Solar Water Heaters for Swimming Pools

RENEWABLE ENERGY
THE INFINITE POWER OF TEXAS

For Grades 6, 7 and 8

OVERVIEW

In this unit students will learn how solar energy can be used for heating swimming pools. Students will distinguish differences in conduction, convection and radiation and how the terms relate to heat loss in swimming pools. Students will measure the rate of heat loss in a simulated swimming pool, apply a simple solution to reduce heat loss and learn the components needed for an efficient solar pool heating system.

OBJECTIVES

See Middle School Teacher Resource Guide for TEKS objectives and additional information regarding this and other middle school units.

SUGGESTED TIMEFRAME

Teacher will need to determine how many class periods to devote to each activity, based on the suggested timeframe and length of classes.

Time	Activity	Content Area
10 minutes	**Activity 1** – Teacher Introduction	
15 minutes	**Activity 2** – Assessment of Current Student Knowledge	Science
45 minutes	**Activity 3** – Reading Passage and Vocabulary **Homework Assignment** – Sentences with Vocabulary	Reading Vocabulary Language Arts
30 minutes	**Activity 4** – Pre-Lab	Science
60 minutes	**Activity 5** – Lab	
30 minutes	**Activity 6** – Post-Lab	Science
30 minutes	**Activity 7** – Assessment	Science

REQUIRED MATERIALS

- copy of the Reading Passage and Student Data Sheets (includes reading comprehension questions, vocabulary and Lab Activity) for each student
- copy of the Assessment Questions for each student
- graph paper
- an equipment kit for each group containing the following:
  - goggles
  - 3 aluminum pie pans
  - 3 thermometers with movable clip (candy thermometer)
  - 1 clear plastic "swimming pool cover," cut from a clear plastic bag to fit inside the pie pan
  - 1 dark-colored plastic "swimming pool cover", cut from a dark-colored (black or brown) trash bag
  - a timer
  - 3 containers, such as large Styrofoam cups, with 300 ml each warm water (approximately 85˚ Fahrenheit)
  - a beaker or graduated cylinder to measure 300 ml

SUMMARY OF ACTIVITIES

Activity 1 – Teacher Introduction (10 minutes)
Explain to the class that for the next unit of study, they will be learning about solar water heaters and how they can be applied to swimming pools. Students will also learn about a simple solution to prevent swimming pool heat loss. Students will work in groups and conduct a Lab Activity making simple models of a swimming pool and evaluating the heat loss over time with an uncovered pool and 2 pools covered with different colored covers.

Activity 2 – Assessment of Current Student Knowledge (15 minutes)

To assess what students already know, prompt a class discussion based on the 3 questions listed below. Based on this discussion, create and display a graphic organizer of the points that were discussed, which can be displayed throughout the unit of study. Refer to the Teacher Resource Guide for sample organizers.

1. Do you think the sun can be used to heat swimming pools? Why or why not?
2. How do you think swimming pools lose heat?
3. What is the difference between conduction, convection and radiation?

See Teacher Resource Guide for alternative or additional assessment activity.

Activity 3 – Vocabulary and Reading Passage (45 minutes)

Each student will need a copy of the Reading Passage and the Student Data Sheets, which include reading comprehension questions, vocabulary words and the Lab Activity. (As an alternative to making copies, the Student Data Sheets can be displayed so the entire class can view them and copy the information into their science notebook.) Instruct students to study the Reading Passage and complete the questions and vocabulary. This activity will help them learn how solar energy can heat swimming pools and some of the concepts involved in heat loss and head transfer in water. This exercise will prepare them for the Lab Activity in which they will observe how a cover can affect heat loss in water. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more of the detailed principles about solar water heating, direct them to the appropriate resources. Suggested resources are included in the Teacher Resource Guide. At the end of this activity, collect and grade the student's work. Return their graded work the following day.

Homework Assignment – Key Vocabulary List

1. Instruct students to create in their science notebooks meaningful sentences that reflect an understanding of the definition of each vocabulary word. Students should have written the definition of the words in their science notebooks during class. See Teacher Resource Guide for alternative vocabulary homework.
2. Collect and grade this assignment the next day.

