Advanced Environmental Science and Earth Science

Student Guide: Handout Masters

PASCO®

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Contents

Earth Systems and Resources

1. Determining Soil Quality

Driving Questions

Determining the quality of soils, particularly top soil, and suggesting remedies for soil problems are important tasks for agricultural outreach agents worldwide.

- What can you find out about the capacity of soil to support plant growth by examining its physical, chemical, and biological characteristics?
- How is this information about soil quality useful?

Background

Soils are complex combinations of inorganic materials, organic materials, and living organisms. (*Organic* means carbon-based. *Inorganic* means not carbon-based.) Some combinations of materials yield soils that provide good support for plant growth. Others do not, or they only support certain types of plant growth.

Ideal soils for plant growth include the following characteristics:

- Being porous, to allow air and water to filter through them
- Being able to retain moisture
- Containing a substantial amount of humus (dead plant material)
- Having a pH in the neutral range from 6.0 to 7.5 and the ability to resist changes in pH
- Not containing too much salt or sodium
- Having a thriving population of decomposers

Decomposers, such as earthworms, ants, beetles, fungi, and bacteria, break down materials to the smallest building blocks that can be used by plants for growth.

Soils are a vital part of the ecosystem, providing the support for terrestrial plant growth. Terrestrial plants comprise an important segment of primary productivity on which all living beings ultimately depend for food. Plants and decomposers are vital links in the global cycles of water, carbon, oxygen, nitrogen, sulfur, phosphorous, potassium, calcium, and other elements that are required for growth of living things. Being able to analyze soils and determine potential remedies for poor soils are important skills for the good of humanity.

Materials and Equipment

For each student or group:

- Data collection system
- Carbon dioxide gas sensor and sampling bottle
- pH sensor
- Conductivity sensor
- Sensor extension cable
- Stirring rod
- Beaker (4), 100-mL
- Beaker, 50-mL
- Graduated cylinder, 100-mL
- Microscope with magnification up to 400x
- Dissecting microscope
- Microscope slides and cover slips (3)
- Microwave oven (1 per class)
- Pipet, disposable
- Digging tool
- Soil samples (from 3 different locations)
- pH calibration standard solution, pH 4
- pH calibration standard solution, pH 7 or 10
- White household vinegar, 4 mL
- Distilled or deionized water, 300 mL
- Wash bottle containing distilled or deionized water
- Plastic bags (4), sealable, about 1-L
- Waste container
- Permanent marker
- Labeling tape

Safety

Follow all standard laboratory procedures.

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.

○	○	○	○	○
First, explore the capacity of soil samples to exhibit cellular respiration (generate CO_2 gas).	Determine the effect of killing all the decomposers in the soil sample with the highest CO_2 generation.	Collect three different types of soil samples, documenting the surroundings from which they were taken.	While collecting CO_2 data, examine the samples visually using both dissecting and regular (400x) microscopy.	After visually examining soil samples, determine the salinity, pH, and buffering capacity of the soil samples.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Obtain samples (day before lab)

Strive for consistency in the collecting technique for each soil sample collected. Strive to collect samples of obviously different types.

1. ☐ Collect a soil sample by doing the following:

- **a.** Clean the digging device.
- **b.** Clear away leaves and any other contaminating debris.
- **c.** With the digging device, loosen the soil as deep as 8 centimeters.
- **d.** Place at least 200 mL (about 3/4 cup) of soil into a plastic bag.
- **e.** Seal the bag to preserve moisture.
- **f.** Label the sample (for instance:, "Vacant lot" or "Hiking trail").

2. ☐ Collect two more soil samples using the same technique.

3. ☐ Why must you maintain the same technique when collecting the three different soil samples?

____

____

4. ☐ In the Data Analysis section, complete the steps for recording soil information for all 3 samples.

You will set up and start "Part 2 – Soil respiration assessment." While you are collecting data for that part, you will complete Parts 3, 4, 5, and 6.

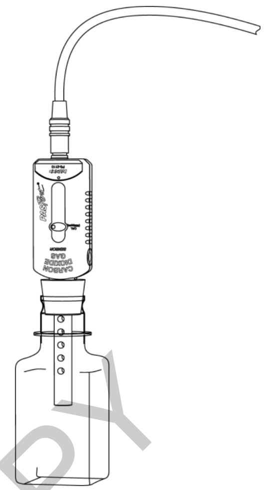
Part 2 – Soil respiration assessment

Set Up

5. ☐ Start a new experiment on the data collection system. �(1.2)

6. ☐ Connect the CO_2 gas sensor to the data collection system using a sensor extension cable. �(2.1)

7. ☐ Display a graph of CO_2 gas versus Time in seconds (s). �(7.1.1)



Soil respiration of Soil Sample 1

8. ☐ Using the 50-mL beaker, add approximately 50 mL (4 tablespoons) of soil from Soil Sample 1 to the sampling bottle.

9. ☐ Lower the CO_2 gas sensor into the bottle and cork it tightly using the attached stopper.

10. ☐ Why are you tightly corking the bottle?

____

11. ☐ Predict which soil sample will have the highest rate of cellular respiration as indicated by the rate of increase in CO_2? Why?

____

____

Collect Data

12. ☐ Start recording data. �(6.2)

13. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

Note: While recording this data, proceed to "Part 3 – Examine the physical characteristics of the soil" and complete that investigation.

14. ☐ After 600 seconds (10 minutes), stop recording data �(6.2) and save your experiment. �(11.1)

15. ☐ Find the value for the CO_2 gas concentration at 600 seconds, �(9.1) and record it in Table 2 in the Data Analysis section.

16. ☐ Carefully remove the stopper.

17. ☐ Vigorously shake the bottle upside down to empty all soil and excess CO_2 gas.

Soil Samples 2 and 3

Note: During the 600-second data recording periods for the second and third soil samples, prepare the soil samples for Part 4, Part 5, and Part 6. You can use the same soil sample preparations to conduct all three of these analyses. Take the readings for Parts 4 through 6 at convenient times (such as after beginning the 600-second CO_2 data recording) during Part 2.

18. ☐ For Soil Sample 2 and then for Soil Sample 3, repeat the steps of the "Soil respiration of Soil Sample 1" subsection.

Choose the Sample to Microwave

19. ☐ Identify the soil sample with the highest increase in CO_2 concentration. Place a 50-mL aliquot of this soil sample in a paper or plastic container and put it into a microwave oven.

20. ☐ Expose the sample to a high level of microwaves for 120 seconds.

21. ☐ What happens to the living organisms in the soil sample when you microwave it?

____

22. ☐ For the microwaved sample, repeat the steps applied to the first sample ("Soil respiration of Soil Sample 1")

23. ☐ What important scientific process is being conducted in this step?

____

____

____

Part 3 – Examine the physical characteristics of the soil

24. ☐ Place a small sample of soil (no larger than a penny) from each soil sample on a sheet of white paper (you can use the back of the previous page).

25. ☐ Spread the small amount of each of the soil samples into its own thin layer.

26. ☐ Compare the soil color, texture, structure, and apparent moisture level of each sample, and enter your observations in Table 1 in the Data Analysis section.

Note: You may need to update some of the information you entered when you initially collected the samples.

27. ☐ Sprinkle a small amount of each soil sample on a microscope slide and label the slides using a marker. Look at each slide under a dissecting microscope.

28. ☐ Enter new observations about soil composition in Table 1 in the Data Analysis section, considering the following:

a. Particle size and characteristics like sand, silt, or clay

b. Plant material such as root or leaf parts

c. Animal parts such as an insect leg or wing

29. ☐ Use the pipet to add a drop of water to the soil on each slide and cover each one with a cover slip.

30. ☐ Look at each slide using a microscope that magnifies the sample 400 times.

31. ☐ Enter new observations to Table 1 about the type of live organisms you observe.

32. ☐ In which sample did you find the most living organisms?

Part 4 – Determine the soil salinity

Set Up

Preparing the soil

33. ☐ Remove any rocks and sticks. Crush Soil Sample 1 into a fine dust with the end of the handle of your digging tool or other suitable instrument.

34. ☐ Why do you need to pulverize the soil?

---

35. ☐ Place 50 mL of Soil Sample 1 into a 100-mL beaker. Label the beaker "#1".

36. ☐ Add an equal volume of distilled water.

37. ☐ Mix the soil and water thoroughly with a stirring rod.

38. ☐ Allow the mixture to sit for at least 5 minutes.

39. ☐ Why are you adding water to the sample?

____

____

40. ☐ Repeat the steps for preparing the soil for the other two samples, rinsing the stirring rod after mixing each sample.

Measure the salinity

41. ☐ Connect the conductivity sensor to the data collection system �(2.1) and monitor live data without recording �(6.1) If necessary, open a digits display of conductivity. �(7.3.1)

42. ☐ Rinse the conductivity probe with distilled or deionized water.

Collect Data

43. ☐ Lower the conductivity probe into the soil-water mixture. Gently stir the solution with the probe during data collection.

44. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

45. ☐ If necessary, adjust the sensitivity of the conductivity sensor. �(4.2)

46. ☐ Wait for the measurement to stabilize.

47. ☐ Enter the soil salinity value in Table 2 in the Data Analysis section.

48. ☐ Repeat the steps for measuring the salinity for the other two samples.

Part 5 – Determining the pH of the soil

Use the soil-water mixtures you prepared in Part 4 of the lab.

Set Up

49. ☐ Calibrate the pH sensor �(3.6)

50. ☐ Why are you calibrating the pH sensor?

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____

Collect Data

51. ☐ Rinse the pH probe with distilled or deionized water. Monitor live data without recording �(6.1) If necessary, open a digits display of pH. �(7.3.1)

52. ☐ Lower the pH probe into the soil-water mixture, and gently stir the solution with the probe during data collection.

53. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

54. ☐ Enter the pH value in the "Initial Soil pH" column of Table 2 in the Data Analysis section.

55. ☐ Repeat the steps for collecting data for the other two samples.

Part 6 - Explore the buffering capacity of the soil

Set Up

In this buffering part of the lab, use the soil-water mixtures you prepared in the soil salinity and soil pH sections of the lab.

56. ☐ Prepare 40 mL of a 10% vinegar solution.

- **a.** Pour 4 mL of vinegar into a graduated cylinder.
- **b.** Fill the cylinder to 40 mL with distilled water to make a 10% vinegar solution.
- **c.** Pour the solution into a 100 mL beaker.

57. ☐ Rinse the pH probe with distilled or deionized water.

Collect Data

58. ☐ Lower the pH probe into the vinegar solution and gently stir the solution with the sensor during data collection.

59. ☐ Determine the pH of the vinegar solution and record it here: _______________.

60. ☐ What does the pH of the 10% vinegar solution indicate?

---

61. ☐ If a soil sample has a high buffering capacity, what will happen to the pH when you add the acid?

Determine the buffering capacity

62. ☐ Add 10 mL of the 10% white vinegar solution to soil-water mixture number 1 and mix thoroughly.

63. ☐ Rinse the pH probe with distilled water.

64. ☐ Lower the pH probe into the soil-water mixture and gently stir the solution with the probe during data collection.

65. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

66. ☐ Enter the pH value in Table 2 in the Data Analysis section.

67. ☐ Repeat the steps of the subsection "Determine the buffering capacity" for the other two soil-water mixtures.

68. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

Data Analysis

Record soil information

1. ☐ Record detailed observations for each soil sample and its environment in Tables 1a, 1b, and 1c, identified by the label on the sample. These should include, where applicable:

- **a.** The appearance of the soil and soil composition, including conditions such as arid or humid; clay, sandy, loamy, or rocky
- **b.** The appearance and types of plants and other organisms in the area from which the soil was collected, for example shrubs, conifers, fungus
- **c.** What you hear, smell, touch, or taste, as well as what you see
- **d.** Animal tracks and the appearance of animals
- **e.** The terrain, holes in the ground, and the geological features of rocks

f. The type of habitat, such as grassland or urban, including any nearby buildings and whether nearby roads are asphalt, cement, gravel, or dirt

g. Anything unusual about the area, especially if it might be relevant to soil health, such as being next to an irrigated area, or a field with runoff from a roadway

Note: If the data is being collected during fall or winter months, it may not be possible to gather information such as yellowing of leaves or deformities on young leaves.

2. ☐ Use the back side of the paper to sketch any site details that might be helpful with your soil analysis. Sketch at least 10 square meters.

3. ☐ Record the site with a digital camera, if possible.

Note: A digital camera is a great source of objective data. Still, include a sketch as part of the recorded observations.

Table 1a: Detailed observations of Soil Sample 1

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Detailed Observations	

Table 1b: Detailed observations of Soil Sample 2

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Other Observations	

Table 1c: Detailed observations of Soil Sample 3

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Other Observations	

Record measured results

4. ☐ Display the graphs for each of your data runs. �(7.1.3) Adjust the scale of the graph to show all data. �(7.1.2)

5. ☐ Make a sketch of each run of data for CO_2 concentration in parts per million versus Time. Label the overall graph, the scale of the y-axis, and the individual data runs.

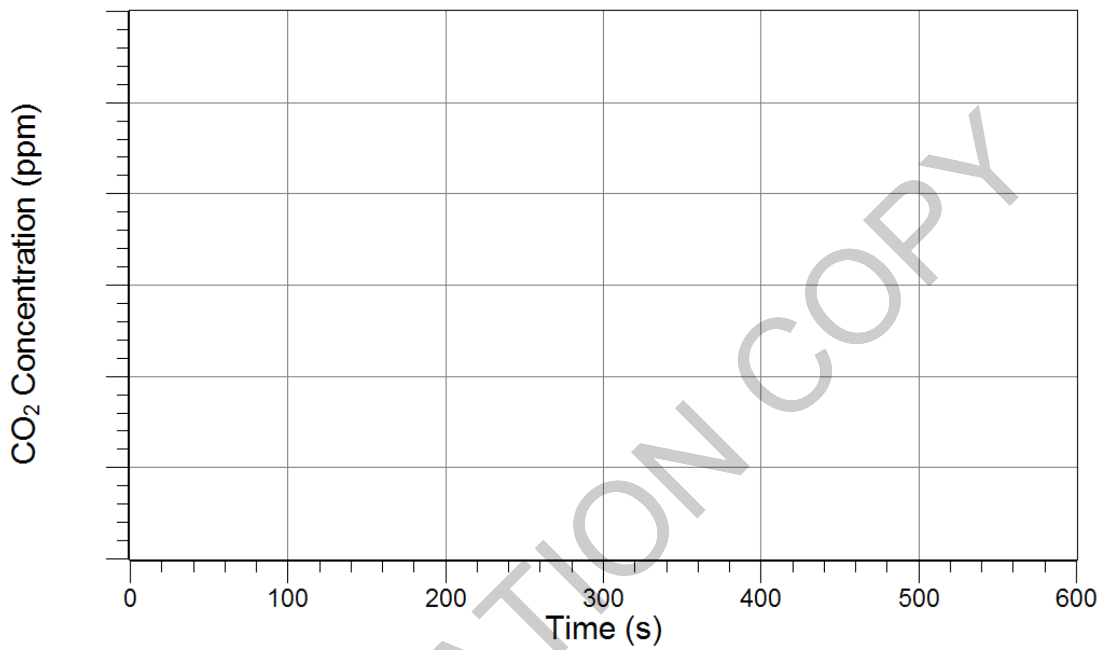

Table 2: Analysis of 3 soil samples

Soil Sample	Data Run	CO_2 Gas Generation (ppm)	Soil Salinity (conductivity) (µS/cm)	Initial Soil pH	Soil pH After Adding 10% Vinegar	Change in pH
1	1					
2	2					
3	3					
	4					

Analysis Questions

1. **The rate of change of CO_2 gas concentration is indicative of the rate of change in cellular respiration. What kind of soil would you expect to produce CO_2 gas at a faster rate—dark, moist soil or dry, clayey soil? Why?**

2. **What were the effects of microwaving the soil? What happened to the rate of CO_2 gas increase after you microwaved the soil sample? Explain.**

3. **In which sample did you find the most soil organisms? Is this also the sample that had the highest rate of increase in CO_2 concentration? Discuss the relationship between respiration rate of soil organisms and changes in CO_2 gas concentration within the sample bottle.**

4. **Which of the three soil solutions had the highest conductivity? Explain why it might be higher than the other two samples. Recall the location of the sample.**

5. **Which soil sample had the greatest buffering capacity? Did you see a relationship between buffering capacity and conductivity measurements? If so, explain why this relationship might exist.**

6. **Which of the soil samples would you predict would have the greatest capacity to support plant growth? Explain.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Based on your results, discuss the roles that soil plays in the carbon cycle.**

2. **What effects do soils of high salinity have on plant growth? Why?**

3. **Each plant type possesses an inherent tolerance level to salinity. In general, a crop should tolerate salinity levels up to 700 microsiemens per centimeter (µS/cm), without a decrease in yield; however, some plants tolerate even higher levels of salinity. If a soil contains more than this level of salt, what types of crops might be successfully grown in it?**

4. **It is best to avoid cultivation of highly saline and sodic (sodium-containing) soils because of the expense of reclaiming the soil. However, if it became imperative to salvage the land, how might you treat saline soil in order to harvest a crop with a high yield?**

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5. **What effects do very acidic or very alkaline soils have on plant growth? Why?**

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6. **Each plant type grows best within a certain range of pH values. What are some plants that will grow well in relatively acidic soils (pH 5.0 to 5.5)? What are some plants that will grow well in relatively alkaline soils (pH 7.5 to pH 8)?**

____

____

____

7. **Describe methods that may be used to adjust the pH of soil.**

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8. **Which of the three soil types would be more efficient at neutralizing acid rain? Explain.**

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____

9. List some possible remedies for the soil samples that seem to be less capable of supporting plant growth.

____

____

____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. In which of the following do soil bacteria play an important role?

- **A.** The water cycle
- **B.** The carbon cycle
- **C.** The nitrogen cycle
- **D.** The phosphorous cycle
- **E.** All of the above

2. To which of the following characteristics of soil does humus *not* contribute?

- **A.** High water-holding capacity
- **B.** High nutrient-holding capacity
- **C.** Mineralization
- **D.** Aeration
- **E.** Water infiltration

3. Soils high in salinity cause plant damage because of which of the following?

- **A.** They are highly toxic to plants.
- **B.** They inhibit plant growth by preventing plant roots from taking in nutrients.
- **C.** They cause plants to wilt by creating osmotic pressure from roots to the soil.
- **D.** Only B and C are true.
- **E.** A, B, and C are true.

4. What can be altered as the result of change in soil pH?

- **A.** Growth of soil microorganisms
- **B.** Solubility of toxic substances in the soil
- **C.** Availability of mineral nutrients
- **D.** All of the above

5. Increase in soil acidity can cause which of the following?

- **A.** Release of toxic metals such as Al, Fe, Mn, and Ni
- **B.** Increase in alkalinity
- **C.** Release of calcium carbonate
- **D.** Increase in salts

6. Which of the following can make soil too acidic?

- **A.** Release of CO2 during soil respiration
- **B.** Release of calcium carbonate by parent rock
- **C.** Release of sulfur from burning of fossil fuels returning to the ground as acid rain
- **D.** Answers A and C

7. The addition of which of the following can raise the pH of acidic soils?

- **A.** Sulfur
- **B.** Salts
- **C.** Lime
- **D.** Compost or mulch
- **E.** Either C or D

2. Insolation and the Seasons

Driving Questions

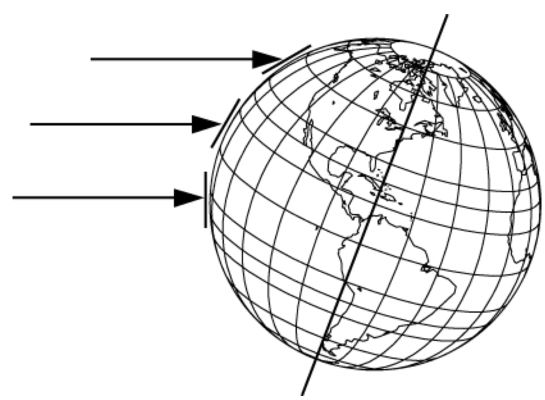
The earth revolves around the sun once a year in an almost-circular (elliptical) path. The earth also rotates around an axis that is tilted about 23.5° from a line perpendicular to the plane of its path around the sun.

- How are these characteristics about the earth's movements related to the change in temperatures observed through the seasons?
- What affect does the angle of solar insolation have on the amount of solar energy delivered to a given area?
- Why do the warmest temperatures of the year often occur a month or two after the summer solstice?
- Why do the coldest temperatures of the year often occur a month or two after the winter solstice?

Background

Energy from the sun is by far the most important factor in our weather and climate. Solar radiation comprises more than 99.9% of the energy that warms the earth, drives the winds, and stirs the ocean currents. The solar energy that the earth receives is called insolation.

When the surface of the earth directly faces the sun at a 90-degree angle, insolation is highest. As the angle increases between the surface and the rays of sunlight, the same amount of energy is spread over a larger region and the insolation is reduced. This is known as the projection effect and is the reason why polar regions are much colder than equatorial regions. Therefore, the amount of insolation that a part of the earth receives during the day depends on the latitude at that part of the earth.



Earth spins daily around its axis (axis of rotation), which is tilted to approximately 23.5 degrees relative to its orbit around the sun. Thus, no matter the time of year, one part of the planet is always exposed to more direct insolation than another. As the earth orbits the sun, the amount of insolation will change at any particular location, causing the seasons to change. With its elliptical orbit, the distance from the earth to the sun varies by only 5 million miles, or about 3% of the average distance from the sun (the average distance from the sun is about 150 million miles) over the course of one year. The earth is closest to the sun (perihelion) around January 4th each year and furthest from the sun (aphelion) in early July.

At any point during the day, the amount of energy that a particular part of the earth receives changes due to the earth's rotation. One half of the earth receives sunlight, while the other half receives none. During rotation, the amount of sunlight reaching a specific location can vary due to terrain, latitude, and many other factors.

Materials and Equipment

For each student or group:

- Mobile data collection system
- Stainless steel temperature sensor
- Small tripod base and rod
- Three-fingered clamp
- Protractor
- Scissors
- Cardboard, 15 x 15 cm
- Black construction paper, 15 x 15 cm
- Drinking straw
- Tape, roll
- Glue, bottle

Safety

Add this important safety precaution to your normal laboratory procedures:

- Do not look directly at the sun.

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.

Align the straw with the sun's rays, and repeat the data collection step. Repeat the cooling step. Move the straw 30° more so the angle of insolation is 30°.	Go outside. Set up the solar panel so it is perpendicular (90°) to the sun. Measure the temperature while exposing the apparatus to the light for 5 minutes.	Construct a solar panel that will absorb light energy and that will allow you to quantitatively change its angle in relationship to the light source and measure the temperature of its surface.	Move the solar panel to a shady location. Move the straw 30° so the angle of insolation is 60°. Fan the solar panel until the temperature cools to its initial temperature.	Repeat the data collection step. Compare the temperature changes of the 3 experimental situations.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

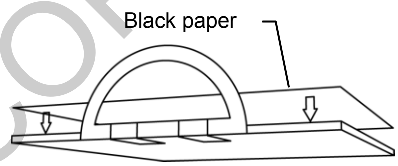
Part 1 – Make the solar panel and test it at 90° insolation

Set Up

1. ☐ Make a solar energy collection panel as follows:

a. Glue a piece of black construction paper to the surface of the cardboard.

b. Tape the protractor to it so it is perpendicular to the surface of the cardboard.



2. ☐ Tape the straw to the protractor so that it is perpendicular (90°) to the cardboard and the end of the straw is about 0.5 cm from the surface of the cardboard.

3. ☐ Tape the temperature sensor to the cardboard with its end near the center of the cardboard.

4. ☐ Take your solar panel, temperature sensor, data collection system, and rod stand outside. Find a sunny location sheltered from the wind.

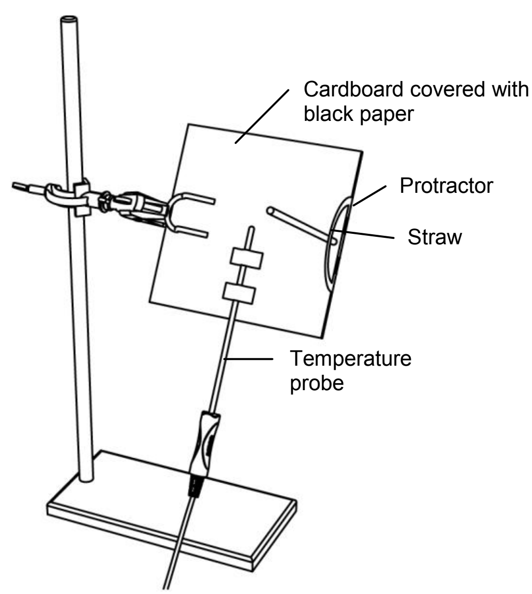
5. ☐ Secure the solar panel using the tripod stand and 3-fingered clamp.

CAUTION: Do not look directly at the sun when performing the next step.

6. ☐ Arrange the angle of the surface of the cardboard so it is perpendicular (90°) to the sun and the straw is pointing at the sun.

Hint: When the surface of the cardboard is perpendicular to the sun, the light coming through the straw will be focused into a tight spot on the solar panel, and the shadow of the cardboard will be at its smallest size.

7. ☐ Start a new experiment on the data collection system. �(1.2)



8. ☐ Connect the temperature sensor to the data collection system. �(2.1)

9. ☐ Set up an appropriate display to view the data while it is being collected. �(7)

10. ☐ Why did you cover the surface of the cardboard with black paper?

11. ☐ You will be testing three experimental situations with the cardboard positioned at:

- ♦ 90° relative to the light source
- ♦ 60° relative to the light source
- ♦ 30° relative to the light source

Will the position of the cardboard influence its temperature after 5 minutes at that position? Why?

Collect Data

12. ☐ Start data recording. �(6.2)

13. ☐ Record data for 5 minutes.

14. ☐ Write your data run number here _____________.

15. ☐ Stop data recording. �(6.2)

Part 2 – Test the solar panel at 60° insolation

Setup

16. ☐ Remove the solar panel and take it to a shaded location.

17. ☐ Remove the straw and tape it 30° from perpendicular on the protractor such that when the straw is perpendicular to the sun, the solar panel will be angled towards the horizon 30°, resulting in an angle of insolation of 60°.

18. ☐ Fan the solar panel to increase the rate of cooling. When it returns to approximately its original temperature, secure it to the tripod stand.

19. ☐ Align the solar panel as you did before. This will angle the solar panel towards the horizon 30° from the last setup, and it will thus receive insolation at 60°.

CAUTION: Do not look directly at the sun.

Collect Data

20. ☐ Start data recording. �(6.2)

21. ☐ Record data for 5 minutes.

22. ☐ Write your run number here ____________.

23. ☐ Stop data recording. �(6.2)

24. ☐ Remove the solar panel and take it to a shaded location.

Part 3 – Test the solar panel at 30° insolation

25. ☐ Repeat the procedure in Part 2 using a 60° tilt of the solar panel towards the horizon, and thus an angle of insolation of 30°.

26. ☐ Write your run number here____________.

27. ☐ Save your file, �(11.1) and clean up according to your teacher's instructions.

Data Analysis

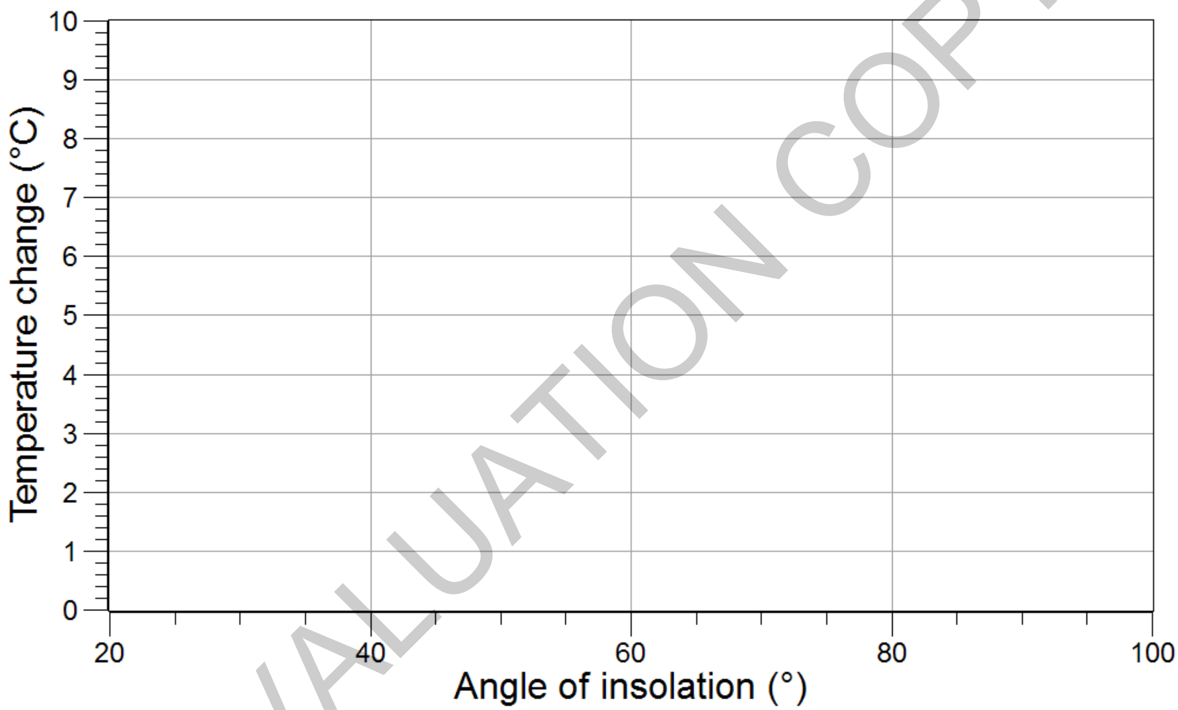
1. ☐ Find the minimum and maximum temperatures for the three data runs and calculate the change in temperature.

2. ☐ Enter these values in Table 1.

Table 1: Temperature comparison at different angles of insolation

Angle of Insolation	Minimum Temperature	Maximum Temperature	Δ Temperature
90°			
60°			
30°			

3. ☐ Plot a graph of angle of insolation on the y-axis with change in temperature on the x-axis. Label the overall graph, the x-axis, the y-axis, and include units and scales on the axes.



Analysis Questions

1. Compare your results with your predictions.

____

____

2. What is the independent variable (the parameter you controlled) in this experiment?

____

3. **What is the dependent variable (the parameter that changed) in this experiment?**

4. **What parameters did you try to hold constant in this experiment (controlled variables)?**

5. **Is the relationship between change in temperature and angle of insolation a linear one? Explain.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Using the results of this activity and what you know about the motion of the earth around the sun as well as the tilt of the earth's rotational axis relative to its orbital plane, explain why seasons occur.**

2. **Why are seasons more pronounced the further you move away from the equator?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. During wintertime in the northern hemisphere, the earth's North Pole is:

- **A.** Tilted towards the sun relative to the South Pole
- **B.** Tilted away from the sun relative to the South Pole
- **C.** The same distance from the sun relative to the South Pole

2. During summertime in the southern hemisphere, the earth's North Pole is:

- **A.** Tilted towards the sun relative to the South Pole
- **B.** Tilted away from the sun relative to the South Pole
- **C.** The same distance from the sun relative to the South Pole

3. At the spring and fall equinoxes, the earth's North Pole is:

- **A.** Tilted towards the sun relative to the South Pole
- **B.** Tilted away from the sun relative to the South Pole
- **C.** The same distance from the sun relative to the South Pole

4. The warm temperatures of summer in the northern hemisphere north of the tropics occur primarily because:

- **A.** The earth is closer to the sun
- **B.** The days are longer
- **C.** The northern hemisphere is tilted towards the sun
- **D.** Wind patterns change to bring warmer temperatures

5. The Tropic of Cancer and Tropic of Capricorn, respectively, are circles of latitude on the earth that mark the northernmost and southernmost latitudes at which the sun may be seen directly overhead (at the June solstice and December solstice, respectively). These circles of latitude are located at approximately

- **A.** 0° latitude
- **B.** 23.5° latitude
- **C.** 30.0° latitude
- **D.** 60.0° latitude
- **E.** 90.0° latitude

3. Investigating Specific Heat

Driving Questions

Have you ever wondered why it feels cooler on a hot summer day near a large body of water as compared to inland, away from that water, or why it feels warmer next to the water late at night?

- ♦ What does the specific heat of water versus land have to do with the differential heating and cooling of water and sand?
- ♦ How different are water and sand in their rates of heating and cooling?

Background

The specific heat of a substance (also known as specific heat capacity) determines how quickly the temperature of that material will rise or fall when it gains or loses heat energy. Specific heat is an intrinsic property of a substance and is dependent on its molecular structure and phase. The stronger the bonds (or intermolecular attractions) are, the higher the specific heat. The higher the specific heat, the more energy is necessary to raise the temperature of a substance and the more energy must be lost to decrease its temperature.

Liquid water has a type of intermolecular attraction (hydrogen bonding) that causes it to have a high specific heat. The hydrogen bonds can absorb a large amount of energy before they break. They keep water molecules from moving relative to each other, resulting in lower kinetic energy for the water molecules, and thus lower heat loss.

Specific heat *c* refers to the amount of energy needed to raise the temperature of 1 gram of a substance 1 degree Kelvin in the same phase. This is expressed in units of joules per gram-degree Kelvin (J/g·K). Often, specific heat is expressed using the Celsius scale (J/g·°C). The specific heat of water, 4.186 J/g·°C, is often represented as its own separate measure, the calorie.

Liquid water's specific heat is one of the highest of any substance. Therefore, liquid water requires more heat energy to increase its temperature than almost any other substance. Likewise, liquid water must lose more energy to decrease its temperature than almost any other substance.

Materials and Equipment

For each student or group:

- Data collection system
- Stainless steel temperature sensors (2)
- Fast-response temperature probes (2)
- Beaker, glass, 500-mL
- Test tube, glass, 18 x 150-mm (large)
- Beakers (2), glass, 250-mL
- Sand, 200 g
- Heat lamp or 150 W incandescent lamp
- Small tripod base, and rod
- Buret clamp (2)
- Disposable insulated cup (2) and lid
- Water, 650 mL
- Tongs
- Stirring rod
- Hot plate
- Mass balance or scale (1 per class)

Safety

Follow all standard laboratory procedures.

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.

Part 1 – Rates of heating and cooling of water versus sand

◯	◯	◯	◯	◯
Weigh 200 g of sand and 200 g of water in separate beakers.	Set up a graph display to show two runs simultaneously. Set it up to show Temperature versus Time.	Determine the change in heating and cooling (Δ°C) for the water and sand. Determine the rate of heating and cooling.	Enter the initial, maximum, and minimum temperatures on the data table.	Heat the beakers for 15 minutes using a bright light, and then cool the beakers for 15 minutes, recording data continuously.

Part 2 – Determining the specific heat of sand

Calculate the specific heat of the sand; compare it to the specific heat of water.	Combine the sand and water and record the temperature until the temperature of the mixture stabilizes. Note that temperature.	Make a calori-meter out of 2 nested insulated cups. Add water. Fill a test tube 1/2 full of sand; measure the sand's mass.	Arrange equipment so you can record the temperature of sand in a test tube as it heats in a beaker of boiling water.	Heat the sand in boiling water. Record the temperatures of the heating sand and the water in the calorimeter for 5 minutes.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Rates of heating and cooling of water versus sand

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect two fast-response temperature probes to your data collection system. �(2.2)

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

4. ☐ Set up the graph display to show two data runs simultaneously. �(7.1.3)

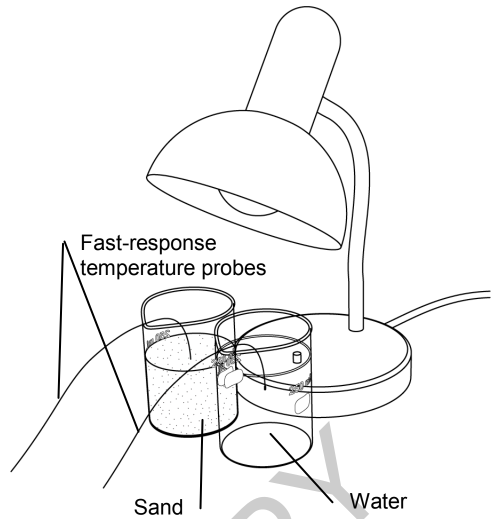
5. ☐ Put 200 g of sand into a 250-mL beaker.

6. ☐ Put 200 g of water into another 250-mL beaker.

7. ☐ Place a fast-response temperature probe in each beaker as shown in the illustration.

Note: Each of the temperature sensors should be approximately one inch below the surface.

8. ☐ Place the heat lamp directly above the beakers so that both beakers receive the same amount of energy from the lamp.



9. ☐ Why is it important to heat both beakers equally?

___

___

___

Collect Data

10. ☐ Start data recording. �(6.2)

11. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

12. ☐ Record data for 30 seconds.

13. ☐ Turn on the light and record data for an additional 5 minutes (300 seconds). *Do not stop recording data!*

14. ☐ How much faster do you think the temperature of the sand will increase than that of the water? How much faster will it decrease when the light is turned off? Give a specific rate comparison (such as twice as fast or twice as slow).

___

___

Note: While the data is recording for 5 minutes, you can begin setting up Part 2 of the procedure.

15. ☐ Turn the light off.

16. ☐ Continue recording data for 5 minutes.

17. ☐ Stop recording data. �(6.2)

18. ☐ Name the data runs "Sand" and "Water". �(8.2)

19. ☐ Save your experiment. �(11.1)

20. ☐ Complete the steps in the Data Analysis section for Part 1.

Part 2 – Determine the specific heat of sand

Set Up

21. ☐ How do you think the specific heat of sand will compare with the specific heat of water? Give a rate comparison (such as twice as fast or twice as slow).

____

22. ☐ Fill the 500-mL beaker about 3/4 full with water.

23. ☐ Place the beaker on the hot plate, and turn it on to the highest setting.

24. ☐ Bring the water to a boil.

25. ☐ Set up the tripod base and rod while you wait for the water to boil. Fasten a buret clamp just above the beaker.

26. ☐ Measure the mass of the test tube: _______________ .

27. ☐ Fill the test tube half full with sand.

28. ☐ Measure the mass of the sand and the test tube: _______________ .

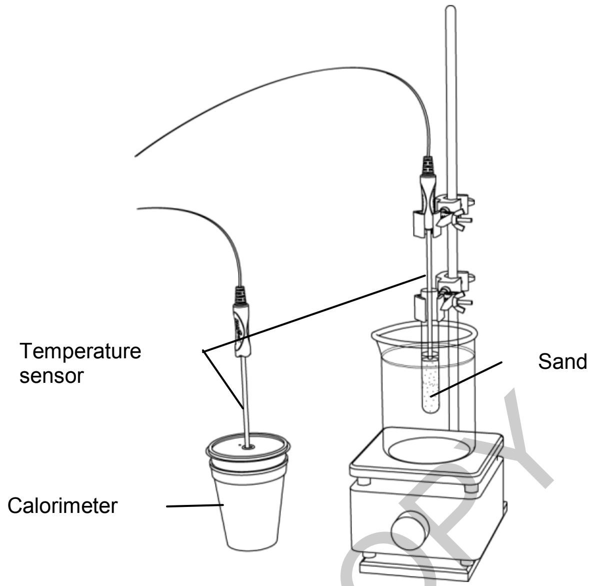
29. ☐ Calculate the mass of the sand alone and write the mass in Table 2 in the Data Analysis section.

