DENSITY
&
SALINITY

Lesson Plan

A CURRICULUM IN MARINE SCIENCES

FOR GRADES 4 - 8

UNIVERSITY OF CALIFORNIA, LOS ANGELES
MARINE SCIENCE CENTER

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DENSITY & SALINITY LESSONS

SEAWATER DENSITY & SALINITY

Introduction:

Water is an amazing solvent. It is able to retain large amounts of salts and other materials in solution. When this occurs, the salts change the properties of water. For example, when salt is dissolved in water the freezing point of water is lowered. Thus, fresh water freezes at 0 ° C., whereas normal seawater freezes at –1.9 degrees C. As ice forms in salt water, there is no room in the crystal for salt. Most of the salt is squeezed out of the ice structure and the resulting ice is less salty than when it began to freeze. In the polar regions, where seawater freezes to form sea ice, the ice is not as salty as the seawater from which it formed. Sea ice, which is different from icebergs, looks like flat ice “plates” floating at the surface in polar seas. In the Antarctic Ocean, most (perhaps 90%) of the sea ice forms anew each winter and melts the next summer, and it is seldom more than about one meter thick. In the Arctic Ocean, however, sea ice often does not melt each summer, but instead a new layer of ice is added each winter, producing multiyear sea ice that can become many meters thick. Icebergs, on the other hand, are formed on land, and thus glaciers are formed entirely of fresh water. Most icebergs are pieces of glaciers, which have broken off and floated away when the glaciers reached the sea. They are jagged chunks of ice that can take many shapes. Most of an iceberg is below the surface of the sea.

Seawater has a higher density than fresh water. Sea water contains many dissolved substances and these add mass to the water within which they are dissolved, thereby producing a greater mass per unit volume, or a density, higher than that of pure water. The amount of salts dissolved in water is called salinity. Salinity is measured in g per 1000 ml and a special symbol is used: 0/00 by weight. Open ocean water has an average salinity of about 35 o/oo (equivalent to 3.5%, if one were to use units of one hundred instead of one thousand for the amount of water. Scientists almost always use metric measurements, however, and express quantities of dissolved substances as grams per liter, or 1000 ml. Thus, we use parts per thousand to express salinity). Salinities near shore vary due to the addition of fresh water by rivers and rainfall. An estuary is a semi-enclosed body of water where incoming seawater is diluted with fresh water coming from the land. Because of differences in density between fresh and salt water, salt water will move upstream in the estuary along the bottom, while fresh water will flow downstream along the surface. Some mixing occurs at the interface where fresh and salt water meet. This is called brackish water. Local conditions of temperature and water circulation may also increase or decrease salinity. Salinities vary in different bodies of water. For example:

Red Sea	**=**	**40 ^{o}/oo**
Mediterranean Sea	**=**	**38 ^{o}/oo**
Average Seawater	**=**	**34.7 ^{o}/oo**
Black Sea	**=**	**18 ^{o}/oo**
Baltic Sea	**=**	**8 ^{o}/oo**

Scientists use a variety of instruments to determine the density of water. Hydrometers work on the principle that an object submerged in water must displace a weight of water equal to that of the object itself. Water (or any liquid) pushes on objects placed within them. If the object is lighter than the water it displaces, this force is directed upward and it is called buoyancy. Buoyancy counteracts the earth's gravitational force, which pulls the objects downwards, towards the center of the earth. Because the density of saltwater is greater than the density of fresh water, objects in seawater float higher than they do in freshwater. Buoyancy is why ships float. Ships float because the force of gravity pulling the ship down is less than the force of the water pushing the ship up. Empty ships ride high in the water. When loaded with cargo a ship rides lower in the water. It is important not to load too much cargo aboard or the ship will take on water and sink. A "Plimsoll mark" is found on all large ships. This mark shows proper loading in fresh or seawater. A ship can hold more cargo in seawater because it floats higher.