Activity 4 – Pre-Lab (30 minutes)

1. Explain to the class that the purpose of the Lab Activity is to gain an understanding of how heat loss can occur in swimming pools through evaporation and to construct a simple remedy to reduce heat loss. For teachers interested in exploring the scientific method more fully as it applies to this Lab, see the Teacher Resource Guide for guidelines. Before performing the lab, students should be given the lab instructions to read and summarize the steps involved. The summary can be in the form of a brief chart. Review safety guidelines before students conduct the lab. See Teacher Resource Guide for general safety guidelines. Demonstrate proper use and care of the equipment used in the activity.
2. Divide the class into equal small groups to test their materials and conduct the activity. To ensure that all students participate, instruct the groups to assign who will be responsible for each step in the activity before beginning.

Activity 5 – Lab Activity (60 minutes)

1. Instruct each group to obtain the materials for one Lab Activity kit.
2. Instruct students to follow the directions outlined in the Lab Activity.
3. Confirm that the students have recorded their time measurements on their Lab Report Form, as well as answers and calculations to the lab questions. Students should also create graphs of their results.

Suggestions:

1. This activity uses pie pans with water to simulate three swimming pools: one covered with a translucent material, one covered with an opaque material and one uncovered. The covers can be made from plastic bags or other similar materials that are translucent and opaque; the covers should be cut into a circle to fit inside the pie pan, covering all the water in the pan.
2. Since the students will test the three "pools" in a shady, outdoor location to be determined by the teacher, provide specific directions for:
   a) where the activity will be performed, and
   b) how the materials will be transported (if teacher is concerned about students spilling water, the teacher can opt to transport the water to the outdoor location).
3. The outside activity will be easier to perform by keeping students in unison for taking temperature readings and moving to the shade.

Sample observations

Students should create a graph from their lab results, such as the following:

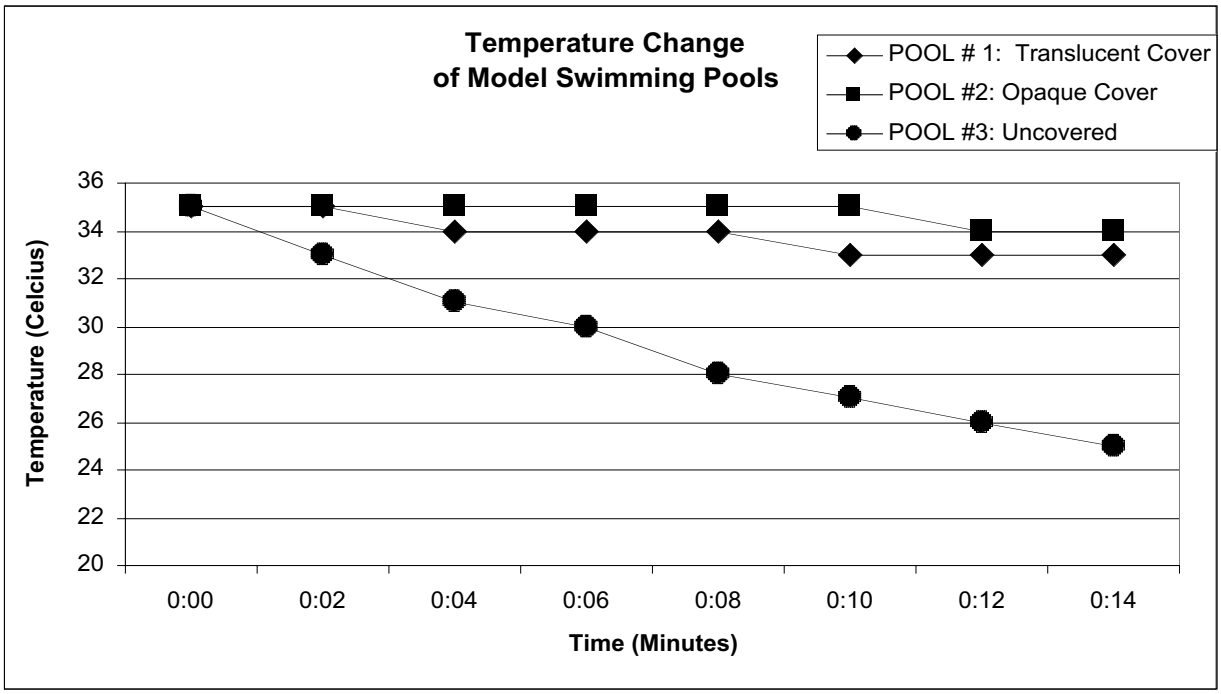

Figure 1. *Sample graph: Time vs. Temperature Measurement of Each Pool*

Activity 6 – Post Lab (30 minutes)

After students have completed their Lab Report Forms and have created graphs, discuss their results and their answers to the lab report questions as a whole class.