30. ☐ Use the buret clamp to secure the test tube in the 500-mL beaker of boiling water. Make sure the sand in the test tube is below the water level.

31. ☐ Connect the two stainless steel temperature sensors to the data collection system. �(2.2)

32. ☐ Place one of the stainless steel temperature sensors into the middle of the test tube. Do not allow the sensor to touch the bottom or sides of the test tube.

33. ☐ Support the sensor with the second buret clamp.



34. ☐ Before making the calorimeter (by nesting two disposable insulated cups), make sure the lid has a hole in it that you can slide the stainless steel temperature sensor and stirring rod through.

35. ☐ Measure 70.0 g of room-temperature water.

36. ☐ Place the two disposable insulated cups together, and add the water into the top cup.

37. ☐ Use the other stainless steel temperature sensor to measure the temperature of the water in the insulated cup. �(6.1)

38. ☐ If necessary, open a graph display that shows Temperature on the y-axis and Time on the x-axis, �(7.1.1) and set up the graph display to show two data runs simultaneously. �(7.1.3)

Collect Data

39. ☐ Start recording data, �(6.2) and adjust the scale of the graph to show all data. �(7.1.2)

40. ☐ Record data for 600 seconds, then stop recording data.�(6.2)

41. ☐ Name the data run "Sand2". �(8.2)

42. ☐ Record the temperature of the sand in Table 2 in the Data Analysis section (T_{initial}).

43. ☐ Turn the hot plate off.

44. ☐ Use the same temperature sensor you used to measure the temperature of the water. Insert the temperature sensor through the hole in the lid (the lid is not on the disposable insulated cup yet).

45. ☐ Insert the stirring rod through the same hole and put the lid on the cup, making sure the thermometer is in contact with the water.

46. ☐ Start recording data, �(6.2) and adjust the scale of the graph to show all data. �(7.1.2)

47. ☐ Use tongs to remove the test tube and quickly pour the contents of the tube into the water in the calorimeter.

48. ☐ Immediately cover the disposable insulated cup with the lid, making sure the temperature sensor doesn't touch the side or bottom of the cup. Stir the water and sand mixture.

49. ☐ Why did you pour the sand into the water?

Hint: The specific heat of water is a known constant: 4.186 J/g °C.

____

____

____

50. ☐ Continue stirring the water and sand mixture.

51. ☐ Record data until the temperature starts to level off, and then stop recording data. �(6.2) (This will take about 1 minute.)

52. ☐ Name the data run "Calorimeter". �(8.2)

53. ☐ Save your experiment. �(11.1)

54. ☐ How did the initial temperature of the water and sand added to the insulated cup compare to the final temperature of the water-sand mixture? Where did the heat energy of the sand go when you put it into the water?

____

____

55. ☐ What was the purpose of using an insulated cup and lid rather than simply using a beaker?

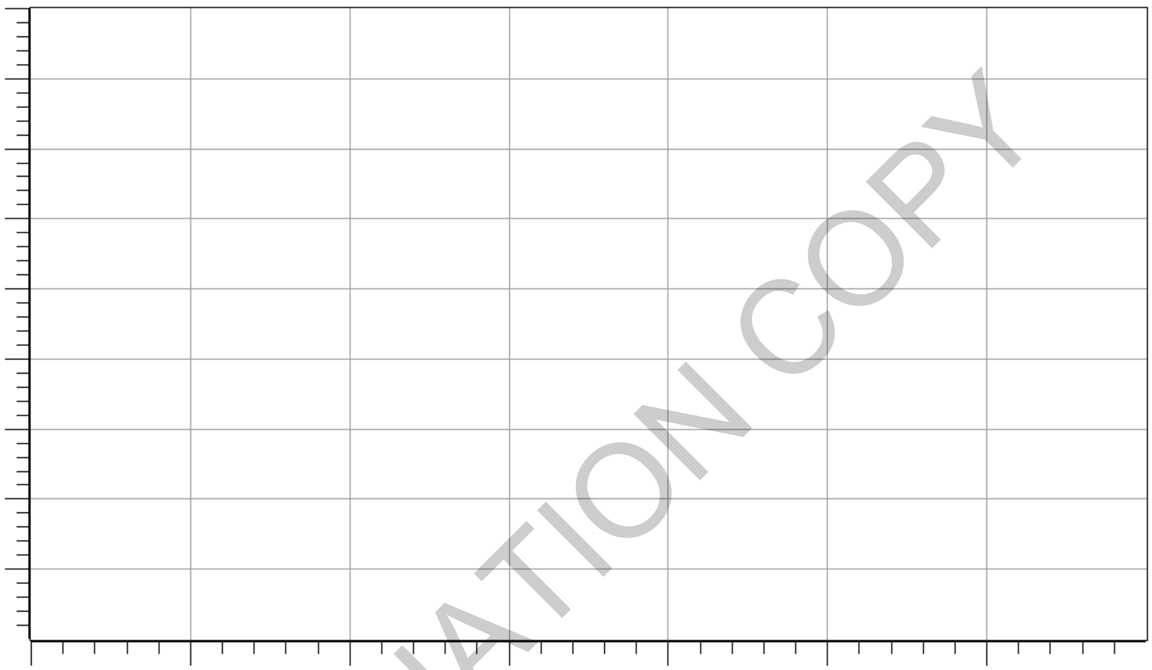
____

____

Data Analysis

Part 1 – Heating and cooling of water versus sand

1. ☐ Sketch your two data runs, "sand" and "water," on the graph. Label both data runs, label the axes with units and a scale, and indicate when the light was turned on and turned off.



2. ☐ Use the graph tools to determine the temperature data points specified in Table 1. [(9.1)]

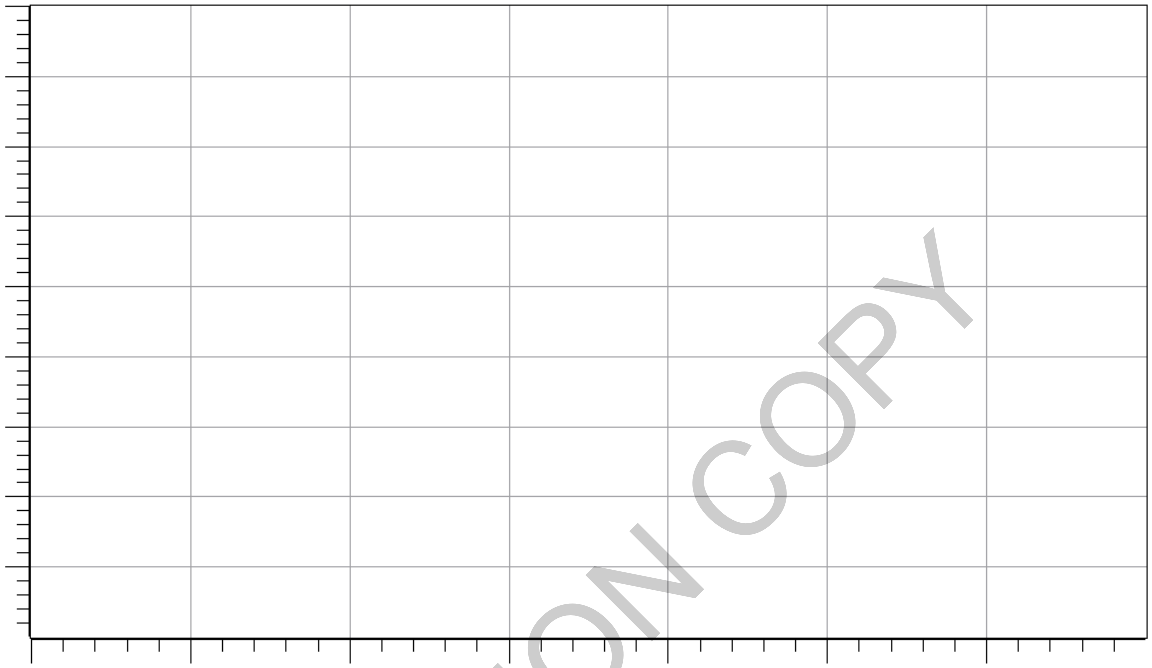
3. ☐ Complete the calculations for Table 1.

Table 1: Rates of heating and cooling of water and sand

	T_{initial} (°C)	$T_{\text{max,light on}}$ (°C)	$\Delta T_{\text{heating}}$ (°C)	$Rate_{\text{heating}}$ (°C/s)	T_{final} (°C)	$\Delta T_{\text{cooling}}$ (°C)	$Rate_{\text{cooling}}$ (°C/s)
Water							
Sand							

Part 2 – Determine the Specific Heat of Sand

4. ☐ Sketch the graph of the third data run of Temperature versus Time for the water-sand mixture. Be sure to label the x-axis and y-axis regarding parameter and units of measurement as well as the data runs.



5. ☐ Find the initial and final temperatures of the data run and enter them in Table 2. �(9.1) (The initial temperature of the sand should have been entered earlier).

6. ☐ Complete the calculations for Table 2.

Hint: Determine the amount of heat gained by the water (*Q*) using the mass of the water (*m*), the specific heat of the water (*c*), and the change in temperature of the water (ΔT.) This relationship is described by the equation: $Q = mc\Delta T$.

Table 2: Determining the specific heat of sand

Material	**Mass *m* (g)**	$T_{initial}$ **(°C)**	T_{final} **(°C)**	ΔT **(°C)**	***Q*** **(J)**	**Specific Heat *c* (J/g °C)**
Water						
Sand						

Analysis Questions

1. **Calculate the ratio of the sand's rate of temperature increase to the rate of the water's temperature increase during the heating condition.**

2. **Calculate the ratio of the sand's rate of decrease to the rate of the water's temperature increase during the cooling condition.**

3. **How much faster did sand heat up and cool down compared to water? How does your prediction regarding the relative rates of heating and cooling compare with the results? Give a quantitative comparison.**

4. **In Part 1 of this exploration, what was the independent variable and the dependent variable, and what factors did you hold constant?**

5. **Compare your results for Part 2 with your prediction, using specific quantities.**

6. **What is the relationship between the specific heat of a substance and the rate of temperature change when the energy content of the environment around it changes?**

7. **What characteristics of water account for its high specific heat?**

8. **In this activity, what does *Q* represent? Why was *Q* the same for the water and the sand?**

9. **List some important sources of experimental error that might occur in this activity.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **How could you modify the experiment to be more confident in this assumption?**

2. Explain how the proximity to a large body of water influences weather. Provide an example.

3. Explain how the proximity to a large body of water influences climate. Provide an example.

4. Explain how a large land mass influences weather. Provide and example.

5. Explain how a large land mass influences climate. Provide and example.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. In Part 2 of this activity, to complete your calculations you relied on the assumption that all of the heat energy in the heated sand was transferred to the water in the insulated cup until the temperatures of the sand and water were equal. Thus, you were counting on

- **A.** The laws of motion.
- **B.** The first law of thermodynamics (energy conservation).
- **C.** The second law of thermodynamics (entropy).
- **D.** The third law of thermodynamics (entropy reduces as temperature lowers but is always present).
- **E.** The law of gravity.

2. All of the following influence global air circulation EXCEPT

- **A.** Uneven heating of the earth's surface.
- **B.** Rotation of the earth on its axis.
- **C.** The difference in specific heat of water compared to that of land.
- **D.** Seasonal changes in temperature and precipitation.
- **E.** The position of Earth's moon relative to Earth.

3. Compared to a substance with a low specific heat, a substance that has a high specific heat

- A. Requires more heat per gram to be added to it to cause an increase in temperature.
- **B.** Requires less heat per gram to be added to it to cause an increase in temperature.
- **C.** Requires the same amount of heat per gram to be added to it to cause an increase in temperature.
- **D.** Has a larger mass.
- **E.** None of these is true.

4. Water has a high specific heat because

- **A.** It changes from a solid to a liquid phase at a relatively high temperature.
- **B.** It has intermolecular hydrogen bonds.
- **C.** It boils at 100 °C.
- **D.** It freezes at 0 °C.

5. The high specific heat of water compared to that of land results in

- **A.** The small range of temperatures in the oceans compared to that on land.
- **B.** Coastal climates that have smaller ranges of temperature compared to those of inland areas.
- **C.** The ability of large fresh water bodies to stay in liquid phase when air temperatures drop below 0 °C.
- **D.** All of these are true.

Name Period Date

4. Monitoring Microclimates

Driving Questions

Air temperature, relative humidity, barometric pressure, and dew point measurements are collected worldwide from thousands of weather stations and processed by computers to produce global weather and climate information.

- What are the instruments used to collect weather and climate measurements, and where are they located?
- What local factors must be considered in choosing sites for the weather stations?
- What features comprise the ideal site for a weather station?

Background

Where does the data used by climatologists and weather forecasters originate? Until the arrival of satellite measurement capabilities, all data came from thousands of weather stations located across countrysides worldwide and on buoys scattered across the oceans. Today, data originating from both satellite observations and ground measurements are merged through complex computerized algorithms. These produce comprehensive results, for example, the low and high temperatures for a day for a particular area, the average temperature for a year in a given area, or the average global temperature for a year.

The features of a site for a weather station must be standardized across weather stations to minimize error introduced by particular aspects of the surrounding area. Inconsistencies can be caused by shade trees, heat reflected from buildings or parking lots, heat added from heating or air conditioning vents, proximity to a large body of water, the type of housing surrounding the weather sensors, and so on. The error introduced by these differences in microclimates can be considerable.

Materials and Equipment

For each student or group:

- Mobile data collection system
- Weather/anemometer sensor
- Cardboard box, 20 cm^3 or larger
- Scissors
- Marking pen

Safety

Follow your normal outdoor class procedures.

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.

Position the sensor and the protective housing and start collecting data.	Stop collecting data. Analyze it for maximum, minimum, and average values.	Set up your data collection system to collect data once per minute (if you will be recording for hours).	Find a suitable location for your weather station and record the characteristics of the site.	Compare your results with those of other microclimates.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

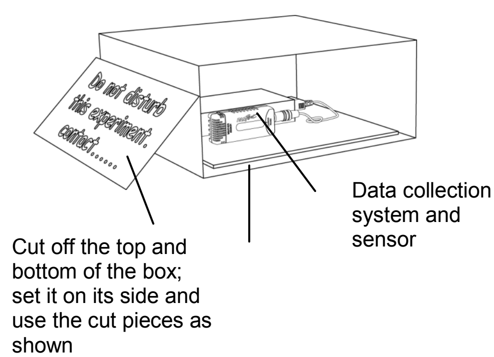
Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide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

Set Up

1. ☐ Using a cardboard box 20 cm by 20 cm or larger, cut the box so that it has no top or bottom, only the four connected sides.

2. ☐ Using the top or bottom cut from the cardboard box, make a sign that says, "Do not disturb this experiment. Contact [your teacher's name]."

Note: This step is necessary only if you are going to leave the weather station unattended.



3. ☐ Use the top or bottom cut from the cardboard box as a mat that you will set inside this "housing" for the weather station.

4. ☐ Find a location outside with unusual characteristics, especially one that is unlike what anyone else has chosen. Here are some examples:

- ♦ Well shaded by trees

- Close to a big parking lot
- Close to a pond or lake
- In the middle of a field
- Next to the vent of an air conditioner
- In a sheltered, sunny area on the south side of a building
- In a sheltered, shaded area on the north side of a building

5. ☐ Check with your teacher to be sure it is safe and otherwise acceptable to set up a weather station in the location you chose.

6. ☐ Start a new experiment on the data collection system. �(1.2)

7. ☐ Connect a sensor to your data collection system �(2.1)

Note: If you are going to collect data for longer than 20 minutes, set the sensor sampling rate to once per minute. �(5.1)

8. ☐ Display temperature data in a table on the data collection system. �(7.2.1)

9. ☐ Place the cardboard housing in the accepted location so that air can circulate through the two open ends and direct sunlight is least likely to shine on the equipment. (See the illustration above.)

10. ☐ Place the cardboard mat on the floor of the cardboard housing.

11. ☐ Place the data collection system and sensor on the mat.

12. ☐ Why are you protecting your weather sensor and other electronics from direct sunlight?

____

____

Collect Data

13. ☐ Collect data for the amount of time your teacher specifies.

Note: For the database of all data collected by the class, data collection for all weather stations should be for the same time period.

14. ☐ Start data recording. �(6.2)

15. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

16. ☐ Record the following in Table 1 in the Data Analysis section:

- Starting time
- Primary physical characteristics of the site, especially anything that might affect temperature
- Prevailing weather conditions (such as cloudy, sunny, windy, or calm)

17. ☐ Will the maximum, minimum, and average temperatures of your site be higher or lower than the average temperature of all the sites? Why?

18. ☐ Stop data recording �(6.2) when instructed by your teacher to do so.

Note: For data collection lasting hours, make appropriate arrangements with other class teachers so you can stop the data recording at the specified time.

19. ☐ Record the time you stopped recording data in Table 1 of the Data Analysis section.

20. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

Data Analysis

1. ☐ Open a graph display �(7.1.1) and display the temperature data on a graph of temperature (°C) versus time (s). �(7.1.7)

2. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

3. ☐ Find the minimum, maximum, and mean values and record these values in Table 2. �(9.4)

4. ☐ Repeat this procedure for the barometric pressure, relative humidity, and dew point measurements. �(7.1.7)

5. ☐ Record your data for the individual weather station (from Table 2) on a table of class data your teacher has provided.

6. ☐ After every group has recorded its data on the class data table, complete Table 2.

Table 1: Weather station and data collection information

Date and time collection started	
Date and time collection ended	
Description of physical characteristics of the site, especially anything that might affect temperature	
Prevailing weather conditions (such as cloudy, sunny, windy, or calm)	

Table 2: Individual and class weather station data

	Individual Weather Station			Average for All Class Stations		
	Minimum	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**
Temperature (°F)						
Barometric Pressure (in Hg)						
Relative Humidity (%)						
Dew Point (°F)						

Analysis Questions

1. How did your data compare with the class data?

2. Compare your actual statistics with your predictions.

Synthesis Questions

Use available resources to help you answer the following questions.

Use available resources, and the following ideal characteristics for a climate monitoring station (according to the United States Climate Reference Network of the National Oceanic and Atmospheric Administration (NOAA)), to help you answer the following questions.

- Flat and horizontal ground
- Surrounded by a clear surface with a slope less than 1/3 (less than 19 degrees)
- Grass or other low vegetation ground cover, less than 10 centimeters high
- Sensors located at least 100 meters from artificial heating or reflecting surfaces, such as buildings, concrete surfaces, and parking lots
- Far from large bodies of water, except if it is representative of the area, and then located at least 100 meters away
- No shading when the sun elevation is greater than three degrees

1. How does the site you chose compare with the characteristics from the NOAA?

2. Do your statistics or the average statistics from the class best describe the weather conditions in your area? Why?

3. Which sites used in class would best contribute to the national climatology database? Why?

____

____

____

4. Besides making sure sensors are calibrated and functioning properly, what site conditions should be monitored regularly to ensure collections of valid data?

____

____

____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Respectively, what are the short-term and long-term atmospheric conditions in a local area known as?

- **A.** Weather, patterns
- **B.** Climate, weather
- **C.** Weather, current
- **D.** Patterns, weather
- **E.** Weather, climate

2. What main environmental factors form the climate of an area?

- **A.** Average temperature
- **B.** Average precipitation
- **C.** Average humidity
- **D.** A and B only
- **E.** All of the above

3. Why do weather stations need to be level?

- **A.** The sensors do not work well if they are not level.
- **B.** They are more likely to fall over if they are not level.
- **C.** Accurate precipitation data require collection chambers that are level.

4. In order for a weather station site to provide useful and reliable data that represents the local climate and not a microclimate, what site characteristics must be satisfied?

- **A.** It is not near a pond or small lake.
- **B.** It does not have high vegetation growing in the surrounding area.
- **C.** I is not shaded.
- **D.** It is not close to buildings, paving, or artificial or reflected heat sources.
- **E.** All of the above

5. Which of the following apply to the calibration and regular maintenance of modern weather sensor equipment?

- **A.** It does not have to be done as often as in earlier times because of advances in technology
- **B.** It has to be done more often than in previous times because of the tendency of electronic equipment to drift off calibrated settings over time.
- **C.** It needs to be done as often today as in the 1800s when data was first being collected for climate studies.

Name **Period** **Date**

5. Sunlight Intensity and Reflectivity

Driving Questions

Air temperatures near the earth's surface result largely from an interplay of the sun's incoming energy and the absorption, reflection, and radiation of that energy by materials on the earth's surface.

- What is the effect of the absorption, reflection, and radiation of the sun's energy by different materials on the earth's surface air temperatures?
- What are characteristics of materials that best reflect the sun's energy and that best absorb and radiate the sun's energy?

Background

The air temperature near the earth's surface depends primarily on two things: the amount of energy provided by the sun and the amount of energy the earth is radiating. When these two factors are added together, the total energy is greatest shortly after the time of greatest sunlight intensity. On a sunny day with little wind, the greatest intensity of sunlight occurs around mid-day. However, typically, the hottest part of the day generally occurs one to several hours later.

The amount of heat the earth's surface can absorb and subsequently radiate depends on the composition of the materials comprising the surface. Dark, rough materials absorb greater amounts of incoming solar radiation and therefore will radiate more energy. Conversely, light-colored, smooth materials reflect greater amounts of solar radiation and as a result have less energy to radiate. The reflectivity of a surface is its *albedo*. The higher the albedo, the more light is reflected and the less energy is absorbed.

Materials and Equipment

For each student or group:

- Mobile data collection system
- Light sensor
- Fast-response temperature probe
- Stainless steel temperature sensor
- Mass balance (1 per class)
- High intensity incandescent lamp
- Large disposable plate
- Tripod base and support rod
- Three-finger clamp
- Rod and clamp
- White sand, 500 g
- Dark sand, 500 g
- White rock, 500 g
- Dark rock, 500 g
- Small cardboard box, $(20\text{ cm})^3$ or larger
- Tape
- Paper and marking pen
- Scissors

Safety

Add this important safety precaution to your normal laboratory procedures:

♦ Do not look directly at the sun.

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.

Part 1 – Measuring reflection and radiation of sand and rock

Mount a light sensor on a stand. Set it next to the plate on the side opposite the light. Aim it towards the plate of sand at the angle of reflection.	Using the stand, position the end of a quick-response temperature probe about 1 cm above the sand.	Cover the bottom of a plate with 500 g of white sand. Set up a high-intensity light on one side of the plate and aim it towards the sand.	Shine the light on the sand. Record light intensity and temperature data for 1 minute. Turn the light off and continue recording data for 3 minutes.	Repeat this process for dark sand, white gravel, and dark gravel. Compare rates of heating and cooling of the solid material and the air above it.

Part 2 – Measuring sunlight intensity and the earth's reflectivity

Set the equipment station in a sunny location that will not receive shade during the day and that also is not on pavement or near a building.	Make sure your mobile data collection system is fully charged.	Connect the sensors to the data collection system and change the sampling rate to 1 sample per minute. Set up a graph display for the 2 parameters.	Make a DO NOT DISTURB sign. Record data until sunset. Stop recording data and save the file.	Make an outdoor equipment station that shields the data collection system from the sun but still exposes the sensors to the sunlight and air.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Measuring reflection and radiation of sand and rock

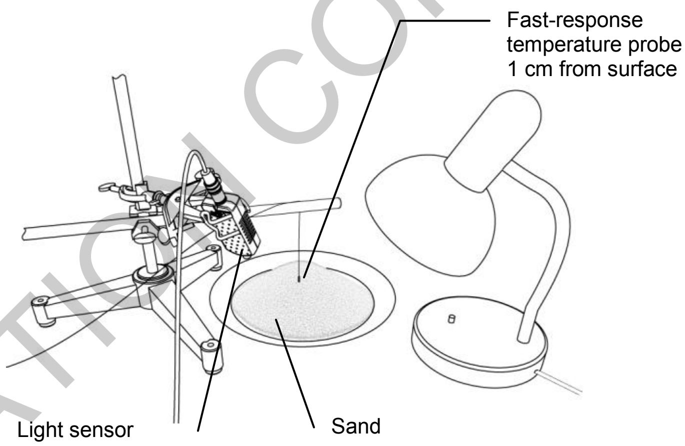
Set Up

1. ☐ Put 500 g of white sand in a large plate.

2. ☐ Start a new experiment on the data collection system. �(1.2)

3. ☐ Connect a light sensor and a fast-response temperature probe to the data collection system. �(2.2)

4. ☐ Set up appropriate displays to view the data as it is being collected. �(7)



5. ☐ Place the lamp on one side of the plate so it will shine down into it at about a 60° angle.

6. ☐ Mount the light sensor on the tripod base and rod stand, using the three-finger clamp. Position it on the other side of the plate, directly opposite the light and angled at approximately the same angle as the light source towards the plate.

7. ☐ Set up the fast-response temperature probe so it hangs about 1 cm above the surface of the sand.

8. ☐ Which material do you predict will have the greatest albedo? Which the least?

____

____

9. ☐ Which material do you predict will absorb the most heat from the light energy?

____

10. ☐ Which material do you predict will radiate the most heat after the light is turned off?

____

11. ☐ Are you measuring direct light or reflected light?

____

Collect Data

12. ☐ Turn on the light.

13. ☐ After 30 seconds, start data recording. �(6.2)

14. ☐ After 60 seconds, turn the light off. *Do not stop recording data.*

15. ☐ Record data for an additional 180 seconds.

16. ☐ Stop data recording. �(6.2)

17. ☐ Put the sand back into the container.

18. ☐ Name your data run. �(8.2)

19. ☐ Save your experiment with an appropriate file name. �(11.1)

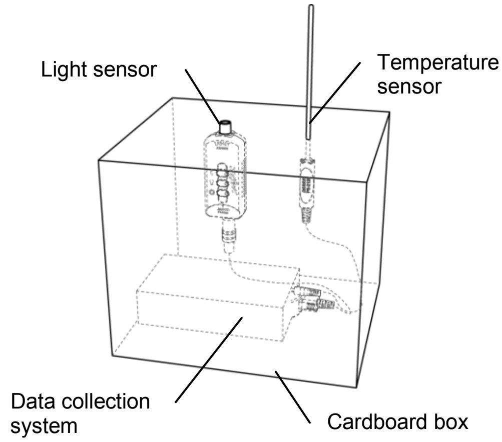
20. ☐ Repeat this procedure for the remaining materials: dark sand, white rock, and dark rock.

Note: Exercise care to keep the positions of the light, plate, temperature sensor, and light sensor constant throughout the testing of the four materials.

Part 2 – Measuring sunlight intensity and the earth's reflectivity

Set Up

21. ☐ Make an outdoor equipment station: Cut two holes in the bottom of a small cardboard box such that a light sensor will be held snuggly in one and a stainless steel temperature sensor will be held snuggly in the other.



22. ☐ Make sure your data collection system is fully charged.

23. ☐ Connect the sensors and change the sample rate to 1 sample per minute. �(5.1)

24. ☐ Set up appropriate displays to visualize the data. �(7)

25. ☐ Select the widest range on the light sensor. �(4.3)

26. ☐ Make a portable experiment station

a. Turn the box upside down

b. Thread the light and temperature sensors through the holes until they fit securely, and point straight up in the air. Use tape if necessary to help secure them.

27. ☐ Make a sign that says: DO NOT DISTURB! EXPERIMENT IN PROGRESS. CONTACT: [YOUR NAME]. THIS EXPERIMENT IS BEING CONDUCTED FROM [DATE] [TIME] TO [DATE] [TIME].

28. ☐ Carry the portable experiment station, sign, and tape outside. Find a location with the following characteristics:

- ♦ It is a safe place to leave the experiment station;
- ♦ It will receive full sun all day with no shading;
- ♦ It is not near (within 5 meters) a building or on pavement;
- ♦ The box will not get wet from sprinklers.

29. ☐ What time of day do you predict the intensity of insolation will be the greatest?

---

30. ☐ What time of day do you predict the air temperature will be the greatest?

Collect Data

31. ☐ Start data recording. �(6.2) Record your starting time in Table 2.

32. ☐ Carefully enclose the data collection system inside the box using tape to hold the flaps closed.

33. ☐ Place the box in the test location. Make sure the sensors are still pointing straight up.

34. ☐ Record data until late afternoon or evening. Then, stop data recording �(6.2), save your experiment �(11.1), and clean up according to your teacher's instructions.

Data Analysis

Part 1 – Measuring reflection and radiation of sand and rock

1. ☐ Display two graphs simultaneously. On one graph, display Light intensity on the y-axis with Time on the x-axis. On the second graph, display Temperature (°C) on the y-axis with Time on the x-axis. �(7.1.11)

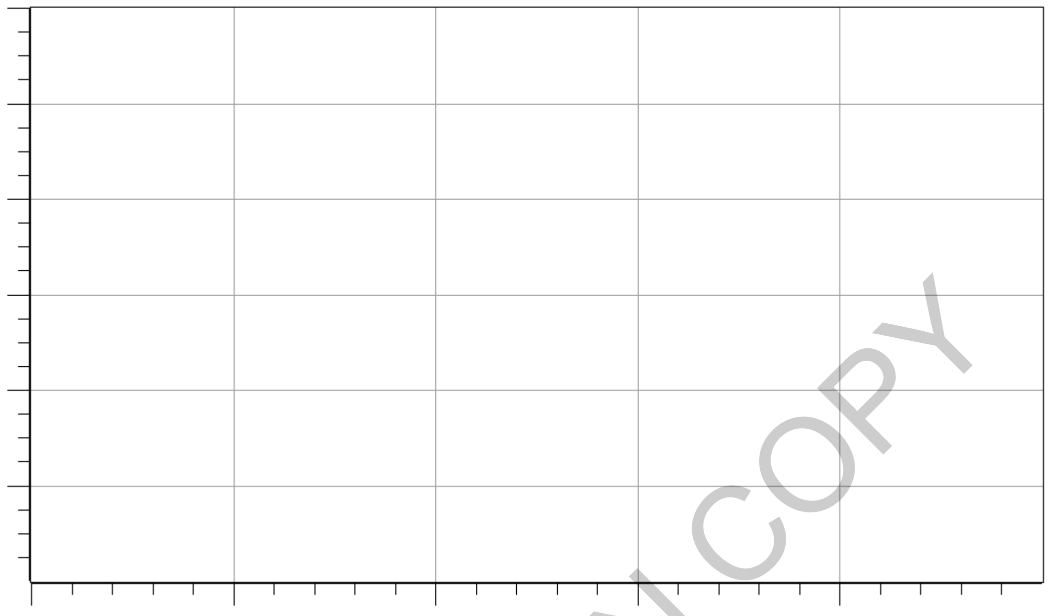
2. ☐ Adjust the scale of the graphs to show all data. �(7.1.2)

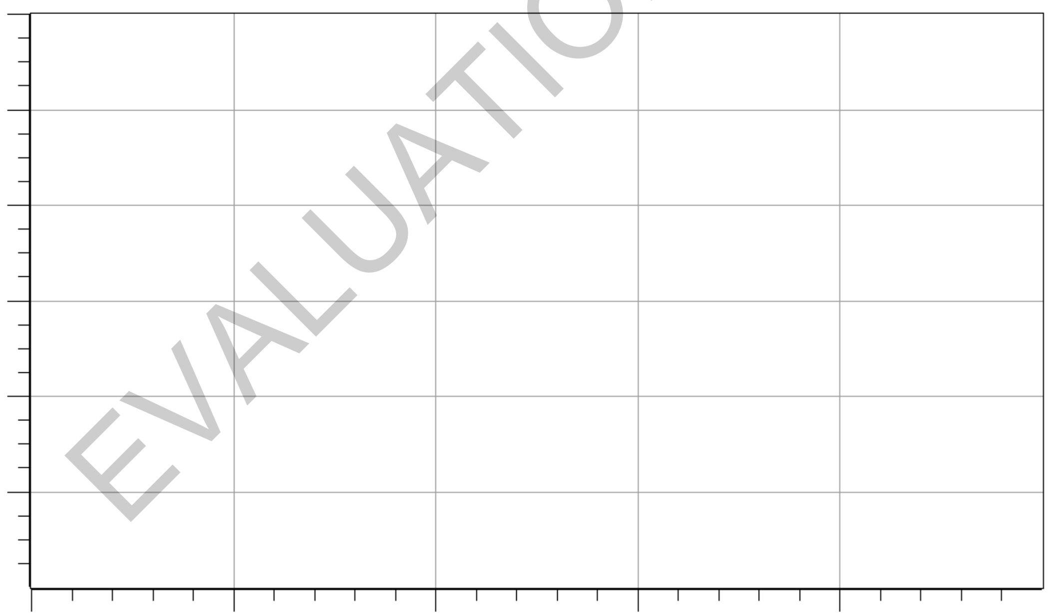
3. ☐ View the statistics for each graph, �(9.4) select the appropriate data points on each data run, �(7.1.4) and record the mean values that are called for in Table 1.

Table 1: Reflection and radiation of sand and rock

Material	Mean Reflected Light Intensity (lux)	Mean Air Temperature (Light Off) (°C)
White Sand		
Dark Sand		
White Rock		
Dark Rock		

4. ☐ Sketch parameter (light intensity, temperature) versus time graphs of your data for the four experimental conditions. Label your four runs, the overall graphs, the x-axes, and the y-axes. Including units and scales on the axes.





Part 2 – Measuring sunlight intensity and the earth's reflectivity

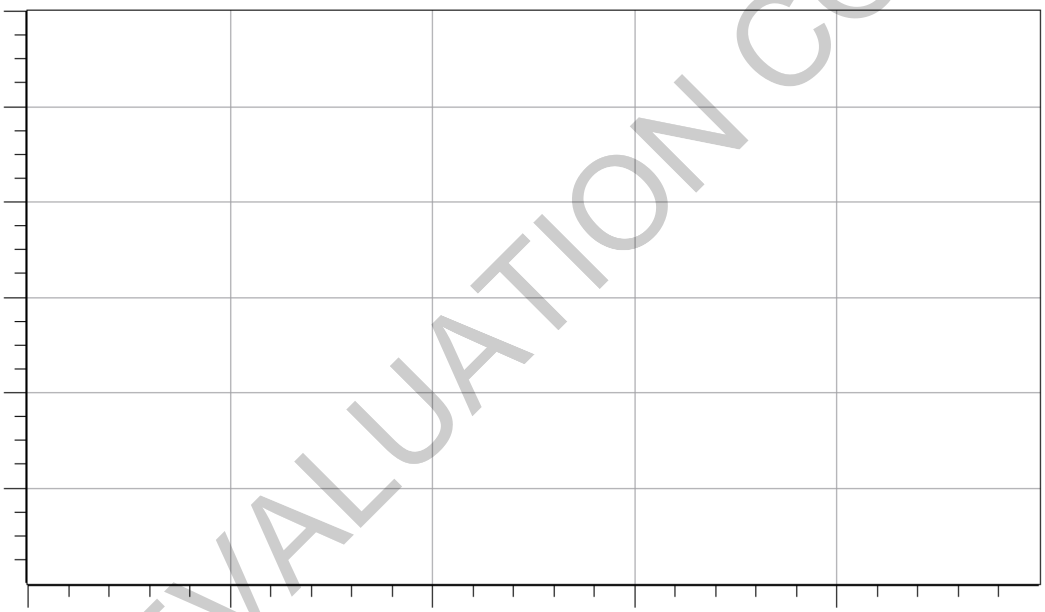
5. ☐ Display both Light intensity and Temperature (°C) on the y-axis of a graph with Time on the x-axis. �[7.1.10]

6. ☐ Find the coordinate values for the maximum temperature and light intensity on the graph, �(9.1) and complete Table 2.

Table 2: Reflection and radiation of sand and rock

	Start Time	**Greatest Value**	**Seconds from Start When Maximum Occurred**	**Time of Day**
Light Intensity (lux)				
Temperature (°C)				

7. ☐ Sketch a parameter versus time graph of your data for the two experimental variables. Use a key to differentiate your two variables. Label the overall graph, the x-axis, the y-axis, and include units on your axes.



Analysis Questions

Part 1 – Measuring reflection and radiation of sand and rock

1. Compare your predictions with your results.

2. **What were the dependent variables in this experiment? The independent variable?**

3. **Why were you careful to leave the same amount of space between each material and the light sensor, temperature sensor, and light source for each data collection?**

4. **Which characteristics of the materials make them good reflectors?**

5. **What is the relationship between the magnitude of the albedo of the material and the final air temperature?**

6. **What happens to the light that is not reflected? What happens to this energy? How might this occurrence affect daily temperatures on the earth's surface?**

Part 2 – Measuring sunlight intensity and the earth's reflectivity

7. **Does your data support your predictions? Explain**

8. **Explain how the warmest temperature of the day could be in the late afternoon when the sun's greatest intensity is earlier in the day.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Discuss what happens to the energy in sunlight when it strikes surfaces that have a high albedo.**

2. **Discuss what happens to the energy in sunlight when it strikes surfaces that have a low albedo.**

3. **Explain how the warmest temperature of the year could be after the date when the sun's greatest intensity occurs.**

4. **What type of material would you use to make a solar heater for a swimming pool? Why?**

5. What type of material would you use to make summer curtains for your home windows? Why?

____

____

6. You want to build a new home using energy efficient passive solar technology. Since you live in Columbus, Ohio, you want your house to be cool in the summer and warm in the winter. Answer the following questions:

a. At latitudes above the Tropic of Cancer and below the Tropic of Capricorn, how does the angle of the sun change with the seasons? How would you use the difference to help you with the design of your new home?

____

____

____

b. What are two ways to enhance solar absorption in the winter?

____

____

c. What are two ways to reduce solar absorption in the summer?

____

____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which factor relates to the reflective nature of a surface?

- **A.** Light intensity
- **B.** Albedo
- **C.** Absorption
- **D.** Angle of incident
- **E.** Temperature

2. Compared with a material with a high albedo, a material with a low albedo:

- **A.** Radiates more heat
- **B.** Radiates less heat
- **C.** Reflects more light
- **D.** Reflects less light
- **E.** Both A and D
- **F.** Both B and C

Name Period Date

6. Tracking Weather

Driving Questions

Analyze atmospheric data to determine how variations in temperature, humidity, barometric pressure, dew point, wind speed, and sky conditions relate to each other and produce specific weather conditions.

- How do changes in barometric pressure affect sky conditions?
- Is there a relationship between temperature and relative humidity?
- What types of clouds produce rain?

Background

Weather is a daily "snapshot" of the atmosphere at a specific place and time. Weather occurs in the troposphere, the atmospheric layer closest to the earth and is about 9 to 16 kilometers thick. This distance, in comparison to the rest of the planet, is as thin as the skin of an apple.

