION APPARATUS DEMONSTRATES HOW WARM AIR RISES.

Gas Convection Apparatus **Touch (smoke) paper** **Candle**

1. Light candle under one chimney of apparatus. Light touch paper and hold over other chimney.
2. Observe as the smoke from the touch paper is drawn **down** the chimney to replace the rising air in the other chimney.

LAB FOUR DEMO—BALL AND RING DEMONSTRATES EXPANSION OF METAL AS HEAT IS ADDED.

Ball and ring **Alcohol lamp or bunsen burner**

1. Demonstrate how the ball fits easily through the ring at room temperature.
2. Heat the apparatus to demonstrate how the metals have expanded and the ball will not fit through the ring.

LAB FIVE DEMO––DEMONSTRATE THE DIFFERENT SPECIFIC HEAT OF SEVERAL METALS.

Specific Heat Demonstrator **Water** **Alcohol lamp or bunsen burner**
Tripod or ring stand **Tongs** **600 ml beaker**
Triple beam balance

1. Weigh metal samples to show that they all have the same mass, then heat them in a beaker of boiling water for several minutes.
2. Place the samples in the wax to demonstrate how equal masses of different metals contain different amounts of heat when they are at the same temperature.

LAB SIX DEMO––PALM GLASS DEMONSTRATES CHANGE OF STATE FROM A LIQUID TO A GAS WITH THE ADDITION OF THERMAL ENERGY.

Palm Glass

1. Hold the bulb of the palm glass with the liquid in your hand to show that the thermal energy from your hand changes the liquid in the bulb into a gas, as indicated by the bubbling of the liquid in the other bulb.

Exploration: Calibrating a Thermometer

GOAL

To develop students' critical thinking skills and introduce them to the concepts of heat by having them calibrate a thermometer without instructions.

PREPARATION AND MATERIALS

1. Place students in six groups.
2. Make the following equipment and materials accessible to the students, but do not instruct them in which equipment or materials to use. For example, you could tell the students they can use any equipment and materials on a given shelf.

- 6—Uncalibrated thermometers
- 6—Permanent fineline, waterproof markers
- 6—Bunsen burners or alcohol lamps
- Ice
- 6—100 ml beakers
- 6—Ring stands or tripods
- Water

PROCEDURE

1. Give each group of students an uncalibrated thermometer and a marker.
2. Instruct the students to review the **Lab Safety Rules** on page 7 of their **Student Lab Guides**.
3. Instruct the students to brainstorm within their groups to devise a method to calibrate their thermometers from -10°C to 120°C. *Depending on the level of your students, you can require them to calibrate the thermometers to both Celsius and Fahrenheit scales.*
4. Instruct each group to write down a list of the materials they will need to accomplish the task and give it to you. If the list of materials is safe and reasonable in your judgment, allow the group to proceed, even if the materials may not accomplish the task.
5. If a group has difficulty devising a list, ask questions to guide them in the right direction, but do not tell them how to proceed.
6. If a group discovers they need additional materials as they proceed, instruct them to obtain your approval before obtaining the materials.
7. After 15-30 minutes, evaluate the activity with the students, checking their calibrations by placing the thermometers in boiling water (100°C—212°F) and at the top of a beaker of ice water (0°C—32°F). The calibrations between the markers should be uniform. You can also use body temperature (37°C–98.6°F) to validate the calibrations.

Student Lab Answer Key

LAB 1 - THINK ABOUT IT

1. Two protons, two electrons, two neutrons.
2. Nineteen protons, 19 electrons, 20 neutrons.
3. H_2O - 18 atomic mass units. CO_2 - 38 atomic mass units.
4. Mass will remain the same, volume will increase.
5. Hot water - more space between the molecules. A given volume of hot water should weigh less than the same volume of cold water.

LAB 1 - MAKE SURE YOU UNDERSTAND IT

1. Mercury - 80 protons, 80 electrons, 121 neutrons.
2. H_2CO_3 - atomic mass of 56.
3. 200 ml + [200 - (200 x 0.05)] ml = 200 + 190 = 390 ml.

LAB 2 - THINK ABOUT IT

1. Diamond.
2. Foam Polystyrene.
3. Tile is a conductor, rug is an insulator.
4. Copper - best conductor.
5. As insulators - to keep things hot or cold, protect us from burns, etc.