Activity 7 – Assessment (30 minutes)

Distribute a copy of the Assessment Questions to each student. Instruct each student to work alone and answer the short answer and multiple-choice questions. Collect the handouts, grade and return them to the students.

ADDITIONAL ACTIVITIES

1. **Lab Activity in the Sun**
   Repeat the activity by placing the 3 pools in a sunny location. Instruct students to graph the results and compare to the results obtained during the initial Lab Activity.

2. **Public Pools in Your Community**
   As a class, research public swimming pools in your community. Find out if the pools are currently being heated and with what method of heating. Draft a letter or memo to the pool director supporting a solar water heater for the pool if other mechanical equipment is currently being used. The class can be divided into groups to research and address the following points to include in the letter:
   a. feasibility of solar water heaters in the area
   b. description of the components in a solar water heater
   c. the cost of typical solar pool heaters
   d. benefits to the pool operations and the community
   e. graphics supporting the points

Solar Water Heaters for Swimming Pools

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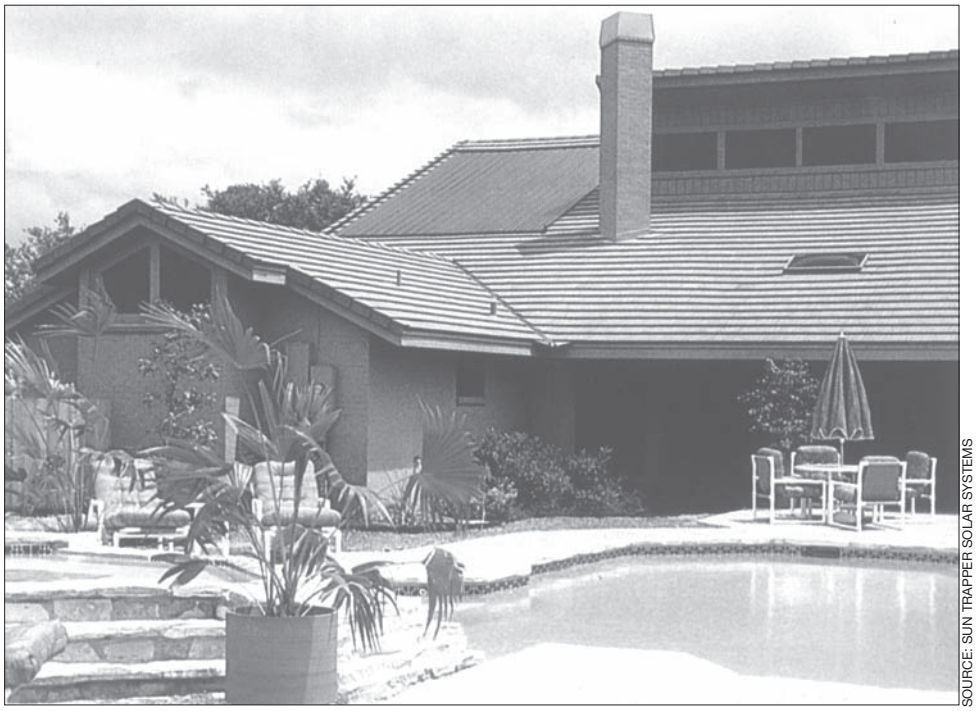
HIGHLIGHTS

- **Solar heaters for swimming pools are cost-effective**
- **Installation is straight-forward**
- **Pool covers dramatically increase efficiency**

SUMMARY

In some parts of Texas, using the sun to heat a swimming pool is an effective way to use solar energy. Solar pool heaters can be connected to the pool's existing water circulation system. They can cost anywhere from $2,000 to $5,000, need very little maintenance and can sometimes allow people to swim during months that are usually too cold to swim.

