

Explain Methods of Heat Transfer

Unit: Preparing Foods

Problem Area: Food Preparation

Lesson: Explain Methods of Heat Transfer

■ **Student Learning Objectives.** Instruction in this lesson should result in students achieving the following objectives:

- 1 Describe heat transfer and media that transfer heat.**
- 2 Explain the three primary methods of heat transfer.**
- 3 List examples of culinary equipment and their heat transfer method.**

■ **Resources.** The following resources may be useful in teaching this lesson:

Gislen, Wayne. *Professional Cooking, College Edition*, 7th ed. Wiley, 2010.

“Gourmet Engineering,” *Tufts School of Engineering*. Accessed Aug. 26, 2010. <http://www.tufts.edu/as/tampl/en43/lecture_notes/notes.html>.

Jarvis, Laurie, and Deb Simonson. “Heat Transfer,” *WISC-Online*. Accessed Aug. 25, 2010. <<http://www.wisc-online.com/objects/ViewObject.aspx?ID=SCE304>>.

McGreal, Michael J. *Culinary Arts: Principles and Applications*. American Technical, 2008.

Zimmerman, Burr. “Heat Transfer and Cooking,” *Cooking for Engineers*. Accessed Aug. 25, 2010. <<http://www.cookingforengineers.com/article/224/Heat-Transfer-and-Cooking>>.



■ Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials
- ✓ *Supplies below are suggested for the Interest Approach:
 - ◆ Microwave oven
 - ◆ Two towels
 - ◆ Water
 - ◆ Stovetop (electric or gas)
 - ◆ Three pots (two of equal size and one large enough to fit one of the smaller ones inside)
 - ◆ Timer or watch with a second hand

■ Key Terms. The following terms are presented in this lesson (shown in bold italics):

- conduction
- convection
- heat
- heat source
- heat transfer
- heat transfer medium
- induction
- infrared energy
- microwaves
- molecules
- radiation
- temperature
- thermal conductivity
- thermal energy

■ Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. Two possible approaches are included here.

APPROACH 1: Have two identical saucepans on hand and one additional pan large enough to hold one of the other two pans, even if it is not a perfect fit. Have two identical burners (electric or gas) available. Place two cups of water in the two identical pans, and put one of them inside the bigger pan. Put the single pan and the “doubled up” pan on the stovetops over identical heat levels. Note

how long it takes both pans of water to boil. Then ask students to explain why the “doubled up” pan took so much longer to boil. Anticipate their explanation will focus on the obvious and may even skirt the real nature of conduction.

APPROACH 2: Gather two identical hand towels. Soak one in water and wring it out. Leave the other towel dry. Put both towels in a microwave oven and heat them on high for one minute. Remove the towels from the oven. (CAUTION: The wet one will be hot.) Allow students to see the steam rising from the wet towel. Ask students to explain why one is hot and one is not.

The issues of thermal energy conduction and microwave energy and conductivity have just been demonstrated. Use an open discussion about the science of heat transfer and what was learned.

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Describe heat transfer and media that transfer heat.

Anticipated Problem: What is heat transfer? What media transfer heat?

- I. Heat transfer and media
 - A. Heat is a combination of kinetic (movement) energy and temperature (a measurement of heat). **Heat transfer** is a form of energy that moves heat to food. In general, heat is transferred from one material to another in one of three ways: conduction, convection, or radiation. When foods are heated, their molecules begin to vibrate and bounce into one another. These collisions cause heat to transfer. Food is a poor conductor of heat. For example, a roast continues to cook for several minutes after being removed from the oven. Many cooking tasks (e.g., braising) require more than one form of heat transfer.
 1. **Heat**, or **thermal energy**, is the relative amount of energy present in matter (more energy equals more heat). **Temperature** is a measurement of that energy (how fast the molecules of an object are moving; the faster they move, the higher the temperature).
 - a. **Molecules** are the microscopic particles that make up all matter.
 - b. Heat always emanates from a **heat source**—a unit generating energy—such as charcoal, a gas burner, an electric coil, radiation, or the sun. Whether the object is a steak or a living room, adding heat means adding energy.