Four main constituents of weather include temperature, wind speed, humidity, and air pressure. Temperature is a measure of the average motion of molecules in the atmosphere. Wind is the air in horizontal motion across the earth. Wind is caused by differences in pressure. Air flows from areas of high pressure to areas of low pressure, in an attempt to balance the pressure. Greater differences in pressure result in faster winds. Humidity is a measure of the amount of water vapor in the air. Atmospheric pressure is the force that air molecules exert upon the Earth's surface. Atmospheric pressure is measured using a barometer, and is often referred to as barometric pressure.

Clouds form when moist air cools and water vapor condenses onto microscopic particles of dust, smoke, or salt in the troposphere. These tiny droplets of water are extremely small; indeed, it takes a million of them to form a single raindrop. Clouds are named according to their height and appearance.

Clouds are named according to their height and appearance. High-forming clouds are assigned the prefix 'cirro', whereas clouds formed at a middle altitude receive the prefix 'alto' (low-forming clouds do not receive a prefix). Rain-producing clouds usually receive the suffix 'nimbus'. Two main cloud types are cumulus or clumped clouds and stratus or layered clouds. Depending on their location, they may have the alto- or cirro- prefixes.

Cumulus clouds typically signal fair weather, but if they expand into the upper part of the atmosphere, they become cumulonimbus or rain clouds. These clouds are tall (can surpass 15 km) and dark. They are an indication of rapidly changing air masses capable of producing lightning, heavy rain, hail, high winds, and tornadoes.

Stratus clouds are layered and not as tall as cumulus types. Precipitation can occur as rain, freezing rain, sleet, hail, and snow with varying intensity. Water droplets with a diameter greater than 0.5 mm are classified as rain, but when smaller than this, as drizzle.

Materials and Equipment

For each student or group:

- ♦ Mobile data collection system
- ♦ Weather/anemometer sensor
- ♦ Brick or board (2)
- ♦ Weather shield[1]
- ♦ Weather data for comparisons[2]

Safety

Add this important safety precaution to your normal laboratory procedures:

- ♦ If students go outdoors to set up their data collection, be aware of hazards both from weather and traffic for students and also for the data collection systems.

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.

◯	◯	◯	◯	◯
Collect temperature, humidity, barometric pressure, wind speed and dew point data for at least 6 hours.	Connect your weather sensor to the data collection system.	Compare your data to data collected in other weather conditions.	Set your sample rate to collect data once every ten minutes.	Analyze the data you collected to determine the relationship between different weather variables and sky conditions.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Set Up

1. ☐ Select a location for your experiment according to your teacher's instructions.

2. ☐ Start a new experiment on the data collection system. �(1.2)

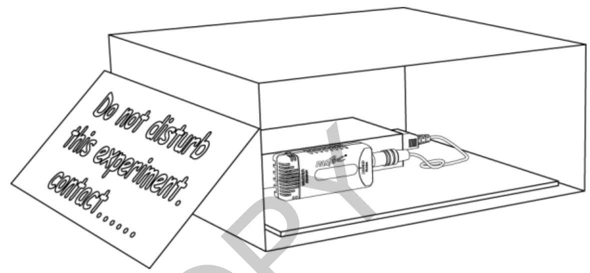
3. ☐ Attach the weather/anemometer sensor to the data collection system. �(2.1)

4. ☐ Display barometric pressure, temperature, relative humidity, wind speed, and dew point in a table. �(7.2.1)

5. ☐ Change the sample rate to once every 10 minutes. �(5.1)

6. ☐ Place the data collection system on a brick or on a couple of boards to keep it off the ground.

7. ☐ Keep the direct sun from shining on your system by placing a weather shield over it.



Collect Data

8. ☐ Start data recording. �(6.2)

9. ☐ Describe the location of the data collection system.

---

10. ☐ Make a careful description of the current sky conditions each hour as the data is being collected.

Table 1: Sky conditions and cloud cover

Time	Sky conditions	Type of clouds present

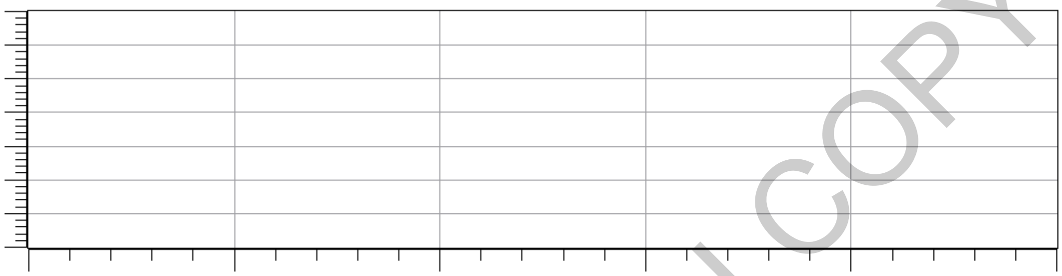
11. ☐ After the data has been collected for at least 6 hours, stop recording data. �(6.2)

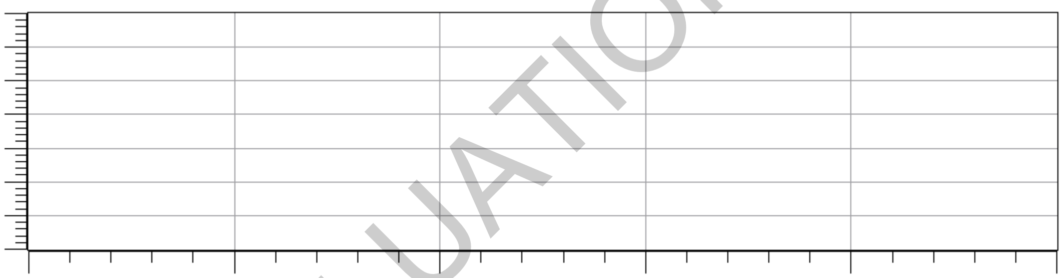
12 ☐ Save your experiment. �(11.1)

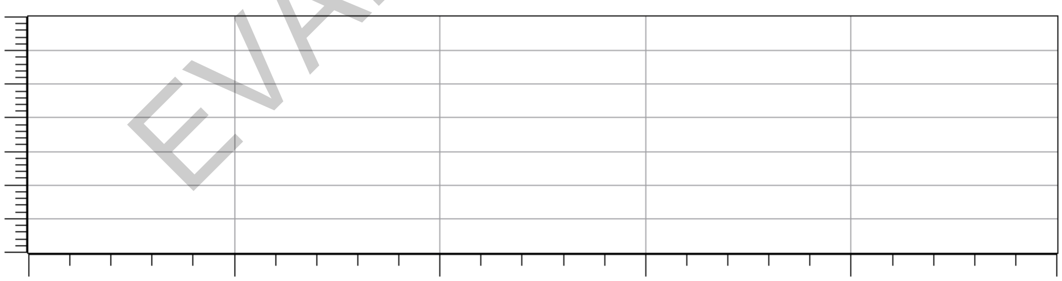
13 ☐ Return the equipment and the data collection system to the classroom.

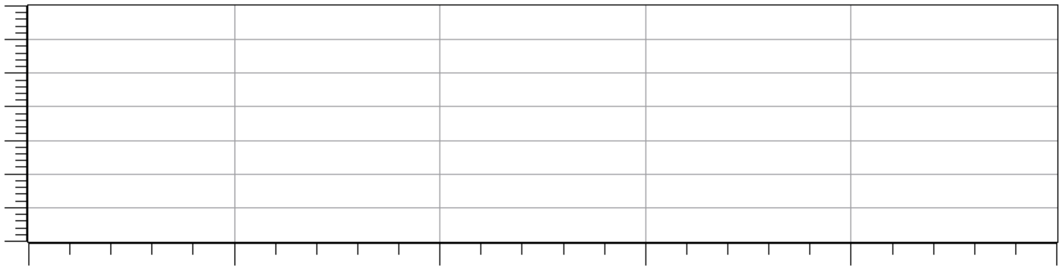
Data Analysis

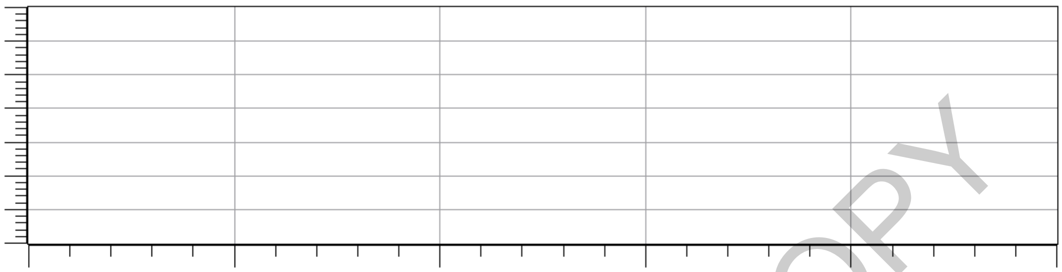
1. ☐ Using your collected data, create graphs for each of the following variables versus time: barometric pressure, temperature, relative humidity, wind speed, and dew point. �(7.1.1) Sketch or print each graph. Label the overall graph, the x-axis, the y-axis, and include units on the axes. �(11.2)











2. ☐ Describe the weather conditions in general over the test period. If clouds were present, what type were they?

3. ☐ How did the barometric pressure change during the data collection period? What weather conditions were related to this change in pressure?

4. ☐ How does the temperature vary as the relative humidity changes?

5. ☐ How did the wind speed vary over the time you collected data? What conditions could explain this observation?

6. ☐ How would you classify the weather conditions during your data collection? Summarize the data you found for this type of weather.

Analysis Questions

1. Compare weather data that was collected on days with different weather conditions. Fill in the first row of Table 2 with the data you collected and get weather data for four other weather conditions from your teacher. Summarize the general trends in the data from your teacher in the remaining four rows in Table 2.

Table 2: Comparisons for weather data

Weather Conditions	Barometric Pressure	Temperature	Relative Humidity	Dew Point	Wind Speed

2. Weather data recorded over several weeks may show trends. Would you be able to predict those trends based on the data you gathered?

3. **In general, what is the relationship between temperature and relative humidity?**

4. **What correlations can you make between the barometric pressure and sky conditions?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **What type of weather would you expect if the atmospheric barometric pressure were dropping quickly and humidity was on the rise?**

2. **How can clouds form if the humidity is less than 100% at your measuring site?**

3. **What atmospheric condition would have to change the most for it to remain windy throughout the day?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. _______________ is the amount of water vapor in the air.

- **A.** Barometer
- **B.** Dew point
- **C.** Troposphere
- **D.** Humidity
- **E.** Temperature

2. If the temperature of an area is increasing what would you expect to happen to the humidity?

- **A.** The humidity is probably increasing.
- **B.** The humidity is probably decreasing.
- **C.** The humidity will probably stay the same.
- **D.** The temperature will keep increasing until it is the same as the humidity.
- **E.** Both C and D are correct.

3. Which of the following conditions will create the strongest winds?

- **A.** An area of high pressure next to an area of low pressure.
- **B.** A vertical movement of air.
- **C.** An area in which the pressure is constant.
- **D.** Water vapor condensing in clouds.
- **E.** All of the above will create wind.

4. Weather is best described as _____________________.

- **A.** Conditions at a specific location measured over a period of at least 30 years.
- **B.** Temperature changes over a period of 24 hours.
- **C.** A daily "snap shot" of the atmosphere at a specific place and time.
- **D.** Changes in the atmospheric conditions as the seasons change.
- **E.** Both A and D together.

5. What type of cloud would most likely cause rain?

- **A.** Altostratus
- **B.** Cirrostratus
- **C.** Cirrus
- **D.** Cumulus
- **E.** Cumulonimbus

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. Weather is generated at the ________________ of large warm and cold ________________. Air property differences occur because the sun heats the earth's surfaces ________________ which in turn influences the air masses above them. Warm air masses expand and generally exert less or ________________ on the earth's surface because they are less dense. Colder air is denser and can be detected as a ________________ air mass or system.

2. When these air masses collide, their leading edges that meet form ________________. When denser, colder air masses collide with stationary warm air masses, their ________________ typically produce ________________ or storm clouds with thunder and lightning. (In the winter these may be snow storms.) ________________ move more gradually over ________________ air. A warm air mass is ________________ and will typically overlay the leading ________________ edge of the stationary colder air mass, gently pushing it out of the way. These warm fronts generally produce overcast ________________ clouds and if they have enough moisture become ________________.

3. Naming clouds is mostly based on two features: their ________________ and their ________________. Middle altitude clouds generally have the prefix ________________ in front of the clouds name. High altitude clouds are called ________________ or have the prefix ________________. Clouds bringing precipitation of any height will either begin with ________________ - or end in ________________. Cloud shapes generally compose the root of the cloud name. Clouds that blanket the sky are called ________________. Light pockets of fluffy clouds are called ________________. Thin wisps of clouds generally form at high altitudes helping the name ________________ to mean both their height and their shape. These terms and their combinations are the most common names used for cloud descriptions in weather ________________. While there are more special names for clouds that form in special geographic regions or interesting conditions, the total combination of common cloud types are: stratus, altostratus, nimbostratus, cirrostratus, cumulostratus, cumulus, cumulonimbus, and cirrus.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2	Paragraph 3
boundaries	bulldozer-shaped	alto
cold fronts	cirrus	height
cumulonimbus	cold fronts	angle
evenly	cumulonimbus	cirrus
fronts	fronts	color
high pressure	high pressure	shape
infrared	less dense	cirro
invisible	more dense	cumulo
low pressure	nimbostratus	nimbus
nimbostratus	stationary	nimbo
temperature	stratus	stratus
unevenly	warm fronts	strato
visible	wedge-shaped	forecasts
warm fronts	velocity	podcasts

7. Earth's Magnetic Field

Driving Questions

How can models be used to visualize the magnetic field lines surrounding Earth?

- ♦ How does the magnetic field strength vary with different locations on Earth?
- ♦ What creates Earth's magnetic field?
- ♦ How does Earth's magnetic field help navigators stay on course during their travels?

Background

All magnetic objects produce invisible lines of force that connect the poles of the object. Although the Earth's magnetic field makes it appear that a powerful bar magnet exists near the Earth's center, such a bar magnet does not exist. The Earth's magnetic field is produced by a complex interaction between the convection currents in the molten outer core and the solid inner core, both of which contain large quantities of ferromagnetic metals, such as iron, nickel, and cobalt.

The north magnetic pole and the geographic North Pole are different. The north magnetic pole is the point at which the geomagnetic field in the north points vertically, that is, the magnetic dip is 90°. Compass needles generally point towards the north and south magnetic poles of the Earth. The north magnetic pole and the north geographic pole are not in the same place. In 2005, the north magnetic pole was at 82.7°N and 114.4°W and the geographic North Pole is by definition 90°N and 0°W. The Earth's magnetic north pole is not a fixed point but is constantly moving. In the past 100 years, the Earth's magnetic north pole has wandered approximately 600 miles to the north to its present location in the Canadian Arctic.

What are magnetic reversals? Considering that ships, planes and scouting groups navigate by it, the Earth's magnetic field is less reliable than you would think. Rocks in an ancient lava flow in Oregon suggest that for a brief time about 16 million years ago magnetic north shifted as much as 6 degrees per day. After little more than a week, a compass needle in the United States would have pointed toward Mexico City. According to this same data, the lava caught the Earth's magnetic field in the act of reversing itself, showing that the magnetic north headed south, and—over about 1,000 years—the magnetic field completely reversed. Geologic evidence, in the form of the "paleomagnetic" record, confirms such reversals have happened many dozens of times in Earth's history. Today, seafloor spreading can be measured by mapping the magnetic reversals in crustal rock in both directions from the diverging boundary in the Mid-Atlantic Ridge. Knowing the width of a band of rock with a similar polarity, and the amount of time it took to be created, the rate at which the plate moved can be determined.

Materials and Equipment

For each student or group:

- Data collection system
- Magnetic field sensor
- Bar magnet
- Small cork
- Sewing needle
- Pin
- Water, 500 mL
- Clear plastic cup
- Magnetic field demonstrator plate (4), 2D
- Degree wheel template
- Map of Earth template

Safety

Add this important safety precaution to your normal laboratory procedures:

- Keep magnets away from electronic equipment.

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.

◯	◯	◯	◯	◯
Float the cork with the magnetized needle in the beaker and label N, S, E, W.	Collect data at several locations around the degree wheel.	Begin by magnetizing the needle. Rub the needle across the south end of the bar magnet 30 to 40 times.	Place the Magnetic Field Demonstrator on the template of Earth; place the magnet on top and sketch the field lines.	Leaving only the magnet in place, align the tip of the magnetic field sensor with the zero degree marking on the template.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Constructing a simple compass

You will build a compass using a needle, a cork, and a magnet. Remember, the needle of a compass always points towards magnetic north.

1. ☐ Magnetize the needle:

- **a.** Hold the needle by the needle's eye.
- **b.** Hold the bar magnet at its north end with the magnet horizontal.
- **c.** Stroke the needle off the south end of the magnet, from the needle's eye to the needle's point and repeat this motion 40 to 50 times.

2. ☐ Test the magnetic ability of the needle by placing the magnetized needle next to a pin.

3. ☐ How do you know whether or not the needle has become magnetized?

____

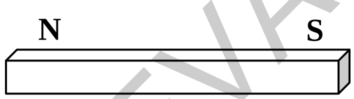
4. ☐ In general, explain how two magnetized objects respond to each other.

____

____

5. ☐ Determine which end of the needle is north and which end of the needle is south by placing the needle next to the bar magnet.

6. ☐ Draw a diagram of your needle next to the south end of the bar magnet you see pictured below. Label which end of the needle is north (N) and which side of the needle is south (S).



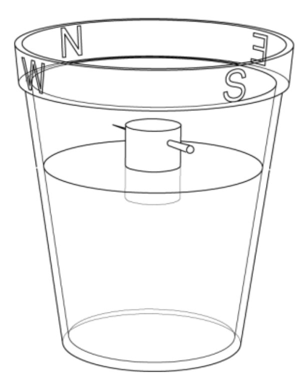
7. ☐ Cut off a small piece of cork and push the magnetized needle through it.

8. ☐ Label a clear plastic cup with the coordinates N, E, S, W.

9. ☐ Fill the cup with water.

10. ☐ Float the cork with the needle in the water.

11. ☐ Rotate the cup so the needle points to the N to complete your simple compass.



12. ☐ Which end of the needle compass is pointing toward the north magnetic pole?

13. ☐ What does this tell you about the polarity of Earth's north magnetic pole?

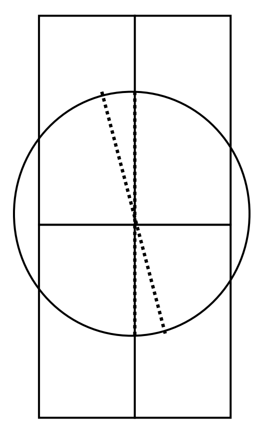
14. ☐ Who uses compasses and why are they used?

15. ☐ Is the north magnetic pole the same as the geographic North Pole?

16. ☐ How do navigators account for any difference?

Part 2 – Visualizing the Earth's magnetic field

17. ☐ Lay all four 2D magnetic field demonstrator plates on top of the Map of Earth template to make a large rectangle as shown.



18. ☐ Place the bar magnet on top of the magnetic field demonstrator plates, lining it up with the magnet diagram on the template.

19. ☐ Ensure that the south pole of the magnet is in the North as shown on the template.

20. ☐ Why is the south pole of the magnet near the North Pole?

21. ☐ Allow the iron pieces within the magnetic field demonstrator plates to orient themselves with the magnetic field of the bar magnet.

22. ☐ Describe the pattern the iron pieces make around the Earth (on the template).

____

23. ☐ Make a sketch showing the alignment of the iron pieces over the template. You might want to use short arrows to indicate how the iron filings pointed relative to the magnet.

Part 3 – Measuring the magnetic field of a bar magnet

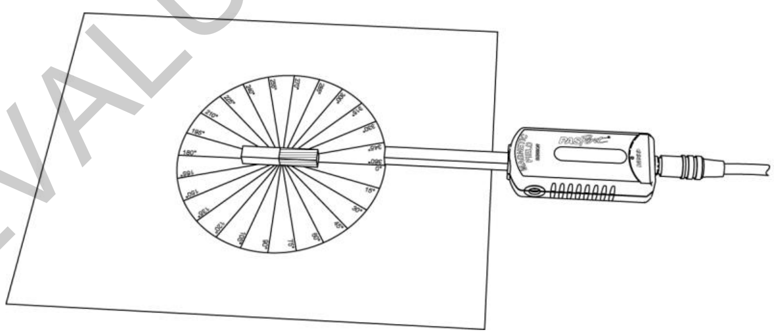
Set Up

24. ☐ Start a new experiment on the data collection system. �(1.2)

25. ☐ Connect a magnetic field sensor to the data collection system. �(2.1)

26. ☐ Put the data collection system into manual sampling mode with manually entered data. Name the manually entered data for the table "Degrees" and add a column to display "Magnetic field strength." �(5.2.1)

27. ☐ Place the bar magnet on the degree wheel template so that the north pole on the magnet points to the 0 degree line on the template.



28. ☐ Position the magnetic field sensor's tip at the 0 degree line on the template as shown in the diagram. The closer you place it, the stronger the field will be; keep the sensor the same distance from the magnet and in line with the circle.

Collect Data

29. ☐ Start a manually sampled data set. �(6.3.1)

30. ☐ Record the magnetic field strength every 15 degrees starting at the 0 degree mark on the template.�(6.3.2)

31. ☐ When you have recorded all of your data, stop the data set. � (6.3.3)

Analyze Data

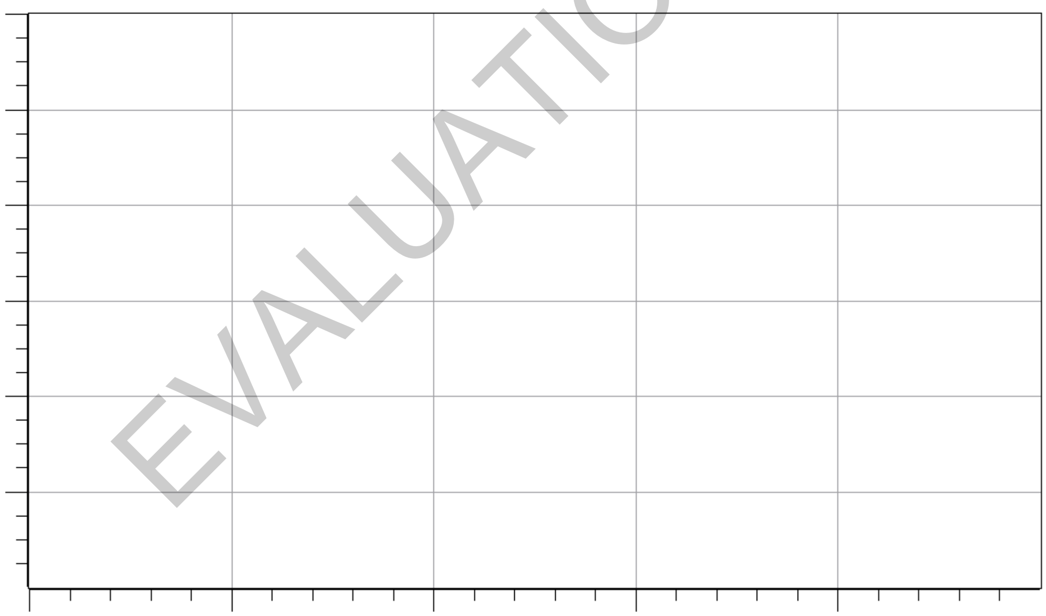
32. ☐ Display Magnetic field strength on the y-axis of a graph with Degrees on the x-axis. �(7.1.1)

33. ☐ Find and label the coordinates of the data point with the highest magnetic strength value and the lowest magnetic strength value. �(9.1)(7.1.5)

34. ☐ What was the highest and lowest magnetic strength value recorded?

____

35. ☐ Sketch or print a Magnetic Field versus Degrees graph. Label the overall graph, the x-axis, and the y-axis. Include units and scales on the axes. �(11.2)



36. ☐ In the data, some of the values are positive and some are negative. What does that mean for the polarity?

____

____

37. ☐ At which locations on the magnet was the field strength the greatest? At which locations was it the least?

38. ☐ Save your file and clean up according to the teacher's instructions. �(11.1)

Data Analysis

1. ☐ If the north pole of the needle magnet pointed to the north magnetic pole, what is the polarity of the north magnetic pole? Explain your reasoning.

2. ☐ Describe how the magnetic field strength on Earth varies.

3. ☐ On the Map of Earth template, label the highest positive magnetic field strength readings and the lowest negative readings at their corresponding degree. What part of the bar magnet does each data point represent?

Analysis Questions

1. Why did the needle on your compass point north? Explain.

2. **Is the Earth's magnetic field a two or three dimensional magnetic field? Do you have any evidence for this?**

3. **What would the graph look like after a magnetic reversal? Explain.**

4. **Do you think the model of the Earth's magnetic field you recorded in the lab would be different if you used a much stronger or much weaker magnet? Explain your answer.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Is the Earth's magnetic field a static, rigidly set magnetic field like a bar magnet? Explain.**

2. Humans use compasses to navigate the world. What other animals use Earth's magnetic field? Explain.

3. How does the magnetic field of the Earth protect the planet in space?

4. What would cause the magnetic field of Earth to disappear altogether? Explain.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The needle on a compass points north because the Earth's magnetic field resembles a

- **A.** Horseshoe magnet
- **B.** Bar magnet
- **C.** Refrigerator magnet
- **D.** Single pole magnet
- **E.** None of the above

2. Which statement best describes the pattern in which the magnetic field of a bar magnet varies with location from 0 or 360 degrees to 180 degrees?

- **A.** Strong positive value at 0 or 360 degrees to strong negative at 180 degrees
- **B.** Strong negative value at 0, 180 and 360 degrees, strong positive at 90 and 270 degrees
- **C.** Strong negative value at 0 or 360 degrees to strong positive at 180 degrees
- **D.** Strong positive value at 0, 180 and 360 degrees, strong negative at 90 and 270 degrees
- **E.** None of the above

3. Which statement best describes the orientation of magnetic field lines around a bar magnet?

- **A.** The magnetic field lines resemble a series of straight lines from the north to the south pole in two dimensions.
- **B.** The magnetic field lines resemble a series of straight lines from the north to the south pole in three dimensions.
- **C.** The magnetic field lines resemble a two dimensional series of loops from one pole to the other.
- **D.** The magnetic field lines resemble a three dimensional series of loops from one pole to the other.
- **E.** The magnetic field lines run perpendicular to the surface of the magnet.

4. Which statement best describes the Earth's magnetic field?

- **A.** The Earth's magnetic field is permanent.
- **B.** The Earth's magnetic field reverses every 1000 years.
- **C.** The Earth's magnetic field has varied in strength and orientation over time.
- **D.** The Earth's magnetic field is static.
- **E.** The Earth's magnetic field varies in strength and orientation with the lunar cycle.

5. Magnetic declination:

- **A.** Varies according to location
- **B.** Is stronger near the South Pole
- **C.** Is constant within a hemisphere
- **D.** Is stronger near the North Pole
- **E.** Is zero when you are standing at the Equator

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

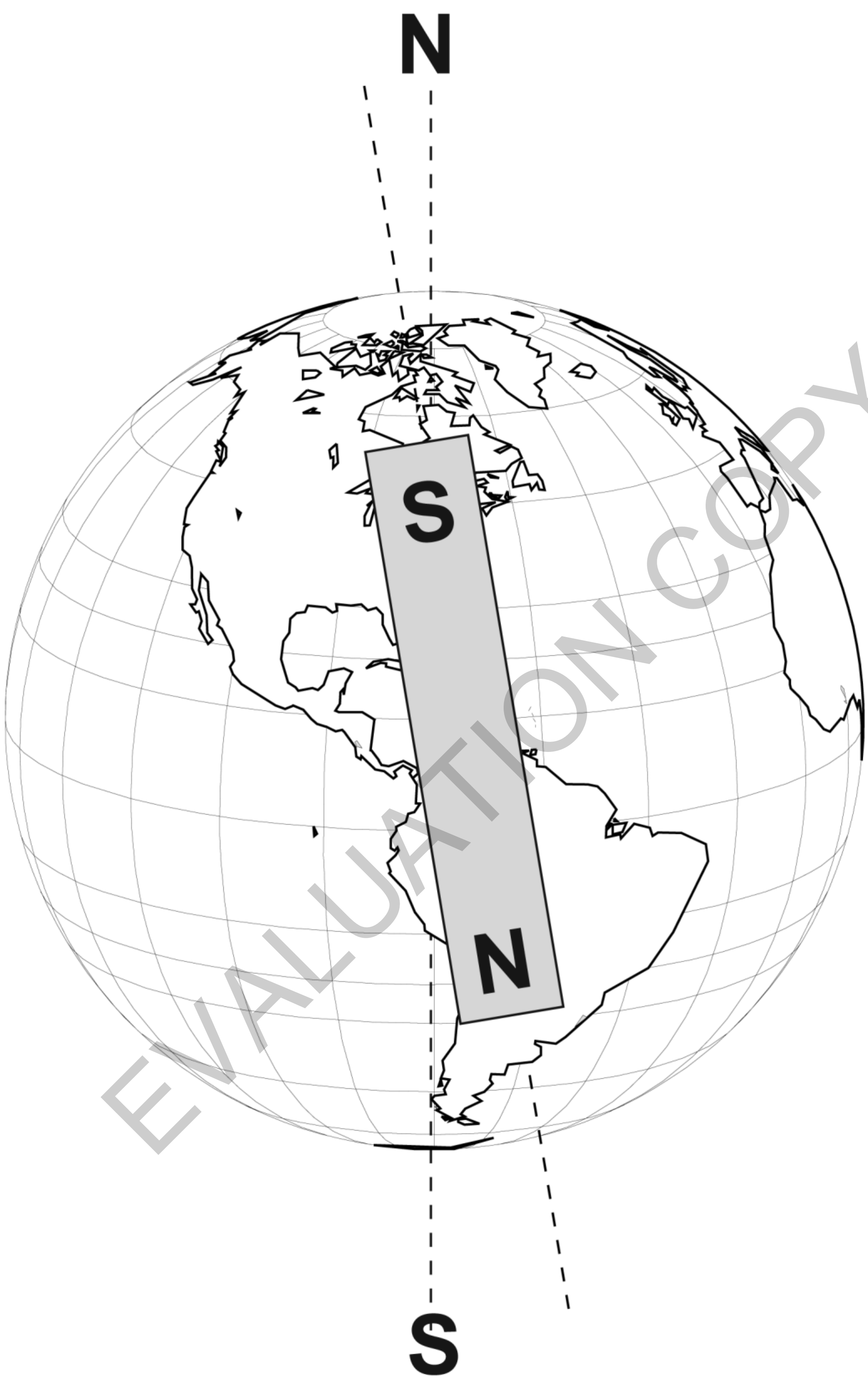
1. At first glance it appears that the Earth contains a giant ________________. However, we know that the temperatures in the Earth's core are too ________________ for the materials to remain permanently magnetized. A widely accepted view of the mechanism responsible for generating the Earth's ________________ suggests that the Earth's magnetic field is produced by a complex interaction between the convection currents in the molten ________________ core and the solid **inner** core, both of which contain large quantities of ________________ metals, such as iron, nickel, and cobalt.

2. The magnetic field of the Earth is ________________ dimensional: the ________________ axis, the ________________ axis, and the radial axis, up from the surface of the Earth. The ________________ of the needle on a compass can be used to help pilots find their latitude. The ________________ of the needle on the compass can help determine variation from ________________ north. Navigators, especially small plane pilots, use both the declination and the inclination from special magnets called ________________ to find their true position.

3. During the 1960s, geophysicists learned that the Earth's magnetic field reverses ________________ periodically. That is, the magnetic north and south poles ________________ positions. The cause of the reversal seems to involve fluctuations in the ________________ of the magnetic field over time followed by a rapid recovery after the new orientation has been established. Evidence for these ________________ can be found in a study of the ________________ of lava fields, and an examination of rock on the seafloor. The study of the magnetic field orientation in rock as it formed is called ________________.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2	Paragraph 3
bar magnet	bar magnet	dip angle
ferromagnetic	declination	magnetic field sensor
geographic	dip needles	magnetism
high	geographic	paleomagnetism
inner	inclination	polarity
latitude	latitudinal	reversals
longitude	longitudinal	strength
magnetic field	three	switch
outer	two	viscosity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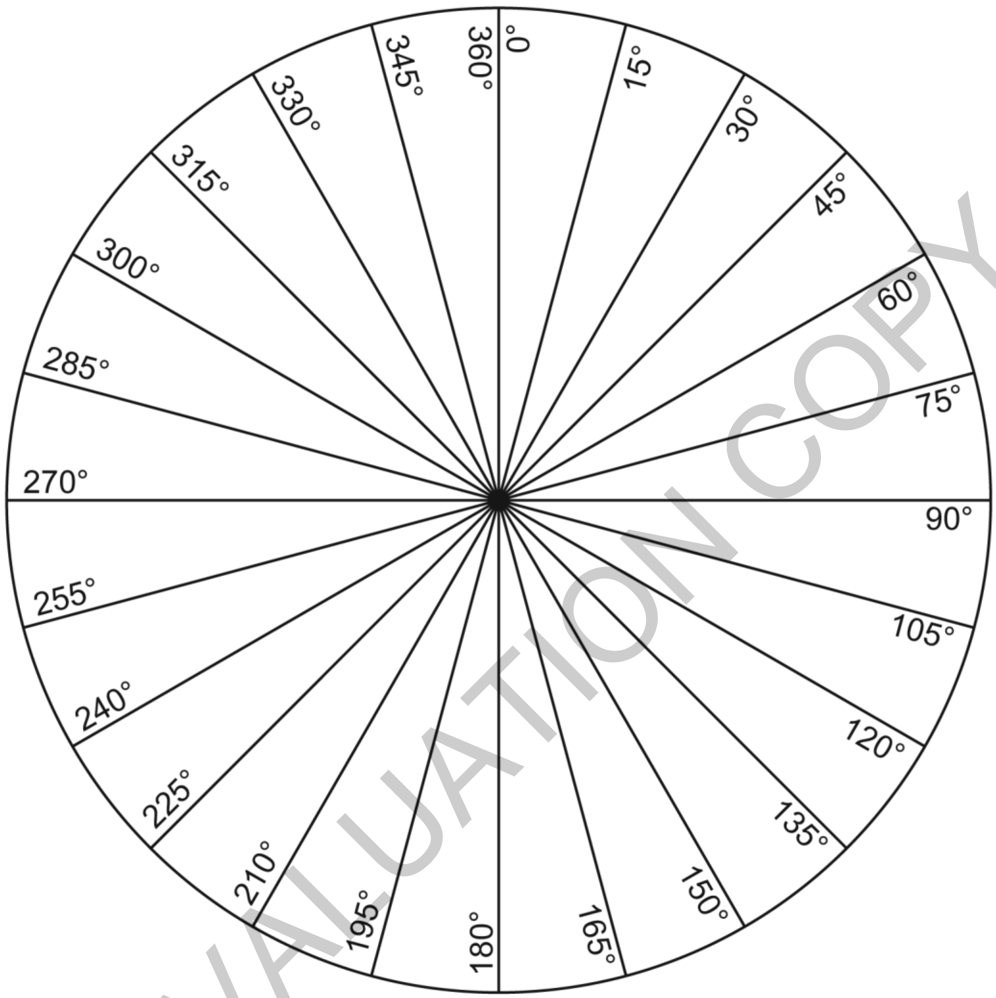


8. Radiation Energy Transfer

Driving Questions

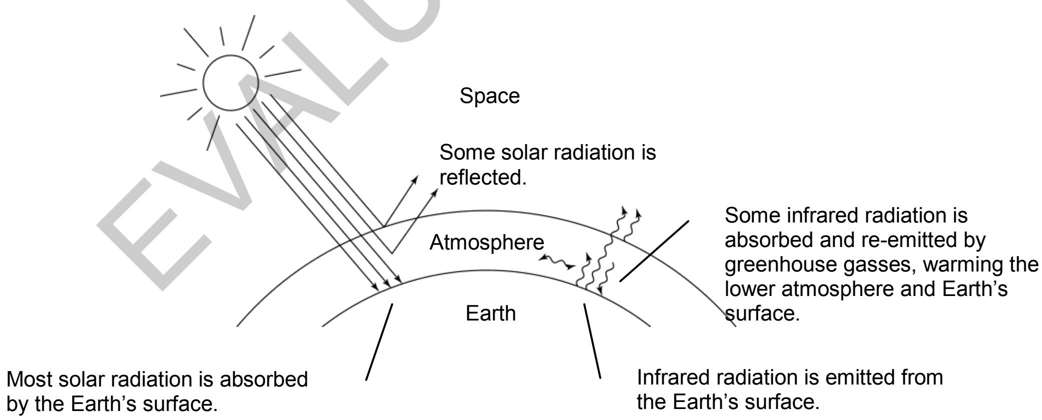
Determine the effect the color of a container has on the temperature of water in the container as it is heated using radiant energy.

- What is radiant energy?
- What is the relationship between an object's color and its ability to absorb energy?
- Does radiant energy heat all of Earth's surfaces equally?

Background

The Earth receives an enormous amount of radiant energy from the sun. Solar radiation is made up of the entire spectrum of electromagnetic waves. Visible light, the light that we can see, is only a tiny part of this spectrum. Other types of electromagnetic radiation produced by the sun include infrared radiation (thermal energy), microwaves, radio waves, ultraviolet light, X-rays, and gamma rays.

Incoming radiation is scattered, reflected or absorbed by the atmosphere or the Earth's surface. The atmosphere protects us from most X-rays, gamma rays and ultraviolet radiation by reflecting these wavelengths of light back into space. The light that travels through our atmosphere is either reflected or absorbed by Earth's surface. Different surfaces absorb and reflect differing amounts of solar radiation. The term albedo is used to compare the degree to which different surfaces reflect incoming solar radiation. Surfaces with high albedo reflect more radiation than surfaces with low albedo. Surfaces with low albedo absorb more radiant energy than they reflect.



When surfaces absorb radiant energy they become warmer. This in turn increases their thermal energy, or total internal energy. Likewise, cooling decreases thermal energy. The total amount of energy the Earth receives is in equilibrium with the total amount of energy the Earth loses and is called Earth's energy budget.

Materials and Equipment

For each student or group:

- Data collection system
- Temperature sensor (2)
- Graduated cylinder, 100-mL
- Heat lamp (or 150-W lamp)
- Radiation can (2), 1 black, 1 silver
- Insulated pad (2)
- Ring stand
- Water, room temperature, 0.5 L

Safety

Follow all standard laboratory procedures.

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.

Place one temperature sensor into each can of water.	Obtain one black radiation can and one silver radiation can and fill each can with 200 mL of water.	Turn on the heat lamp and collect Temperature versus Time data for 20 minutes.	Compare the Temperature versus Time data collected for the two cans of water.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Label one temperature sensor "1" and the second temperature sensor "2".

3. ☐ Connect temperature sensor 1 to the data collection system. �(2.1)

4. ☐ Connect temperature sensor 2 to the data collection system.