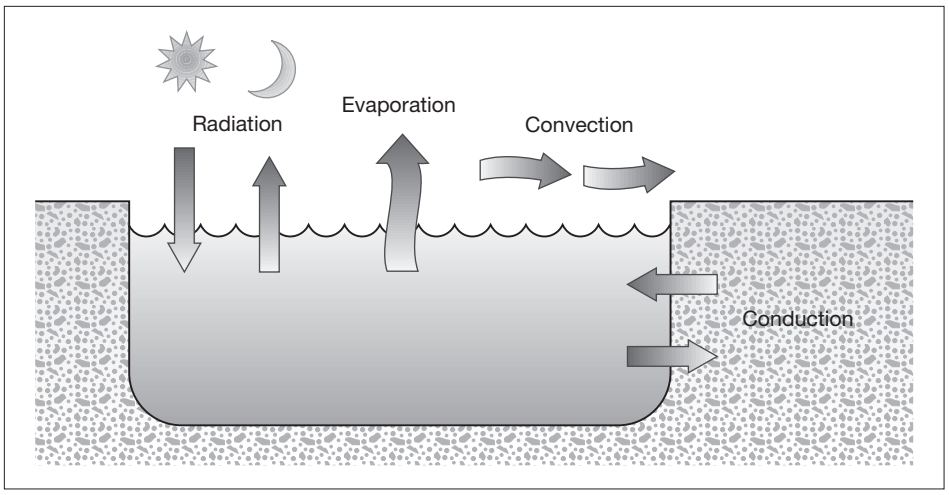
COLLECTORS: SIZING AND ORIENTATION



SOURCE: SUN TRAPPER SOLAR SYSTEMS

SOLAR PANELS *The solar panels are on the upper left section of the roof.*

A typical solar pool heater consists of a collector that is made of plastic panels. The panels have tubes (called headers) on the top and bottom of the panel that allow water to flow into and out of the plastic panel. The headers are connected by many small tubes through which water flows and gets heated by the sun. The size of a collector needed for a swimming pool depends on several factors including the size of the pool, climate, desired water temperature,



HEAT LOSS *Swimming pools can loose heat rapidly.*

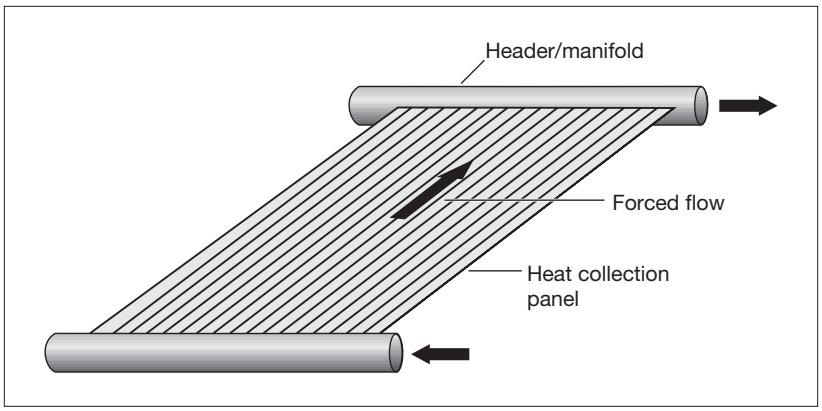
wind conditions, how shaded the pool is and how often the pool will be used. Normally, the total area (square footage) of the solar collector will be at least half of the pool surface area. For example, if the pool covers 500 square feet, the collectors should be at least 250 square feet.

Collectors should face south and be tilted at an angle equal to the latitude of the pool's location minus 10 to 15 degrees. If this is not possible and the collectors must be laid flat or must face west, the collector will not get as much sunlight. In this case, a larger collector area will be needed to make up for the decrease in collector efficiency resulting from less sunlight. Pool collectors can either be mounted on the roof of a building or mounted on a frame on the ground near the pool. Where the collectors get placed depends on how much space is available and how much sunlight shines on the space.