LAB 2 - MAKE SURE YOU UNDERSTAND IT

1. Aluminum is more than twice as conductive as brass.
2. Nickel silver is 11 times as conductive as glass - 11,000 calories per second.
3. Nickel silver - 8 minutes 15 seconds. Steel - 4 minutes 45 seconds. Brass - 35.5 seconds. Aluminum - 9.75 seconds. Copper - 6 seconds.

LAB 3 - THINK ABOUT IT

1. Radiation is striking your skin, producing heat.
2. Heat the first floor - the heat would rise to the second floor.
3. Convection currents carry the molecules of smoke all over the house.
4. In hot sun, it is cooler with long sleeves on to protect yourself from sun burn and the heat from radiant energy. Light colors reflect more radiant energy.
5. The land heats up faster than the ocean. As the air over the land heats up, it rises, and the cooler air over the ocean rushes in to take its place.

LAB 3 - MAKE SURE YOU UNDERSTAND IT

1. Energy from the sun in the form of radiation heats the concrete and the air. The heat in the concrete warms the water in the pool by conduction. The heat in the air warms the water by convection. The water in the pool warmed by convection and conduction warms the rest of the water by convection. The water at the top of the pool is warmest because heat rises. When the sun goes down, the concrete, which has a higher conductivity than water, cools more quickly and conducts heat away from the water. The water heats the air directly above it by conduction. That warm air rises and cooler air flows in. The water on the top of the pool has given some of its energy to the air - it sinks and warmer water rises and gives some of its heat to the air.

Student Lab Answer Key

LAB 4 - THINK ABOUT IT

1. Air and gases expand the most.
   Pyrex glass expands the least.
2. Steel and concrete have the same cubic expansion rate. If a different metal is used, it might crack the concrete as it expands or contracts.
3. Low expansion rate so it won't crack teeth or fall out.
4. Pyrex expands very little when heated, much less than regular glass.
5. Expansion of materials in summer, contraction in winter.
6. Ethyl alcohol would register the slightest changes because it expands the most.

LAB 4 - MAKE SURE YOU UNDERSTAND IT

Question 1.

Volume change = $(10m^3) \cdot (500\ °C) \cdot (0.000069/C°)$

Volume change = $0.345m^3$

New volume = $10.345m^3$

Question 2.

10ml = (500ml)·(100ºC)·(cubic expansion rate)

10ml/50,000mlCº = cubic expansion rate = 0.0002/Cº

Question 3.

1.1L = (100L)·(temperature change)·(0.00112/Cº)

1.1L = (0.112L/Cº)·(T)

1.1L/0.112L/Cº = T = 9.8ºC

LAB 5 - THINK ABOUT IT

1. Generally, as the density of a substance increases, the specific heat decreases.
2. Generally, as the atomic mass of a substance increases, its specific heat decreases.
3. Water
4. Gold & Lead
5. The human body is mostly water. The temperature of a body could tell a detective how long ago the murder had occurred.

LAB 5 - MAKE SURE YOU UNDERSTAND IT

Question 1.

Heat lost = Heat gained
(10g)·(150ºC-T)·(0.092cal/gCº) = (50g)·(T-30ºC)·(1.0cal/gCº)
T = final temperature of copper sample and water
(0.92g cal/g Cº)·(150ºC-T) = (50g cal/g Cº)·(T-30ºC)
(0.92cal/Cº)·(150ºC-T) = (50cal/Cº)·(T-30ºC)
138cal-0.92T cal = 50T cal-1500cal
1638cal = 50.92T cal
1638cal/50.92cal = T = 32.17ºC

Student Lab Answer Key

Question 2.
Temperature change for metal = (125ºC-22.75ºC) = 102.25ºC
Temperature change for water = (22.75ºC-20ºC) = 2.75ºC
Heat lost by the metal = Heat gained by the water
(Specific Heat)•(102.25ºC)•(10g) = (1.0cal/gCº)•(40g)•(2.75ºC)
(Specific Heat)•(1022.5gCº) = (110cal g Cº/g Cº)
Specific Heat = 110cal/1022.5g Cº
Specific Heat = 0.107cal/g Cº = iron

Question 3.

Lead has the lowest specific heat, then iron, then aluminum. Lead would gain and lose heat the fastest, the iron, then aluminum. Eventually, all would reach the same temperature.