The relationship between density of a fluid, weight of an object, and buoyancy is an absolutely basic concept for all students of the sea or fresh waters, because density directly affects everything in the water. Scientific understanding of this basic science concept was first elucidated more than 2,000 years ago by Archimedes, a Greek scientist and middle school teacher (he was the private tutor for Alexander the Great). Archimedes was interested, among other things, in why things float. He answered this question by a series of careful experiments in which he weighed the water displaced by each of the objects he tried to float and then weighed the object. Archimedes found that the weight of the water displaced by the floating object is greater than or equal to the weight of the object.

Another quality of seawater is its ability to conduct electricity. When salts are dissolved in water they dissociate and become ions that carry positive or negative charges. It is the ions that are dissolved in water that conduct electricity. Conductivity increases as the amount of dissolved salts, or ionic content, increases. Oceanographers generally use conductivity meters to determine the salinity of seawater rather than hydrometers because conductivity meters are more sensitive.

A very important property of water, in both freshwater and in the sea, is the heat capacity of water. Heat capacity is the amount of heat needed to raise the temperature of 1 gram of a substance by 1 degree Centigrade, and this amount of heat, one Calorie, is used as the international standard against which all other substances are compared. Most substances, such as air, rock, iron, glass, etc., require less heat per gram to warm one degree C than water. Only liquid ammonia has a higher heat capacity than does water. Because of its high heat capacity, the ocean is refractory to sudden temperature changes. The ocean holds an enormous amount of heat, even at the poles. It is important to remember that temperature and heat are different. Heat is a quantity of energy, whereas temperature is how rapidly molecules are moving. The flame of a candle has a higher temperature than does a bucket of hot water, but the bucket of water contains more heat.

If seawater had different properties, such as a different heat capacity, the ocean currents would transport different amounts of heat around the globe, and the climate of the earth would be different. If water compressed when it froze (as does almost every thing else), ice would sink to the bottom of the sea bed and, in the absence of energy from the sun, it would never melt, ice would accumulate, and the world oceans would be in a solid phase rather than liquid water.

Lastly, when compared to many substances, water is relatively viscous, or sticky. Viscosity is important for rapidly swimming animals that must overcome the resistance of water in order to move rapidly forward during hunting, avoiding predators, or during long distance migrations. Streamlined morphology is far more important in the sea than it is in air (which has a low viscosity) for rapidly moving animals. Viscosity is also exceptionally important for very small animals, such as plankton. To a very small animal, like a copepod only 1 mm long, water is much like molasses. Copepods must exert lots of energy to move forward, and when they stop swimming, they do not glide forward, as we do in a swimming pool, but instead they stop instantly because of surface friction and the viscosity of water. Plankton also exploit viscosity to their advantage by the presence of spines and foliose appendages which increase their contact with the surrounding sea water and thereby increasing their resistance to sinking

Density and Salinity

Concepts Related to the California State Standards

Grade Eight:

Density and Buoyancy

8. All objects experience a buoyant force when immersed in a fluid. As a basis for understanding this concept:

a. *Students know* density is mass per unit volume.

b. *Students know* how to calculate the density of substances (regular and irregular solids and liquids) from measurements of mass and volume.

All Grades:

Investigation and Experimentation

9. Scientific progress is made by asking meaningful questions and conducting careful investigations.

Concepts Related to the National Science Standards

1. Salinity level affects the time it takes water to freeze.
2. As salt water freezes, the salt is squeezed out of the ice crystal.
3. Fresh water separates from salt water and freezes.
4. Ice is less dense than liquid water, causing it to float.
5. More of an iceberg is found below the water level than above.
6. Water mixes or forms layers due to the amount of salinity
7. Water with the most dissolved salt tends to form the bottom layer (most dense).
8. Water with the least dissolved salt usually forms the top layer.
9. Density differences between two volumes of water can prevent them from mixing.
10. Salt content of water is measured in grams of salt per kilogram of seawater (g/kg) expressed as parts per thousand (o/oo).
11. A hydrometer is a tool used to determine density in a water sample.
12. Liquids with dissolved salts (ions) conduct electricity.
13. Solids with metals conduct electricity.
14. Objects float differently in fresh and salt water
15. The shape of an object affects its ability to float.
16. As object sinks of floats in the water based on the weight of the liquid displaces.
17. Fresh and salt water have different properties.