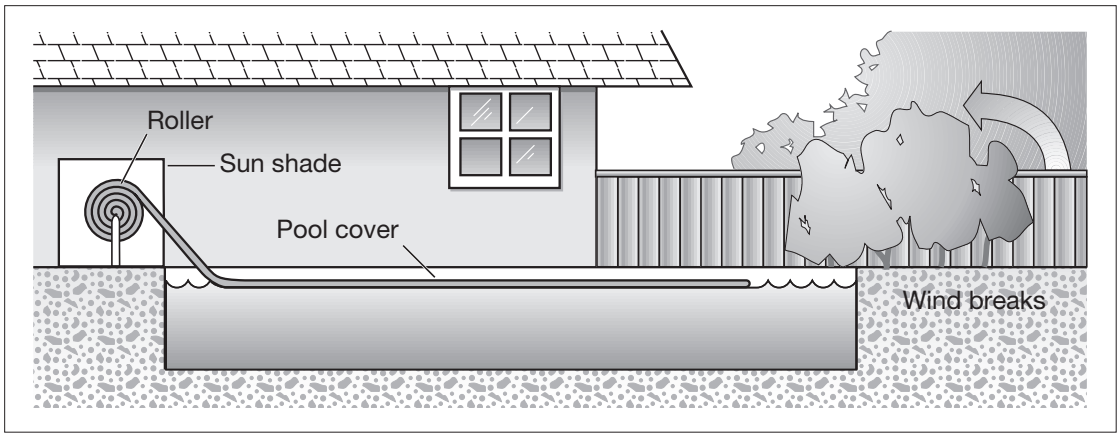
COVER UP

Pools lose heat through convection, evaporation and radiation from the pool surface, and by conduction from the sides or walls of the pool. The amount of heat that is lost depends on many factors, such as the water temperature, air temperature, humidity, pressure, and wind across the pool surface. On average, outdoor pools lose almost 90% of their heat from the water surface: 70% by convection and evaporation, which are related, and 20% by radiation to the sky. About 10% is lost by conduction from the sides and bottom.

The best way to prevent the heat loss from evaporation is with a plastic pool cover. A pool cover costs about 50 cents per square foot and can last up to five years. A clear or translucent cover works better than a dark or opaque cover because it allows sunshine to warm the pool through the day. Placing a cover over the pool can raise water temperatures between 5˚F and 10˚F. The actual amount depends on the type of cover, when and how long it is used during the day, and how much sunlight the pool gets.



TYPICAL POOL COLLECTOR *Square footage depends on several factors, such as the size of the pool and the desired water temperature.*



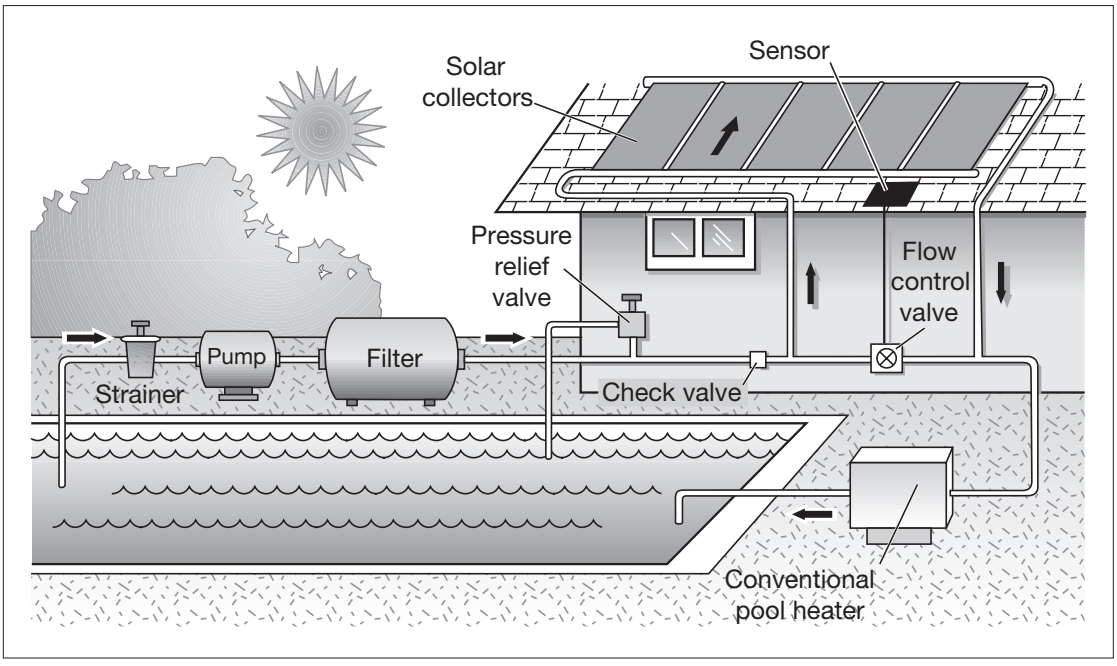
POOL COVERS *Placing a cover over the pool is the simplest way to prevent heat loss.*

Although covering and uncovering the pool requires more work, covers are an inexpensive way to keep the pool water warm and reduce the amount of water lost to evaporation.

