# 8. Investigating Solar Energy

## *Black Coffee*

## Driving Question

How much heat is in sunlight?

## Materials and Equipment

### *For each student or group:*

- ☐ Mobile data collection system
- ☐ Stainless steel temperature sensor
- ☐ Graduated cylinder, 25- or 50-mL
- ☐ Polystyrene coffee cups (2), small, that nest within each other
- ☐ Black coffee, cold, 15 mL
- ☐ Rubber bands (2)
- ☐ Large insulated container or Thermos™ bottle (optional)
- ☐ Clear plastic wrap (2 pieces) ~6 in. × 6 in.

## Safety

Add these important safety precautions to your normal laboratory procedures:

- ■ Never look directly at the sun—severe eye damage can result.
- ■ Consider the coffee as chemicals; it is not for drinking.

## Thinking about the Question

Almost all the energy on earth arrives as light from the sun. Sunlight striking an object is partly reflected and partly absorbed. The absorbed light hits molecules, making them vibrate faster. We sense this as a rise in temperature.

Discuss with the members of your group how a black liquid is affected by the light that falls on it. Record your thoughts below. Be prepared to share your thoughts with the class.

_____

_____

_____

## Sequencing Challenge

☐ **The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.**

| | | | | |
|---|---|---|---|---|
| Make sure each lab group member is aware of safety rules and procedures for this lab. | Pour 15 mL of cold black coffee into an insulated polystyrene cup, cover it with clear plastic wrap and nest it inside another cup. | Cover the nested cups with a second layer of clear plastic wrap. Place them in your chosen location. | Determine the temperature change and compare it to the temperature change of coffee placed in another location. | Insert the temperature sensor and record the temperature of the coffee in the chosen location for 10 minutes. |

## Investigating the Question

☐ **Note:** When you see the symbol "**[2]**" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

### Part 1 – Making predictions

1. ☐ Predict how fast the temperature of the cold coffee will change when placed outside.

_____

2. ☐ Describe and explain your prediction.

_____

_____

### Part 2 – Setting up

3. ☐ Using the graduated cylinder, measure 15 mL of cold coffee and transfer it into an insulated polystyrene cup. Record the volume $V$ of the coffee in milliliters. The coffee should be colder than the air.

   $V_{coffee}$ = _____ ml

4. ☐ Cover the top of the cup with clear plastic wrap, and secure the plastic with a rubber band.

5. ☐ Place the covered cup inside the second cup so they are nested together.

6. ☐ Cover both cups with another layer of plastic wrap, and secure this in place with the second rubber band.

7. ☐ Poke a small hole in the plastic wrap to insert the temperature sensor (don not insert the temperature sensor yet).

8. ☐ Quickly take the cup with the coffee, the temperature sensor, the instructions for using the data collection system if you need them, and the data collection system to your selected location.

9. ☐ Start a new experiment on the data collection system. ◆(1.2)

10. ☐ Connect the temperature sensor to the data collection system. ◆(2.1)

11. ☐ Display temperature in a digits display. ◆(7.3.1)

### Part 3 – Determining the temperature change

12. ☐ Monitor the temperature without recording. ◆(6.1)

14. ☐ Set the sampling rate to 1 sample per second. ◆(5.1)

15. ☐ Push the temperature sensor through the clear plastic wrap covering the cups and down into the coffee, making as small a hole as possible.

16. ☐ Gently swirl the cups so the coffee mixes as you record the initial temperature. Be sure the sensor tip is always covered with coffee.

17. ☐ Display Temperature on the y-axis of a graph with Time on the x-axis. ◆(7.1.1)

18. ☐ Start data recording. ◆(6.2)

19. ☐ Record the initial temperature ($T_{initial}$) of the coffee at your chosen location in Table 1.

20. ☐ After 10 minutes, stop data recording and record the final temperature ($T_{final}$) in Table 1.

21. ☐ Record the type of sunlight in your selected location and the length of time you recorded data in both Table 1 and Table 2.

22. ☐ Obtain the amount of sunlight, air temperature, time interval, and the initial and final temperatures of the coffee from your partner group and record them as required in Table 1 and Table 2.

Table 1: Temperature change of coffee in varying levels of sunlight (raw data)

| Sunlight Condition | Time Interval (s) | Coffee Temperature (°C) | |
|---|---|---|---|
| | | Initial | Final |
| | | | |
| | | | |

## Answering the Question

### Analysis

1. Determine the rise in temperature. You may need to adjust the scale of the graph (7.1.2)
Show your calculations below and record the answer in Table 2.

2. Find the rate of temperature increase by calculating the increase per time. Show your calculations.

3. Calculate the amount of sunlight energy (J) absorbed by the coffee. The equation for this is:

mass × energy needed to change 1 g of water 1 °C × temperature change = amount of heat transferred

The energy needed to change 1 g of water 1 °C is 4.19 J/(g °C), so the equation to use to calculate the amount of sunlight energy absorbed by the coffee is:

$m \times 4.19\ \text{J/(g °C)} \times \Delta T = Q$

where $m$ is the mass, $\Delta T$ is the change in temperature, and $Q$ is the symbol for the amount of heat transferred.

☐ **Note:** 1 milliliter of water has a mass of 1 gram. For this calculation, assume that this is the same for the coffee.

4. Obtain the data from your partner group and enter it in Table 2.

Table 2: Determination of energy from sunlight

| Sunlight Condition | Time Interval (s) | Temperature Change (°C) | Amount of Energy Absorbed (J) |
|---|---|---|---|
| | | | |
| | | | |

5. Compare the amount of sunlight energy (J) absorbed by the coffee at your location with the results of your partner group and other students that had different amounts of sunlight heating their coffee. How does the amount of sunlight affect the amount of energy transferred to the coffee?

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## Multiple Choice

☐ **Circle the best answer or completion to each of the questions or incomplete statements below.**

1. A change in the amount of heat energy present in an object can be measured by the change in

   A. Time
   B. Mass
   C. Temperature

2. An insulated cup of cold coffee is taken outdoors on a sunny day. It first spends 15 minutes in the shade, then 15 minutes in full sun, followed by 15 minutes in a partially sunny area. Which temperatures might have been measured at 15 minutes, 30 minutes, and 45 minutes?

   A. 22 °C, 35 °C, 37 °C
   B. 37 °C, 50 °C, 22 °C
   C. 22 °C, 37 °C, 35 °C

3. Which aspect of a temperature versus time graph indicates the rate of change in heat energy?

   A. The label on the y-axis
   B. The slope of the curve
   C. The final temperature recorded

4. Which statement below about the sun's energy is not correct?

   A. Visible light is the only type of energy from the sun that we can use.
   B. The sun's energy is essentially unlimited.
   C. Thermal and light energy from the sun reach the earth's surface.

## Key Term Challenge

☐ **Fill in the blanks from the randomly ordered words below:**

| | | | |
|---|---|---|---|
| temperature | heat | warm | cold |
| sunlight | time | Joules | degrees Celsius |
| increase | energy | | |

1. Almost all of the _____ available on Earth comes from the sun.

2. A measure of the average kinetic energy of the particles of a substance is _____.

3. Heat energy always flows from a _____ object to a _____ object.

4. We see some of the sun's energy as visible light, and we feel part of the sun's energy as _____.

5. Scientists and engineers look for ways to use _____ as a renewable and clean source of energy.

6. In the SI system of measurement, energy is measured in units called _____.