2. Heat sources are dry or moist. Heat makes food palatable and easier to digest. These actions result when heat is used:
 - a. Fats melt.
 - b. Water evaporates.
 - c. Starches gelatinize (swell or thicken).
 - d. Proteins coagulate (harden).
 - e. Sugars caramelize (brown).
- B. The following equipment may be used for heat transfers: pans, pots, grills, griddles, ovens, steamers, and double boilers. Heat transfer can occur via air, liquid water, steam, or fat media.
 1. Air (dry) media uses the following methods:
 - a. Baking
 - b. Broiling
 - c. Grilling (indoor and outdoor)
 - d. Roasting
 2. Liquid water (moist) media uses the following methods:
 - a. Boiling
 - b. Braising
 - c. Poaching
 - d. Stewing
 3. Steam (moist) media uses the following methods:
 - a. Steaming food on a rack above boiling or simmering water
 - b. Steaming food in a pan surrounded by water under pressure
 4. Fat (moist) media uses the following methods:
 - a. Deep fat frying
 - b. Pan frying
 - c. Sautéing

Teaching Strategy: Use VM–A to review heat transfer and the effects of heat on food. Use VM–B to review heat transfer media and typical cooking methods associated with each.

Objective 2: Explain the three primary methods of heat transfer.

Anticipated Problem: By which methods is heat transferred?

II. Heat transfer methods: conduction, convection, and radiation

- A. **Conduction** is the transfer of heat directly from one source to another—direct physical contact. Heat through conduction is demonstrated as simply as putting a pan on a stove and turning on the flame (or coil). The heat (or energy) from the stove physically touches the pan. The heat moves from the bottom of the pan,

through the pan, and into the food in the pan. So conduction is heat traveling through food.

1. Steaming, boiling, deep frying, and sautéing cause effective heat transfer by conduction.
 2. Variables to consider with heat transfer are thermal conductivity and heat transfer medium. **Thermal conductivity** is the extent to which a material absorbs and transfers heat. For instance, aluminum conducts heat better than glass, which is why aluminum cookware is common and glass cookware is not. A **heat transfer medium** is the actual “material” the heat is moving through: a pan, air, water, oil, etc. The medium has a direct affect on how rapidly a food cooks.
 - a. Copper, aluminum, and iron are excellent conductors of heat. Stainless steel does not heat food as evenly as these other metals and is often clad with copper or another metal.
 - b. Chicken placed in a 350°F oven will take much longer to cook than in a 350°F deep fryer. Fat is a much more efficient medium than air for cooking.
 3. Of particular interest is the growth of specialized induction stovetops. **Induction** is the process of releasing magnetic currents (generated by a high-frequency induction coil) that react only with certain ferrous (containing iron) metals that allow the heat energy to pass into the metal and then into the food. No flame or red coil is visible, and the “burner” surface emanates no heat of any kind. Induction is pure energy transfer using conduction properties from magnetic waves through reactive metals into the food.
- B. Another type of energy is **convection**, which is the bulk movement of thermal energy, not just the conduction of it from point A to B to C. Convection heat transfer involves natural (warm air rises; cool air falls) and/or mechanical (fans, stirring) movements. The heat travels in the air or through a fluid—liquid or gas. For example, while water is heating to a boil, the water on the bottom of the pot is hotter than the water at the top before reaching the boil. If the water is stirred, the heat will transfer more rapidly throughout the water as a whole. The physical movement of the water to transfer heat from the bottom of the pot is the use of convection heat transfer. The same is true for ovens in which fans are present. The fans move the hot air around the oven (horizontally) instead of letting it rise from the bottom.
1. Steaming, baking, and roasting cause effective heat transfer by convection. Because of convection transfer, foods thaw quicker under cold running water than by submerging them in cold water.
 2. As with conduction heat, the heat transfer medium is a variable that will have a direct bearing on the heating process. Therefore, boiling (moving) water will cook foods faster than moving air would cook the same foods.
 3. Convection ovens cause hot air to circulate around food (horizontally), resulting in the food cooking and browning more evenly; no part of the oven is hotter than the other. These ovens cook 25 percent faster at a temperature 25 percent lower than a conventional oven.