Note: Temperature 2 will be displayed on the data collection system as $Temperature_2$.

5. ☐ Set the data collection system so that both temperature sensors are collecting data once every five seconds. �(5.1)

6. ☐ Display a graph with Temperature 1 and Temperature 2 on the y-axis and Time on the x-axis. �(7.1.10)

7. ☐ Confirm that you know how each temperature sensor is displayed on your device. Explain below how you confirmed this.

___

___

___

8. ☐ Place each radiation can on an insulated pad. Keep the cans away from drafts.

9. ☐ Why are you asked to place each radiation can on an insulated pad and to keep the cans away from drafts?

___

___

10. ☐ Fill each can with 200 mL of room-temperature water (the cans should be the same size so that the water level in both is the same).

11. ☐ Put temperature sensor #1 into the water in the black can and temperature sensor #2 into the water in the silver can.

12. ☐ Place the heat lamp so it is about 20 cm in front of the two cans. Make sure the lamp is the same distance from each radiation can to ensure even heating.

13. ☐ How do you think the change in water temperature in the black can will compare to that of the silver can? Explain your reasoning.

___

___

Collect Data

14. ☐ Turn on the lamp and start data recording. �(6.2)

15. ☐ Continue recording data for 20 minutes.

Note: If necessary, adjust the scale of the graphs to show all data. �(7.1.2)

16. ☐ How will you know which can absorbed the most radiation?

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17. ☐ What surfaces on Earth could the black can represent?

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18. ☐ What surfaces on Earth could the silver can represent?

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19. ☐ Stop data recording. �(6.2)

20. ☐ Save your experiment and clean up according to your teacher's instructions. �(11.1)

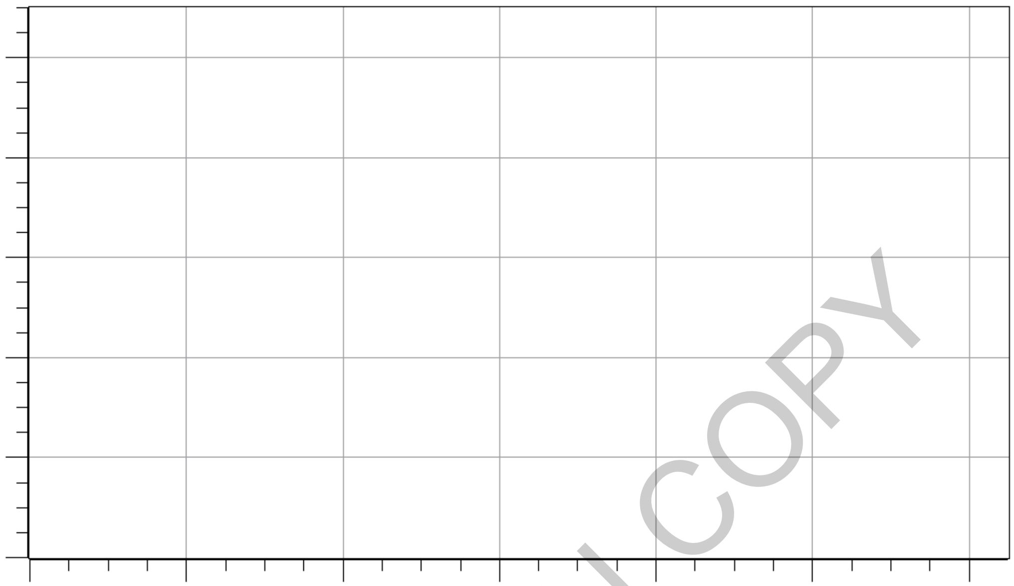
Data Analysis

1. ☐ Use the graph of Temperature versus Time to determine the initial temperature, final temperature, and change in temperature for each radiation can and record the answers in Table 1. �(9.1) (9.2)

Table 1: Recorded and calculated temperatures

	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)
Silver Can			
Black Can			

2. ☐ Sketch or print a copy of the graph of Temperature versus Time. Include the data for both radiations on the same set of axes. Label each trial as well as the overall graph, the x-axis, the y-axis, and include numbers on the axes. �(11.2)



Analysis Questions

1. Examine your Temperature versus Time graph and Table 1. Which can absorbed more radiant energy? Use your data to support your answer.

____

____

____

2. Compare the slope of data collected for the black can to the slope of the data collected for the silver can. What does this tell you about the efficiency of the black can's ability to absorb radiant energy?

____

____

____

3. **What is the relationship between the color of an object and the object's ability to absorb heat?**

4. **Does radiant energy affect all Earth's surfaces equally? Use your data to support your answer.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Suppose you had to choose a roof color for a new house and were given two choices: dark grey or light grey. Which would you choose to keep the house cooler in the summer? Why?**

2. **On a sunny summer day would you expect an asphalt street or a cement driveway to feel hotter? Explain.**

3. **Would you expect the albedo of a mountain range to change after the first snowfall? Explain.**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. What is the Earth's source of radiant energy?

- **A.** Earth's moon
- **B.** The oceans
- **C.** The sun
- **D.** Electricity
- **E.** None of the above

2. What happens to incoming solar radiation when it reaches Earth?

- **A.** It is reflected.
- **B.** It is absorbed.
- **C.** It is scattered.
- **D.** It is reflected, absorbed, and scattered.
- **E.** None of the above.

3. What surface has the highest albedo?

- **A.** Dark colored rocks
- **B.** Grass
- **C.** Soil
- **D.** Snow
- **E.** Pavement

4. What color radiation can you expect to absorb the most radiant energy?

- **A.** A blue can
- **B.** An orange can
- **C.** A green can
- **D.** A yellow can
- **E.** A white can

5. What process causes an objects temperature to increase the most?

- **A.** Scattering radiant energy
- **B.** Reflecting radiant energy
- **C.** Absorbing radiant energy
- **D.** Emitting radiant energy
- **E.** Transferring radiant energy

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. The sun gives off radiant energy in the form of _________________ waves or small disturbances in space that carry energy much like waves in the ocean carry gravitational energy. These waves travel at the speed of light (300 million m/s) in straight lines until they are scattered, reflected, or _________________. Smooth, metallic, and lightly colored surfaces tend to _________________ light and have a high _________________. Rough, dark objects tend to absorb light and have a _________________ albedo. When a surface absorbs light their _________________ increases causing their temperature to increase.

2. While some energy from the sun is _________________ in all the colors of the spectrum, the sun also emits energy with shorter and longer wavelengths than our eyes can see. Some of these are familiar to us. _________________ radiation causes our skin to burn if we receive too much sunlight. Because of _________________ radiation the pavement heats up during the day and windows get hot to the touch in sunlight. The Earth receives far more energy as _________________ radiation than is used to keep the Earth warm. Some of this excess solar energy is reflected off the atmosphere, and some is simply re-emitted back into space as _________________ infrared radiation. In the end, the total amount of solar radiation the Earth receives remains in _________________ with the total amount of radiation the Earth loses.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
absorbed	scattered
albedo	solar
high	gamma
low	ultraviolet
reflect	equilibrium
thermal energy	absorbed
tidal energy	emitted
electromagnetic	terrestrial
opaque	infrared
scattered	long-wave
energy budget	microwave

9. Seafloor Spreading and Plate Tectonics

Driving Questions

Explain the evidence that is used to support the theory of plate tectonics.

- How does seafloor spreading causes Earth's plates to move?
- How does paleomagnetism provide evidence for seafloor spreading?
- What are magnetic reversals and how do they affect polarity in rock?

Background

The theory of plate tectonics states that the Earth's lithosphere is fragmented into a dozen or more large and small plates that are moving relative to one another as they ride atop the hotter, more mobile asthenosphere (upper layer of Earth's mantle).

Seafloor spreading causes the Earth's plates to move. New oceanic crust is created when magma rises to the surface along mid-ocean ridges, cracking the overlying basalt and forcing its way to the surface. The new basaltic lava spreads out and cools, leaving the older oceanic crust further away from the ridge and newer cooling basaltic rock closest to the ridge. As this process is repeated over time, matching layers of progressively older rock can be found on either side of the spreading center. As the seafloor spreads it pushes the plates away from each other causing the plates to move.

Paleomagnetism, the study of magnetism in rocks, provides evidence for seafloor spreading. The basaltic lavas that make up the oceanic crust contain the magnetic mineral magnetite. As the basaltic lava cools, the magnetic orientation of iron within the magnetite aligns with the magnetic field of the Earth.

The Earth's magnetic field reverses at irregular intervals lasting from a few thousand to millions of years. When a reversal does occur, basaltic material formed at the spreading center is orientated magnetically opposite the rocks that previously formed. This discovery led to the understanding that the Earth's magnetic field reverses—the north pole becomes south and the south pole becomes north. Magnetic polarity reversals provide further evidence of seafloor spreading.

Materials and Equipment

For each student or group:

Station 1

- Strip of paper, 10 cm × 28 cm
- Colored pencils or markers, red and green
- Tape
- Scissors
- Cardboard or card stock, 15 cm × 20 cm

Station 2

- Data collection system
- Magnetic field sensor
- Bar magnet

Station 3

- Data collection system
- Magnetic field sensor
- Basalt, hand size specimen
- Magnetite, hand size specimen

Station 4

- Data collection system
- Magnetic field sensor
- Seafloor spreading model[1]

Safety

Add this important safety precaution to your normal laboratory procedures:

- Keep magnets away from electronic equipment.

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.

○	○	○	○	○
Visit each of the stations your teacher has set up, in any given order.	Perform the measurements at each of the given stations, and record your data and answers carefully.	Relate evidence for seafloor spreading to larger processes of plate tectonics.	Relate the magnetic field reversals in the model to magnetic field reversals in the planet.	Compare the model of the seafloor to the actual sea floor, and identify the pattern.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Station 1 – Constructing a paper spreading seafloor model

1. ☐ Color the long strip of paper (10 cm × 28 cm) so that there are several alternating red and green colored bands of differing thicknesses across the width of the paper.

2. ☐ What do the red and green bands represent?

---

3. ☐ Fold the paper in half lengthwise so that the top length lies over the bottom length and the bands match up. Cut the paper down the fold.

4. ☐ Tape the strips together at one end.

5. ☐ What causes a switch in the polarity of magnetism in bands of rock on the sea floor (one color band to another color band on your model)?

---

6. ☐ Cut three slits in the 15 cm × 20 cm piece of cardboard: one in the center and the other two about two centimeters from each edge.

7. ☐ Feed the un-taped ends through the center slit from the underside up and allow them to open and spread toward the slits on the sides exposing the colored bands. Do this slowly.

8. ☐ What do you notice about the pattern created by the strips moving away from each other?

---

9. ☐ What type of boundary does the center slit in the cardboard represent on the ocean floor?

___

10. ☐ When the strips reach the side slits in the cardboard, pull them down through the side slits.

11. ☐ What type of boundary does pulling the strips down through the side slits on the cardboard represent on the ocean floor?

___

___

12. ☐ Carefully remove the colored strip of paper from the cardboard.

13. ☐ Re-feed the un-taped ends through the center slit from the underside and number each pair of colored bands similarly (the first color band that comes out of the slit will be numbered "1" on both the right and the left sides of the paper strip, the second color band will be numbered "2" on both the right and the left sides, and this process is continued until all the band s are numbered).

14. ☐ When the strips are mostly pulled out, look at the numbering. Where are the first colored bands located? Where are the last colored bands located?

___

___

15. ☐ What does this pattern tell you about the age of the bands of rock as they emerge from the spreading center on the sea floor?

___

___

___

Station 2 – Measuring the magnetic field of a bar magnet

Set up

16. ☐ Start a new experiment on the data collection system. �(1.2)

17. ☐ Connect a magnetic field sensor to the data collection system. �(2.1)

Collect Data

18. ☐ Monitor live magnetic field data in a digits display. �(6.1)

19. ☐ Position the magnetic field sensor's tip at the north pole of the bar magnet and record the value on the diagram below. (Positive Gauss values represent north magnetic polarity; negative Gauss values represent south magnetic polarity.

Note: the magnetic field sensor should be in the same plane as the bar magnet (the tip of the sensor should NOT be perpendicular to the magnet).

20. ☐ Move the magnetic field sensor's tip to the south pole of the bar magnet, allow the reading to stabilize, and record the value on the diagram.

21. ☐ Move the magnetic field sensor's tip to the point midway between the bar magnet's north and south poles, allow the reading to stabilize, and record the value on the diagram.

Analyze Data

22. ☐ Describe what happens to the strength of the magnetic field as you move the sensor up one side of the magnet and down the other.

23. ☐ How does the field strength on the magnet relate to magnetic field lines on the Earth?

Station 3 – Comparing the magnetism of magnetite and basalt

Set up

24. ☐ Draw an illustration of your sample of magnetite and your sample of basalt in the space provided. Label each illustration.

25. ☐ Start a new experiment on the data collection system. �(1.2)

26. ☐ Connect a magnetic field sensor to the data collection system. �(2.1)

Collect Data

27. ☐ Monitor live magnetic field data in a digits display. �(6.1)

28. ☐ Use the magnetic field sensor to map out the magnetic field strength of each specimen:

- **a.** Determine the magnetic field strength in one location on a specimen.
- **b.** Allow the reading to stabilize and record the value (including the positive or negative sign) on the illustrations you drew above.
- **c.** Repeat this process until you have found at least 5 different magnetic field values on each specimen.

29. ☐ Do both hand specimens appear to be magnetic?

____

30. ☐ What type of rock is oceanic crust made up of? Is the collected data consistent with your knowledge of the oceanic crust?

____

____

____

31. ☐ Were there regions in the magnetite specimen that were either strongly positive or strongly negative? What does this suggest about the orientation of individual magnetite crystals at those locations?

___

___

___

Station 4 – Magnetism as Evidence for Seafloor Spreading

Set Up

32. ☐ Start a new experiment on the data collection system. �(1.2)

33. ☐ Connect a magnetic field sensor to the data collection system. �(2.1)

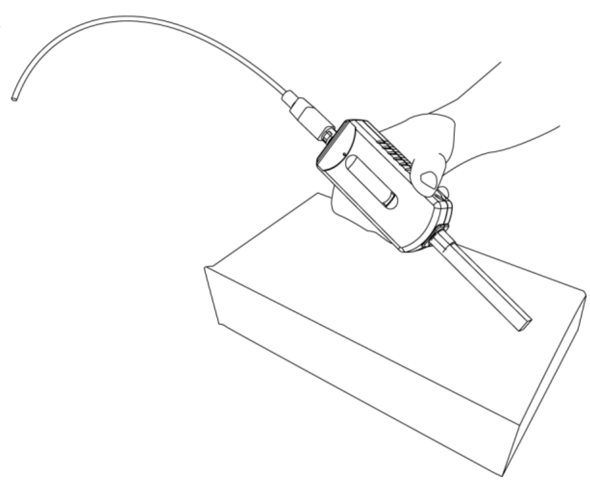
Collect Data

34. ☐ Create a graph with Magnetic Field on the y-axis and Time on the x-axis. �(7.1.1)

35. ☐ Hold the magnetic field sensor perpendicular to one end of the seafloor spreading model.

36. ☐ Start data collection. �(6.2)

37. ☐ Slowly move the tip of the sensor from one end of the model to the other. It should take about 15 to 30 seconds to move across the model.

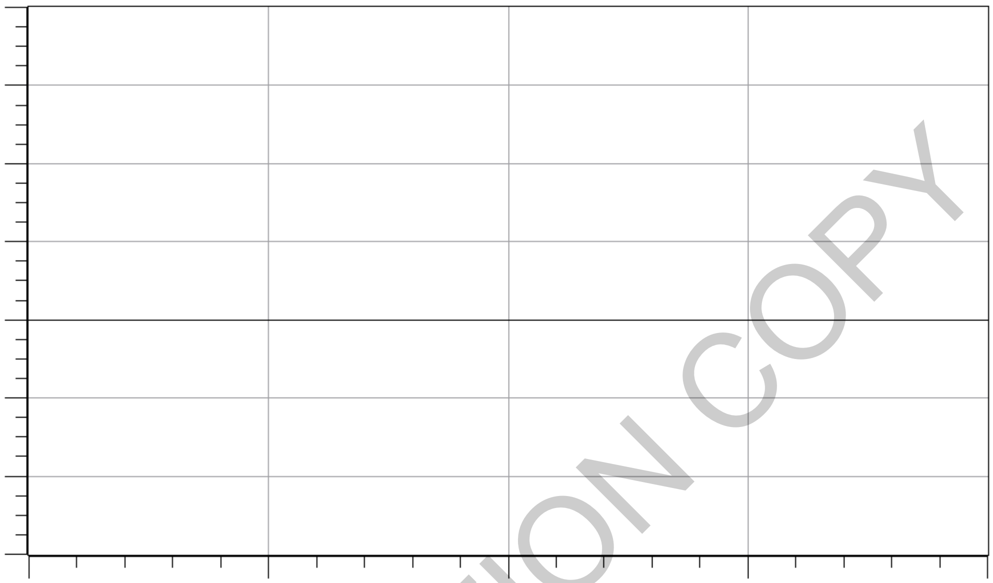


Note: Adjust the scale of the graph as necessary. �(7.1.2)

38. ☐ Stop data collection. �(6.2)

Analyze Data

39. ☐ Sketch or print a copy of the graph of Magnetic Field versus Time. Label the overall graph, the x-axis, the y-axis, and include numbers on the axes. �(11.2)



40. ☐ Label the positive and negative peaks as either north or south. Then, label the spreading center (rift zone) and draw arrows showing the direction of plate motion.

41. ☐ Is the pattern of magnetism symmetrical about the spreading center?

42. ☐ Do you think the mechanism for moving the rock to either side of the spreading center is a pulling mechanism or a pushing mechanism? Explain your reasoning.

Analysis Questions

1. **How does seafloor spreading causes Earth's plates to move?**

____

____

____

2 **What are magnetic reversals and how do they affect paleomagnetism in rock?**

____

____

____

3. **How does paleomagnetism provide evidence for seafloor spreading?**

____

____

____

Synthesis Questions

Use available resources to help you answer the following questions.

1. **What is the relationship between the mid-Atlantic ridge and the puzzle-like fit of Africa and South America?**

____

____

2. **Describe the relationship between convergent boundaries and divergent boundaries on the Earth's crust. Use terms like subduction and spreading center in your description. How do these processes affect the size of the planet?**

____

____

3. Describe how the crystals in magnetite are "frozen" into the magnetic field in the basaltic rocks that make up the oceanic crust.

____

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____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. According to the seafloor spreading theory, the oldest rock on the seafloor is located ______________________.

- **A.** Near the continents
- **B.** In the center of the ocean floor
- **C.** Halfway between the center of the ocean and the continents
- **D.** Near the North Pole
- **E.** Rock is the same age everywhere on the seafloor

2. Why do Earth's plates move?

- **A.** They are blown by the wind.
- **B.** They are pushed apart by the formation of new rock at spreading centers.
- **C.** The less dense oceanic crust float on top of the more dense continental crust.
- **D.** The continents float on the surface of the ocean.
- **E.** All of the above are correct.

3. Magnetic patterns associated with mid-ocean ridges are configured as:

- **A.** Concentric circles around a rising plume of hot, mantle rocks and magma
- **B.** Reversed magnetizations along the rift valleys and normal magnetizations along the trench
- **C.** Normal and reversed magnetized strips parallel to the ridge axis (spreading center)
- **D.** Normal and reversed magnetized strips perpendicular to the ridge axis (spreading center)
- **E.** Both A and D are correct

4. Which of the following provides evidence for seafloor spreading?

- **A.** Volcanic eruptions
- **B.** Lithosphere
- **C.** Asthensophere
- **D.** Paleomagnetism
- **E.** Both B and C are correct

5. When do the magnetic particles in rock align themselves with the magnetic north pole?

- **A.** During erosion
- **B.** When the rock is formed
- **C.** It takes about 100 years after the rock is formed for magnetic aligning to take place
- **D.** Rocks do not contain magnetic particles
- **E.** Both A and C are correct

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. When seafloor spreading occurs, new basaltic ________________ material is added to the seafloor. This material is ________________ when it is extruded at the spreading center. Since ________________ contains iron, it is aligned with the Earth's magnetic field when it cools below the ________________ point; thus, when the ________________ cools it is magnetized by the magnetic field of the Earth. So the magnetic field that forms at any time on the seafloor is ________________ with the Earth's magnetic field at that time.

2. The Earth's magnetic field reverses at ________________ intervals lasting tens of thousands of years. When a reversal does occur, basaltic material formed at the ________________ is orientated magnetically ________________ the rocks that previously formed. This discovery led to the understanding that the Earth's ________________ reverses—the magnetic north pole becomes south and the magnetic south pole becomes north. Magnetic ________________ reversals provide further evidence of seafloor spreading. Scientists measure the magnetic polarity of the ocean floor using ________________ that record the strength and direction of the magnetic field in the region.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
aligned	equal
basalt	irregular
carbon	magnetometers
crustal	magnetic field
Curie	misshapen
Cuvette	opposite
gaseous	paleomagnetism
iron	polarity
mantle	regular
molten	spreading center
opposed	unequal
solid	

The Living World

10. Modeling an Ecosystem

Driving Questions

An ecosystem is a community of species that interacts with one another and the physical and chemical surroundings. Ecosystems can be both large and small. Measuring and monitoring an ecosystem allows us to understand what an ecosystem is, and how it can be protected.

- What makes up an ecosystem?
- How does human-introduced pollution affect an ecosystem?

Background

The term "ecosystem," coined by British botanist Roy Clapham in 1930, refers to any system of living, or biotic, organisms that functions with non-living, or abiotic, chemical or physical factors in the environment. The central idea behind the ecosystem is that all biotic organisms are continually engaged in a relationship with other biotic and abiotic components. The ecosystem develops as a product of each organism's relationship with every other organism. Ecosystems are highly sensitive to change, and introducing new elements can have dramatic effects on both the biotic and abiotic organisms present.

An environment does not have to be large or exotic to be considered an ecosystem. A system as small as a single plant and soil, or one as large as a rainforest, can be considered an ecosystem. Any ecosystem is governed by the sum of individual responses from all organisms in the ecosystem. Prominent ecosystems include the Amazon Rainforest, the Great Barrier Reef, and Yellowstone Park.

In this activity, you will be asked to design 3 individual chambers, which will be interlinked. There are many types of environments you could attempt to emulate including aquatic, decomposition, and terrestrial. You can add living organisms to your design, including plants, fish, and insects and you can use different soil types and organic material in the different chambers.

It is important to first brainstorm and then clearly identify what to put into each terrarium prior to setting up the activity. Things they should keep in mind include: 1) the type of water to add (for example, distilled, tap, or from a local water source), 2) the types of living organisms to add to the ecosystem and how they will be obtained, 3) soil sources and how the soil will be obtained, and 4) the parameters they want to monitor.

Materials and Equipment

For each student or group:

- ♦ Data collection system (one or more per group, depending on the experimental design)
- ♦ Oxygen gas sensor [1]
- ♦ Carbon dioxide sensor[1]
- ♦ Temperature sensor[1]
- ♦ pH sensor [1]
- ♦ Conductivity sensor[1]
- ♦ Weather sensor[1]
- ♦ Water quality colorimeter[1] and sample vials (nitrate and ammonia recommended)
- ♦ USB hub (depending on data collection system)
- ♦ Sensor extension cable
- ♦ EcoZone™ System
- ♦ Different types of living organisms
- ♦ Strong incandescent or full-spectrum fluorescent light source
- ♦ Plant seeds or seedlings, or moss
- ♦ Water, dechlorinated (quantity depends on design)
- ♦ Pollution source
- ♦ Compost or soil

[1]These are a sample of the sensors for this student-designed activity. Not all are needed for a successful experiment.

Using Your Data Collection System

You may be using the following technical procedures in this activity. Your teacher will provide you with a copy of the instructions for these operations. If you are not familiar with a procedure, locate that operation in the list below. Use the tech tip number (identified by the number following the symbol: "�") to find the corresponding instructions.

- ♦ Starting a new experiment on the data collection system �(1.2)
- ♦ Connecting a sensor to your data collection system �(2.1)
- ♦ Using an extension cable �(2.1)
- ♦ Connecting multiple sensors to your data collection system �(2.2)
- ♦ Calibrating a CO_2 gas sensor �(3.1)
- ♦ Calibrating a dissolved O_2 sensor �(3.3)
- ♦ Calibrating an O_2 gas sensor �(3.5)
- ♦ Calibrating a pH sensor �(3.6)
- ♦ Calibrating a turbidity sensor �(3.7)
- ♦ Setting up a conductivity sensor for a particular measurement range �(4.2)
- ♦ Changing the sample rate �(5.1)

- Starting data recording �(6.2)
- Stopping data recording �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Displaying multiple data runs �(7.1.3)
- Selecting data points in a graph �(7.1.4)
- Finding the values of a point in a graph �(9.1)
- Measuring the distance between two points in a graph �(9.2)
- Saving your experiment �(11.1)

Safety

Add these important safety precautions to your normal laboratory procedures:

- Consult the manufacturer's material safety data sheets (MSDS) for instructions on handling, storage, and disposing of hydrochloric acid. (You can find these on the Internet.) Keep these instructions available in case of accidents.
- Do not touch the hydrochloric acid (HCl). Handle the pipet with HCl with extreme care.
- After completing the lab, wash your hands.
- Wear safety glasses and lab coats or aprons.

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.

○	○	○	○	○
Design your experiment: determine your question and the ecosystems and parameters to measure in order to answer the question.	Set up the data collection system to record data.	Brainstorm ways to set up the EcoZone chambers.	Gather your materials and set up the chambers, including all materials and sensors.	Repeat the procedure, changing the independent variable.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

There are three chambers to the EcoZone™ System. Each of these chambers can be filled with any abiotic material or living organism you can bring in from home or that your teacher can provide for you.

Discuss with your team the important factors in building an ecosystem. Remember that adding live organisms to these zones means you are responsible for providing them with all of the necessities of life.

Part 1 – Design your experiment

1. ☐ Write a brief outline of the procedure you will use to set up the EcoZone chambers and collect data. Include the following information:

a. What are your principle design considerations (what is the goal of your experiment)?

____

____

____

b. What are the independent variables? What are the dependent variables? What are you keeping the same? What parameters will you measure?

____

____

____

c. What are the biotic and abiotic components you are adding to each chamber?

____

____

____

Note: Part of your experiment should determine the effect of the addition of a pollutant.

2. ☐ Draw a diagram of the experimental setup you will use. Be sure to label the biotic and abiotic materials in each chamber and the sensor or sensors that will be in each chamber.

3. ☐ What roles will you and your research team play in creating, monitoring, and analyzing the EcoZone system?

4. ☐ Will the system remain closed? Will you open the system periodically to water plants or feed organisms? How will you account for your influence on the system if it is opened?

Part 2 – Set up your experiment and collect data

5. ☐ Calibrate sensors that require calibration, according to the instructions provided with the sensor.

Note: Keep the file open that contains this calibration information. The sensor calibration remains with the file that was open when you performed the calibration.

6. ☐ Why is it necessary to calibrate sensors?

7. ☐ Add the materials to each chamber.

8. ☐ Seal the chambers so they are airtight.

Hint: One way to be sure that the terrarium is airtight is to exhale several times into the empty chamber to raise the CO_2 level of the air in the terrarium relative to the room air. Then seal the terrarium and monitor the CO_2 level for several minutes with a carbon dioxide gas sensor. After the reading stabilizes, the level should not drop. If it does, you probably have a leak. Once you have learned how to make the terrarium airtight, use this procedure in your investigations.

9. ☐ Insert the sensors and begin collecting data. Collect data for at least 24 hours. Your teacher may want you to monitor data for an extended period of time.

Note: For longer investigations, you may need to decrease the sampling rate of the sensors. Choose a time interval that will provide adequate information while limiting the number of data points collected to a practical quantity. �(5.1) For example, if you choose to monitor the terrarium for 24 hours, you might set the sampling rate to 1 sample every 10 minutes. Or if you choose to monitor for a week, you might set the sampling rate to 1 sample every 30 minutes.

Note: Take detailed notes about the status of your chambers, including the live organisms, daily. Do not wait for an organism to begin dying to intervene – you can manipulate the chambers as you see fit during the experiment as long as it is properly documented.

Part 3 – Add a pollutant and monitor data

10. ☐ After a minimum of 24 hours of data collection, add the pollutant provided by your teacher to at least one of the chambers.

11. ☐ Why do you need to wait 24 hours before adding a variable?

____

____

____

12. ☐ What type of pollutant did you add to your system? What chamber did you add the pollutant to?

____

____

____

13. ☐ What effect do you think the pollution will have on the measurements being recorded in each chamber?

14. ☐ Why is the substance you added to the chamber considered a pollutant?

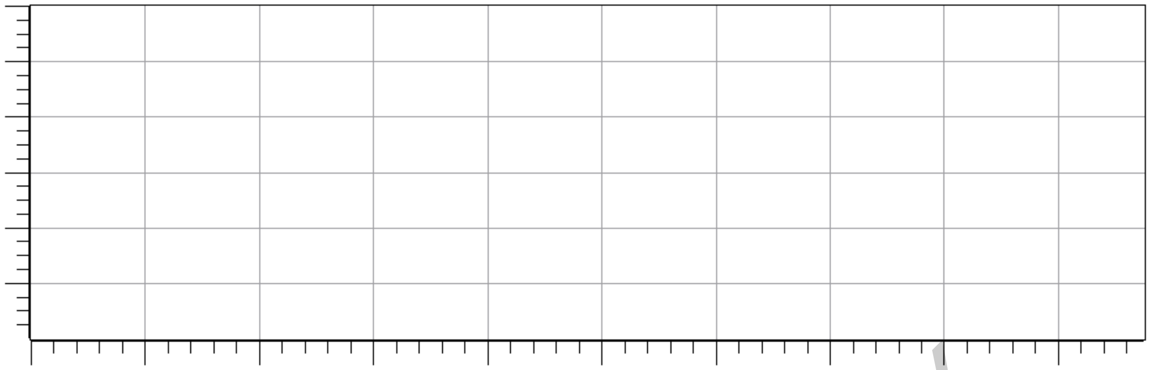
Data Analysis

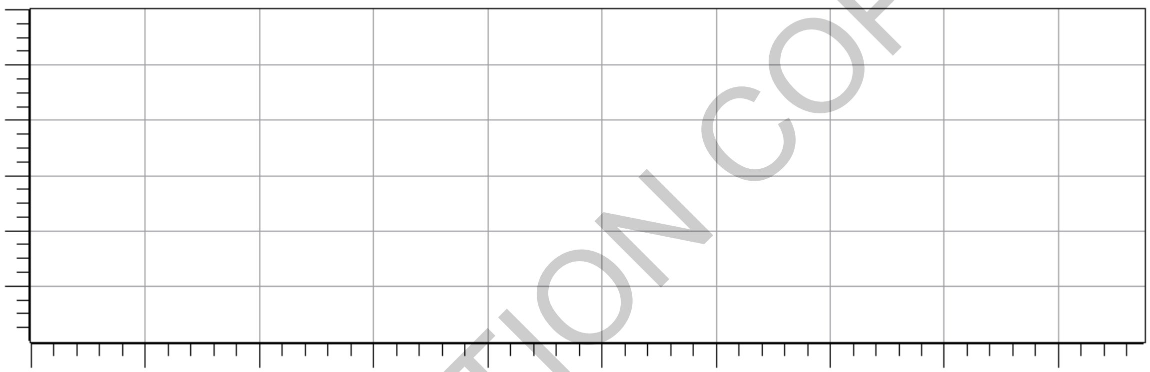
1. ☐ Record any changes made to your experimental design, or any time the system was opened to the external environment

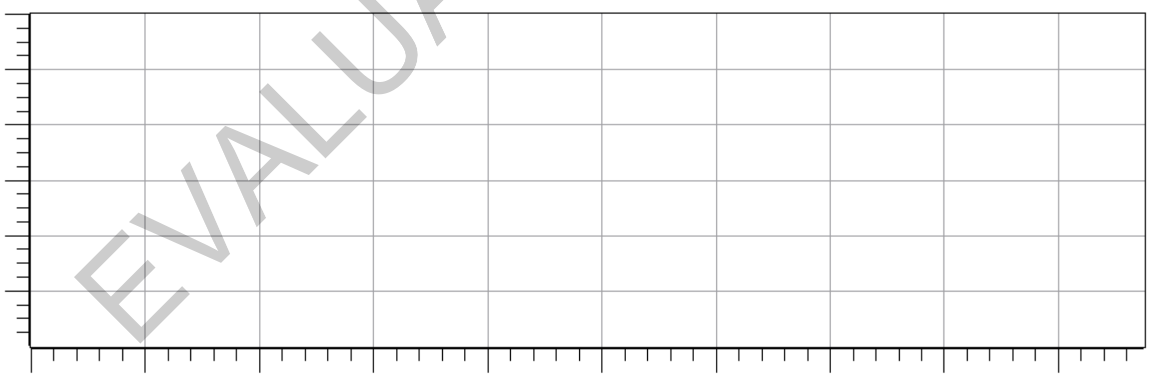
2. ☐ Create a table below that displays data you feel is relevant for others to know about the experiment *before* the pollutant was added. Below the table, add comments regarding the conditions in the chambers throughout the course of the experiment.

3. ☐ Create a table below that displays data you feel is relevant for others to know about the experiment *after* the pollutant was added.

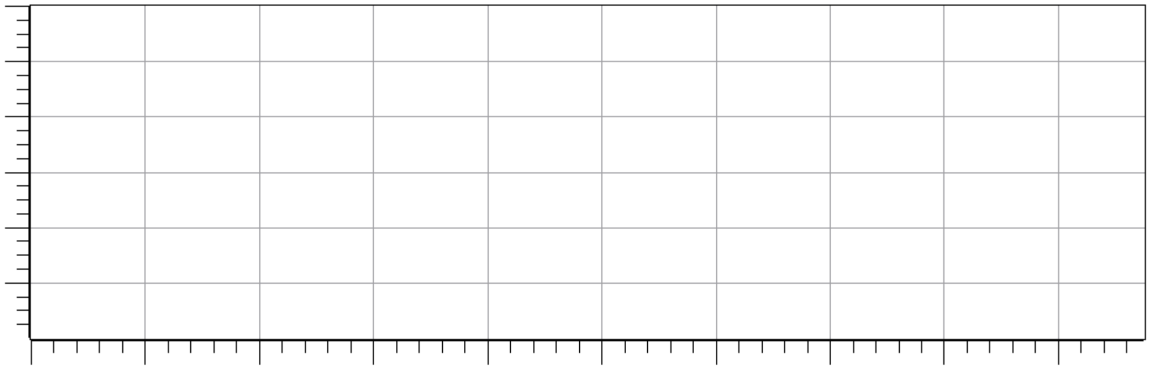
4. ☐ Graph the set of data that changed the most over the period of data collection prior to adding the pollutant.

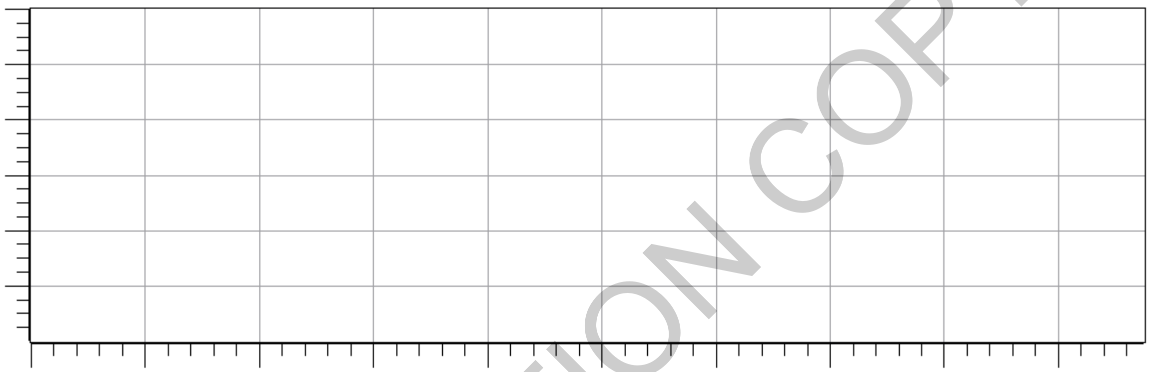


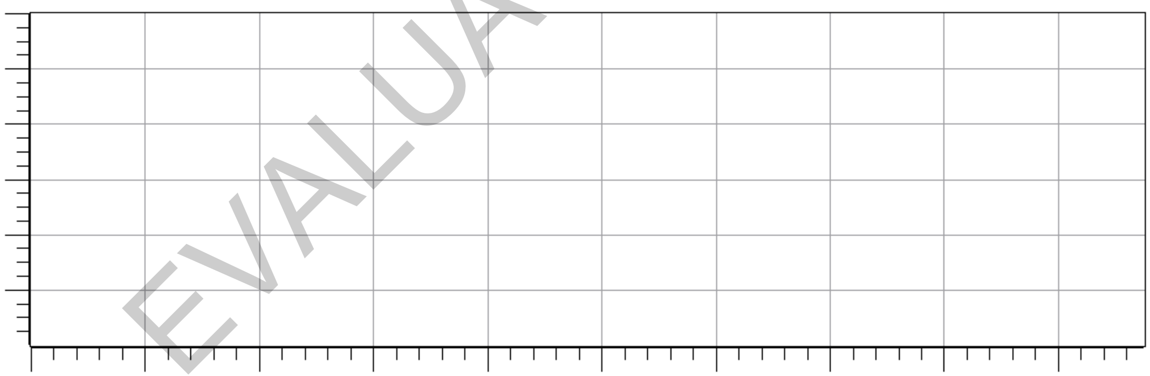




5. ☐ Graph the set of data that changed the most after the pollutant was added.







Analysis Questions

1. Describe any significant changes you observed in the chambers during the course of the experiment

2. What parameter changed the most prior to adding the pollutant? Explain why you think that factor changed the most.

3. What parameter changed the most after the pollutant was added? What is the significance of this?

4. The pollutant may, or may not, have affected your chambers.

a. If there was a significant change, what further tests would you want to conduct to determine if the pollutant was the sole cause of the change?

b. If there was no significant change, what further tests would you want to conduct to determine if the concentration of the pollutant is important?

Synthesis Questions

Use available resources to help you answer the following questions.

1. Design an additional study to determine how a different pollutant could affect the ecosystem. What pollutant would you use? What changes would you expect to see? How would you measure those changes?

2. Consider the type of pollutant you added to your system. Where could you find a similar pollution source in a natural environment?

3. Agricultural farming typically requires fertilizer to be added to the soil to ensure high quality crops. Rain and runoff wash excess fertilizers into local waterways. Based on your experience, what type of positive and negative consequences could result from this runoff?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following are considered consumers?