LAB 6 -THINK ABOUT IT

1. There is no direct correlation.
2. It takes more energy to change a liquid into a gas because almost all the force of attraction between the atoms or molecules is being eliminated.
3. Gold requires the most amount of heat energy to change from a liquid into a gas.
4. Mercury requires the least amount of heat energy to change from a solid into a liquid.
5. There is no direct correlation.

LAB 6 - MAKE SURE YOU UNDERSTAND IT

Question 1.
(20g)•(80cal/g) + (20g)•(T-0ºC)•(1.0cal/g Cº) = (50g)•(100 ºC-T)•(1.0cal/g Cº)
T = Final temperature of water
(1600g cal/g)+(20g T cal/g Cº) = (5000 ºC cal g/g Cº)-(50g cal T/g Cº)
1600cal+20cal T = 5000cal-50cal T
70cal T = 3400cal
T = 3400cal/70cal = 48.57 ºC

Question 2.
(2g)•(540cal/g)+(2g)•(100 ºC-T)•(1.0cal/g Cº) = (50g)•(T-20ºC)•(1.0cal/g Cº)
1080cal+(2g cal/g Cº)•(100 ºC-T) = (50g cal/g Cº)•(T-20ºC)
1080cal+200cal-2cal T = 50cal T-1000cal
2280cal = 52cal T
2280cal/52cal = T = 43.85ºC

Question 3.
Steam temperature change = 100ºC-82ºC = 18ºC
Water temperature change = 82ºC-20ºC = 60ºC
(Xg)•(540cal/g)+(Xg)•(18ºC)•(1.0cal/g Cº) = (90g)•(62ºC)•(1.0cal/g Cº)
540X cal+18X cal = 5580cal
558X cal = 5580cal
X = 5580cal/558cal = 10g

Question 4.
(100g)•(80cal/g)+(100g)•(T-0ºC)•(1.0cal/g Cº) =
(20g)•(540cal/g)+(20g)•(100ºC-T)•(1.0cal/g Cº)
8000cal+100cal T = 10800cal+2000cal-20cal T
120cal T= 4800cal
T = 40ºC

ThermoDynamics Unit Exam

Questions 1-20 are worth 2 points each.

1. The word *thermodynamics* means...

a. production of heat   b. movement of heat   c. both a and b   d. neither a nor b

2. Approximately what percentage of matter is made of empty space?

a. 99.99%   b. 90%   c. 10%   d. zero

3. What holds the molecules in solids together?

a. The gravitational attraction between the atoms

b. The electrical attraction between the protons and electrons of adjoining atoms

c. The magnetic forces of attraction between electrons of adjoining atoms

d. Nuclear forces of attraction between protons of adjoining atoms

4. Approximately how many elements, or types of atoms, make up the universe?

a. 100   b. 1000   c. 5000   d. an infinite number

5. As the vibration of the molecules in a substance increases, the temperature of the substance...

a. increases   b. decreases   c. remains the same

6. In which state is there little force of attraction between the molecules?

a. solids   b. liquids   c. gases   d. all states are the same

7. In which state is the force of attraction between molecules the strongest?

a. solids   b. liquids   c. gases   d. all states are the same

8. In which state does the volume of a substance increase most when thermal energy is added?

a. solids   b. liquids   c. gases   d. all states are the same

9. When liquids are heated, the force of attraction between the molecules...

a. increases   b. decreases   c. remains the same

10. Three containers—one large, one medium, and one small—are filled with sand and placed in a room at 22°C for 24 hours. In which container are the sand molecules vibrating at the greatest rate?

a. large   b. medium   c. small   d. all at the same rate

11. Which of the three containers of sand in Question 10 contains the most thermal energy?

a. large   b. medium   c. small   d. all are the same

12. Generally, as density increases, the amount of energy needed to increase the temperature of a substance...

a. increases   b. decreases   c. remains the same

13. Substances in which state of matter cannot transfer thermal energy by convection?

a. solids   b. liquids   c. gases   d. all three can

14. Half of your bare foot (at 37ºC) stands on a tile floor, the other half on a rug. If the temperature of the room is 24ºC, which statement below is true?

a. The temperature of the rug and tile are the same.

b. Your foot is supplying thermal energy to both the rug and the tile.

c. The part of your foot on the tile will feel colder than the part on the rug.

d. All three statements are correct.