CARE OF THE POOL HEATER

Most swimming pools have filtering systems to maintain good water quality in the pool. The plumbing of a solar pool heating system is connected to the pool's existing filter system. Special equipment controls the water flow between the pump, the filter, the solar collector and the pool.

If solar collectors are being added to an existing pool, a new circulation pump may need to be added because the existing pump may be too small to move the water through the collectors. In parts of Texas where freezing temperatures are common, special equipment should be installed to allow all water to drain when the system is turned off so the pipes will not freeze and become damaged.



SOLAR WATER HEATER SYSTEM *Solar collectors become part of the existing system.*

Understanding the Reading Passage

1. How can a solar water heating system be useful for a swimming pool?

_____

_____

_____

2. Describe a solar collector that would be used for a swimming pool.

_____

_____

_____

3. How is most of the heat lost in a swimming pool?

_____

_____

_____

4. How does a cover prevent heat loss in a swimming pool? _____

_____

Which is better: a clear cover or a colored cover? _____

Why? _____

_____

STUDENT DATA SHEET

Vocabulary

Based on the Reading Passage, write down your understanding of these words or word pairs and verify your definitions in a dictionary, on the Internet if available or with your teacher:

collector _____

conduction _____

convection _____

effective _____

efficiency _____

evaporation _____

latitude _____

opaque _____

radiation _____

translucent _____

Lab Activity – Testing Swimming Pool Covers

Introduction

The purpose of this activity is to observe and record the effect of swimming pool covers on water temperature.

Before You Start

Review the vocabulary words from the Reading Passage. Ask your teacher if you are unsure of any of the meanings. Divide up all the steps in the Lab Activity first, so that everyone has a clear job to do.

Materials

Obtain an equipment kit from your teacher. Check that it contains the following materials:

- goggles
- 3 aluminum pie pans
- 3 thermometers
- 1 clear plastic "swimming pool cover"
- 1 dark-colored plastic "swimming pool cover"
- a timer
- 3 containers with 300 ml each warm water
- a beaker or graduated cylinder to measure 300 ml

Performing the Activity (wear goggles)

1. As the teacher directs, gather the materials in the equipment kit.
2. Go to the shaded outdoor area selected by your teacher to conduct the experiment.
3. Place the 3 aluminum pans in your work area. The aluminum pans are your 3 "swimming pools." Pour 300 ml of warm water into each pan.
4. Immediately clip a thermometer to the edge of each pan and record the 3 temperature readings on your Data Table. Use caution handling the thermometers.
5. Cover pool #1 with the clear plastic material. Make sure there is no air between the water and the cover, that it covers all the water in the pan and that you can still read the thermometer inside the pan. You can poke a small hole in the plastic for the thermometer so you can still read it.
6. Cover pool #2 with the opaque or dark colored plastic material. Make sure there is no air between the water and the cover, that it covers all the water in the pan and that you can still read the thermometer inside the pan. You can poke a small hole in the plastic for the thermometer so you can still read it.
7. Leave pool #3 uncovered with the thermometer placed in it.
8. Record the temperatures in each pan every 2 minutes for 14 minutes.

Lab Report Form – Testing Covers on Swimming Pools

Date _____

Purpose of this lab is to _____

_____

Instructions:
Follow the instructions listed in the Lab Activity and record your measurements in the Data Table below. Once you have completed all the measurements and calculations, answer the questions at the end of this form and create a graph according to your teacher's instructions.

DATA TABLE. Temperature Measurements of Thermal Mass In Water Baths

Time	Pool # 1 Translucent Cover	Pool # 2 Opaque Cover	Pool # 3 Uncovered
00:00			
00:02			
00:04			
00:06			
00:08			
00:10			
00:12			
00:14			
Total Temperature Change			

DATA ANALYSIS

1. In which pool did the temperature change the most? _____
2. In which pool did the temperature change the least? _____
3. In order to keep a pool warm, what would you do (check one):

   ___ Place a translucent cover over it

   ___ Place an opaque cover over it

   ___ Keep it uncovered

4. Explain how the water's heat loss was different between the 3 pools in your activity?

   _____

   _____

   _____

STUDENT DATA SHEET

Assessment Questions

1. How can a solar pool heater be beneficial?

_____

_____

_____

2. What would happen if the bottom of a swimming pool were painted black?

_____

_____

_____

3. In your own words, describe how conduction, convection and radiation cause a pool to lose heat.

_____

_____

_____

_____

_____

Multiple Choice Questions

1. The number of solar collectors required to heat a swimming pool depends on:
   a) pool shading b) size of pool
   c) number of swimmers d) answers a and b