- **A.** Green plants
- **B.** Photosynthetic protists
- **C.** Parasites associated with plants and animals
- **D.** Chemosynthetic bacteria

2. Bacteria found in the soil are important in which of the following cycles?

- **A.** The water cycle
- **B.** The carbon cycle
- **C.** The nitrogen cycle
- **D.** The phosphorus cycle
- **E.** All of the above

3. The transitional zone found between two adjacent ecosystems is called the:

- **A.** Community
- **B.** Biome
- **C.** Ecotone
- **D.** Optimum
- **E.** Zone of tolerance

4. What types of organisms are found in the first trophic level in an ecosystem ?

- **A.** All heterotrophs
- **B.** Carnivores
- **C.** Herbivores
- **D.** All autotrophs
- **E.** A and B

5. Which of the following is not a natural process that occurs in ecosystems?

- **A.** Production of pollutants
- **B.** Erosion control and topsoil building
- **C.** The control of the earth's climate
- **D.** Maintaining of biogeochemical cycles
- **E.** Regulation of global carbon dioxide

6. Ecosystems are comprised of which of the following components:

- **A.** Living organisms only
- **B.** Non-living structures in the environment only
- **C.** Both biotic and abiotic factors
- **D.** Flora and fauna
- **E.** Fauna only

Name Period Date

11. Photosynthesis and Primary Productivity

Driving Questions

All life on earth is directly or indirectly reliant on the primary productivity of autotrophs, also known as primary producers.

- How do you determine the primary productivity of a plant?
- Why is primary productivity important?

Background

Primary productivity is principally the production of carbohydrates from carbon dioxide gas, electromagnetic radiation from the sun, and water, through the process of photosynthesis. All life on Earth is directly or indirectly reliant on primary production. The organisms responsible for primary production are known as primary producers, or autotrophs, organisms that can make their own food, usually through the process of photosynthesis. These primary producers form the base of the food chain, functioning at the first trophic level.

In terrestrial ecosystems, autotrophs are primarily vascular plants. In aquatic ecosystems, primary producers include photosynthetic bacteria, phytoplankton (single-celled photosynthetic aquatic organisms), multicellular algae, and vascular plants, such as *Elodea sp*. Most photosynthetic organisms contain chloroplasts, organelles that contain chlorophyll and in which photosynthesis takes place.

Primary productivity can be expressed as gross primary productivity (GPP) or net primary productivity (NPP). Net primary productivity is the total amount of carbohydrates produced in the ecosystem (the GPP) minus the carbohydrates consumed by the producers for their own aerobic cellular respiration (R). Net productivity reflects the carbohydrates available to other organisms in the ecosystem. Net primary production is the excess food produced by autotrophs that is available for consumption by other organisms in the food chain. The equation for calculating NPP is: NPP = GPP – R.

Materials and Equipment

For each student or group:

- Data collection system
- Dissolved oxygen or water quality sensor
- Photosynthesis tank
- Rubber stopper, #3 (included with photosynthesis tank)
- *Elodea sp.* plant (several sprigs)
- Magnetic stirrer and stir bar
- Black cloth, opaque, 50 cm x 50 cm
- Lamp, 100 W or high-intensity
- Dechlorinated tap water, 1 L[1]
- Ice (optional)

Alternative to the photosynthesis tank:

- Shallow pan or dish, large
- Large base and support rod
- Mineral oil
- Erlenmeyer flask, 250-mL
- 3-finger clamp

Safety

Follow all standard laboratory procedures.

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.

Set up an airtight chamber that contains *Elodea* plants, water, and a stir bar. Position the end of the DO probe about 1 cm above the stir bar.	Add water to the cooling chamber. Position a bright light near the chamber and turn on the light. Turn on the stirrer. Record data for 15 minutes.	Determine the rate change of the DO concentration for the two experimental conditions. Determine the primary productivity of the plant.	Connect a dissolved oxygen (DO) sensor to your data collection system. (You do not need to calibrate the DO sensor.)	Turn off the light, and cover the chamber with a dark cloth. Continue data recording for 15 minutes.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect the dissolved oxygen sensor (or water quality sensor) to the data collection system. �(2.1)

3. ☐ Display Dissolved oxygen concentration (mg/L) on the y-axis of a graph with Time on the x-axis. �(7.1.1)

Note: Another way of indicating "dissolved oxygen concentration" is by using brackets around the abbreviation for dissolved oxygen, "DO" as follows: [DO].

4. ☐ Put a stir bar into the photosynthesis tank.

5. ☐ Put several sprigs of *Elodea* plant in the tank so that it is loosely full of the plant, and fill the tank to the top with dechlorinated tap water.

6. ☐ Put the large two-hole stopper into the top of the tank.

Note: Water will overflow into the outer chamber.

7. ☐ Fill the outer tank to within about 2 cm from the top with tap water.

8. ☐ Why are you putting water in the outer chamber?

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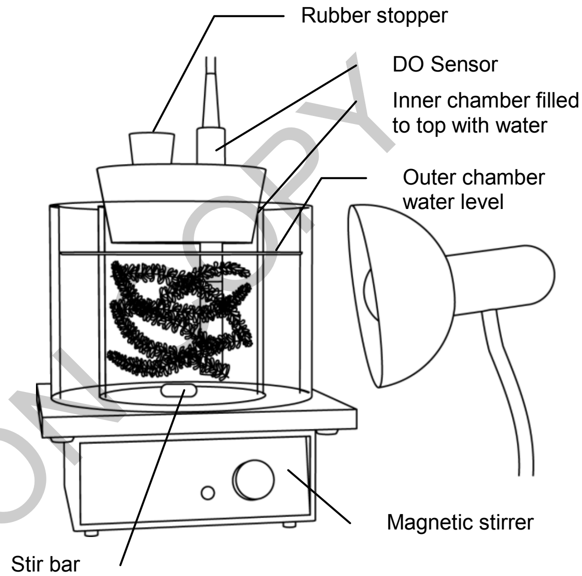
9. ☐ Place the photosynthesis tank on the magnetic stirrer.

10. ☐ Remove the dissolved oxygen sensor from the storage bottle.

Be sure to remove the white cap from the sensor, being careful not to touch the membrane at the end of the sensor.

11. ☐ Insert the end of the dissolved oxygen probe carefully through the larger opening in the two-hole stopper. Push the probe down until the end is positioned just above the stir bar (within 1 cm of the stir bar) and so the end is not touching the plant.



Note: Positioning the end of the probe is important so that the vigorous motion of the water will knock any air bubbles off the end of the probe.

Note: If the plant obstructs the end of the probe, take the stopper out of the tank and rearrange the plant. You may need to add more water to ensure the tank stays completely full and to eliminate all air pockets.

12. ☐ Place the photosynthesis tank on the magnetic stirrer.

13. ☐ Put a #2 or #3 rubber stopper into the other hole of the large two-hole stopper.

14. ☐ Place the lamp very near the photosynthesis tank so the light will shine on the *Elodea* plant.

Collect Data

15. ☐ Turn on the magnetic stirrer to a high speed so that the water circulates in the tank.

16. ☐ Turn on the light to its brightest setting.

17. ☐ Why are you using a magnetic stirrer? *Hint:* Consult the user manual for the dissolved oxygen sensor.

____

____

18. ☐ Start data recording. �(6.2)

19. ☐ Adjust the scale of the graph so the data fills the graph vertically and you can better see the changes in concentration of DO while recording. �(7.1.2)

Note: The initial concentration of DO should be between 4 and 8 mg/L; if it is not in that range, check the DO sensor to be sure it is in good working order.

20. ☐ Continue to record data with the light on for 15 minutes. *Do not stop recording data!*

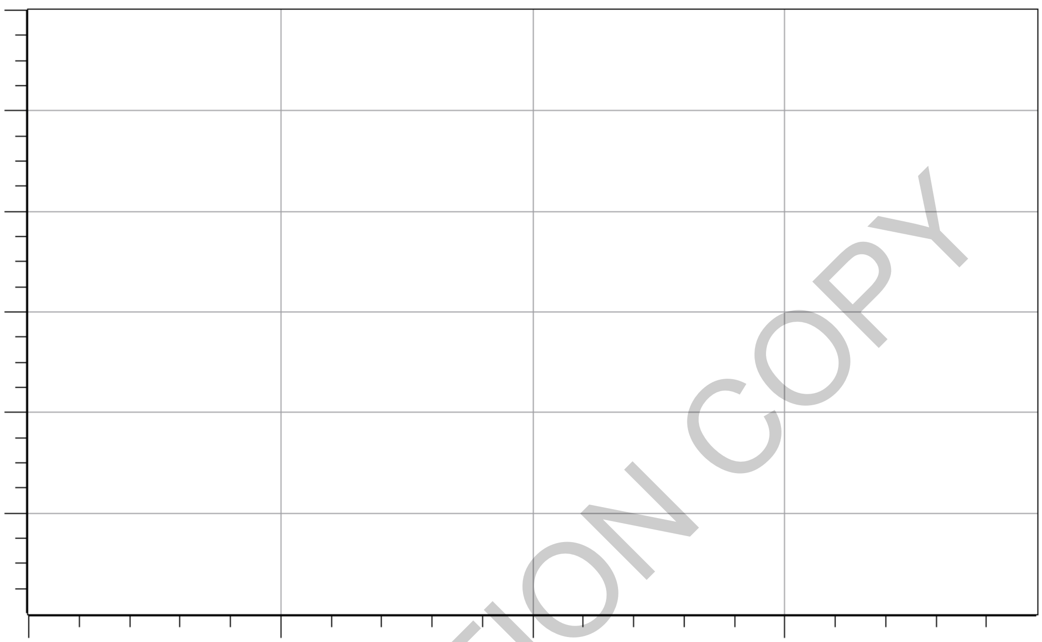
21. ☐ Turn the lamp off and carefully cover the setup with a black opaque cloth so the plant is in darkness.

22. ☐ Record data with the plant in darkness for 15 minutes, and then stop recording data. �(6.2)

23. ☐ Save your experiment. �(11.1)

Data Analysis

1. ☐ Draw a sketch of the Dissolved oxygen concentration versus Time graph. Label the x-axis and y-axis, including parameters and units as well as the point at which you turned off the light and covered the setup with the black opaque cloth.



2. ☐ Use your recorded data to find the rate of change in DO concentration when the light is shining on the plant and the rate of change in DO concentration when the plant is in darkness. Use 2 methods: 1) the slope of a linear fit line �(9.6) (7.1.4) and 2) the 2-point method. �(9.1) Show your work.

3. ☐ Record these values in Table 1.

Note: The rate of change in [DO] in darkness correlates to the consumption of carbohydrates due to cell respiration. A negative slope, which indicates a decrease in the dissolved oxygen concentration, refers to a positive value of cell respiration (R). For example, if the rate of change in [DO] is -1.0×10^{-3} mg/(L·s), then R is 1.0×10^{-3} mg/(L·s).

Table 1: Rate of change of dissolved oxygen concentration comparison

Light Setup	Initial [DO] (mg/L)	Final [DO] (mg/L)	Total Change in [DO] (mg/L)	Rate of Change in [DO] (mg/(L·s) (Linear Fit)	Rate of Change in [DO] (mg/(L·s) (2-Point Method)
Bright light					
Darkness					

Analysis Questions

1. **Describe how you would find the GPP rate, and then perform the calculation.**

2. **Describe how you would calculate the net amount (in mg) of glucose produced (NPP) by the plant in 24 hours if the present conditions were maintained and the plant was in darkness for 12 of those hours. Then perform the calculation.**

3. **How did the rate of change calculated using the two-point method compare with the rate of change as determined by the slope at a linear region of the plotted data?**

4. **What does a negative slope (rate of change) value indicate?**

5. **What processes are causing the change in dissolved oxygen concentration under the conditions of bright light?**

6. **What process causes the change in dissolved oxygen concentration under the conditions of darkness?**

7. **Does the dissolved oxygen that you measured under lighted conditions represent the gross primary productivity (GPP) or the net primary productivity (NPP) rate? Explain.**

8. **In this exploration, which is the independent variable, which is the dependent variable, and which factors are controlled?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. What do you think would happen to this closed system if it were maintained for 2 weeks under these conditions?

2. What are some of the methods currently used by scientists to determine primary production levels regionally and globally?

3. What are some limitations to these methods of determining primary production?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The first trophic level in an ecosystem refers to

- **A.** Carnivores
- **B.** Consumers
- **C.** Herbivores
- **D.** All autotrophs
- **E.** B and D

2. Autotrophs responsible for primary productivity in the oceans include

- **A.** Kelp
- **B.** Zooplankton
- **C.** Photosynthetic bacteria
- **D.** Phytoplankton
- **E.** A, C, and D
- **F.** All of the above

3. Most of the primary production in the oceans occurs in the

- **A.** Euphotic zone
- **B.** Dysphotic zone
- **C.** Aphotic zone
- **D.** Abyssal zone
- **E.** Twilight zone

4. Gross primary productivity is equivalent to net primary productivity plus

- **A.** The amount of dead organic material that sinks to the bottom of a body of water or falls as litter to the ground
- **B.** The amount of organic material consumed in cellular respiration
- **C.** The amount of water transpired by plants
- **D.** None of these is true

5. In this activity, the gross primary productivity was measured by

- **A.** Determining the mass of the plant
- **B.** Determining the rate of oxygen gas consumption during cellular respiration
- **C.** Determining the rate of oxygen gas production during photosynthesis
- **D.** B and C
- **E.** All of the above

12. Photosynthesis and Cell Respiration in a Terrarium

Driving Questions

Terrariums are excellent closed systems for environmental studies. Terrariums allow you to change one variable at a time, control other variables, and monitor multiple variables in an easily maintained system.

- How can you create a test system using a terrarium that will help you explore the effects of environmental factors on photosynthesis and cellular respiration?

Background

Environmental studies require investigations both in the field and in the laboratory. Because the earth's environment is complex, an investigator in the field must collect a wide variety of data and look for patterns and correlations. When patterns or correlations are discovered, these can be further investigated in controlled laboratory environments.

The test system for this lab is a closed system for examining factors that affect photosynthesis and cellular respiration. The end points (dependent variables) are the rate of change in concentration of CO_2 gas and O_2 gas. The rates of change in CO_2 gas and O_2 gas are used as end points because these factors are tightly coupled with plant growth and aerobic cellular respiration, often manifesting within minutes of changing the independent variable. These types of evidence of effects on plant growth and cellular respiration can be augmented with other evidence, such as rates of increase in plant mass, measurable evidence of growth, or visual evidence of disease.

Some of the topics that could be investigated using this test system include the effect on the rates of photosynthesis or aerobic cellular respiration, or both, of the following: light intensity, light wavelength, light source types, elevated CO_2 gas concentration in the atmosphere, acid conditions, introduced organisms, fertilizers, toxins, and temperature. No doubt there are many more topics you would like to explore.

Materials and Equipment

For each student or group:

- Data collection system
- Oxygen gas sensor
- Carbon dioxide gas sensor
- Temperature sensor
- Sensor extension cable
- USB hub (depending on data collection system)
- EcoChamber™
- Fast-growing, small, potted plant
- Opaque cloth, about 1 m
- Strong incandescent or full-spectrum fluorescent light source

Safety

Follow all standard laboratory procedures.

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.

○	○	○	○	○
Set up your data collection system to monitor CO_2 gas, O_2 gas, and temperature.	Turn the light off and cover the EcoChamber with an opaque cloth. Continue recording data for another 900 seconds.	Analyze your data and develop ideas for how to use this system to investigate questions in environmental studies.	Place a light source near the EcoChamber and turn it on. Record data for 900 seconds (15 minutes.)	Set up the EcoChamber with CO_2 gas, O_2 gas, and temperature sensors, put a plant in it, and make it airtight.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

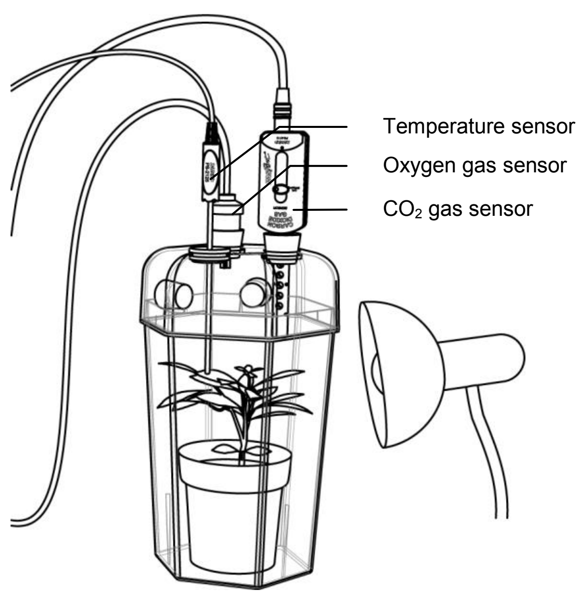
Set Up

1. ☐ Put a fast-growing potted plant that has moist (not wet) soil into the EcoChamber™.

2. ☐ Arrange the CO_2 gas sensor, O_2 gas sensor, and temperature sensor so they can detect changes inside the EcoChamber.

3. ☐ Seal the EcoChamber so it is airtight.

Hint: One way to be sure that the EcoChamber is airtight is to exhale several times into the empty EcoChamber to raise the CO_2 level of the air in the EcoChamber relative to the room air. Then seal the



EcoChamber and monitor the CO_2 level for several minutes. After the reading stabilizes, the level should not drop. If it does, you probably have a leak. Once you have learned how to make the EcoChamber airtight, use this procedure in your investigations.

4. ☐ Start a new experiment on the data collection system. �(1.2)

5. ☐ Connect all three sensors to the data collection system. �(2.2)

Note: Use the sensor extension cable to connect the CO_2 gas sensor.

6. ☐ Set up appropriate displays to view the data while it is being collected.

Note: For longer investigations, you may need to decrease the sampling rate of the sensors. Choose a time interval that will provide adequate information while limiting the number of data points collected to a practical quantity. �(5.1) For example, if you choose to monitor the EcoChamber for 24 hours, you might set the sampling rate to 1 sample every 10 minutes. Or if you choose to monitor for a week, you might set the sampling rate to 1 sample every 30 minutes.

7. ☐ Set up a strong light source near the EcoChamber and shine it directly at the plant inside.

Collect Data

8. ☐ Start data recording. �(6.2)

9. ☐ Continue to record data with the light on for 15 minutes.

10. ☐ After 15 minutes, turn the lamp off and carefully cover the setup with an opaque cloth so the plant is in darkness. *Do not stop recording data.*

11. ☐ Record data with the plant in darkness for 15 minutes, and then stop data recording. �(6.2)

12. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

Data Analysis

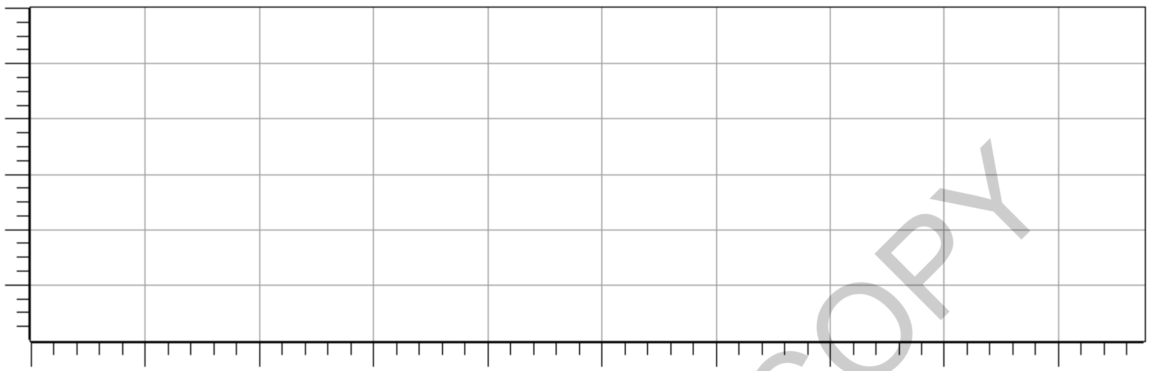
1. ☐ Display your data as graphs. �(7.1.1)

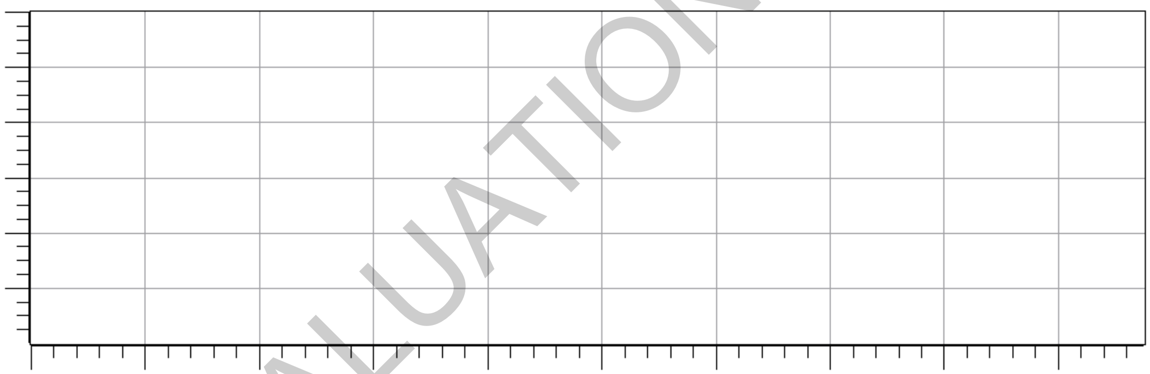
2. ☐ Adjust the graphs to fill the screen vertically, and adjust the x-axis to make the time scales equivalent between graphs. �(7.1.2)

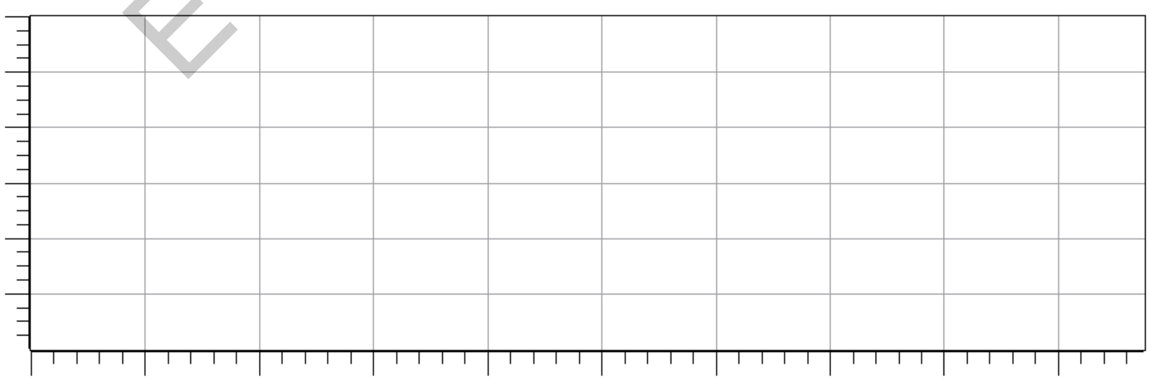
3. ☐ Sketch your graphs. Label the overall graph, the x-axes, the y-axes, and include units on your axes.

4. ☐ Indicate on your graphs where you turned on the bright light and where you turned the light off and covered the EcoChamber with a cloth.

5. ☐ Label the areas on the graphs where the pattern of data changes with numbers or letters.







Analysis Questions

1. Which does the CO_2 gas concentration represent: the rate of aerobic cellular respiration, the rate of photosynthesis, or the combination of rates of aerobic cellular respiration and photosynthesis? Why?

2. Which does the O_2 gas level represent: the rate of aerobic cellular respiration, the rate of photosynthesis, or the combination of rates of aerobic cellular respiration and photosynthesis? Why?

3. Why are the changes in CO_2 gas concentration more apparent than those of O_2 gas? *Hint:* Think about the relative levels of these gases in the atmosphere.

4. Discuss what was occurring in the areas where the pattern of data changed (label or letter the areas on your graph for easy reference).

5. What was the independent variable in this activity?

6. **What were the dependent variables in this activity?**

7. **What factors did you try to hold constant during this activity?**

8. **How could you design an investigation that controls the change in temperature?**

Synthesis Questions

Use available resources to help you answer the following questions.

Begin designing an experiment that investigates an aspect of the weather, using the EcoChamber. These questions will assist you in developing a proposal.

1. **What question would you like to investigate using this system?**

2. **What independent variables will you test to investigate the question? Why?**

3. What will be the hypothesis to test this issue using the EcoChamber?

4. How will you design the investigation to test your hypothesis?

5. How will you analyze the results of your experiment?

6. What materials and equipment will you need to conduct your investigation?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The design of a research study generally includes:

- **A.** A hypothesis to test
- **B.** A defined test system that controls variables
- **C.** A controllable independent variable
- **D.** A measurable dependent variable
- **E.** Control or baseline measurements
- **F.** All of the above

2. In a scientific experiment, an independent variable is:

- **A.** A variable that has nothing to do with other variables
- **B.** Something that changes in response to another variable
- **C.** Something that you change to affect another variable
- **D.** Something that you try to keep constant

3. In a scientific experiment, a dependent variable is:

- **A.** A variable that has nothing to do with other variables
- **B.** Something that changes in response to changes in another variable
- **C.** Something that you change to affect another variable
- **D.** Something that you try to keep constant

4. In the test system in this activity, the independent variable is:

- **A.** Temperature
- **B.** Light energy
- **C.** Carbon dioxide gas level
- **D.** Oxygen gas level
- **E.** Both C and D

5. In the test system in this activity, the dependent variable is:

- **A.** Temperature
- **B.** Light energy
- **C.** Carbon dioxide gas level
- **D.** Oxygen gas level
- **E.** A, C, and D

13. Cellular Respiration and the Carbon Cycle

Driving Questions

When dormant seeds are exposed to water, they begin to germinate. By measuring the level of CO_2 gas in closed systems containing dormant or germinating seeds, you can explore the following:

- What happens to carbon dioxide gas concentrations in a closed system containing germinating seeds and air?
- What does cellular respiration have to do with the carbon cycle?
- Can germinating seeds serve as a model for cellular respiration? Why or why not?

Background

In the germinating seed, cells within the growing plant embryo use energy-storage molecules (oils, starches, sugars) stored in the seed for food to fuel its life processes. The energy from the food is extracted through a process of cellular respiration. In a series of hundreds of biochemical reactions, the carbon atoms that are bound in the large energy-storage molecules are combined with oxygen gas to produce carbon dioxide gas, water vapor, and energy that is vital to living processes.

The carbon dioxide gas that is released into the environment is then available to plants for use in the process of photosynthesis. During photosynthesis, plants trap energy from the sun to convert carbon dioxide gas and water into complex sugar molecules that store potential chemical energy. The carbon dioxide gas and water vapor molecules released into the atmosphere during cellular respiration also function as natural "greenhouse gases," causing the atmosphere to retain more of the sun's energy through the natural greenhouse effect.

Materials and Equipment

For each student or group:

- Data collection system
- CO_2 gas sensor
- Sensor extension cable
- Sampling bottle or Erlenmeyer flask (2), 125-mL
- Dissecting microscope or magnifying glass
- Knife or scalpel
- Parafilm® (if using an Erlenmeyer flask)
- Dry bean seeds (11)
- Germinating bean seeds (11)

Safety

Add this important safety precaution to your normal laboratory procedures:

- Use care with the knife or scalpel.

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.

○	○	○	○	○
Insert the sensor into the bottle and seal the chamber to create a closed system.	Put dry seeds in one bottle and soaked seeds in the other.	Analyze data, comparing test conditions.	Measure the concentration of CO_2 inside the bottle containing dry seeds.	Repeat the measurement of CO_2 in the bottle containing soaked seeds.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Observing and comparing the morphology of dormant and germinating bean seeds

1. ☐ Obtain one dry seed and one soaked seed. Use a knife or scalpel to bisect the seeds longitudinally into halves.

2. ☐ Use a magnifying glass or dissecting microscope to observe the interior of the seed.

3. ☐ Sketch the major morphologic features of the bean seed. Label the cotyledon, embryo, and seed coat.

4. ☐ List some differences you observe in the appearance of the dry versus the soaked seed.

5. ☐ What is a sign that the seed has changed from a dormant state to a growing state, in other words, that the seed is germinating?

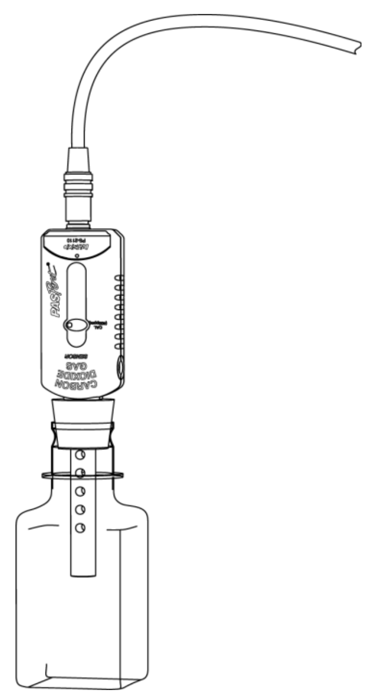
Part Two – Comparing the CO_2 gas concentrations of a closed system containing dormant seeds versus a closed system containing germinating seeds

Set Up

6. ☐ Start a new experiment on the data collection system. �[1.2]

7. ☐ Connect a CO_2 gas sensor to the data collection system using an extension cable. �[2.1]

8. ☐ Display CO_2 gas concentration on the y-axis of a graph with Time on the x-axis. �[7.1.1]



9. ☐ Why is a parameter versus time graph chosen to view the data? What is another way to view the data?

10. ☐ Put 10 dry seeds into one sampling bottle and 10 soaked seeds in the other sampling bottle.

11. ☐ Insert the end of the CO_2 gas sensor into the sampling bottle containing the dry seeds and firmly plug the end of the sampling bottle with the rubber stopper.

Note: If you are using an Erlenmeyer flask rather than a sampling bottle, seal the top with Parafilm®.

12. ☐ Why are you using dry and soaked seeds?

____

____

____

13. ☐ Why are you sealing the bottles with a rubber stopper or Parafilm?

____

____

14. ☐ Predict what will happen to the CO_2 concentration during data recording? Why?

____

____

____

Collect Data

15. ☐ Start data recording and record data for 10 minutes. �(6.2)

Note: Avoid bumping the equipment because jarring or bumping the sensor might cause the sensor to record erratically.

16. ☐ Stop data recording. �(6.2)

Write the run number here____ _____.

17. ☐ Switch the sensor to the other sampling bottle, seal with Parafilm if necessary.

18. ☐ Record data for 10 minutes. �(6.2)

19. ☐ Stop data recording. �(6.2)

Write the run number here___________.

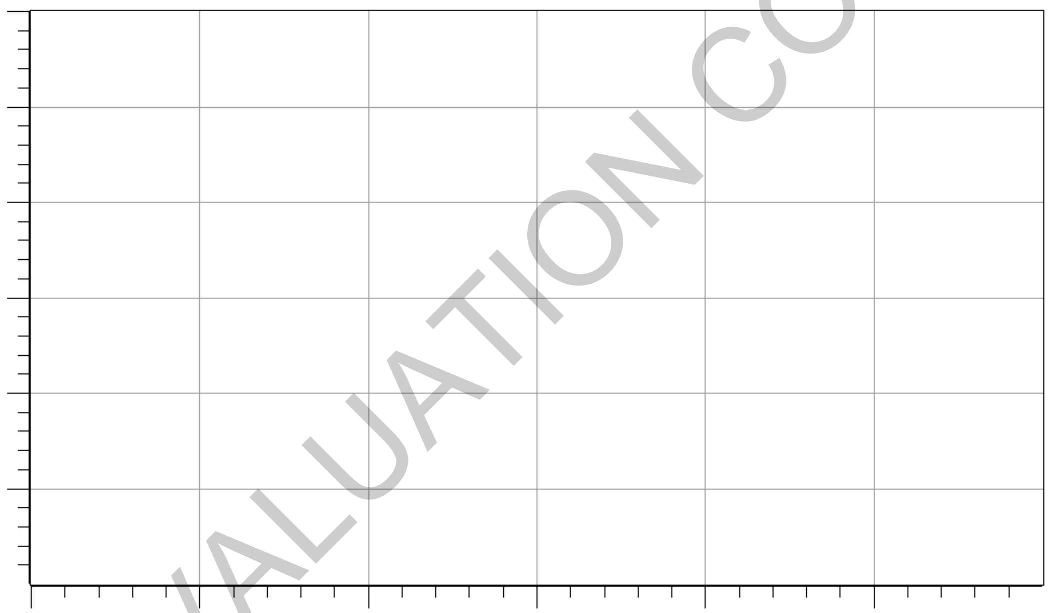
20. ☐ Save your experiment, �(11.1) and clean up according to your teacher's instructions.

Data Analysis

1. ☐ Display both data runs on the graph display. �(7.1.3)

2. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

3. ☐ On the graph below, sketch the plotted data on your graph display. Be sure to label the x-axis and y-axis regarding parameter and units of measurement. Label each data run.



4. ☐ Find the initial and final CO_2 concentrations for each run �(9.1) and record them in the data table.

5. ☐ Calculate the change in CO_2 concentration for each experimental condition and record these values in Table 1.

Table 1: CO_2 concentration of dry seeds and germinating seeds

	Initial CO_2 Concentration (ppm)	Final CO_2 Concentration (ppm)	Change in CO_2 Concentration (ppm)
Dry seeds			
Germinating seeds			

Analysis Questions

1. **Compare the change in CO_2 concentration for dry seeds versus soaked seeds.**

2. **What can you conclude about the soaked seeds regarding CO_2?**

3. **Compare your prediction to the data you collected. Were you correct or incorrect in your prediction? Explain.**

4. **In this experiment, what is the independent variable and what is the dependent variable?**

5. **What would you expect to happen to the concentration of oxygen gas in the bottle? Why? How could you test this hypothesis?**

6. **What are the gaseous products of cellular respiration that are released from the cells of the germinating seeds?**

7. **Where did the seed get the fuel (glucose) for cellular respiration?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Consider the following overall summary equation of the hundreds of biochemical reactions involved in aerobic cellular respiration:**

$$C_6H_{12}O_6 + 6O_2 + ADP + P_{inorganic} \rightarrow 6CO_2 + 6H_2O + ATP$$

Write this equation using words instead of chemical symbols. Write an equation for this process using chemical notation.

2. **In this activity, a germinating seed is used as a model to represent cellular respiration in all living things. Why is it reasonable to create a model for cellular respiration?**

3. What is the effect of cellular respiration on the atmosphere? How is the natural greenhouse effect influenced?

4. What role does cellular respiration in plants and other living organisms play in the carbon cycle?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. In this activity, which of the following is an example of a chemical element being recombined as it passes through a link in the food web?

- **A.** Carbon dioxide is being passed from the energy storage molecule in the bean seed to the atmosphere.
- **B.** Carbon from the energy storage molecule (glucose) in the bean seed is being recombined with oxygen and passed as CO_2 gas into the atmosphere.
- **C.** Oxygen gas (O_2) from the atmosphere is being recombined in the bean seed into different molecules (H_2O and CO_2).
- **D.** Both B and C are examples.

2. How did the energy-storage molecules in the bean seed get there?

- **A.** The bean seed gathered these molecules from its surrounding environment.
- **B.** The plant that made the seeds gathered energy from the sun through photosynthesis and stored it in the energy-storage molecules in the seed.
- **C.** The germinating seed gathered energy from the sun and stored it in the energy-storage molecules.
- **D.** Both B and C are correct answers.

3. The food energy that the plant uses for cellular respiration is stored in the seed's

- **A.** Cell wall
- **B.** Embryo
- **C.** Cotyledons
- **D.** DNA

4. Beans and coal both have stored energy. Where did the energy originally come from that is stored in beans and coal?

- **A.** From the earth's gravity
- **B.** From the sun's light
- **C.** From the heat in the earth's core
- **D.** From the carbon dioxide in the air

5. What natural "greenhouse gases" were produced by the bean seeds during cellular respiration?

- **A.** Carbon dioxide gas
- **B.** Oxygen gas
- **C.** Water vapor
- **D.** Both A and C are correct

Name Period Date

14. Energy Content of Food

Driving Questions

All organisms on earth depend on the ability of plants to capture energy from sunlight and store it in chemical bonds in energy-rich molecules, which they can use as food for their own energy needs.

- How much energy is stored in some common food items?
- Which type of food contains the most concentrated amounts of energy?

Background

The entire food web depends on the primary productivity of plants. Plants consume much of the energy they capture by photosynthesis. They also store some of this energy in large energy-storage molecules. These are formed into energy-rich substances known as food. Other organisms eat this food to supply themselves with energy.

The amount of energy stored in food is measured in terms of calories. One calorie is equal to the amount of heat energy required to increase 1 gram (g) of water by 1 degree Celsius (°C). One calorie equals 4.186 joules (J), another unit used to measure energy. This calorie is also called a small calorie or gram calorie. There are 1000 small calories in each large Calorie. Thus, declaring that an average adult man needs about 2000 Calories of food each day means that he needs 2,000,000 small calories; 8,272,000 joules; or 8,272 kilojoules per day.

Materials and Equipment

For each student or group:

- Mobile data collection system
- Temperature sensor
- Fast-response temperature probe
- Electronic balance
- Large base and support rod, rod and clamp
- Graduated cylinder, 100 mL
- One-hole rubber stopper (4), ~1 1/2" top diameter
- Aluminum pie pan (4)
- Marking pen
- Plastic straw
- Food sample (4)
- Wooden matches or starter wand
- Paperclip, large (5)
- Aluminum soda can (4)
- Water, 200 mL
- Tape
- Cardboard box, large

Safety

Add these important safety precautions to your normal laboratory procedures:

- ♦ Use appropriate caution with burning and hot materials, such as matches, starter wands, and foods.
- ♦ Conduct the lab in a well-ventilated area, preferably outside or under a ventilated hood.

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.

◯	◯	◯	◯	◯
Collect temperature data while burning each of the food samples.	Determine the mass of the water, food sample, paper clip, rubber stopper and pie pan before burning.	Set up the equipment, including items to hold the food, hang the can of water, and secure the probe.	Take the equipment to set up outside or to a ventilated hood.	Analyze the data, and determine who won the contest.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Preparation

Set Up

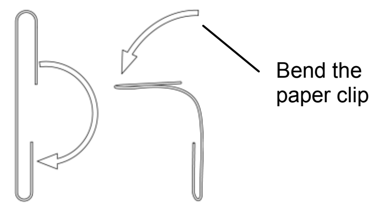
1. ☐ Start a new experiment on the data collection system. � (1.2)

2. ☐ Connect the fast-response temperature sensor to the data collection system. � (2.1)

3. ☐ Display data on the graph to show Temperature versus Time. �(7.1.1)

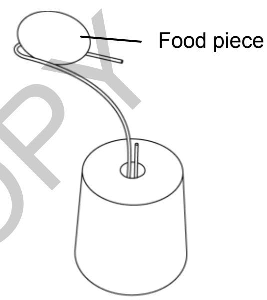
4. ☐ Label each of four aluminum soda cans with one of the following: marshmallow, popcorn, peanut, and cashew.

5. ☐ Open a large paper clip, and bend the top half so it is perpendicular to the bottom half.



Note: Bend the paper clip over the side of a piece of cardboard or cover of a hard-cover book. The paper clip should form a flat platform to hold the food piece.