- C. Radiation as a heat transfer method is extremely different from conduction and convection. **Radiation** is a type of heat transfer that occurs by moving energy waves of heat or light through molecules. Infrared waves (e.g., toasters, broilers, or microwaves) are common. No heat transfer medium is necessary. In fact, a medium would only “get in the way” by blocking the rays from coming in direct contact with the food. The food absorbs the raw radiant energy and is cooked.
1. **Microwaves** are short electromagnetic radiant (photon) energy waves emitted from a magnetron tube. The tube in the top of the microwave spins around and showers the food inside the oven with microwaves. Cooking occurs when water molecules in the food absorb the microwave energy. As the water molecules begin to move, the food cooks from the outside to the inside by simple conduction. The ovens are designed not to emit energy when the door is open, thereby preventing the accidental exposure of microwaves to human skin.
 - a. Broiling, grilling, and microwaving all cause effective heat transfer by radiation.
 - b. As microwaveable foods are being heated and cooked by water molecules, they generally do not brown or crisp without special sleeves or cookware. This is the same reason glass, china dishes, paper towels, etc. do not burn in a microwave oven. If the coverings feel hot after cooking, it is due to heat being transferred from the food to the cookware or covering, not from the microwaves. The waves pass harmlessly through nonporous cookware, but they will bounce off, spark, and react violently when they come in contact with tin, aluminum, or similar metals.
 2. **Infrared energy** is electromagnetic (e.g., a microwave) light energy that causes organic food molecules to vibrate and cook. Although people cannot physically “see” infrared energy, their bodies and food items detect it as heat and often view a red or orange glow when food is cooking. These waves transmit energy directly to the food without the use of a heat medium (e.g., pan, air, or oil).
 - a. Examples of infrared heat transfer are broilers and heat lamps. In broilers, the heat moves upward, but the infrared waves move in all directions, including down on the food. With heat lamps, the energy is visible as light shining on the food to maintain heat.
 - b. Conduction and convection are not required for infrared energy to cook foods, but they can affect it. Adding aluminum foil to foods in the oven shields them from infrared energy, keeping the food from browning too much, even though conductive heat is passing through. On the other hand, the use of a dark pan or dish under an infrared heat source will absorb more of that energy than a white or shiny surface, thereby speeding the heating process.

Teaching Strategy: Use VM–C to review. Also, provide examples of the three types of heat transfer: conduction, convection, and radiation. You may want to give the students time to define conduction, convection, and radiation in their own words. Then you can collect their definitions and review them to determine their comprehension.

Objective 3: List examples of culinary equipment and their heat transfer method.

Anticipated Problem: How does commercial cooking equipment transfer heat?

III. Heat transfer via culinary equipment

- A. Conduction is by far the most commonly used method of heat transfer in commercial kitchens. In general, anything cooked on a stovetop or in an oven uses conduction heat transfer. Commercial kitchens use numerous pieces of equipment that produce conduction heat, such as:
 - 1. Flattop grills/griddles
 - 2. Fryers
 - 3. Steamers
 - 4. Braisers
 - 5. Steam-jacketed kettles
 - 6. Steam tables
 - 7. Grills
 - 8. Commercial corn poppers (not hot air)
 - 9. Fondue pots
 - 10. Coffee makers
 - 11. Food warmers
- B. Convection energy cooks food more rapidly and is now commonly used in homes as well as in commercial kitchens. For convection heat transfer to be present, the key element is movement.
 - 1. Convection ovens with fans are the most typical example, particularly for commercial equipment. The fans move hot air horizontally around food for even cooking and browning. Again, they cook foods 25 percent faster at a temperature 25 percent lower than a conventional oven—a time and energy saver.
 - 2. Boiling water is an example of convection energy. Food cooks much faster at 212°F in a rolling boil instead of in water at 211°F that is not moving (or moving rapidly).
 - 3. Other examples that meet the convection heat transfer criteria are:
 - a. Steam-fitted equipment in which the gas (live steam) constantly moves within the cooking space
 - b. Deep-fat fryers in which food moves about freely
 - c. Hot air corn poppers and rotisseries that move foods to effect heat transfer
 - d. Hot dogs rolling on heated cylinder trays
- C. Radiant energy equipment is common in commercial kitchens.
 - 1. Infrared equipment sources are often easily identifiable by an orange or red-dish glow being emitted from the heat source. Examples are:
 - a. Broilers
 - b. Heat lamps