15. To heat a room efficiently, the heating elements or vents should be placed...

a. on the ceiling b. on the floor c. either

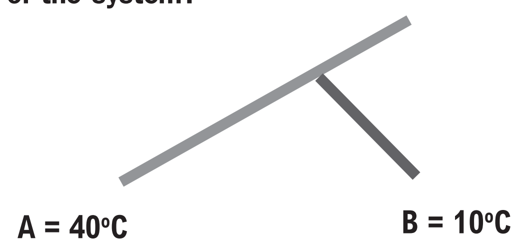
16. The diagram on the right shows a metal bar-A at 40ºC placed so that it is touching metal bar-B, which is at 10ºC. Which statement best describes the thermodynamics of the system?

a. Thermal energy is traveling from A to B.

b. Thermal energy is traveling from B to A.

c. Cold energy is traveling from A to B.

d. Cold energy is traveling from B to A.



17. If two different metal samples—with masses of 50 grams at 100ºC—are placed into beakers with 200 ml of water at 10ºC, which metal will produce the greater increase in water temperature? The metal with the...

a. higher specific heat b. lower specific heat c. higher heat of fusion d. lower heat of fusion

18. When a substance changes from a liquid into a gas at a constant temperature...

a. energy is needed b. energy is given off c. no energy is exchanged

19. Which of the following contains the greater amount of thermal energy?

a. one gram of steam at 100ºC

b. one gram of water at 100ºC

c. both water and steam have equal amounts of thermal energy at 100ºC

20. Thermal energy is added to a substance, yet its temperature remains the same. This is because ...

a. the substance is a good conductor of thermal energy.

b. the substance is a good insulator of thermal energy.

c. the substance is using the thermal energy to change its state of matter.

d. an increase in temperature will always accompany an increase in thermal energy.

Thermodynamics Equations

Heat lost = Heat gained

Heat gained or lost = (Specific Heat)•(Mass)•(Temperature Change)

Heat gained or lost = (Heat of fusion or Heat of vaporization)•(Mass)

Cubic Expansion = (Original volume)•(Temperature change)•(Cubic Expansion Rate)

Thermodynamics Table

Substance	Specific Heat *(cal/g^{o}C)*	Cubic Expansion *(m^3/^{o}C)*	Conductivity *[cal/(sec x m x ^{o}C)]*	Melting Point *(^{o}C)*	Heat of Fusion *(cal/g)*	Boiling Point *(^{o}C)*	Heat of Vaporization *(cal/g)*
Lead	0.030	87×10^{-6}	147	327	5.5	1,750	205
Copper	0.092	51×10^{-6}	1,633	1,083	49.5	2,566	1,130
Aluminum	0.215	69×10^{-6}	1,005	660	76.8	2,519	3,905
Water	1.000	207×10^{-6}	3	0	80.0	100	540

PART II. To answer Questions 21-28, refer to the table above.
Questions 21-24 are worth 2 points each. Questions 25-28 are worth 8 points each.

21. Which solid will expand the most when thermal energy is added?

22. Which substance is the best conductor of thermal energy?

23. Which metal will turn into a liquid first when put into an industrial oven?

24. Which substance would require the most thermal energy to increase the temperature of a one gram sample 1^{o}C?

25. How much thermal energy must be added to a 10 gram sample of aluminum to increase its temperature from 100^{o}C to 120^{o}C?

26. A block of aluminum with a volume of 100m^3 at 0^{o}C is heated to 200^{o}C. What is the block's new volume?

27. A 50 g piece of ice at 0^{o}C is placed in 100 g of water at 100^{o}C. When the ice has completely melted, what is the resulting temperature of the water?

28. A 10 gram sample of copper at 983^{o}C is heated until it turns into a liquid at 1083^{o}C. How much thermal energy is required?

PART III. Answer two of the following questions. Each question is worth 10 points.

I. A drinking glass is taken out of the freezer and placed on a table on a warm humid day. Explain what happens to the glass in the first 30 seconds, in 30 minutes, and in 24 hours.

II. On a very cold day—and on a dare—a student who doesn't understand thermodynamics touches his/her tongue to a metal pole. The temperature of the metal is –10ºC. Explain in thermodynamic terms what happens and why?

III. You want to store the thermal energy collected by your passive solar home during the day. You want to build planters in the room with large, south facing windows to store the energy. What material should you use to build the planters—wood, concrete, or metal—and why? What else should you do to prevent heat loss from conduction?