6. ☐ Insert one end of the paper clip into a one-hole rubber stopper as shown in the illustration.



7. ☐ Make three more paper clip platforms and insert each one in a rubber stopper.

Note: For the following instructions, use the balance to determine mass, and use Table 1 in the Data Analysis section when instructed to record data.

8. ☐ Determine the mass of each empty aluminum can, and record the data in Table 1.

9. ☐ Pour 50 mL of water into each can.

10. ☐ Determine the mass of each can plus water, and record the data in Table 1.

11. ☐ Determine the mass of each sample of food, and record the data in Table 1.

12. ☐ For each food sample, put a paper clip, rubber stopper and the sample of food into a pie pan.

13. ☐ Determine the mass for each set of a paper clip, a rubber stopper, a sample of food, and a pie pan, and record the data in Table 1.

14. ☐ Make a hanger for the soda can by bending open another paper clip.

15. ☐ Tape a plastic straw to the cord just above the bulb of the quick-response temperature probe.

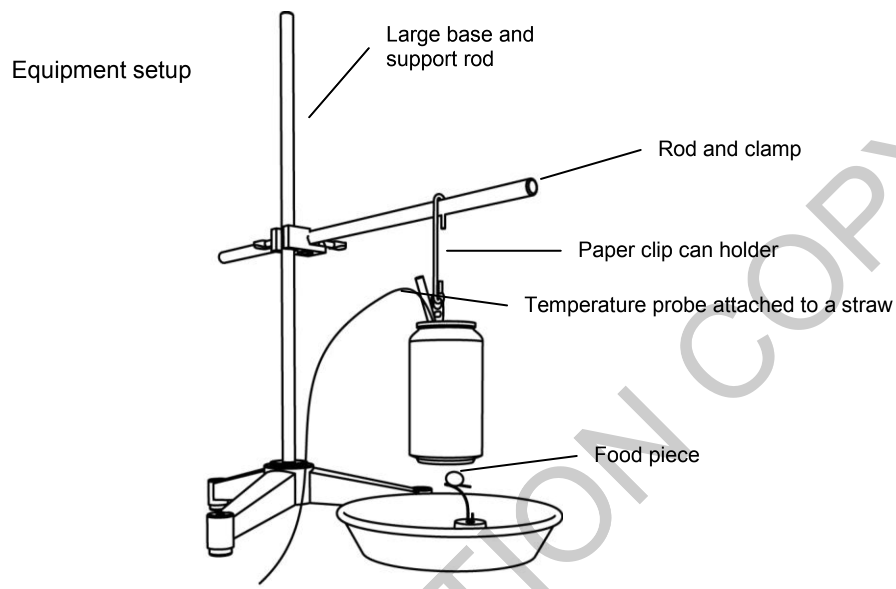
Note: The straw taped to the sensor cord helps prevent the sensor from touching the can. This helps assure accurate measurements.

16. ☐ Take the setup to a ventilated hood inside or, alternatively, use a cardboard box outside as a wind break.

Note: The setup includes the data collection system, temperature sensor with a straw taped to the cord, and four sets of food samples with a paper clip and rubber stopper in a pie pan.

Part 2 – Measure the energy content of the marshmallow

17. ☐ Hang a soda can to the rod with the paper clip, and adjust the height of the rod stand so the bottom of the can is about one centimeter above the food sample on the paper clip platform in the pie pan.



Note: Testing this adjustment before proceeding helps assure that the flame of the burning food sample will directly heat the can of water.

18. ☐ Hang the soda can labeled "marshmallow" on the rod with a paper clip.

19. ☐ Insert the straw taped to the sensor cord into the water, and tape the cord to the can so that the end of the probe does not touch the bottom or sides of the can.

20. ☐ Put the paper clip and rubber stopper in a pie pan close to the aluminum can, but not directly under it, and place the marshmallow on the paper clip platform.

Collect Data

CAUTION: Keep hair, clothing, and other items away from open flames.

Note: Whether indoors or outdoors, minimize air circulation when the food is burning. This helps assure that the flame stays lit and remains in contact with the bottom of the aluminum can. You can use a large cardboard box set on its side with the lid flaps extended to shelter the burning food from air movement. If the day is windy, consider postponing the activity until a day when the winds are calm.

21. ☐ Start data recording. �(6.2)

22. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

23. ☐ Using the wooden match or starter wand, begin burning the food sample.

24. ☐ Adjust the rod with the hanging soda can so the bottom of the soda can is directly over the burning food sample on the paper clip above the pie pan as shown in the equipment setup graphic.

25. ☐ Immediately after the food sample stops burning, gently twirl the can to stir the water with the probe still in it.

26. ☐ Stop recording data when the temperature stops rising, which may be about 30 seconds after the food sample stops burning. �(6.2)

27. ☐ Name the data run "Marshmallow". �(8.2)

28. ☐ Remove the sensor from the soda can, and take the hanging soda can off the paper clip hanger.

Part 3 – Popcorn, peanut, and cashew

29. ☐ Repeat the steps in Part 2 for the popcorn, the peanut, and the cashew.

30. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

Data Analysis

For each food sample, many of the rows in Table 1 were filled in while completing the steps in the Procedure section. The following instructions help you calculate the remaining rows.

1. ☐ Display your run named "Marshmallow" on a graph of Temperature versus Time. �(7.1.7) Adjust the scale of the graph to show all data. �(7.1.2)

2. ☐ Find the initial and final temperatures �(9.1) and record these values in Table 1.

3. ☐ Repeat this procedure for your other three data runs.

4. ☐ For each food trial, determine the following and record the values in Table 1:

- **a.** mass of the water
- **b.** change in mass of the food sample after burning
- **c.** change in temperature of the water
- **d.** heat Q (in joules) transferred to the water ($Q = m \% c \% \Delta T$)
- **e.** the energy content (calories) of the burned food sample in terms of calories, that is, the portion of the heat that was transferred to the water, which is equal to Q/(4.186 calories/joule)
- **f.** energy (Calories) per gram of food burned
- **g.** total energy (Calories) contained in the food piece

Table 1: Mass, temperature, and energy data for food samples

Item	Marsh-mallow	Popcorn	Peanut	Cashew
Mass of empty can (g)				
Mass of can + water (g)				
Mass of water (g)				
Mass of food sample (g)				
Before burning, mass of food sample + clip + rubber stopper + pie pan (g)				
After burning, mass of food sample + clip + rubber stopper + pie pan (g)				
Change in mass of food sample (g)				
Water temperature before burning (°C)				
Water temperature after burning (°C)				
Change in temperature, ΔT (°C)				
Heat Q transferred to the water (joule)				
Energy content of burned food (calorie), Q/(4.186 calories/joule)				
(Large) Calories/gram of food sample				
Total Calories in food sample (Calorie)				

Analysis Questions

1. **According to the United States Department of Agriculture (USDA), there are about 5.9 Calories in 1 gram of peanuts. What percentage of this accepted value was measured in your calorimeter?**

2. **Assume you had similar percentage for the other food items. What would be the accepted value for the other food samples?**

3. **Compare your predictions with your data.**

4. **For the contest, add the total (adjusted) Calories from the four samples. Add this total to the total of every experiment in the class. Divide this grand total by the number of experiments in the class to calculate the average number of Calories for these four samples. The guess that came closest to this average wins the contest.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Carbohydrates and proteins contain 4 Calories/gram, whereas fats contain 9 Calories/gram. From this information, what can you say about the composition of the 4 food items you tested?**

2. **What happened to the heat that was not captured in this calorimeter?**

3. **What happened to the mass that was lost during burning?**

4. **Conduct research on the process using bomb calorimetry that is usually used to determine the caloric content of food. Describe the process.**

5. **Discuss the role of plants in the energy cycle of living organisms. Why is the productivity of plants of concern to other organisms?**

6. **Discuss the similarities and differences of aerobic cellular respiration and oxidative combustion (burning).**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. A calorie is defined in terms of a certain amount of what?

- **A.** Food
- **B.** Weight in milligrams
- **C.** Heat
- **D.** Fat
- **E.** Carbohydrate

2. Which foods have the greatest density of calories?

- **A.** Carbohydrates
- **B.** Sugars
- **C.** Starches
- **D.** Fats
- **E.** Proteins

3. When foods are burned by combustion or oxidized during cellular respiration, in what form is the mass lost to the environment?

- **A.** Energy
- **B.** Carbon dioxide
- **C.** Water vapor
- **D.** Oxygen gas
- **E.** Both B and C

15. Weather in a Terrarium

Driving Questions

Terrariums are excellent closed systems for environmental studies, allowing the investigator to change one variable at a time, control other variables, and monitor multiple variables in an easily maintained system.

- How can you create a test system using a terrarium that will help you explore the effects of environmental factors on weather parameters?

Background

Environmental studies require investigations both in the field and in the laboratory. Because the earth's environment is complex, an investigator in the field must collect a wide variety of data and look for patterns and correlations. When patterns or correlations are discovered, these can be further investigated in controlled laboratory environments. Terrariums are excellent closed systems for environmental studies, allowing the investigator to change one variable at a time, control other variables, and monitor multiple variables in an easily maintained system.

Student-designed investigations are important components of Advanced Environmental Science courses, and long-term projects are appropriate. During this activity, students become familiar with a test system, pose a hypothesis, and then design investigations to test the hypothesis. This activity provides some ideas for investigation and a structure to get students started with their inquiries. It also includes methods for reporting results, and you can choose which is appropriate for the classroom situation.

The test system for this activity is a closed system for examining factors that affect weather. The terrarium functions as a model for the earth and its troposphere. The dependent variables are temperature, barometric pressure, relative humidity, absolute humidity, and dew point. Some topics that could be investigated include the effect on the dependent variables of the following: light intensity, vegetation, water bodies, and land materials. No doubt your students will have many more creative ideas for what they would like to test.

Materials and Equipment

For each student or group:

- Data collection system
- Weather sensor
- Light sensor
- Sensor extension cable (2)
- EcoChamber
- Strong incandescent or full-spectrum fluorescent light source
- Fast-growing, small, potted plant

Safety

Follow all standard laboratory procedures.

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.

○	○	○	○	○
Add a potted plant to the terrarium. Continue recording data for another 5 minutes.	Set up a weather sensor so it can measure the temperature, humidity, barometric pressure, and dew point inside a terrarium.	Determine the effects of light energy and vegetation on the weather variables in the terrarium.	Seal the terrarium airtight. Collect data for 5 minutes. Turn on the light and collect data for another 5 minutes.	Set up a strong light source so it will shine into the terrarium.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Set Up

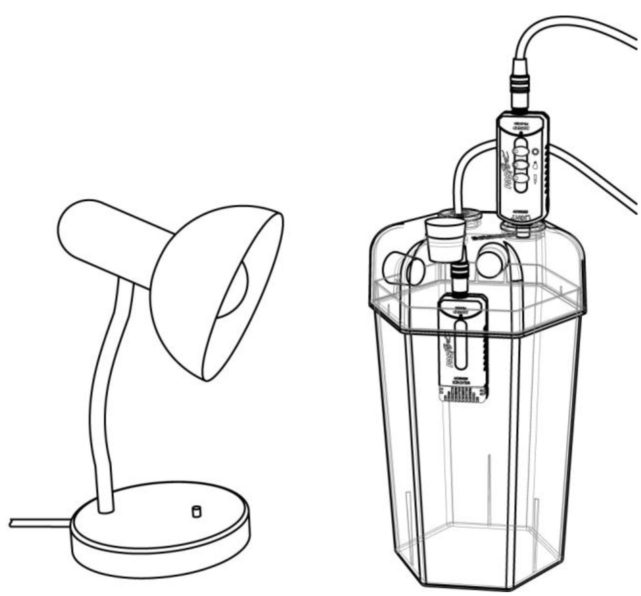
1. ☐ Arrange the weather and light sensors so they can detect changes inside the terrarium.

2. ☐ Seal the terrarium so it is airtight.

3. ☐ Start a new experiment on the data collection system. �(1.2)

4. ☐ Connect the sensors to the data collection system using the sensor extension cables. �(2.2)

5. ☐ Set up appropriate displays to view the data while it is being collected.



6. ☐ Set up a strong light source near the terrarium to shine directly at it. *Do not turn it on yet.*

7. ☐ What is the light source a model for? What is the terrarium a model for?

Collect Data

8. ☐ Start recording data. �(6.2)

9. ☐ Continue to record data with the light off for 5 minutes. *Do not stop recording data.*

10. ☐ Turn the light on and continue recording data for 5 minutes. *Do not stop recording data.*

11. ☐ Open the terrarium and add a potted plant. Close the terrarium. Continue recording data for 5 minutes.

12. ☐ Stop recording data. �(6.2)

13. ☐ Turn off the light.

14. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

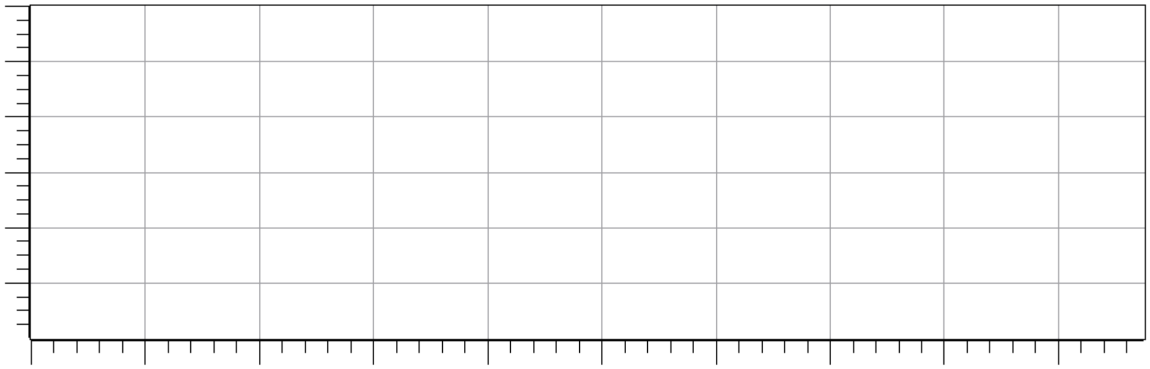
Data Analysis

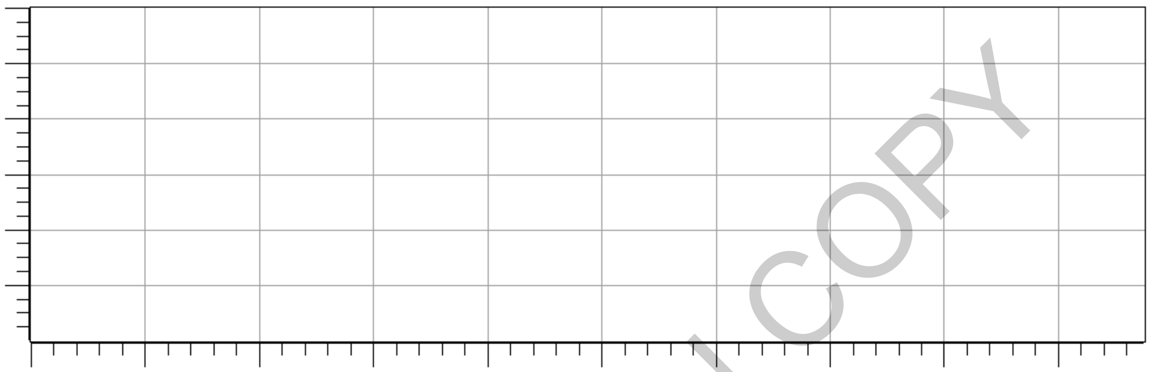
1. ☐ Display your data as graphs, and adjust the graphs to fill the screen vertically. �(7.1.1) Adjust the x-axis to make the time scales equivalent between graphs. �(7.1.2)

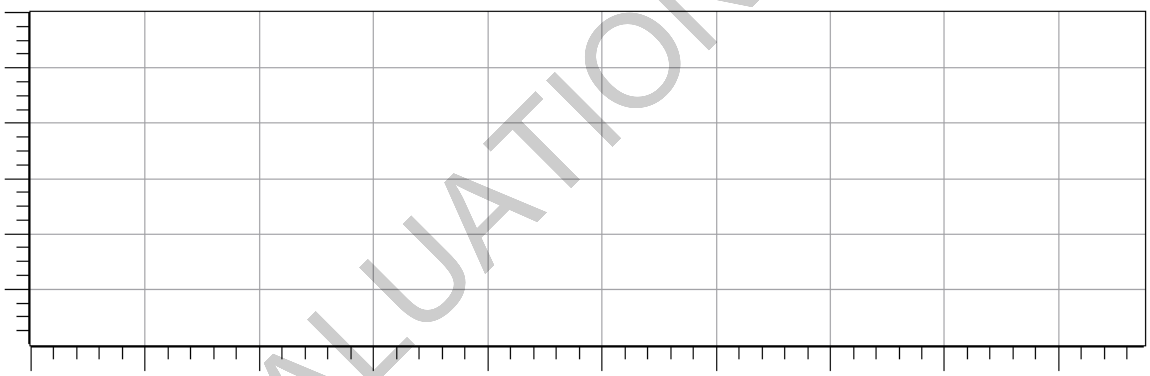
2. ☐ Sketch the graphs of light intensity, temperature, barometric pressure, relative humidity, absolute humidity, and dew point. Label the graphs and the axes, including the units and scales.

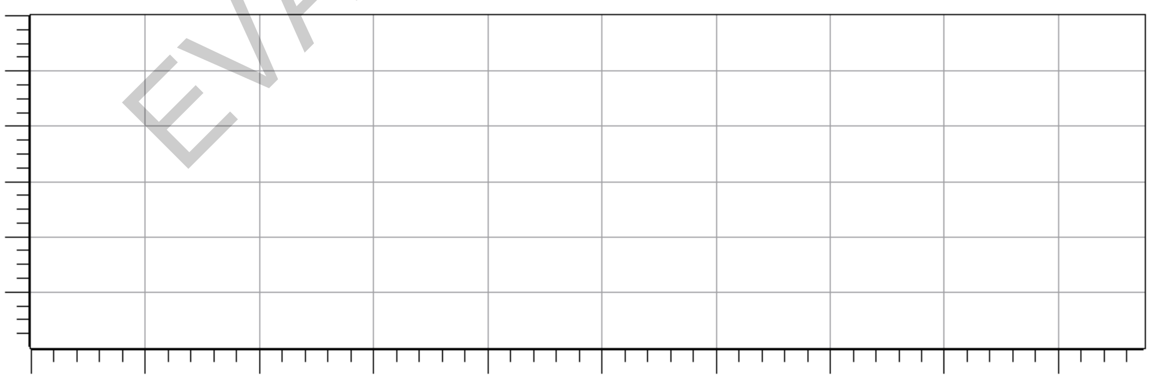
3. ☐ Indicate on the graph where you turned on the bright light and where you added the plant.

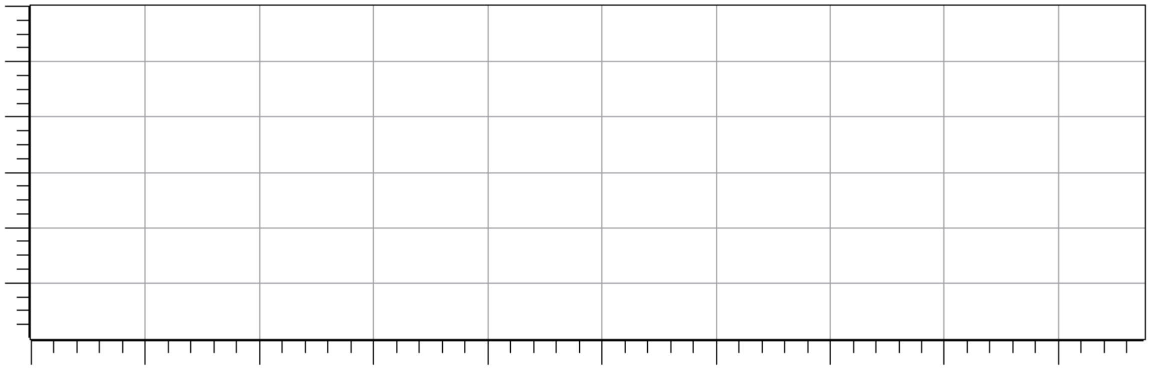
4. ☐ Label the areas you think are interesting on the graphs with numbers or letters.

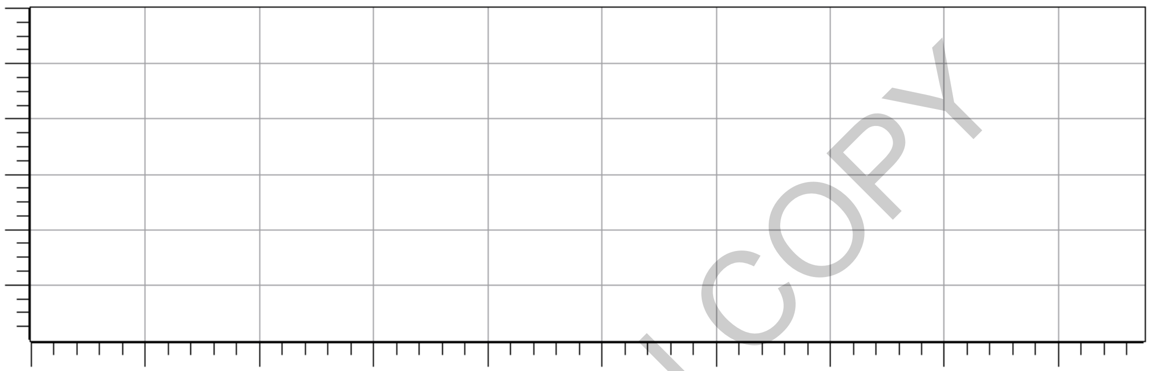












Analysis Questions

1. **Discuss the different patterns on the graphs. What do you think are explanations for the patterns?**

2. **What were the independent variables in this activity?**

3. **What were the dependent variables in this activity?**

4. **What factors did you try to hold constant during this activity?**

Synthesis Questions

Use available resources to help you answer the following questions.

Begin designing an experiment that investigates an aspect of the weather, using this test system. These questions will assist you to develop a proposal.

1. How could you use the data you collected in this activity in additional investigations?

2. What question would you like to investigate using this system?

3. What independent variables will you test to investigate the question? Why?

4. What will be a hypothesis for a test of this issue using this system?

5. How will you design the investigation to test your hypothesis?

6. How will you analyze the results of your experiment?

---

7. What materials and equipment will you need to conduct your investigation?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The design of a research study must include:

- **A.** A hypothesis to test
- **B.** A defined test system that controls variables
- **C.** A controllable independent variable
- **D.** A measurable dependent variable
- **E.** Control or baseline measurements
- **F.** All of the above

2. In a scientific experiment, an independent variable is:

- **A.** A variable that has nothing to do with other variables
- **B.** Something that changes in response to another variable
- **C.** Something that you change to affect another variable
- **D.** Something that you try to keep constant

3. In a scientific experiment, a dependent variable is:

- **A.** A variable that has nothing to do with other variables
- **B.** Something that changes in response to changes in another variable
- **C.** Something that you change to affect another variable
- **D.** Something that you try to keep constant

4. In the test system in this activity, an independent variable is:

- **A.** Temperature
- **B.** Light energy
- **C.** Vegetation
- **D.** Humidity level
- **E.** Either B or C

5. In the test system in this activity, a dependent variable is:

- **A.** Temperature
- **B.** Light energy
- **C.** Vegetation
- **D.** Humidity level
- **E.** Either A or D
- **F.** Either B or C

16. Yeast Respiration

Driving Questions

Yeast cells can serve as simple models for studying both aerobic and anaerobic cellular respiration.

- What are some conditions in which yeasts can undergo cellular respiration?
- How do yeasts participate in the carbon cycle?

Background

The term "respiration" refers to the exchange of gases between an organism and its environment. This intake of oxygen gas and exhalation of carbon dioxide gas is closely linked to the production of ATP at the cellular level, a process called cellular respiration. ATP is generated by mitochondria within the cell. During cellular respiration, the energy stored within macromolecules such as glucose is released and harnessed to phosphorylate ADP, producing ATP.

In the presence of oxygen, glucose can be fully oxidized releasing large amounts of energy. The process of cellular respiration also produces water and carbon dioxide gas as waste products.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + \text{energy}$$

Organisms that utilize oxygen for the breakdown of glucose are called aerobic organisms. Plants and animals are both examples of aerobic organisms. Even dormant plant seeds undergo respiration, although at a much lower level than after germination starts.

Yeasts are actually facultative anaerobes, organisms that have the ability to undergo aerobic respiration and anaerobic respiration. With oxygen present, yeast will preferentially undergo aerobic respiration. If no oxygen is present, yeast cells use an anaerobic respiration. These reactions are summarized as follows:

$$\text{glucose} + \text{ADP} \rightarrow \text{carbon dioxide gas} + \text{ethanol} + \text{ATP}$$

Yeast cells participate in the carbon cycle by breaking down large, organic molecules, releasing carbon into the environment as carbon dioxide gas. The carbon dioxide gas is then available to plants for use in the photosynthesis process. Yeast cells participate in the oxygen cycle by using oxygen gas during aerobic cellular respiration to oxidize glucose, producing carbon dioxide gas and dihydrogen oxide (water vapor).

Materials and Equipment

For each student or group:

- Data collection system
- Dissolved oxygen sensor
- Carbon dioxide gas sensor
- Stainless steel temperature sensor
- EcoChamber
- Beaker, 1-L
- Graduated cylinder, 500-mL or 1-L
- Pipet, disposable
- Microscope with magnification to 400x
- Microscope slide and cover slip
- Activated baker's yeast, 7-g packet
- Sugar, 100 g
- Hot plate with magnetic stirrer and stir bar
- Magnetic stir plate with stir bar
- Water, 1 L

Safety

Follow all standard laboratory procedures.

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.

◯	◯	◯	◯	◯
Heat sugar water, make an activated yeast solution, and set up your data collection system to show CO_2 and DO.	Observe the activated yeast solution and the sugar and water solution under a microscope.	Set up an airtight transparent chamber in which you can measure dissolved oxygen (DO) and carbon dioxide (CO_2) gas simultaneously.	Pour sugar water into the chamber, seal it from air, and collect data. Stir the solution slowly with the magnetic stirrer.	Put the yeast solution into the collection chamber and keep recording data.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Set Up

1. ☐ Heat a liter of water and 100 g sugar solution in the 1-L beaker on a hot plate to about 40 °C.

a. ☐ Connect the temperature sensor to your data collection system. �(2.1)

b. ☐ Insert the temperature sensor into the solution and adjust the hot plate temperature control until 40 °C is reached.

Note: Make sure the sensor is not in contact with the bottom of the beaker when you measure the temperature.

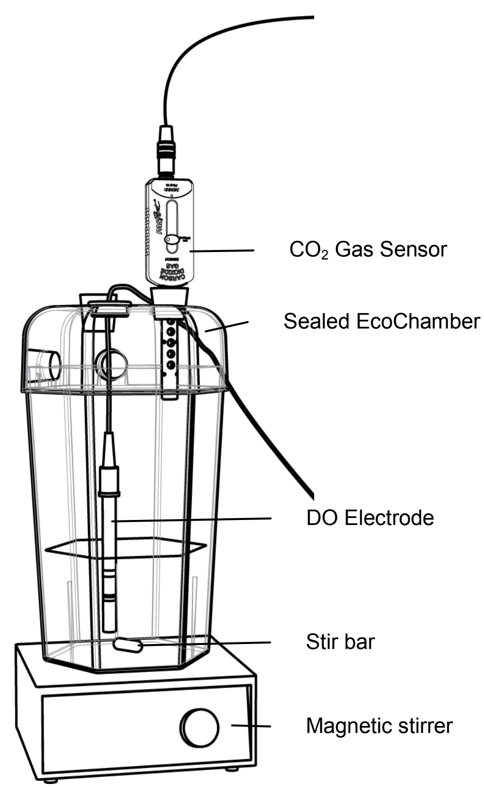
c. ☐ Adjust the temperature control on the hot plate to maintain the solution at 40 °C. Monitor the temperature for two minutes to make sure it has stabilized.

2. ☐ Set up the EcoChamber to measure dissolved oxygen (DO) and carbon dioxide (CO_2) gas simultaneously.

a. Place a stir bar in the chamber and set it on a magnetic stirrer.

b. Make sure the end of the dissolved oxygen sensor is about 1 cm above the bottom of the chamber.

c. Arrange the CO_2 gas sensor so the end is completely inside the container but will not get wet.



3. ☐ Start a new experiment on the data collection system. �(1.2)

4. ☐ Connect the DO and CO_2 sensors to your data collection system. �(2.2)

5. ☐ Display both DO and CO_2 on the y-axis of the graph, with time displayed on the x-axis. �(7.1.10)

6. ☐ Pour 500 mL of the sugar water into the chamber, and seal the chamber airtight.

7. ☐ Turn on the magnetic stirrer.

8. ☐ Maintain the remaining solution at about 40 °C.

Note: The goal is to pour enough liquid into the chamber to allow the dissolved oxygen sensor to be submerged up to the silver ring.

9. ☐ What do you predict will happen to the levels of dissolved oxygen and CO_2 gas with this setup?

____

____

____

Collect Data

10. ☐ Start data recording. �(6.2) Record data for about 10 minutes, but *do not stop recording data.*

11. ☐ Adjust the scale of the graph so the data fills the screen. �(7.1.2)

Note: While you record data, you can continue with the next two steps.

12. ☐ Pour a package of activated baker's yeast into the remaining sugar-water, and stir until the yeast is dissolved in the water.

13. ☐ Observe the yeast solution, and describe its appearance and any activity in it. What do you think is happening?

____

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14. ☐ After recording data for 10 minutes, pour about 250 mL of this mixture into the chamber, and re-seal the chamber so that it is airtight.

Note: The goal is to pour about half of the yeast solution into the chamber.

15. ☐ Why do you seal the chamber to isolate it from the surrounding air?

16. ☐ What do you predict will happen to the levels of dissolved oxygen and CO_2 gas with this setup?

17. ☐ Continue recording data for 20 minutes. While data is recording, perform the following three steps.

18. ☐ Using the pipet, put a drop of the yeast solution on a glass slide and cover it with a cover slip.

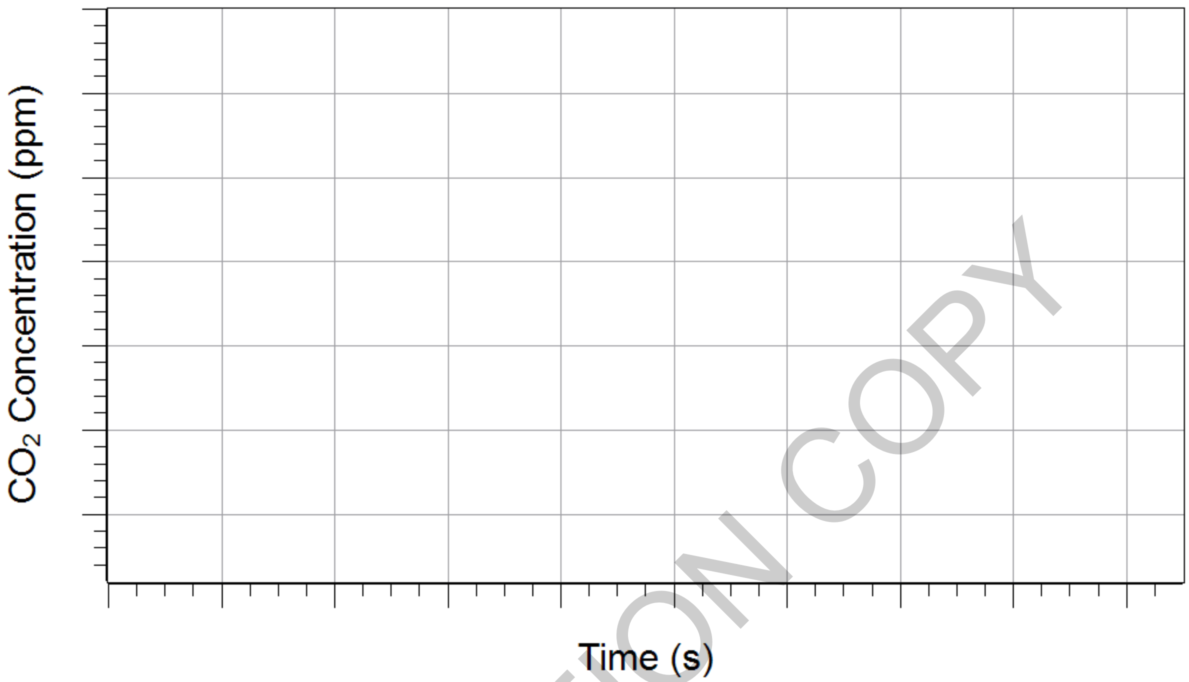
19. ☐ Examine this preparation under a microscope at up to 400x magnification. Record your observations below, including a sketch of what you see at the highest magnification.

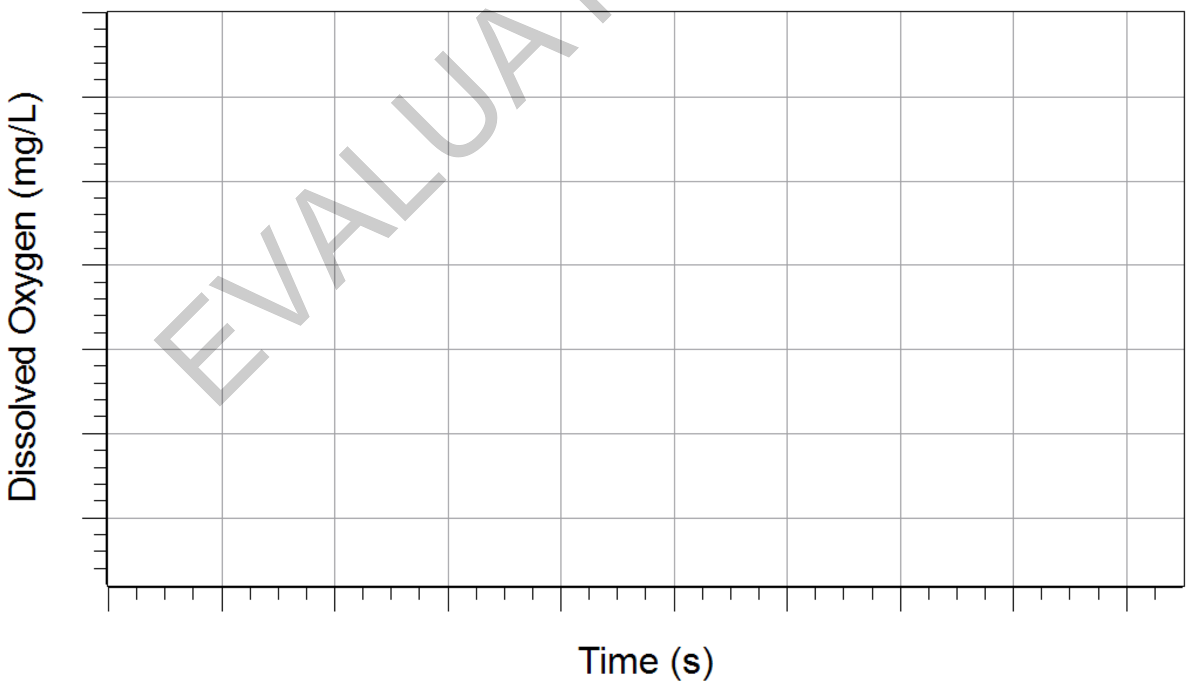
20. ☐ In studying cellular respiration in yeast, why would you measure dissolved oxygen and carbon dioxide gas?

21. ☐ After 20 minutes, stop recording data �(6.2) and save your experiment. �(11.1)

Data Analysis

1. ☐ Sketch graphs of your recorded data in the spaces provided, including the appropriate scale. Indicate when the yeast cell solution was added.





2. ☐ Use graph tools to identify the data points �[(9.1)] to complete Table 1.

Table 1: Change in dissolved oxygen and carbon dioxide gas concentrations

	Dissolved Oxygen (mg/L)			**CO_2 gas (ppm)**		
	Initial	**Final**	**Δ**	**Initial**	**Final**	**Δ**
Sugar water						
Sugar water with yeast						

Analysis Questions

1. How do the results of the data compare with your predictions?

____

____

2. The following summarizes the chemical reactions during aerobic cellular respiration:

oxygen gas + glucose → carbon dioxide gas + water vapor + energy (ATP)

Did you see any evidence that aerobic cellular respiration took place? Record all kinds of evidence, including visual observations.

____

____

3. The following summarizes the chemical reactions during anaerobic cellular respiration:

glucose → carbon dioxide gas + ethanol + energy (ATP)

Did you see any evidence that anaerobic cellular respiration took place? Record all kinds of evidence, including visual observations.

____

____

Synthesis Questions

Use available resources to help you answer the following questions.

1. How do yeast cells participate in the carbon cycle?

2. How do yeast cells participate in the oxygen cycle?

3. List one reason why yeast cells are frequently used as models in medical and scientific research.

4. List one way that yeast cells are now being used in medical or scientific research.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Yeasts are

- **A.** Single-celled organisms containing chlorophyll
- **B.** Single-celled organisms that do not have a nucleus
- **C.** Single-celled organisms that have a nucleus and organelles typical of eukaryotes
- **D.** Single-celled bacteria
- **E.** Multicellular organisms

2. Yeasts get their energy for life processes from

- **A.** Aerobic cellular respiration
- **B.** Anaerobic cellular respiration
- **C.** Alcoholic fermentation
- **D.** Only A and B are correct
- **E.** A, B, and C are all correct

3. Yeasts release the following as byproducts of cellular respiration:

- **A.** Oxygen gas
- **B.** Carbon dioxide gas
- **C.** Ethanol
- **D.** Water
- **E.** Only B and C are correct
- **F.** Only B, C, and D are correct

4. Yeasts participate in the carbon cycle by

- **A.** Decomposing complex carbohydrates
- **B.** Capturing CO_2 gas from the atmosphere and incorporating it into sugars
- **C.** Incorporating elemental carbon into foods that other organisms can use
- **D.** Fermenting sugars, releasing CO_2 gas
- **E.** A and B are correct
- **F.** A and D are correct

5. Yeasts participate in the oxygen cycle by

- **A.** Decomposing complex carbohydrates
- **B.** Capturing O_2 gas from the atmosphere and incorporating it into sugars
- **C.** Incorporating elemental carbon into foods that other organisms can use
- **D.** Fermenting sugars, releasing CO_2 gas
- **E.** A and B are correct
- **F.** A and D are correct

Pollution

Name Period Date

17. Properties of Water

Driving Questions

Explore the properties of water and use the molecular structure of water to explain these properties.

- ♦ Why is water the only substance that naturally exists as a solid, liquid, and a gas on Earth?
- ♦ Does water behave the same on all surfaces? Why or why not?
- ♦ How does the volume of ice compare to the volume of liquid water? Is this unusual? Why?
- ♦ How are the properties of water important to processes on Earth such as physical erosion and the hydrologic cycle?