- c. Some specialty ovens and grills
2. Microwave energy is only found in microwave ovens. However, many of those ovens now incorporate conduction and convection heat as part of the system to promote a more even, traditional, and pleasing browning of foods.

Teaching Strategy: Use VM–D to review typical types of commercial cooking equipment associated with each type of heat transfer. Then assign LS–A to have students observe, assess, and record the results of two heat transfer experiments conducted by you. The physical demonstration of basic heat transfer is a great help to student understanding.

- **Review/Summary.** Use the student learning objectives to summarize the lesson, and remind students about the specifics of demonstrations. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. Questions at the ends of chapters in the textbook may also be used in the review/summary.
- **Application.** Use the included visual master(s) and lab sheet(s), along with practical experiment/demonstration to apply the information presented in the lesson.
- **Evaluation.** Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

■ **Answers to Sample Test:**

Part One: True/False

1. F
2. T
3. T
4. F
5. T
6. T
7. F
8. F
9. T

Part Two: Completion

1. molecules
2. fan
3. microwave, infrared
4. thermal conductivity
5. infrared

6. conduction, convection, radiation
7. heat to transfer
8. melt, evaporate
9. air, liquid water, steam, fats

Part Three: Short Answer

1. Glass, wood, and plastic would all be poor choices for baking dishes because of poor thermal conductivity.
2. Conduction heat continues to cook the bird because of the hot air moving through the bird. However, the foil blocks the infrared rays and keeps the skin from browning.
3. Heat is the relative amount of energy present in matter (the more energy, the more heat). Temperature is a measurement of that energy (how fast the molecules of an object are moving; the faster they move, the higher the temperature).

Explain Methods of Heat Transfer

► Part One: True/False

Instructions: Write *T* for true or *F* for false.

- _____ 1. Microwave ovens use infrared rays to heat food.
- _____ 2. Thermal energy is another way of saying “heat.”
- _____ 3. Heat transfer media include air, water, and oil.
- _____ 4. Broilers use magnetron tubes.
- _____ 5. Gas stoves use conduction heat transfer to cook foods.
- _____ 6. Heat transfer is a form of energy that moves heat to food.
- _____ 7. Food is an excellent conductor of heat.
- _____ 8. Boiling water is an example of conduction energy.
- _____ 9. Conduction is by far the most commonly used method of heat transfer in commercial kitchens.

► Part Two: Completion

Instructions: Provide the word or words to complete the following statements.

1. The microscopic particles that make up all matter are called _____.
2. The most common piece of commercial equipment to use convection energy is a convection oven. It uses a _____ to circulate hot air horizontally around food to promote even cooking and browning.
3. Radiation energy includes _____ and _____ waves.



4. How well a material absorbs and transfers energy is known as _____.
5. Broilers use _____ energy to cook food.
6. In general, heat is transferred from one material to another in one of three ways:
_____, _____, or
_____.
7. When foods are heated, their molecules begin to vibrate and bounce into one another. These collisions cause _____.
8. The effects of heat on food are to make food palatable and easier to digest. Two effects include making fats _____ and water _____.
9. Heat transfer media include cooking equipment (pans, pots, etc.) and
_____, _____, _____,
and _____.

► Part Three: Short Answer

Instructions: Answer the following.

1. What material would be a poor choice for a baking pan and why?

2. Putting aluminum foil over a roasting turkey keeps the skin from getting too brown, but the bird still cooks. Why?

3. Explain the difference between “heat” and “temperature.”

WHAT IS THE EFFECT OF HEAT ON FOOD?

Heat transfer is a form of energy that gets heat to food by conduction, convection, or radiation.