IV. Thermos bottles can keep liquids cold or warm, because they have a partial vacuum between the inner container holding the liquid and the highly reflective outer surface. Explain the reason for this construction.

Unit Exam Answer Key

1. b
2. a
3. b
4. a
5. a
6. c
7. a
8. c
9. b
10. d
11. a
12. b
13. a
14. d
15. b
16. a
17. b
18. a
19. a
20. c
21. lead
22. copper
23. lead
24. water
25. $(10g)\cdot(20^{o}C)\cdot(0.215\ cal/g^{o}C) = 43.0cal$
26. Expansion = (Original Volume) • (Temperature Change) • (Expansion Rate)
    Expansion = $(100m^3)\cdot(200°C)\cdot(6.9x10^{-6}/C°)$
    Expansion = $(1.38x10^{-1}m^3) = 0.138m^3$
    New Volume = $100.138m^3$
27. Heat lost = Heat gained
    $(50g)\cdot(80cal/g)+(50g)\cdot(T\text{-}0°C)\cdot(1.0cal/g\ C°) = (100g)\cdot(100°C\text{-}T)\cdot(1.0cal/g\ C°)$
    4000°C+50T C° = 10000°C-100T C°
    150T C° = 6000°C
    T = 40 = Final temperature 40°C
28. Heat required = $(10g)\cdot(100^{O}C)\cdot(0.092cal/g/^{O}C)+(10g)\cdot(49.5cal/g)$
    Heat required = 92cal+495cal = 587cal

I. Water molecules are always in the air, especially on humid days. When these water molecules strike the ice-cold glass (coming directly from the freezer, the glass is less than $0^{O}C$), they give off a lot of their energy to the less energetic molecules of the glass. The energy loss is so great for gas molecules that they turn directly into ice, and in 30 seconds you get a frosted glass.

The glass continues to absorb energy from the warm room and its temperature begins to rise. Now the heat from the glass provides enough energy to the molecules of ice to break the forces of attraction that kept the molecules in the solid state. The ice will change into water.

In addition to the melted ice water on the glass, water molecules in the air continue to strike the glass, changing into water now instead of ice. In 30 minutes, the glass reaches room temperature, and is covered with drops of water.

In a day, all the water molecules gain enough energy to leave the forces of attraction of the glass and other water molecules and fly off into the air. The water evaporates and changes back into gas molecules.

II. The atoms and molecules in the $–10^{O}C$ metal pole possess little internal energy. The saliva on the child's tongue is mostly water. When these body temperature ($37^{O}C$) water molecules come in contact with the $–10^{O}C$ metal pole they transfer a great deal of their energy to the less energetic atoms in the pole. The water molecules on the child's tongue and on the pole lose so much energy that they freeze into ice, trapping the child until the ice melts, one way or another.

III. A planter that could store a lot of thermal energy during the day, so that it could release more energy during the night, would be the best choice. Concrete has the highest specific heat of the three potential products. This means concrete will take longer to heat up, but will also provide more thermal energy to the room when the sun is gone.

A well insulated home will prevent this valuable solar thermal heat from leaving the building. The trapped air in the insulation does not conduct heat well, therefore keeping the heat in the building longer.

IV. The partial vacuum between the inner and outer shells of the container prevents heat transfer by conduction and convection for most areas of the bottle. The reflective surface of the outer shell reduces the amount of radiant energy absorbed by the shell. Together, these two factors slow heat from entering or escaping from the bottle.

THERMODYNAMICS
Evaluation Form

State: ___ _ **Grade Level:** ___ _ **Number of Students:** ___ _

1. Did you conduct the entire activity?	Yes	No
2. Were the instructions clear and easy to follow?	Yes	No
3. Did the activity meet your academic objectives?	Yes	No
4. Was the activity age appropriate?	Yes	No
5. Were the allotted times sufficient to conduct the activity?	Yes	No
6. Was the activity easy to use?	Yes	No
7. Was the preparation required acceptable for the activity?	Yes	No
8. Were the students interested and motivated?	Yes	No
9. Was the energy knowledge content age appropriate?	Yes	No
10. Would you use the activity again?	Yes	No

How would you rate the activity overall (excellent, good, fair, poor)?

How would your students rate the activity overall (excellent, good, fair, poor)?

What would make the activity more useful to you?

Other Comments:

Please fax or mail to:

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PO Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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