Background

Solid iron sinks in liquid iron. Solid lead sinks in liquid lead. Nearly all substances in their solid state sink when placed in their own liquid. This occurs because the atoms or molecules making up these substances are closer together in the solid state than in the liquid state. Is this true for water? No, ice floats in water because ice is less dense than water.

The properties of water seem normal to us because water is all around us. What other chemical substance can you think of that exists as a solid, liquid and a gas at the temperatures and pressures found on Earth? Couldn't think of anything, right? Water is the only substance that naturally exists in all three states on Earth. Water is unique.

These strange behaviors of water enable life to exist on Earth. They also are responsible for many of the processes on Earth such as physical erosion and the hydrologic cycle. All this strange behavior of water can be explained by the molecular structure of water.

Water is a polar molecule because it has a partially positive side and partially negative side. These two different sides attract to each other (opposites attract). In water this is a special type of intermolecular attraction called hydrogen bonding. This hydrogen bonding explains why solid ice is less dense than liquid water, why water can exist in all three states on Earth, and why water is attracted to and easily mixes with some substances (like salt), but is repelled away from and refuses to mix with other substances (like oil).

Materials and Equipment

For each student or group:

- Data collection system
- Stainless steel temperature sensor
- Beaker, 600-mL
- Beaker, 100-mL
- Utility clamp
- Ring stand
- Hot pads or mittens
- Hot plate
- Crushed ice, 300 mL
- Eye dropper or disposable pipet
- Paper towel
- Wax paper
- Foam tray
- Other materials to test
- Water, 50 mL

Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not touch the hot plate or hot glassware.
- Do not allow the temperature sensor's wires to touch the hotplate at any time.

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.

Part 1 – Phase change of water

○	○	○	○	○
Place the beaker with ice on a hot plate with a temperature sensor positioned in the ice.	Fill the beaker with ice	Start collecting Temperature versus Time data.	Stop collecting data after the water has boiled for approximately 10 minutes.	Mark the following features on your graph: ice only, ice and water, water only, water and water vapor, melting, and boiling.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Phase change of water

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect a stainless steel temperature sensor to the data collection system. �(2.1)

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

4. ☐ Attach a utility clamp to a ring stand, and securely tighten a stainless steel temperature sensor to the utility clamp.

5. ☐ Plug in the hotplate and turn it on to its highest setting.

CAUTION: Ensure that papers and wires do not touch the hot plate.

6. ☐ Fill the 600-mL beaker with crushed ice to approximately 300 mL.

7. ☐ Place the beaker with crushed ice onto the hot plate.

8. ☐ Lower the stainless steel temperature sensor into the ice, positioning the tip of the sensor approximately 2 cm below the surface of the ice. Make sure the sensor does not touch the bottom or the sides of the beaker.

Collect Data

9. ☐ Start data recording. �(6.2)

10. ☐ Adjust the scale of the graph as needed. �(7.1.2)

11. ☐ Collect data until the water has been boiling for 10 minutes. Be sure that the tip of the sensor is always under the ice or the water. You may have to adjust its position as the experiment continues.

12. ☐ What changes do you expect to happen that may cause the volume of ice and water in the beaker to decrease as the beaker is heated?

13. ☐ Record the elapsed time when each of the changes listed in Table 1 occurred.

Table 1: Phase changes

Change	Elapsed Time (s)
Ice started melting	
The last piece of ice melted	
Water started boiling	

14. ☐ Describe the characteristics (in regard to volume and shape) of ice that make it a solid.

15. ☐ What is hydrogen bonding and how does it explain the properties of ice listed above?

16. ☐ Describe the characteristics of water that make it a liquid. Explain how hydrogen bonding is involved.

17. ☐ Describe the characteristics of water vapor that make it a gas. Explain whether or not hydrogen bonding occurs.

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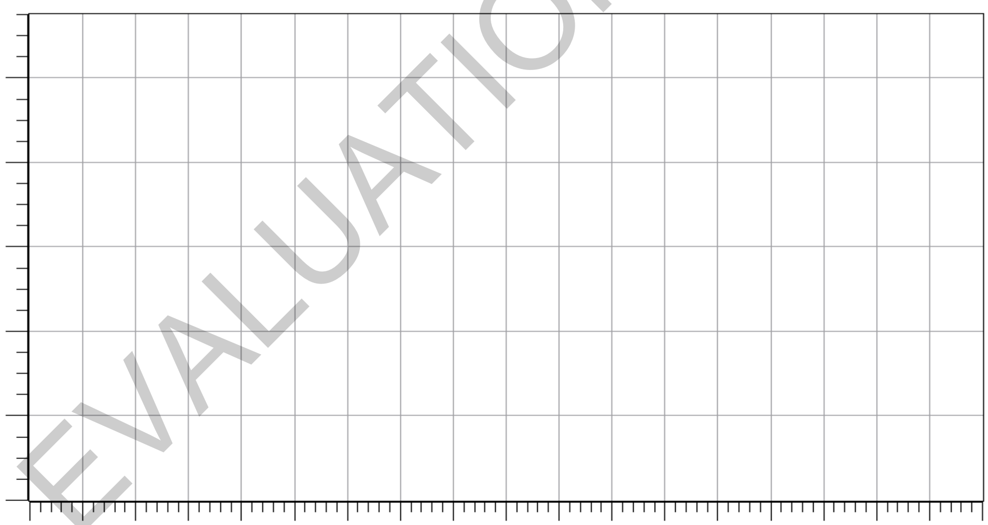
18. ☐ When the water has been boiling for approximately 10 minutes, stop data recording. � (6.2)

19. ☐ Save your experiment and clean up according to your teacher's instructions. � (11.1)

Analyze Data

20. ☐ Print or sketch a graph of Temperature versus Time where heat is added to allow ice to change to water and then to water vapor. Label the overall graph, the x-axis, the y-axis, and include units on the axes. � (11.2)



21. ☐ Label the items below on your temperature versus time graph above.

a. Ice alone

b. Ice and water

c. Water only

d. Water and Water Vapor

e. Melting

f. Boiling

22. ☐ In this lab, what was added to the ice in order to make it melt and then make the water boil? On Earth, what causes these processes to occur?

23. ☐ What needs to happen for the reverse process to occur (water vapor to turn to water, and water to change to ice? Does this occur on earth? Explain.

Part 2 – Waters behavior on different surfaces

24. ☐ Fill a 100-mL beaker with approximately 50 mL of water.

25. ☐ Place 10 drops of water on a piece of wax paper.

26. ☐ Slightly lift the edges of the wax paper and slowly move the water from side to side. Record your observation in Table 2.

Table 2: Behavior of water on known surfaces

Surface	Molecular Structure	Observations
Wax paper	Non- polar	
Foam food tray	Non-polar	
Paper towel	Polar	
Untreated wood	Polar	

27. ☐ Repeat the process for a foam food tray, a paper towel, and an untreated piece of wood:

a. Place 10 drops of water on the surface.

b. Slightly life the edges of the surface and slowly move the water from side to side.

c. Record your observation in Table 2.

28. ☐ How does water behave when placed on non-polar surfaces? Explain using the terms cohesion, adhesion, and hydrogen bonding.

29. ☐ How does water behave when placed on polar surfaces? Explain using the terms cohesion, adhesion, and hydrogen bonding.

30. ☐ How does the polarity of water affect the behavior of water on different surfaces? Provide evidence to support your answer.

31. ☐ Pick 5 different surfaces and predict the polarity of these surfaces. Record the name of each surface and your prediction in Table 3.

Table 3: Determining the polarity of unknown surfaces

Surface	Polarity Prediction	Observations	Polarity

32. ☐ Test each of your surfaces to determine how water behaves on each and record your observation in Table 3.

33. ☐ Use your results to determine the polarity of each surface. Record your answers in Table 3.

34. ☐ Were your predictions correct? Explain why or why not.

____

____

35. ☐ Clean up according to your teacher's instructions.

Part 3 – Volume of ice versus water

Complete the following steps to design an experiment to determine how the volume of ice compares to the volume of water (with equal mass).

36. ☐ How do you think the volume of ice compares to that of water? What physical evidence do you have to support your prediction?

____

____

____

37. ☐ Explain your prediction using what you know about the molecular structure of water. The following terms should be used in your explanation: hydrogen bonds, crystal structure, and water molecule.

____

____

____

38. ☐ Explain how you plan to test your prediction.

____

____

39. ☐ Write a procedure for the plan you described.

40. ☐ If time permits your teacher may allow you to perform your experiment.

Analysis Questions

1. **List two behaviors of water you observed in this lab and explain how hydrogen bonding is involved in each.**

2. **List one behavior of water that you experimented with in this lab and explain why it is unique compared to other chemicals on Earth.**

3. **Explain how one (or more) of the properties you observed in this lab is involved in a physical process on Earth.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. Are changes of state physical or chemical changes? How do you know?

____

____

____

2. How can the cohesive forces between water molecules be reduced? Why might this be necessary?

____

____

3. Does it take more energy for ice to melt or for water to evaporate? Why is this important on Earth?

____

____

____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. What type of attractions hold water molecules to other water molecules?

- **A.** Hydrogen bonds
- **B.** Covalent bonds
- **C.** Adhesion
- **D.** Application
- **E.** All of the above

2. Water will absorb into _________________________.

- **A.** Non-polar surfaces
- **B.** Polar surfaces
- **C.** All surfaces
- **D.** Surfaces that are already wet
- **E.** None of the above

3. What happens to the temperature of boiling water when more heat is added?

- **A.** The temperature of the water increases.
- **B.** The temperature of the water decreases.
- **C.** The temperature of the water stays the same.
- **D.** Heat cannot be added to water that is boiling.
- **E.** None of the above.

4. What is the molecular structure of water vapor?

- **A.** H_2 gas molecules
- **B.** O_2 gas molecules
- **C.** H^2O gas molecules
- **D.** A mixture of A and B
- **E.** None of the above

5. Which of the following properties of water increase the rate of physical erosion?

- **A.** Water expands as it freezes.
- **B.** Water molecules are polar.
- **C.** Water is odorless and colorless.
- **D.** Water boils at 100 °C.
- **E.** All of the above.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. Water has many unique properties. These properties are derived from water's ability to ________________ to neighboring water molecules. This happens because water is a ________________ substance, meaning it has a partially positive and partially negative side to it. Water's partially ________________ side in one molecule is attracted to water's partially negative side in ________________ water molecule. This attraction is what holds water molecules together in the liquid and ________________ state. This attraction is also the reason that ________________ must be added or removed to change water from one state to another. The polarity of water also explains why water absorbs into some surfaces, but ________________ on other surfaces.

2. The unique properties of ________________ enable life to exist on Earth. Ice is less dense than water which means that ice ________________ in water. This allows fish and other aquatic animals to survive in the extremely ________________ regions. The properties of water are also responsible for many of the processes on Earth such as ________________. The polar nature of water enables it to be absorbed into ________________. When the water freezes it ________________ inside the rock and causes the rock to break apart. This is an important process in the rock cycle and helps to create soil. The ________________ is also a result of hydrogen bonding in water. Water is constantly cycled from one area to another. Solar radiation causes ice to melt and water to ________________. Cool weather causes water vapor to ________________ and water to freeze.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
another	cold
beads up	condense
gaseous	contracts
heat	evaporate
hydrogen bond	expands
negative	floats
non-polar	freeze
polar	hot
positive	hydrologic cycle
solid	melt
spreads out	physical erosion
the same	rocks
	sinks
	water

18. Air Pollution and Acid Rain

Driving Questions

In this activity, you will use chemical reactions to generate gases that are common man-made (anthropogenic) air emissions.

- Can anthropogenic gases in the atmosphere significantly lower the pH of rain, snow, and fog?
- If so, what are some chemical reactions that lead to this change in pH?

Background

Acid rain is rain, or any other form of precipitation that is acidic. As this acidic water flows over and through the ground, it affects a variety of plants and animals. It can also accelerate the dissolving of metals found in soils and rock. The strength of the effects depends on many factors, including 1) the acidity of the water, 2) the chemistry and buffering capacity of the soils involved, and 3) the types of fish, trees, and other living things that rely on the water.

Acid rain produces stressful and sometimes deadly fluctuations in water systems, causing aquatic life to experience chemical “shock” effects. For example, as the pH drops to 5.5, plankton, certain insects, and crustaceans begin to die. Trout eggs do not hatch well.

The effects of acid rain are widespread. Acid rain can damage concrete, stone, and metal structures. It can reduce crop productivity and forest growth rates, and may remove protective layers from plant leaves, causing them to be more susceptible to disease. Acid rain accelerates the rate at which "heavy" metals such as lead and mercury, and nutrient cations such as magnesium (Mg^{2+}) and potassium (K^{+}), are leached from soils, rocks, and sediments of surface water. Scientists believe acid rain causes increased concentrations of methylmercury in bodies of water—methylmercury is a neurotoxic molecule that is accumulated in fish tissues and can cause birth defects in populations that ingest high concentrations of it.

Materials and Equipment

For each student or group:

- Data collection system
- pH sensor
- Erlenmeyer flask, 50-mL
- 1-hole rubber stopper for flask
- Beaker, 40-mL
- Graduated pipet, 4-mL and pipet bulb
- Glass tubing for rubber stopper
- Flexible Teflon® tubing to fit glass tubing, 20 cm
- Graduated cylinder, 50- or 100-mL
- Sodium bicarbonate ($NaHCO_3$), 5 g
- Sodium bisulfite ($NaHSO_3$), 5 g
- Sodium nitrite ($NaNO_2$), 5 g
- 1 M HCl (15 mL)
- Water or deionized water, 1 L
- Wash bottle containing distilled or deionized water

Safety

Add these important safety precautions to your normal laboratory procedures:

- ♦ Work under a vented hood when creating sulfur dioxide and nitrogen dioxide.
- ♦ Do not touch the hydrochloric acid (HCl). Handle the pipet with HCl with extreme care.
- ♦ Do not remove the rubber stopper from the Erlenmeyer flask once the reaction has started.
- ♦ After completing the lab, wash your hands.
- ♦ Wear safety glasses and lab coats or aprons.

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.

◯	◯	◯	◯	◯
Repeat the gas generation and data collection for NO_2 and SO_2.	Rinse out the gas generation bottle, beaker, and tubing.	Generate CO_2 gas and collect data as it's bubbled through water.	Determine the changes in the pH of the water for each gas.	Set up the equipment. Open the graph display.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Create gas generators, and measure pH

You will create CO_2, NO_2, and SO_2, as follows:

Mix sodium bicarbonate ($NaHCO_3$) with hydrochloric acid (HCl) to produce carbon dioxide gas (CO_2).
Mix sodium nitrite ($NaNO_2$) with hydrochloric acid (HCl) to produce nitrogen dioxide (NO_2).
Mix sodium bisulfite ($NaHSO_3$) with hydrochloric acid (HCl) to produce sulfur dioxide gas (SO_2).

1. ☐ Make predictions: What do you think will happen to the pH of the water when you dissolve these gases in it? Which gas will produce the largest change in pH?

Part 1 – Making carbon dioxide (CO_2) gas and measuring its effect on the pH of water

Set Up

2. ☐ Start a new experiment on the data collection system. �(1.2)

3. ☐ Connect the pH sensor to the data collection system. �(2.1)

4. ☐ Display pH on the y-axis of a graph with time on the x-axis. �(7.1.1) (7.1.2)

5. ☐ Measure 20.0 mL of water using the graduated cylinder.

6. ☐ Pour the water into the 40-mL beaker.

7. ☐ Thoroughly rinse the pH electrode with distilled water.

8. ☐ Place the rinsed pH electrode in the beaker.

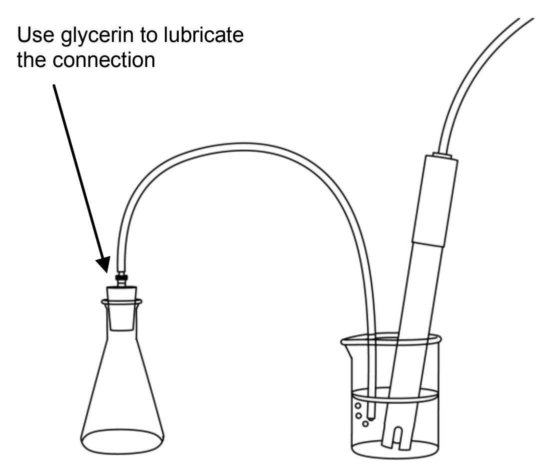
9. ☐ Obtain a sample of powdered sodium bicarbonate ($NaHCO_3$) from the teacher.

10. ☐ Measure 5 grams of $NaHCO_3$

11. ☐ Place the measured $NaHCO_3$ in the Erlenmeyer flask.

12. ☐ Assemble the stopper, glass tubing or barbed connector, and flexible tubing.

Note: If necessary, use glycerin to lubricate the connection so that the connector or glass tubing is well seated in the rubber stopper



13. ☐ Pipet 4 mL of 1.0 M hydrochloric acid (HCl) into the Erlenmeyer flask, and immediately stopper the flask.

CAUTION: Hydrochloric acid is a strong acid. Handle with care. Flush any spillage with a lot of water.

Collect Data

14. ☐ Place the free end of the flexible tubing in the water in the beaker, and immediately start recording data. �(6.2)

15. ☐ Record data for about 200 seconds (until the change in pH stops or stabilizes), and then stop recording. �(6.2)

16. ☐ Name your run to reflect the sample type. �(8.2)

17. ☐ Dispose of the contents of the flask and beaker as directed by your instructor.

18. ☐ Rinse the beaker, flask, and tubing with water.

Part 2 – Making sulfur dioxide (SO_2) gas and measuring its effect on the pH of water

19. ☐ Repeat the steps in Part 1 using 5 g $NaHSO_3$ instead of $NaHCO_3$.

Part 3 – Making nitrogen dioxide (NO_2) gas and measuring its effect on the pH of water

20. ☐ Repeat the steps in Part 1 using 5 g $NaNO_2$ instead of $NaHCO_3$.

21. ☐ Save your experiment �(11.1), and clean up according to your teacher's instructions.

Data Analysis

1. ☐ From the graph display for each run, determine the maximum and minimum pH values, and record them in Table 1. �(9.4)

2. ☐ Complete Table 1.

Table 1: pH change due to gases dissolved in water

Gas	Final pH	Initial pH	Change in pH (pH_{final} - $pH_{initial}$)
Carbon dioxide			
Sulfur dioxide			
Nitrogen dioxide			

Analysis Questions

1. Was your prediction correct regarding what would happen to the pH when you dissolved the gases in it? Why or why not?

2. The following chemical reactions are involved in this lab. Write each formula using chemical notation.

a. One molecule of carbon dioxide gas dissolves in water to form one bicarbonate ion and one hydrogen ion.

b. Two nitrogen dioxide gas molecules dissolve in water to form one nitrate ion, one nitrite ion, and two hydrogen ions.

c. One sulfur dioxide gas molecule dissolves in water to form one bisulfite ion and one hydrogen ion.

3. Which gas created the smallest change in pH of the water?

4. **Compare your results with those from other groups. What factors might have caused some of the variability in the change of the observed pH?**

5. **For the three reactions of gas dissolving in water, what caused the reduction of the pH of the water in which these gases are dissolved?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **What industrial or other man-made (anthropogenic) gases emitted into the atmosphere are considered the primary gases that cause acid rain? What are some sources of these gases?**

2. **Scientists have found that sulfuric acid is the primary acid that causes acid rain. What are some of the chemical reactions that produce sulfuric acid in the atmosphere? Why does radiation from the sun speed up this reaction?**

3. **Coal from states in the western United States, like Montana and Wyoming, has a lower percentage of sulfur impurities (lower sulfur content) than coal found in the eastern United States. How would burning low-sulfur coal change acid rain?**

4. Discuss the relationship between acid rain and the sulfur and nitrogen cycles.

5. What are some ways to treat the effects of acid rain?

6. What are some ways to prevent the formation of acid rain?

7. Although carbonic acid produces only a small decrease in the pH of water, why is it of concern in the environment?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following is true about acid rain?

- **A.** Acid rain is linked to NO_x and SO_x molecules in the atmosphere.
- **B.** Acid rain can result in the death of many species of water-dwelling organisms when it causes the pH of lakes to decrease to a level outside their tolerance.
- **C.** Acid rain affects soil chemistry and the ability of plant roots to take in nutrients.
- **D.** Acid rain increases the mobility of toxic metals in ecosystems.
- **E.** All of the above are true.
- **F.** Only A, B, and C are true.

2. Which of the following play important roles in the formation of acid rain?

- **A.** Solar radiation
- **B.** Buffers in soils and water
- **C.** Water in the atmosphere
- **D.** Nitrogen gas (N_2) in the atmosphere
- **E.** All of the above
- **F.** Only A and C

3. In general, rain exerts harmful effects on ecosystems when it falls below a pH of

- **A.** 3.6
- **B.** 4.6
- **C.** 5.6
- **D.** 6.6
- **E.** 7.6

4. Acid rain has been linked to

- **A.** Contamination of fish with highly toxic methylmercury
- **B.** Damage to fish through reactions that create high aluminum concentrations in the water.
- **C.** Reduced nutrient uptake by tree roots
- **D.** Weakening trees, so they become more susceptible to other types of damage
- **E.** All of the above

19. Monitoring Water Quality

Driving Questions

Monitoring the quality of a natural body of water is an important part of good stewardship of the environment.

- How can you determine the quality of the water in a body of water?
- What is the quality of the water in a body of water in your area?
- How does water quality change in response to changes in the environment?

Background

Water quality is the suitability of water for a given use. Water in a natural ecosystem has to have the right balance of dissolved oxygen, nutrients, temperature, pH, salts, and light penetration to sustain a healthy aquatic ecosystem. Drinking water must have acceptable levels of contaminants to be deemed safe. Treated wastewater must also be of acceptable quality before it is released into the environment.

Natural bodies of water have many chemical and physical characteristics that can vary from one location to another. Water quality indicators can fluctuate depending on the characteristics of the surrounding watershed as well as from varying weather conditions. Water quality at a given point in a stream or river reflects the effects of upstream activities. We can measure different aspects of water quality at different locations to assess the health of a natural body of water and to locate possible sources of pollution.

Materials and Equipment

For each student or group:

- Mobile data collection system
- Water quality sensor
- Turbidity sensor
- Weather/anemometer sensor
- GPS sensor (optional)
- Sensor user guides with calibration instructions and tables
- Chemical test kit (optional)
- Buffer solution, pH 4, 25 mL
- Buffer solution, pH 10, 25 mL
- Wide-mouth sampling jar or small plastic bucket with a handle
- Long-handled sampling device
- Duct tape and scissors
- Wash bottle containing distilled or deionized water
- Wading boots (optional)

Safety

Add these important safety precautions to your normal laboratory procedures:

- Practice appropriate caution around bodies of water, steep terrain, and harmful plants or animals. Point out hazards you observe at the site.
- Use a buddy system and follow the established procedure in case of trouble.

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.

Measure the turbidity of the water, the pH, temperature, conductivity, and dissolved oxygen. Compare with the in situ measurements you made.

Determine the barometric pressure and temperature, and then calibrate the pH and dissolved oxygen sensors.

Find a second location on the body of water and repeat the measurement procedure.

Find a suitable place to collect water samples and take measurements. Make note of the surrounding environment and appearance of the water.

(Optional) Repeat the monitoring activity in a different season of the year.

Collect a water sample from at least 1 meter away from the shore and from below the surface level of the water

Take in situ measurements of temperature, pH, conductivity, and dissolved oxygen at least 1 meter from the shoreline.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Work with your teacher to find a good place to take your measurements.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect the weather/anemometer sensor to the data collection system. �(2.1)

3. ☐ Monitor live data without recording. �(6.1)

4. ☐ Determine the current barometric pressure and record below:

   Barometric pressure:_____________.

5. ☐ Why is it necessary to determine the barometric pressure?

____

____

____

6. ☐ Connect the water quality sensor, using a sensor extension cable, to the data collection system. �(2.1)

7. ☐ Make sure the conductivity sensor is adjusted to measure the quality of fresh (not salt) water. �(4.2)

8. ☐ Calibrate the dissolved oxygen sensor. �(3.3)

Note: Determine the 100% saturation point for the dissolved oxygen sensor with the sensor's storage bottle submerged in the water you plan to monitor.

9. ☐ Why is it important to calibrate the dissolved oxygen sensor at the same temperature as the water you are testing?

____

____

____

10. ☐ Use pH 4 and pH 10 buffer solutions to calibrate the pH sensor. �(3.6)

11. ☐ Why is it necessary to calibrate the pH, dissolved oxygen, and turbidity sensors?

Note: Keep the file open that contains this calibration information. The sensor calibration remains with the file that was open when you performed the calibration.

12. ☐ Use duct tape to secure the data collection system and the sensor cables to the extension pole so the probes dangle from the end of the pole.

Collect Data – In situ

13. ☐ Start data recording, �(6.2) and gently lower the probes into the water at least 1 meter from the shoreline and to at least 1/3 meter below the surface of the water. If the water is stagnant, gently move the sensors back and forth for 1 minute.

CAUTION: Do not let the data collection system get wet!

14. ☐ Carefully remove the probes from the water, return them to the shore, and stop data recording. �(6.2)

Write the run number here ____________ .

15. ☐ Remove the sensors and recording device from the extension pole.

Collect Data – From a water sample

16. ☐ Use duct tape to attach a clean bucket or other container to the end of the extension pole.

17. ☐ Collect a sample of water from approximately the same spot that you just monitored with the sensors.

18. ☐ Test the quality of the water in the bucket (measure the temperature, pH, conductivity, and dissolved oxygen) using the same procedure used for the in situ sample.

Record the run number here ____________ .

19. ☐ Calibrate the turbidity sensor. �(3.7)

20. ☐ Stir the water in the bucket and measure the turbidity of the water.

Record the run number here ____________ .

21. ☐ Record the turbidity in Table 1.

22. ☐ (Optional) Test other water quality parameters as indicated by your teacher, using the water in the bucket as your sample.

23. ☐ (Optional) Record the GPS coordinates.

24. ☐ Find another site to monitor the water quality (Site 2), repeating the data collection procedure above.

Data Analysis

1. ☐ Show your first data run in a graph. �(7.1.1)

2. ☐ Complete Table 1 as follows:

a. Use the graph tools to identify the value of each parameter that best represents the measured parameter. �(9.1)

Note: This is a value in the area of the graph where the measurements have stabilized.

b. Record these values in Table 1.

c. Repeat this process for your second data run.

Table 1: Water quality measurements from two locations

Test	Temperature (°C)	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Site 1: In situ					
Site 1: Sample					
Site 2: In situ					
Site 1: Sample					

3. ☐ Describe the first test site. (For example, note the presence and types of surrounding vegetation, shade or full sun, signs of soil erosion, presence or absence of insects or other animals, and evidence of point-source pollution.)

4. ☐ Describe the second test site.

Analysis Questions

1. **Was there a sizable difference between measurements made in situ and measurements of the water sample? Do you think it is worth the effort to take measurements in situ?**

2. **What do you think could be responsible for any differences you found between sites?**

3. **Dissolved oxygen levels below 3 mg/L indicate low water quality for many aquatic animals. Do you think the water you tested had enough dissolved oxygen to support most aquatic animals? Explain.**

4. **Dissolved oxygen levels above 9 mg/L indicate accelerated eutrophication and low water quality, due to rapid algae growth in nutrient-dense, warm water. These algal blooms are usually followed by very low dissolved oxygen levels. The algae die and are decomposed by bacteria, which consume the dissolved oxygen during aerobic cellular respiration. Does the body of water you investigated show evidence of accelerated eutrophication? Explain.**

5. **Does the body of water show signs of acid rain or other acid deposition? Explain.**

6. **Conductivity is a measure of salts dissolved in the water. Conductivity levels above 200 to 300 µS/cm in a fresh-water surface body of water may indicate pollution by runoff from cities or agricultural regions. Does the body of water you investigated show signs of pollution? If so, what do you think might be contributing to this pollution?**

7. **In the United States, turbidity levels higher than 1 nephelometric turbidity unit (NTU) in drinking water are unlawful, and the World Health Organization recommends levels lower than 1 NTU for drinking water. If the body of water you investigated served as a drinking water source, would the water have to be filtered to remove suspended solids? Explain.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. Design an additional study to determine levels of pollutants in the body of water you tested. Use the evidence you collected in the field study to identify 3 additional tests you think would be useful to conduct, and explain why you picked these.

2. Design a water quality monitoring process to test whether point-source pollution is significantly affecting the body of water you investigated. If this body of water does not have an obvious point source for pollution, create a hypothetical one.

(Examples of point-source pollution include heat from power plants; nitrogen-, phosphorous-, and phosphate-containing effluent from agricultural sources or runoff from cities; salt-containing effluent; and treated or untreated sewage.)

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following statements is true?

- **A.** A watershed delivers runoff, sediment, and dissolved substances into the body of water.
- **B.** A coastal delta is an example of a watershed.
- **C.** A watershed is the land area bordering a body of water
- **D.** Both A and C are true.
- **E.** A, B, and C are true.

2. Point-source pollution:

- **A.** Can usually be identified within a given area
- **B.** Is dispersed and difficult to identify
- **C.** Is more easily controlled than non-point-source pollution
- **D.** A and C
- **E.** A, B, and C

3. Fish kills can be caused by:

- **A.** Decreased dissolved oxygen levels due to decomposition of sewage by bacteria
- **B.** Decreased dissolved oxygen levels due to high summer temperatures
- **C.** Excessive cultural (or accelerated) eutrophication, in which plant matter is decomposed by bacteria
- **D.** A and C
- **E.** A, B, and C

4. Nitrates, potassium, and phosphorous found in plant fertilizers are considered water pollutants because they:

- **A.** Directly reduce the dissolved oxygen in water
- **B.** Form toxic compounds in water
- **C.** Cause increased algae growth rates
- **D.** Are harmful to fish and humans
- **E.** None of the above

5. Cultural (or accelerated) eutrophication can be caused by:

- **A.** Plant nutrients found in fertilizers
- **B.** Organic wastes from waste treatment facilities
- **C.** Human recreational activities such as swimming or boating
- **D.** A and B
- **E.** All of the above

6. Bodies of water that are eutrophic or hypereutrophic typically exhibit:

- **A.** High turbidity
- **B.** High nutrient levels
- **C.** Low turbidity
- **D.** A low level of primary productivity
- **E.** A and B

Name **Period** **Date**

20. Toxicology Using Yeast

Driving Questions

Toxicology is the science of assessing chemical hazards.

- How can yeasts be used in toxicity studies?
- Which is more toxic to yeast cells—household bleach or household vinegar?

Background

Toxicologists must concern themselves with the degree of toxicity—that is, the capacity to cause harm or death to living organisms—that exists for chemicals in the environment. Their studies must consider the dose (the amount of the substance that organisms are likely to be exposed to). They must also consider the genetic makeup of a species that might cause it to be sensitive to damage by a given chemical.

Toxicologists must select organisms for toxicity testing that are genetically similar to the organisms they want to protect from toxic chemical effects. Because of ethical considerations, substitutes for the organism of concern are often needed. Organisms further down in phylogeny that, nevertheless, have critical genetic characteristics similar to those of humans, are preferred test subjects.

Yeasts are good candidates for toxicology screening tests because 1) they are easy to grow, 2) they are relatively simple single-celled organisms yet are eukaryotic, 3) they have many metabolic processes that also occur in humans and other organisms further up in phylogeny, and 4) they have a known genetic code.

Materials and Equipment

For each student or group:

- Data collection system
- CO_2 sensor
- pH sensor
- Sensor extension cable
- EcoChamber
- Magnetic stir plate and stir bar
- Beaker, 100-mL (for vinegar)
- Beaker, glass, 2-L
- Graduated cylinder, 25-mL or 10-mL
- Graduated cylinder, 1-L or 500-mL
- Erlenmeyer flask, 125-mL (for bleach)
- Rubber stopper for Erlenmeyer flask
- Stirring rod
- Rapid-rise activated baker's yeast, 7-g packet
- Sugar, 100 g
- White vinegar, 50 mL
- Household bleach, half-strength, 50 mL
- Water, 1 L

Safety

Add these important safety precautions to your normal laboratory procedures:

- ♦ If the room is not well-ventilated, handle open containers of bleach and bleach solutions under a ventilated hood.
- ♦ Wear safety glasses and a lab coat.
- ♦ Have running water or an eyewash station in close proximity.

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.

◯	◯	◯	◯	◯
At 3-minute intervals, add 10 mL of vinegar. Continue collecting data until the CO_2 levels stop rising.	Repeat the test procedure using a 1:1 solution of bleach and water. Compare the toxicity of bleach and vinegar. Evaluate the role of pH in toxicity.	Set up the airtight EcoChamber to measure carbon dioxide gas (CO_2) and pH. Have a removable plug that will allow addition of toxins.	Pour half of the yeast solution into the EcoChamber and seal it from air. Slowly stir the solution with the magnetic stirrer. Collect data for 3 minutes.	Heat sugar and water, make the yeast solution, and set up your data collection system to show CO_2 and pH measurements.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Prepare the yeast culture

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect the CO_2 sensor and the pH sensor to the data collection system to record pH and CO_2 gas simultaneously. �(2.2)

3. ☐ Display pH on the y-axis of a graph and CO_2 gas on the y-axis of another graph; show Time on the x-axes of these graphs. �(7.1.11)

4. ☐ Heat 1 L of water and 100 g of sugar in a 2-L beaker to about 40 °C on a hot plate.

5. ☐ Remove the beaker from the hot plate and turn off the heat.

6. ☐ Add a package of activated yeast, and stir thoroughly.

7. ☐ Allow the mixture to activate for 15 minutes, stirring occasionally.

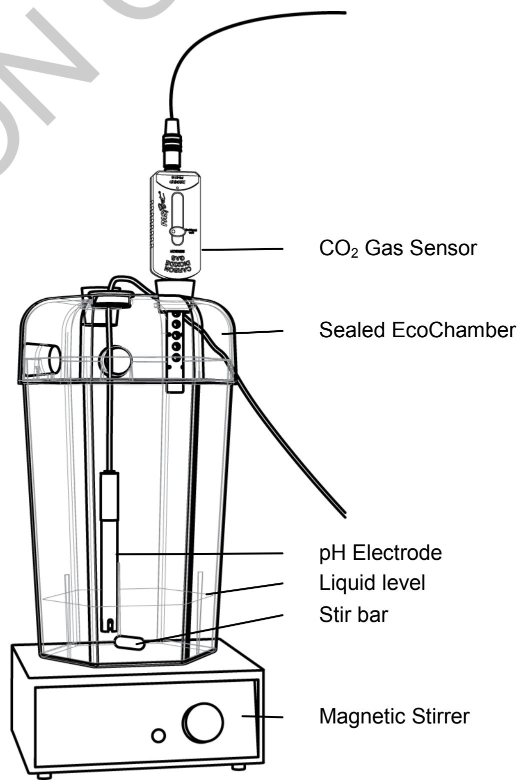
Note: The formation of bubbles indicates the yeast is activating.

Part 2 –Test the toxicity of vinegar

Set Up

8. ☐ Set up the EcoChamber to measure pH and CO_2 gas simultaneously, as follows:

- **a.** Place a stir bar in the chamber and set it on a magnetic stirrer.
- **b.** Make sure the end of the pH probe is about 1 cm above the bottom of the chamber.
- **c.** Arrange the CO_2 gas sensor so the end is completely inside the container, but will not get wet.
- **d.** Using the graduated cylinder, measure and pour 500 mL of the yeast cell culture solution into the chamber and seal it airtight.
- **e.** Turn on the magnetic stirrer.



Collect Data

Important! Record data continuously until you have added all 50 mL of vinegar.

9. ☐ Start data recording. �(6.2) Adjust the scale of the graph so the data fills the screen. �(7.1.2)

10. ☐ Measure 10 mL of vinegar using the graduated cylinder while data is recording.

11. ☐ After recording data for 3 minutes, remove the stopper from a port at the top of the chamber and add the 10 mL of vinegar. Replace the stopper.

Note: Do not stop recording data!

12. ☐ Record data for 3 additional minutes and again add 10 mL of vinegar.

Note: Do not stop recording data!

13. ☐ Repeat this procedure until a total of 50 mL of vinegar has been added.

14. ☐ Record data for 3 additional minutes.

15. ☐ Stop recording data. �(6.2)

16. ☐ Name the data run appropriately. �(8.2)

17. ☐ Discard the yeast solution as instructed by your teacher, and rinse the chamber and pH sensor.

18. ☐ Predict which will be more toxic to the yeast cells—half-strength bleach or full-strength vinegar? Explain your reasoning.

____

____

____

19. ☐ Why are you measuring the CO_2 gas concentration?

____

____

____

20. ☐ Why are you measuring the pH of the solution?

____

____

____

Part 3 – Test the toxicity of half-strength bleach

Set Up

21. ☐ Set up the EcoChamber to measure pH and CO_2 gas simultaneously, as follows:

- **a.** Place a stir bar in the chamber and set it on a magnetic stirrer.
- **b.** Make sure the end of the pH probe is about 1 cm above the bottom of the chamber.
- **c.** Arrange the CO_2 gas sensor so the end is completely inside the container, but will not get wet.
- **d.** Using the graduated cylinder, measure and pour 500 mL of the yeast cell culture solution into the chamber and seal it airtight.
- **e.** Turn on the magnetic stirrer.

Collect Data

Important! You should record data continuously until you have added all 50 mL of half-strength bleach.

22. ☐ Start data recording. �(6.2) Adjust the scale of the graph so the data fills the screen. �(7.1.2)

23. ☐ Measure 10 mL of half-strength bleach using the graduated cylinder while data is recording.

24. ☐ After recording data for 3 minutes, remove the stopper from a port at the top of the chamber and add the 10 mL of vinegar. Replace the stopper.

Note: Do not stop recording data!

25. ☐ Record data for 3 additional minutes and again add 10 mL of half-strength bleach.

Note: Do not stop recording data!

26. ☐ Repeat this procedure until a total of 50 mL of half-strength bleach has been added.

27. ☐ Record data for 3 additional minutes.

28. ☐ Stop recording data. �(6.2)

29. ☐ Name the data run appropriately. �(8.2)

30. ☐ Discard the yeast solution as instructed by your teacher, and rinse the chamber and pH sensor.