Effects of Heat on Food

1. Fats melt.
2. Water evaporates.
3. Starches gelatinize (swell, thicken).
4. Proteins coagulate (become firm, harden).
5. Sugars caramelize (brown).



HEAT TRANSFER MEDIA AND COOKING METHODS

◆ Air (dry) media includes the following methods:

- Baking
- Broiling
- Grilling (indoor and outdoor)
- Roasting



◆ Liquid water (moist) media includes the following methods:

- Boiling
- Braising
- Poaching
- Stewing



◆ Steam (moist) media includes the following methods:

- Steaming food on a rack above boiling or simmering water
- Steaming food in a pan surrounded by water under pressure



◆ Fat (moist) media includes the following methods:

- Deep fat frying
- Pan frying
- Sautéing



Equipment media (e.g., pans, pots, grills, griddles, ovens, steamers, and double boilers)

IMAGES OF WORKING ENERGY

Lava lamps are a great example of working **conduction energy**. Heat from the light bulb passes through the glass and melts the “lava.” When the lava gets warm enough, it rises to the top. When it cools, it sinks to the bottom.



Boiling water illustrates **convection energy**. It allows heat to move from the flame through the glass and into the water. If the water were just hot, it would still cook food, but notice the movement of water when it boils. Movement of the water indicates convection energy is present. Cooking in boiling water is much faster than cooking in hot water.



This fellow is anxious for his popcorn, but what is happening in the oven to make the corn pop? There is no heat in the oven... but there is **radiant energy from microwaves** passing through the bag, heating and expanding the droplets of water in the corn to make the corn pop.



Infrared energy usually comes from a source that glows red or orange. Notice the orange coil above the chicken in this oven. Heat rises (away from the chicken), but infrared energy goes in all directions, allowing this chicken to be broiled (cooked) with a heat source above the food.



COMMERCIAL KITCHEN EQUIPMENT AND ENERGY FORMS

- ◆ Stovetops are a common example of conduction heat, but there are many types. The flame releases heat that rises into the pan above that passes the heat into the food.



- ◆ Ovens use conduction energy, too. In this case, heat fills the oven cavity and passes through the glass roaster into the food.



- ◆ Convection ovens are the most common form of convection heat in the commercial kitchen. Notice the fan.



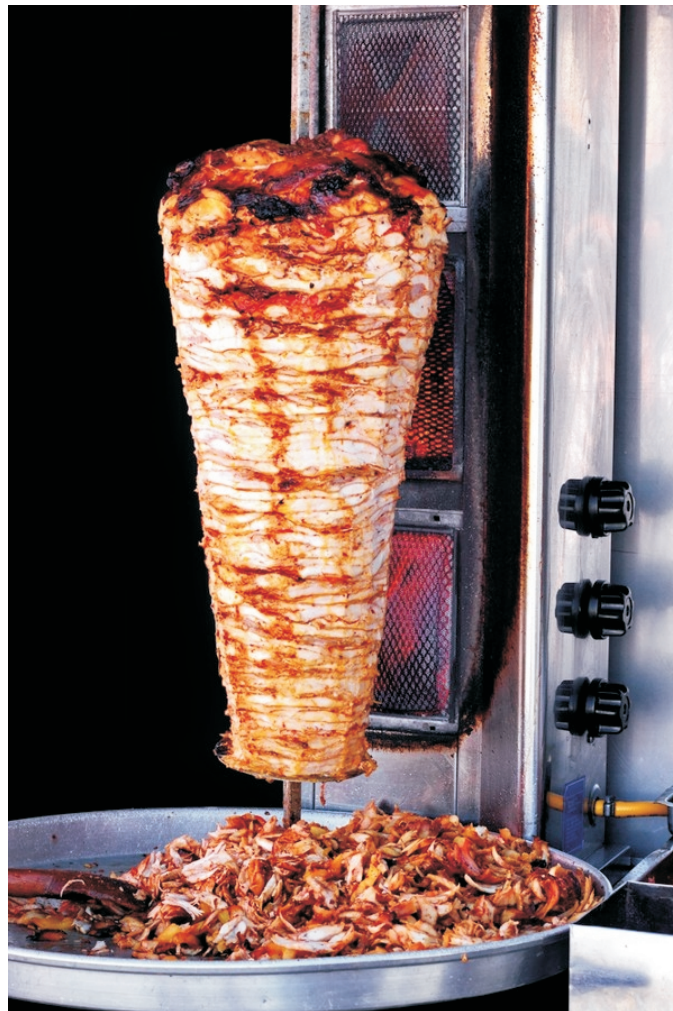
- ◆ This steamer pot stacks multiple perforated pans atop one another and uses convection heat to cook the food in each pan. The perforations (holes) in the bottom of each pan allow the steam to pass through the pans. As steam moves throughout the pan, it speeds the cooking of food as opposed to using just conduction heat to rise up through the pots.