2. If the pool covers 600 sq. feet, the collector should be at least:
   a) 100 sq. feet b) 50 sq. feet
   c) 800 sq. feet d) 300 sq. feet

3. Collectors should face:
   a) south b) north
   c) east d) west

4. Swimming pools can lose heat by:
   a) radiation b) evaporation
   c) conduction d) all answers a, b, and c

5. To reduce heat loss due to evaporation:
   a) face the collector east
   b) use a pool cover
   c) increase water temperature
   d) use fewer collectors

6. If 2 containers were placed in the sun and one was covered and the other was uncovered, the covered container:
   a) would lose heat more slowly
   b) would heat up to a higher temperature
   c) would heat and cool exactly the same as the open container
   d) both a and b

7. If you had a swimming pool in a cold climate:
   a) you would consider using a heater and a cover
   b) you would leave it uncovered
   c) you would consider using a solar collector
   d) a and c

8. The sun heats the water in the pie pan "pool" by:
   a) conduction b) radiation
   c) evaporation d) condensation

TEACHER ANSWER KEY

Understanding the Reading Passage

1. They are a way to heat a pool that requires little maintenance and can extend the swimming season.
2. A collector is made of plastic panels that have tubes (called headers) on the top and bottom of the panel that allow water to flow into and out of the plastic panel. The headers are connected by many small tubes through which water flows and gets heated by the sun.
3. Pools lose heat through convection (evaporation) and radiation from the pool surface, and by conduction from the sides or walls of the pool. On average, outdoor pools lose almost 90% of their heat from the water surface: 70% by evaporation, and 20% by radiation to the sky. About 10% is lost by conduction from the sides and bottom.
4. A cover prevents evaporation resulting in heat loss and can raise pool temperatures between 5˚F and 10˚F. Clear or translucent covers work better than dark or opaque covers because they allow sunshine to warm the pool through the day.

Lab Activity Data Analysis

1. Answer will depend on actual results. Typically the pool that was uncovered will change temperature the most.
2. Answer will depend on actual results. Typically the pool with a translucent cover will change temperature the least.
3. Best answer: Place an opaque cover over it.
4. Answers will depend on actual results. Typically, the heat loss will be less for the covered swimming pools because the covers should keep the heat from escaping. And typically, a translucent cover will maintain a warmer temperature than an opaque cover because it allows direct sunlight to warm the pool. An uncovered pool would have the greatest heat loss because the heat can easily escape through the 3 forms of heat transfer: convection, evaporation and radiation.

Assessment Questions

1. A solar pool heater is a good way to use solar energy, it needs very little maintenance and can allow us to swim more days throughout the year like during months that are usually too cold.
2. The water would heat faster and to a higher temperature.
3. Students' answers should include their understanding of the definitions of the 3 words and how it relates to heat loss in a swimming pool: Pools lose heat through convection, evaporation and radiation from the pool surface. Heat loss through convection occurs as heat is transferred by movement through water at the surface of the pool. Evaporation occurs at the surface of the pool when water is turned into steam emitted into the air. Radiation occurs when heat energy is transmitted from the surface to the sky. The amount of heat that is lost depends on many factors, such as the water temperature, air temperature, humidity, pressure, and wind across the pool surface. On average, outdoor pools lose almost 90% of their heat from the water surface: 70% by convection and evaporation, and 20% by radiation to the sky.

Multiple Choice Questions

1 d; 2 d; 3 a; 4 d; 5 b; 6 d; 7 d (best answer); 8 b

Vocabulary Definitions

collector – plastic panel with top and bottom headers connected by a large number of small tubes, through which the pool water flows

conduction – transfer or spread of heat through a solid material

convection – transport of heat by the movement of parts of a fluid (air or water); cool air is denser than warm air and as it settles the cool air pushes the warm air upward

efficiency – the ratio of the output to the input of any system; in this unit, the energy efficiency is the ratio of the energy output (heat in the pool) to the energy input (the sun's heat)

effective – producing or achieving a desired result

evaporation – the process of a liquid gradually turning into a gas (water turning into steam)

latitude – the location north or south in reference to the equator, which is designated at zero (0) degrees; parallel lines that circle the globe both north and south of the equator

opaque – does not allow light to pass through

radiation – energy transmitted in the form of waves through open space (like sunlight)

translucent – allowing light to pass through

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