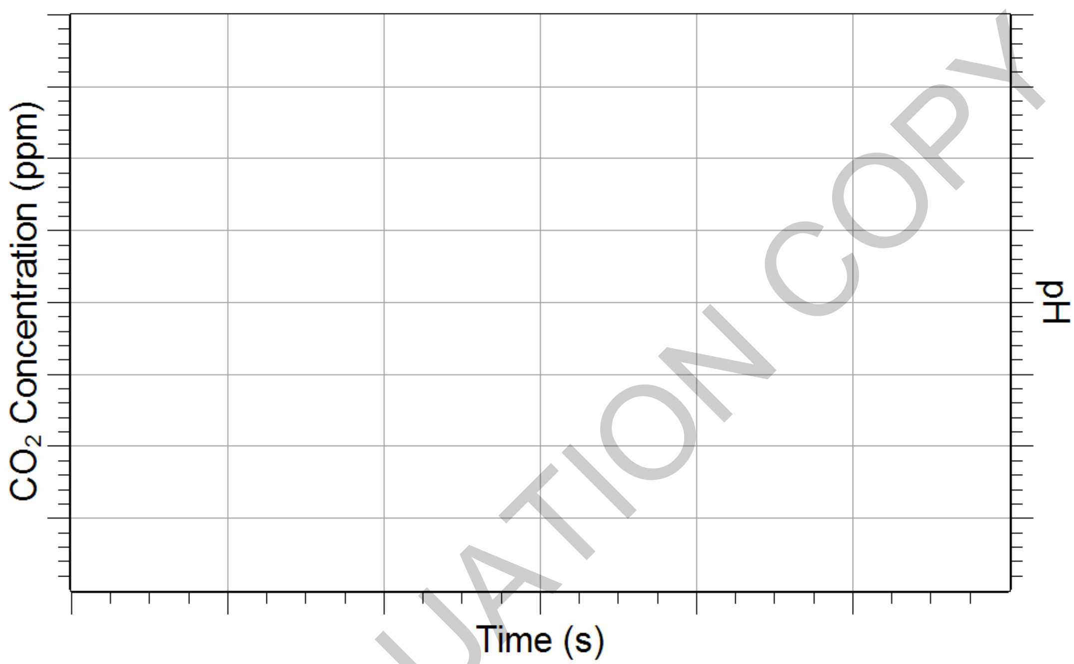
31. ☐ Save your experiment and clean up according to your teacher's instructions. �(11.1)

Data Analysis

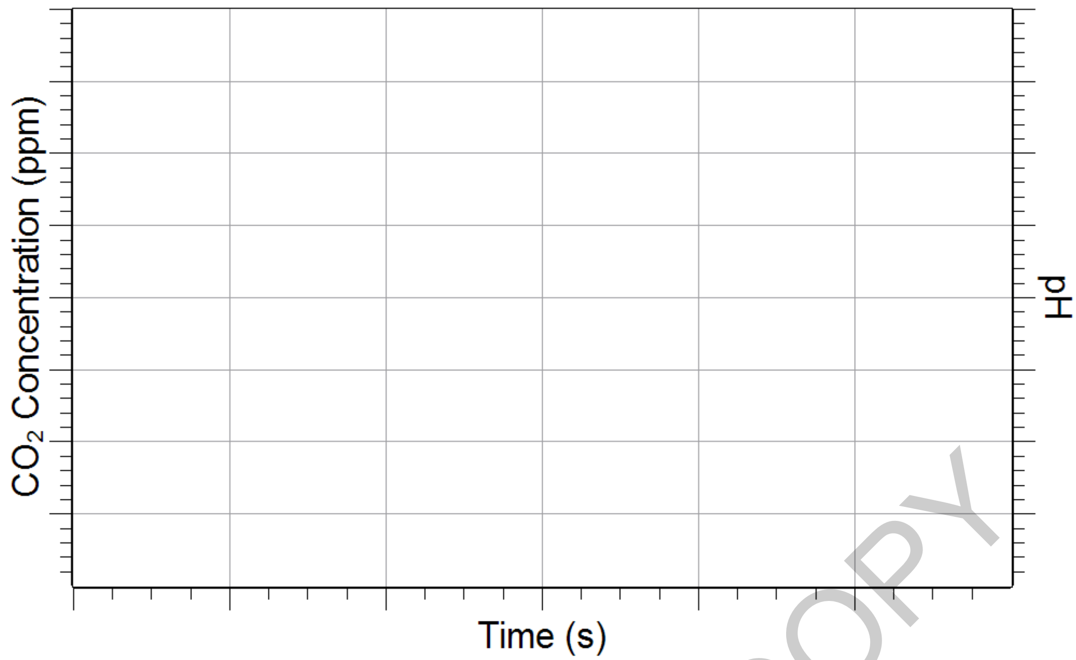
1. ☐ Display the dependent variable on the y-axis of a graph and time on the x-axis for both measurements (pH and CO_2 gas concentration) for each toxin. �(7.1.11)

2. ☐ Adjust the scale of the graph so the data fills the screen. �(7.1.2)

3. ☐ Sketch the graphs on the blank graphs. Sketch one graph for the vinegar trial and one graph for the half-strength bleach trial. Indicate the appropriate scale on the axes. Indicate the points at which the toxins were added to the system.



Effect on CO_2 concentration and pH of adding aliquots of full-strength vinegar



Effect on CO_2 concentration and pH of adding aliquots of half-strength bleach

4. ☐ Use graph tools to find the value of data points to complete Table 1. �(9.1)

Hint: To find the rate of CO_2 production (parts per million/second) for selected regions of the CO_2 data plot, use the linear fit tool to determine the slope of a best-fit line. �(9.6) To find the pH value for selected regions of the pH plot, use the statistics tool to find the mean value. �(9.4)

Table 1: Enter the rate of production of CO_2 gas and the pH change for each of the toxins

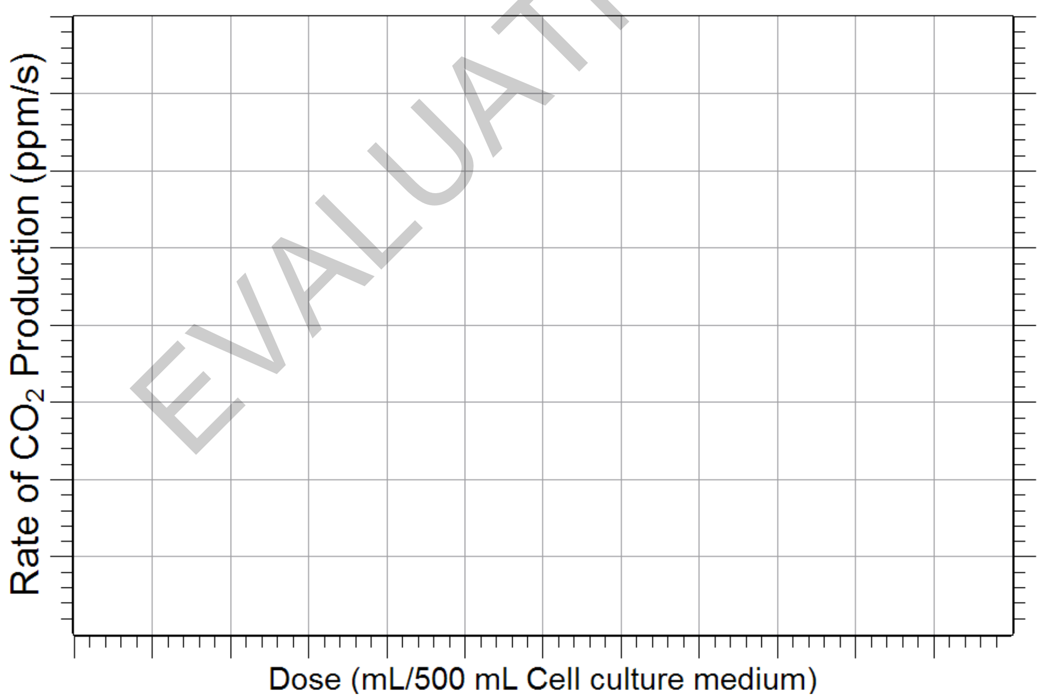
	Rate of production of CO_2 gas (ppm/s)						**pH**					
Toxin (total volume added)	**0 mL**	**10 mL**	**20 mL**	**30 mL**	**40 mL**	**50 mL**	**0 mL**	**10 mL**	**20 mL**	**30 mL**	**40 mL**	**50 mL**
White Vinegar												
Bleach: water 1:1												

5. ☐ Toxicologists often report the strength of a toxin in terms of LD_{50} or ED_{50}. Which of these terms is most appropriate for the results of this experiment? Explain.

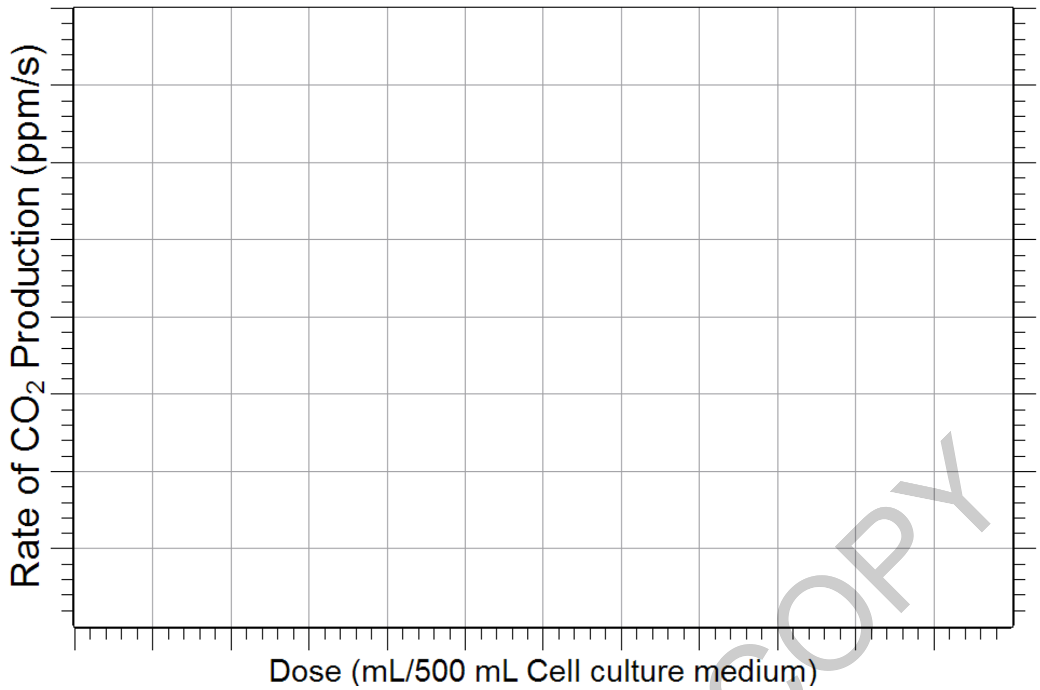
Note: The LD_{50} is the dose of a substance at which 50% of the organisms are killed—that is, the lethal dose for 50% of exposed organisms. In many cases, the end point of interest is a sublethal effect, such as affecting the ability to reproduce or inhibiting metabolism. In these cases, the strength of a toxin is reported in terms of ED_{50}—that is, the effective dose causing 50% inhibition.

6. ☐ Use your data to extrapolate the ED_{50} of the half-strength bleach solution and the full-strength vinegar solution. To do this:

- **a.** Plot the rate of CO_2 gas production versus the dose administered (mL toxin solution/500 mL).
- **b.** Then connect the points and use this curve to extrapolate the volume of toxin (mL toxin/500 mL yeast culture) required to reduce the rate of CO_2 gas production in half (ED_{50}).
- **c.** Adjust the dose calculation to terms of mL toxin/L yeast culture.



Toxicity of full-strength vinegar



Toxicity of half-strength bleach

ED_{50} of full-strength vinegar ______________

ED_{50} of half-strength bleach: ______________

Analysis Questions

1. **What is the independent variable in this experiment?**

____

2. **What are the dependent variables?**

____

3. **What are the controlled variables in this experiment?**

____

____

4. **How do the data compare with your prediction?**

5. **What does the rate of CO_2 gas production indicate regarding the yeast culture? Explain why the rate of CO_2 gas production by a yeast culture can be used as an indicator of the toxicity of an added substance.**

6. **Why do you think pH was measured in this experiment? What was the relationship of pH to toxicity? Was a large change in pH necessary for a toxic effect to occur?**

7. **For the best interpretation of the data, what additional test should be run with this assessment? Explain.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. Determine the mean and standard deviation (SD) of the ED_{50} data obtained from the several trials conducted in your class. Compare the results of your trial to that of your classmates. Discuss possible reasons for the variations seen. Which value do you think is closest to the true value?

2. In what ways are yeast cells good subjects for toxicity studies?

3. What are some limitations of using yeast cells as subjects for toxicity studies?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The toxicity of a substance depends on

- **A.** Genetic makeup or sensitivity of the organism
- **B.** Frequency of exposure
- **C.** Ability of the body to detoxify
- **D.** The amount or dose
- **E.** All of the above

2. An LD_{50} is a determination of

- **A.** The amount of a toxin required to inhibit growth by 50%
- **B.** The amount of a toxin required to inhibit reproduction by 50%
- **C.** The amount of a toxin required to kill 50% of a population
- **D.** The lethal dose of a chemical after 50 days of exposure

3. An ED_{50} is a determination of

- **A.** The amount of a toxin required to inhibit growth by 50%
- **B.** The amount of a toxin required to inhibit reproduction by 50%
- **C.** The amount of a toxin required kill 50% of a population
- **D.** The lethal dose of a chemical after 50 days of exposure
- **E.** Both A and B could apply

4. Yeast cells can be useful in toxicology studies because

- **A.** They are eukaryotic.
- **B.** They have many metabolic pathways that are similar to those of humans.
- **C.** They are easy to grow.
- **D.** Their genetic code is largely mapped.
- **E.** All of the above.

5. Which of the following characteristics of baker's yeast is *not* a limitation in using yeast cells for toxicology studies?

- **A.** They have some metabolic pathways that are not found in humans.
- **B.** They are not pathogenic.
- **C.** They do not have similar detoxification mechanisms compared with those of humans.
- **D.** They are single-cellular organisms.
- **E.** They reproduce differently than humans.

6. In this activity, the rate of CO_2 gas production was used as an indicator of toxicity to yeast cells because

- **A.** It indicates the relative amount of cellular respiration by actively growing yeast cells.
- **B.** CO_2 is consumed by yeast cells during aerobic cellular respiration.
- **C.** Yeast cells release CO_2 gas when they die.
- **D.** The toxin reacts to substances in the yeast cells to produce CO_2 gas.
- **E.** A and D are correct.
- **F.** None of the above.

21. Water Treatment

Driving Questions

Both drinking water and wastewater need to be treated to remove critical contaminants. Various methods of filtration and other processes are used by water treatment agencies to accomplish this.

- What are some processes used in water treatment, and what contaminants do they remove?
- Can you design an effective water treatment system?

Background

There are several steps in the water treatment process common to both drinking water and wastewater treatment. Among these processes are coagulation, flocculation, and filtration.

Filtration technology is abundant and can be used to remove nearly any impurity from water. However, using only filtration devices is not cost effective, so usually filtration is combined with other water treatment methods.

Both types of water treatment—for drinking water and for wastewater—start by passing the water through a screen to remove larger objects. Then, a coagulant is added to the water. Salts of aluminum (alum) or water-soluble organic polyelectrolytes are often used as coagulants. Coagulants cause suspended particles to form clumps. Next, these clumps aggregate into larger clumps, or flocs. These flocs are dense enough to settle out of the water in a process called sedimentation. The water is then filtered through a variety of media of varying porosities, including activated carbon, sand, and gravel. Filtration works by trapping impurities in the spaces between the granules of the media and allowing the water to flow through it.

While the water looks clean at this point, several precautions must be taken to eliminate viruses or bacteria in the water that can cause disease. Three of the most common ways to disinfect water include: 1) treatment with chlorine, 2) bubbling with ozone, or 3) exposure to ultraviolet light. More advanced (and expensive) filtration methods use membranes—for example, reverse osmosis and micropore filtration—for special purposes.

Materials and Equipment

For each student or group:

- Data collection system
- Water quality sensor (or pH and conductivity sensors)
- Turbidity sensor
- Beaker (4), 150-mL
- Beaker, 50-mL
- Beaker, large ("wastewater" container)
- Test tube, 18-mm OD or greater
- Graduated pipet, 50-mL, and bulb
- Graduated cylinder, 100-mL
- Transfer pipet, 2 mL
- Stirring rod
- Balance (1 per class)
- Buffer solution pH 4, 25 mL
- Buffer solution pH 10, 25 mL
- Soda bottle (2), empty, 500-mL
- Paper napkins (12), dinner, white, smooth
- Paper towels(4), white
- "Wastewater" sample, 500 mL
- Swimming pool water clarifier solution, 4%, 2 to 4 mL
- Wash bottle containing water
- Activated charcoal, 2 g
- Water, 300 mL
- Lint-free lab tissue

Safety

Follow all standard laboratory procedures.

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 a paper membrane filter. Make an activated charcoal-paper membrane filter.	◯ Set up your data collection system to monitor pH, conductivity, and turbidity. Calibrate the pH and turbidity sensors.	◯ Design a water treatment technique selecting from the techniques just tested. Test your design and evaluate the results.	◯ Set up the samples and set aside the sedimentation and coagulation samples for at least 30 minutes.	◯ Test the various filtration systems and treatments for effectiveness in purifying the water.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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 – Determining effects of different water treatment processes

Set Up

1. ☐ Stir the "wastewater" sample to uniformly mix it.

2. ☐ Pour 100 mL of the well-mixed "wastewater" sample into each of four 150-mL beakers.

3. ☐ Label the beakers as follows:

- Beaker 1, "#1 Untreated"
- Beaker 2, "#2 Activated Charcoal"
- Beaker 3, "#3 Sedimentation"
- Beaker 4, "#4 Coagulation"

4. ☐ Set Beaker 3 aside for at least 30 minutes. Enter the starting time: __________

5. ☐ Put 2 mL of the 4% swimming pool clarifier solution in Beaker 4 and use the stirring rod to stir vigorously.

6. ☐ Note any changes in appearance and record these in Table 1 in the Data Analysis section.

7. ☐ Periodically during the next 30 minutes, slowly stir this solution.

Note: Swimming pool clarifier solution contains coagulating agents similar to those used in municipal water treatment facilities.

8. ☐ Start a new experiment on the data collection system. �(1.2)

9. ☐ Connect a water quality sensor (or pH and conductivity sensors) and a turbidity sensor to the data collection system. �(2.2)

10. ☐ Display pH, conductivity, and turbidity in a digits display. �(7.3.1)

11. ☐ Use pH 4 and pH 10 buffer solutions to calibrate the pH sensor. �(3.6)

12. ☐ Calibrate the turbidity sensor. �(3.7)

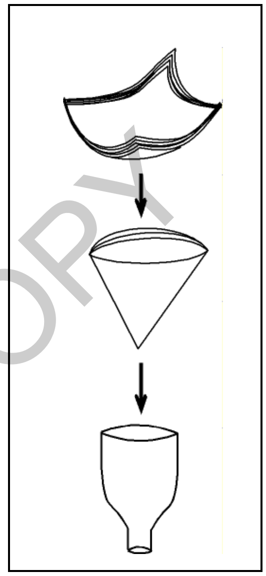
Note: It is not necessary to calibrate the conductivity sensor for this activity.

13. ☐ Prepare a paper membrane filter as follows:

a. Cut off the top half of a 500-mL soda bottle to use as a funnel.

b. Fold a paper towel in half, and then fold it in half again. Separate the layers to make a funnel-shaped filter.

c. Stack 3 paper napkins together, and shape them into a shallow bowl. Tuck these into the paper funnel, and push the entire paper membrane construction into the funnel, forming a bowl to hold the filtrant.



14. ☐ Prepare an activated charcoal–paper membrane filter as follows:

a. Make another paper membrane filter as described in the previous step.

b. Measure and add 1 gram of activated charcoal to 100 mL of tap water and stir.

c. Pour this slurry into the filter.

d. After that aliquot has been filtered, slowly pour another 100 mL of tap water into the filter.

e. You should now have a paper membrane filter covered with a layer of activated charcoal. If the water filtering through it is not clear, filter an additional 100 mL of tap water.

Note: This step ensures that the activated carbon becomes fixed inside the filter and is not leaking into the filtrate.

Note: Activated charcoal is specially prepared so that it is extremely porous and can thus trap and remove molecules from water, especially large organic molecules such as those responsible for odors and colors. The activated charcoal must also be filtered out of the water.

15. ☐ Which water treatment method do you think will have the greatest effect on the following?

Odor ____________________________

Color ____________________________

pH ______________________________

Conductivity _____________________

Turbidity ________________________

16. ☐ Which water treatment method do you think will have the least effect on the following?

Odor ___________________________

Color ___________________________

pH _____________________________

Conductivity ____________________

Turbidity _______________________

Collect Data – Untreated waste water

17. ☐ Examine the untreated "wastewater" sample (Beaker 1). Note its odor, color, and general appearance, and record these in the Table 1 in the Data Analysis section.

18. ☐ Monitor live data without recording. �(6.1)

19. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 1.

Collect Data – Paper membrane filtration

20. ☐ Now test the effect of filtration on the untreated wastewater sample.

- **a.** Slowly pour the untreated sample into the paper filter, being careful to keep the liquid contained inside the paper napkin "bowl".
- **b.** Collect the filtrate in the 50-mL beaker.

21. ☐ Determine the odor, color, and general appearance of the filtrate, and record these in Table 1.

22. ☐ Transfer the filtrate to a large test tube.

23. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 1.

24. ☐ Rinse the beakers and test tube.

Collect Data – Activated charcoal-paper membrane filtration

25. ☐ Using the activated charcoal–paper membrane filter you prepared earlier, filter 100 mL of the "wastewater" from Beaker 2 into the graduated cylinder.

26. ☐ Discard the first 30 mL of filtrate. Collect the remaining filtrate in the 50-mL beaker.

27. ☐ Note the odor, color, and general appearance of the filtrate, and record these in Table 1.

28. ☐ Transfer the filtrate to the large test tube.

29. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 1.

30. ☐ Rinse the beakers, graduated cylinder, and test tube.

31. ☐ What effects did adding activated charcoal to the paper membrane filtration have on the results of the filtration?

____

____

Collect Data – Coagulation plus paper membrane filtration

32. ☐ Observe the coagulated sample (Beaker 4). Compare it with an untreated sample and record your observations here:

____

____

33. ☐ Determine the pH, conductivity, and turbidity and record the data in Table 1 (in the row labeled "Coagulation").

34. ☐ Prepare another paper membrane filter as described previously.

35. ☐ Filter the coagulated sample using this paper membrane filter.

36. ☐ Note the odor, color, and general appearance of the filtrate, and record these in Table 1.

37. ☐ Transfer the filtrate to the large test tube.

38. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 1.

39. ☐ Rinse the beakers and test tube.

Collect Data – Sedimentation

40. ☐ From Beaker 3, carefully pipet a 30-mL sample from the top of the solution, being careful not to disturb the solution.

41. ☐ Place the sample in the test tube.

42. ☐ Note the odor, color, and general appearance of the sample, and record these in Table 1.

43. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 1.

44. ☐ Rinse the beakers and test tube.

Part 2 – Designing and testing a water treatment system

Set Up

45. ☐ Design a water treatment procedure using the techniques presented in Part 1 of this activity.

46. ☐ Record the water treatment steps in your design and explain why you chose this design. Refer to your test results in Part 1.

____

____

____

Collect Data

47. ☐ Treat 100 mL of the "wastewater" using the system you designed.

48. ☐ Note the odor, color, and general appearance of the sample, and record these in Table 2.

49. ☐ Transfer the filtrate to the large test tube.

50. ☐ Determine the pH, conductivity, and turbidity, and record them in Table 2.

51. ☐ Clean up according to your teacher's instructions.

Data Analysis

Table 1: Water treatment process results

Water Treatment Type	pH	Conductivity (µS/cm)	Turbidity (NTU)	Odor	Appearance (Color, Transparency, Other Observations)
Untreated "wastewater"					
Paper membrane filtration					
Activated charcoal + paper membrane filtration					
Coagulation					
Coagulation + paper membrane filtration					
Sedimentation					

1. ☐ Compare the data obtained from your designed water treatment system with the data collected in Part 1 and complete the "Best Individual Test System" row in Table 2.

2. ☐ Share the data from your designed water treatment system with those collected by classmates and then complete the "Best Designed System in the Class" row in Table 2.

Table 2: Results of the designed water filtration systems

Water Treatment Data Set	pH	Conductivity (µS/cm)	Turbidity (NTU)	Odor	Appearance (Color, Transparency, Other Observations
My designed treatment system					
Best individual test system (from Part 1)					
Best designed system in the class					

Analysis Questions

1. **Compare your predictions with your results. Which result surprised you the most?**

2. **What was the effect of filtration using a paper membrane?**

3. **What was the effect of treatment with the activated charcoal and membrane filtration?**

4. **What was the effect of treatment with a coagulating agent? What was the effect of coagulation and paper membrane filtration?**

5. **What was the effect of treatment with sedimentation?**

6. **What quality of water is measured with the conductivity sensor?**

7. **Which treatment method worked best for odors?**

8. **Which treatment method worked best for removing turbidity? Which was least effective?**

9. **What was the effect of the various treatments on pH?**

10. **Compare the results obtained with your custom-designed filtration process to those you got with the individual filter media. Be sure to make comparisons regarding the rate of filtration. (Why might this be important?)**

11. **Based on your results and those of your classmates, which combination of treatments produced the best results? Explain, using your data to support.**

12. How did your class's best design measure up to the United States Environmental Protection Agency's Drinking Water Standards? Describe one way you might improve your system or the evaluation of your system.

The United States Environmental Protection Agency's Drinking Water Standards specify the following maximum contamination levels for the parameters you measured:

- pH: 6.5 to 8.5
- Conductivity: total dissolved solids, 500 mg/L (which corresponds to a conductivity of approximately 1000 μS/cm)
- Turbidity: 1 NTU
- Odor: 3 threshold odor number (a threshold odor number is defined as the greatest number of dilutions of a sample with "odor-free" water yielding a definitely perceptible odor)

Synthesis Questions

Use available resources to help you answer the following questions.

1. What are some differences between water treatment for human consumption compared with wastewater treatment for discharge into the environment?

2. What treatment methods would you include if you had to design a wastewater treatment system that resulted in drinking water? Explain.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The main purpose of sewage treatment is to:

- **A.** Kill pathogenic bacteria and reduce odor
- **B.** Remove biodegradable materials from the water and to kill pathogenic bacteria
- **C.** Kill pathogenic bacteria and remove plant nutrients
- **D.** Kill pathogenic bacteria, remove biodegradable materials, and make the water safe for human use
- **E.** None of the above

2. The main purpose of drinking water treatment is to:

- **A.** Kill pathogenic bacteria and reduce odor
- **B.** Remove biodegradable materials from the water and kill pathogenic bacteria
- **C.** Kill pathogenic bacteria and remove plant nutrients
- **D.** Kill pathogenic bacteria, remove biodegradable materials, and make the water safe for human use
- **E.** None of the above

3. What factor is NOT generally included in treating water for human use?

- **A.** Cost effectiveness
- **B.** Killing microorganisms
- **C.** Removing suspended solids
- **D.** Removing dissolved solids
- **E.** A and C

22. Greenhouse Gases

Driving Questions

How do greenhouse gases interact with the atmosphere and cause a temperature increase?

- ♦ Can we reproduce a greenhouse environment and study the effect of an introduced harmful gas?
- ♦ What are some possible solutions to global warming and ozone-depletion?

Background

Greenhouse Gases Absorb Incoming Solar Radiation

Carbon dioxide and methane are greenhouse gases – atmospheric gases that absorb reradiated energy from the earth's surface and trap heat in the atmosphere. Solar radiation from the sun passes through the atmosphere and is partially absorbed by the earth's surface. This energy is then reradiated from the surface of the planet in the form of longwarm infrared energy (IR). Some of this radiation passes through the atmosphere and into space, while greenhouse gases absorb the remainder, trapping heat in the atmosphere. This is called the greenhouse effect. Without greenhouse gases, the earth's climate would be extremely cold and uninhabitable, and most life on this planet would be gone.

Many other types of greenhouse gases exist whose ability to trap heat in the atmosphere far exceeds carbon dioxide, methane, or water vapor. Chlorofluorocarbons (CFCs), for example, were used throughout the 20th century as a refrigerant and in common aerosol cans but were found to contribute heavily to ozone(O_3) depletion by binding with oxygen atoms. In cases where CFCs were used as a propellant, they were replaced by difluoroethane and tetrafluoroethane. These compounds do not contribute to ozone-depletion to the same degree as CFC's, but they are strong greenhouse gases.

Ozone-Depletion versus Global Warming Potential

Ozone-depletion and global climate change are two very distinct and different issues. Concerns over ozone-depletion are almost entirely biological and are directed at the effect of decreased protection against cancer-causing UV rays and decreased health of the polar environment rather than any increase in global temperatures.

While one compound may be an ozone-depleting gas, it may not also be a greenhouse gas and vice versa. The latter is true in the case of tetra- and difluoroethane. Neither of these compounds have the ozone-depletion potential of CFCs, but their ability to trap heat in the atmosphere far exceeds that of carbon dioxide, with difluoroethane having a global warming potential of 1800 according to the Intergovernmental Panel on Climate Change (IPCC 1995). The global warming potential of a compound is its estimated contribution to global warming, relative to a scale that compares that compound to carbon dioxide (whose GWP is 1 by definition). NOAA (National Oceanic and Atmospheric Administration) estimates that global surface temperatures have risen between 0.5°C and 0.9°C during the 20th century, and in the last 50 years there has been an increase of 0.13°C per decade. These increases are small but they are significant.

Materials and Equipment

For each student or group:

- Data collection system
- Fast-response temperature probe
- EcoChamber with stoppers
- Size 5 or 5 1/2 solid stoppers (2)
- Dark aquarium rocks or dark sand (approximately 200 g)
- Heating lamp
- Ring stand
- Balance (1 per class)
- Canned keyboard duster (fresh)
- Heavy-duty tape

Safety

Add these important safety precautions to your normal laboratory procedures:

- Pressurized cans of difluoroethane can become very cold, especially when inverted, and may burn your hands or even cause frostbite if propellant is continually released for long periods of time. Activate the can in short bursts only. Hold the can upright, and do not shake the can.
- Inhaling excessive concentrations of difluoroethane causes dizziness and can be fatal. Avoid direct inhalation. In addition, it is flammable. Use in a well-ventilated area and follow all safety precautions printed on the can.

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.

◯	◯	◯	◯	◯
Seal off all remaining holes in the Ecochamber with stoppers and heavy duty tape.	Set up the EcoChamber and insert one fast-response temperature probe into one hole on the top of the chamber.	Collect data for 5 minutes of heating and 5 minutes of cooling.	Introduce the tetrafluoroethane into the chamber and reseal it tightly.	Collect data again for 5 minutes of heating and 5 minutes of cooling. Compare your results.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" 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.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Set up the EcoChamber as indicated in the following steps.

3. ☐ Place 3 flat stoppers into the holes on the top of each EcoChamber. These stoppers have small holes to accommodate the temperature sensor. Plug two of these holes with the small rubber dowels.

4. ☐ Thread the temperature sensor through the hole in the last stopper on the lid of the chamber. Pull the temperature sensor through the stopper until the sensor hangs down approximately halfway in the chamber.

5. ☐ Once the temperature sensor is in place, cover the hole with heavy-duty tape.

6. ☐ Connect the fast-response temperature probe to the data collection system. �(2.2)

7. ☐ Measure out approximately 200 grams of aquarium rocks or enough to cover the bottom of each chamber. Place these in the chamber.

8. ☐ Place the lid on the chamber, and stopper the holes on the sides of the chamber with solid stoppers (size 5 or 5 1/2 will work). If the stoppers are not solid, cover them with heavy-duty tape to ensure a good seal.

9. ☐ Why do you think the holes in the sides need to be sealed, as well as the extra hole in the top?

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10. ☐ Position the heating lamp so that it will shine on the chamber, angled slightly downward to increase the amount of solar radiation hitting the rocks. Do not turn the light on yet.

Collect Data

11. ☐ Display Temperature on the y-axis of a graph with Time on the x-axis. �(7.1.10)

12. ☐ Turn on the lamp and begin recording data. �(6.2)

13. ☐ After 5 minutes, turn the lamp off and continue to record data for 5 minutes more.

14. ☐ Stop recording data. �(6.2)

15. ☐ Adjust the scale of the graph. �(7.1.2)

Set Up

16. ☐ Open the EcoChamber and allow it to cool completely. You may want to replace the rocks with room temperature rocks, but use the same mass of rocks as you did before.

17. ☐ If you decide to replace the rocks, why is it necessary to use the same amount of rocks as you used the first time?

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18. ☐ Replace the lid on the EcoChamber. Ensure that the temperature probe is hanging as it was in the first trial, and that the lamp and the chamber are positioned exactly as they were in the first trial.

19. ☐ Place the plastic straw that accompanies the keyboard duster into the nozzle of the can. Do not shake the can. When the trigger is pulled, the propellant should leave the can in a steady, concentrated stream.

20. ☐ Peel back the tape on the rubber stopper on the side of the chamber and place the straw of the keyboard duster into the hole. Fill the chamber with difluoroethane by pulling the trigger on the can in a series of short bursts. Keep the can upright while dispensing.

21. ☐ Begin recording data without turning on the lamp �(6.2) and continue to dispense the difluoroethane in short bursts.

22. ☐ Watch the data carefully. Once the temperature inside the chamber is below the starting temperature of the control run, stop dispensing difluoroethane.

23. ☐ Remove the straw and immediately plug the hole.

24. ☐ Watch the temperature on the graph. When the temperature is 2 to 3 degrees below the starting point of the first run, stop recording data. �(6.2)

25. ☐ Why is it necessary to wait for the experimental chamber to reach room temperature, or at least the same temperature as the control chamber?

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26. ☐ Hide this last run of data. �(7.1.7) You will not need it.

Collect Data

27. ☐ Turn on the light and begin data recording. �(6.2)

28. ☐ Collect data for 5 minutes under the lamp. Then, turn off the light and continue to collect data for an additional 5 minutes while the chamber cools.

29. ☐ Stop data recording. �(6.2)

30. ☐ Adjust the scale of the graphs if necessary. �(7.1.2)

31. ☐ Save your experiment. �(11.1)

Data Analysis

1. ☐ Find the initial, final, maximum, and change in temperature for both chambers �(9.1) and enter this data in Table 1.

Table 1: Temperature data

Chamber	Initial Temp. °C	Maximum Temp. °C	Increase in Temp. °C	Final Temp. °C	Change in Temp. °C
Control (air)					
Experimental (difluoroethane)					

2. ☐ What is the change in temperature for the heat gain in both cases after the light was turned on?

3. ☐ What was the change in temperature for the heat loss in both cases after the light was turned off?

4. ☐ Which system retained heat longer? How do you know?

5. ☐ How did the change in temperature from initial to final temperature for the experimental run compare to the change in temperature for the control run?

Analysis Questions

1. How significant are the differences that you observed in heat retention and maximum temperature?

2. In analyzing this data, which of the following is more valuable to compare: the overall change in temperature, the heating change in temperature, the cooling change in temperature, or the difference in maximum temperatures? Explain your reasoning.

3. **In what ways can you use the results from this demonstration to predict the effects of this gas on the atmosphere?**

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4. **In what ways does this demonstration fail to predict what effect this gas would have on the atmosphere?**

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Synthesis Questions

Use available resources to help you answer the following questions.

1. **Considering the severity of the IR absorption of the difluoroethane and its increased ability to trap heat, why are scientists so concerned about carbon dioxide and not gases like difluoroethane and other man-made gases?**

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2. **In some cases, one solution to an environmental problem can result in another environmental problem. In this case, ozone-depleting chlorofluorocarbons (CFCs) were replaced by tetrafluoroethane, which contributes to global warming. What are some ways to avoid this situation?**

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3. **At your home, examine canisters and other sources of propellants to see what, if any, greenhouse gases discussed in this lab may be contained within those canisters. Make a list of the products here, and the propellants they contain.**

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Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following is NOT true of chlorofluorocarbons (CFCs)?

- **A.** CFCs were commonly used as propellants and refrigerants.
- **B.** CFCs are extremely toxic and harmful to human health.
- **C.** CFCs cause ozone-depletion and contribute to the growing of the hole in the ozone layer.
- **D.** CFCs are greenhouse gases associated with increased global warming trends.
- **E.** All of the above are true.

2. Atmospheric pollution affects which area(s) of the atmosphere?

- **A.** Mesosphere
- **B.** Stratosphere
- **C.** Troposphere
- **D.** Ionosphere
- **E.** B and C

3. What makes a gas an ozone-depleting gas?

- **A.** The gas will re-radiate longwave infrared energy into the ozone.
- **B.** The gas will absorb ozone molecules.
- **C.** The gas will bind with one of the oxygen atoms in the molecule, reducing it to O_2.
- **D.** Ozone-depletion only occurs when temperatures rise and the atmosphere warms up.
- **E.** Any gas can become an ozone-depleting gas if there is enough of it.

4. What is the main cause of atmospheric warming from greenhouse gases?

- **A.** Greenhouse gases usually have a high specific heat and get very hot.
- **B.** Greenhouse gases make the atmosphere much thicker and more polluted, so they trap the sun's direct rays and warm the air.
- **C.** Greenhouse gases absorb and re-emit IR waves that enter the atmosphere from the sun.
- **D.** Greenhouse gases absorb and re-emit IR waves that are radiated from Earth's surfaces.
- **E.** None of the above are true.

5. Why is difluoroethane used in place of chlorofluorocarbons today as a propellant?

- **A.** Difluoroethane is much less of an ozone-depleter than chlorofluorocarbons.
- **B.** Difluoroethane is much less of a greenhouse gas than chlorofluorocarbons.
- **C.** Even though difluoroethane is more of a greenhouse gas, it was chosen because it is less of an ozone-depleter than chlorofluorocarbons.
- **D.** All of the above are true.
- **E.** Both A and C are true.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. Carbon dioxide and methane are greenhouse gases – atmospheric gases that absorb reradiated energy from the earth's surface and trap heat in the atmosphere. Solar radiation from the sun passes through the ________________ and is partially absorbed by the earth's surface. The heat that is absorbed by the ground is radiated to the atmosphere in the form of ________________ radiation (IR), It is this longwave ________________ energy that greenhouse gases can trap and re-emit to ________________ the atmosphere even further.

2. Many other types of greenhouse gases exists whose ability to trap heat in the atmosphere far exceeds ________________, ________________, or ________________. Chlorofluorocarbons, for example, were used throughout the 20th century as refrigerants and in common ________________ cans but were found to contribute heavily to ozone-depletion. In cases where CFCs were used as a propellant, they were replaced by ________________ and tetrafluoroethane.

3. It is possible that a compound may be a greenhouse gas, without actually depleting the **ozone** layer as badly as CFC's. This is true for ________________ and difluoroethane. Neither of these compounds have the ozone-depletion potential of CFCs, but their ability to trap ________________ in the atmosphere far exceeds that of carbon dioxide, with ________________ having a global warming potential ________________ of 1800. The global warming potential of a compound is its estimated ________________ to global warming. Many other types of greenhouse gases have a GWP greater than that of ________________, but they are available in such ________________ quantities that they are not considered an immediate ________________ to global warming.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2	Paragraph 3
greenhouse gases	oxygen	tetrafluoroethane
greenhouse warming	chlorofluorocarbons	chlorofluorocarbons
cooling	carbon dioxide	ozone
warm	ozone depletion	difluoroethane
shortwave	hydrocarbons	GWP
longwave	water vapor	carbon dioxide
electromagnetic	difluoroethane	heat
radiant	gasoline	large
	methane	small
	aerosol	threat