- ◆ Microwave ovens are the only source of microwave energy used in cooking.



- ◆ Heat lamps and vertical broilers provide infrared energy.



Heat Transfer Experiments

Purpose

The purpose of this activity is to observe, assess, and analyze heat transfer.

Objectives

1. Observe two heat transfer demonstrations.
2. Assess and record the outcome of each demonstration.
3. Analyze the practical applications of heat transference.

Materials

- ◆ lab sheet
- ◆ writing utensil

Procedure

1. Work individually to complete this lab sheet. This is an interactive heat transfer lab activity in which two experiments will be conducted in front of you. Your job is to observe, assess, and record your answers to the following questions.
2. Questions: Experiment #1
 - a. What type of energy cooked the chicken breast?
 - b. Did the napkin's temperature change? Why or why not?



- c. The chicken came out of the oven white in color. Why didn't the surface color of the chicken change to a golden brown?
- d. Describe the texture of the chicken and explain what you think happened to cause that texture.
- e. What was the "heat transfer medium" in this experiment?

3. Questions: Experiment #2

- a. Two chicken breasts were cooked by two different methods.
 - (1) What type of energy was used in the fry or sauté pan?
 - (2) What type of energy was used in the small pot or saucepan?
- b. Which method cooked the chicken faster? Record the total heating and cooking time to reach 165°F for each method. What would explain this?
- c. Was radiation in any form used in either preparation? If yes, explain how.
- d. Was thermal energy used in either preparation? Explain how you determined this answer.
- e. Both methods used a different heat transfer medium. Which medium proved to have more efficient heat conductivity? Explain your answer.

Heat Transfer Experiments

1. These two demonstration experiments are designed to help students observe, assess, and analyze heat transfer and record their findings on Lab Sheet A. The labs are to be conducted in front of the class.

EXPERIMENT #1:

2. Materials:
 - a. Microwave oven
 - b. 1 boneless, skinless chicken breast
 - c. A microwave safe plate
 - d. Standard knife and fork
 - e. Cloth or paper napkin
 - f. A metal probe-type thermometer
3. Procedure:
 - a. Place the chicken on the plate (no seasoning, no water, no plastic wrap, and no cover), and put it in the microwave.
 - b. Place a folded napkin in a corner of the oven, not on the plate with the chicken.
 - c. Cook the chicken on high power for 3 to 4 minutes, depending on the oven size and power. The internal temperature of the chicken must be 165°F to be safely eaten. Ideally, the chicken will be overcooked based on these instructions.
 - d. Remove the chicken and the napkin from the oven. Wrap the napkin around the probe-type thermometer, and check the internal temperature of the napkin. Then check the internal temperature of the chicken. Report the internal temperatures you measure.
 - e. Allow students to observe and smell the chicken, and have them record their observations of its appearance. Then cut it into pieces and allow one or more students to taste it. Instruct the tasters to focus on the texture of the meat above all else and to report their findings to the class.
 - f. Allow students time to fill out their lab sheet questionnaire. Then debrief Experiment #1 with the class using the lab sheet questionnaire. Sample questionnaire responses follow in the LS–A Teacher Information Sheet.

EXPERIMENT #2

4. Materials:
 - a. Small fry or sauté pan

- b. Small pot or saucepan with a lid
 - c. 2 boneless, skinless chicken breasts
 - d. 2 tablespoons vegetable oil
 - e. 3 cups of water
 - f. Tongs
 - g. Stovetop or portable burners (gas or electric)
 - h. Towel or hot pad
 - i. 2 serving plates
 - j. Knife to cut chicken
 - k. Forks for tasting
 - l. Metal probe-type thermometer
 - m. Timer or wristwatch with second hand
5. Procedure:
- a. This is a two-part demonstration and may be conducted concurrently or one at a time. The timer should be started during heating of the oil or the water for a total cooking time.
 - b. PART 1: Place the oil in the fry pan and heat over medium-high heat. Turn on the timer. When the oil is hot, put one chicken breast in the fry pan and cook on both sides until an internal temperature of 165°F is reached. Remove it from the pan, and note the elapsed heating and cooking time. Place the chicken breast on a plate and allow students to view the meat. Cut it into pieces, and allow one or more students to taste it. Instruct them to pay attention to the texture above all else and to describe the texture to the class.
 - c. PART 2: Place the water in the pot, add the lid, and turn the heat to high. Turn on the timer. Remove the lid when the water is at a rapid boil. Keep the heat on high, and place the chicken breast in the water. Keep close tabs on the internal temperature, cooking to 165°F. [NOTE: *This cooking method will cook the chicken faster than the fry pan method.*] Remove the boiled chicken with the tongs, and place it on a plate. Let students examine it. Then cut it in pieces and let a student or students taste it with the same instructions: Pay attention to the texture.
 - d. Although texture and color may be part of the student discussion, it is not relevant to the questions on the student lab sheet.
 - e. Allow students time to complete their lab sheet questionnaire. Then debrief Experiment #2 with the class using the lab sheet. Sample questionnaire responses follow in the LS–A Teacher Information Sheet.

Heat Transfer Experiments

EXPERIMENT #1 Sample Questionnaire Responses

- a. What type of energy cooked the chicken breast?

Microwave energy cooked the chicken breast.

- b. Did the napkin's temperature change? Why or why not?

No. The napkin's temperature did not change. It didn't change because dry cloth or paper does not conduct or absorb microwaves.

- c. The chicken came out of the oven white in color. Why didn't the surface color of the chicken change to a golden brown?

The chicken did not become a golden brown because microwaves only manipulate water molecules. Microwaves are incapable of browning or crisping foods without special equipment.

- d. Listen carefully to the evaluation of the student or students who taste the chicken. Ask them to describe the texture of the chicken and to offer an opinion on what happened to cause that texture.

Anticipate that the students who taste it will respond that the chicken is dry and chewy—even rubbery. This texture is a typical result of microwave cooking and the manipulation of water molecules in the food. As water cooks out of the food, the result is dry and rubbery meat.

- e. What was the "heat transfer medium" in this experiment?

Air would be the only possible medium inside the microwave oven, although microwaves do not require a medium to cook foods.

EXPERIMENT #2 Sample Questionnaire Responses

- a. Two chicken breasts were cooked by two different methods.

- (1) What type of energy was used in the fry or sauté pan?

Conduction energy was used in the fry pan.

- (2) What type of energy was used in the small pot or saucepan?

Convection energy was used in the pot of boiling water.

- b. Which method cooked the chicken faster? What would explain this?

The boiled chicken cooked faster. It cooked faster because convection energy is more efficient than conduction energy. Additionally, water is a more efficient heat medium than air or metal (fry pan).

- c. Was radiation in any form used in either preparation? Explain.

Neither microwave nor infrared energy was used in either preparation. Microwaves are only available in a microwave oven, and neither food was exposed to rays from a red glowing radiation source such as a heat lamp or a broiler.

- d. Was thermal energy used in either preparation? Explain how you determined this answer.

Both examples used thermal energy. Heat from the stovetop was the thermal energy source that cooked both pieces of chicken.

- e. Both methods used a different heat transfer medium. Which medium proved to have more efficient heat conductivity? Explain your answer.

The heat transfer medium in the fry pan was the metal pan itself. The pot used water as the heat transfer medium. Since the boiled chicken cooked faster, it proves that water is a more efficient conductor of heat.