Vocabulary

Archimedes	A Greek scientist and mathematician.
Brackish Water	The type of water found where fresh water and salt water mix. The water is considered neither fresh nor salt.
Buoyancy	Ability to float in liquid or air.
Conductor	The ability of a substance to permit the flow of electricity.
Density	Mass per unit volume of a substance.
Displace	To remove physically out of position.
Dissolve	The process by which a solid, liquid, or gas is completely and uniformly mixed with a liquid.
Hydrometer	An instrument used to measure density or specific gravity of a liquid.
Icebergs	Chunks of land ice, usually of glacial origin, that have broken off and floated to sea.
Ionic Bond	A chemical bond resulting from attraction between oppositely charged ions.
Ions	An atom or group of atoms that has an electrical charge resulting from the gain or loss of one or more electrons.
Plimsol Mark	Line on a ship which indicate how low it can safely ride in the water; load limit.
Salinity	Measure of the quantity of dissolved salts in seawater.
Sea Ice	Flat "plate" ice formed when seawater freezes.
Solution	A homogeneous mixture of two or more substances where the substances are not chemically changed.
Specific Gravity	The ratio of the density of a substance relative to the density of pure water at 4 degrees Celsius.
Solvent	A liquid.

Activity #1 - Sea Ice

Concepts # 1 and 2

#1 Salinity level affects the time it takes water to freeze.
#2 As salt water freezes, the salt is squeezed out of the ice crystal.

Objective:

Students will observe the freezing times and temperatures of water with varying levels of salinity and determine how icebergs form, how they act and what they may be made of.

Materials:

- one cup of ordinary table salt
- tablespoon
- plastic ice cube tray with divided water tight sections
- tap water
- thermometer
- 8 jars (at least 8 oz), beakers (at least 300 mL) or recycled (cut off) 2L plastic soda bottles

Procedures:

1. Label 8 jars two labelled "A," two "B," two "C," and two "D." In each jar mix salt and water solutions as follows:
2. Jars A - mix 9 T salt with 1 cup water in each.
3. Jars B - mix 6 T salt with 1 cup water in each.
4. Jars C - mix 3 T salt with 1 cup water in each.
5. Jars D - pure tap water 1 cup in each.

NOTE: One set of jars A-D will be used to fill an ice cube tray. Put the second set in a refrigerator if available, otherwise set them aside in a cool, shaded area of the room.

6. Label each ¼ section of the ice cube tray as section A, B, C, and D.
7. Pour salt solutions into their labeled sections.
8. Place the tray in a freezer.
9. On data chart provided, students observe and record water temperature and conditions after 1 hour, 24 hours, and 48 hours. Water temperatures are taken in the liquid water, under any ice formations, if present. If not present, draw an "X through that data entry. Conditions include degree of solidity, color, texture, volume, layering, etc.
10. With teacher permission, have a volunteer taste an iceberg from each section and record this on your chart too.
11. Test and record how well each kind of iceberg (A, B, C, D) floats in each salt solution. Use the second set of salt solutions that were set aside for this test.
12. At the end of 48 hours, plot a line graph of your temperatures using the graph paper provided.

Evaluation:

➢Did any solution not freeze? Which one? (Depends upon the experimental results. The highest salt concentration, solution A, does not completely freeze.)

➢Which solution was first to freeze? (Usually solution D is the first to freeze)

➢What other differences between the icebergs did you notice: taste? texture? color? volume? layering?

➢Summarize what happens to the ability of water to freeze as you add more and more salt. (The higher the salinity, the longer it takes to freeze. Actually, the higher the salinity the lower the freezing point.)

➢What does the graph of your data tell us about how salinity affects the temperature of the water over time?

➢From your experimental results, are icebergs salt or fresh water? Explain.
(Icebergs are fresh water. Solutions 2 and 3 which show partial freezing show the fresh water portion leaving as ice.)

➢If the ice sank, what might happen to life on the seafloor under the Antarctic ice? Explain.

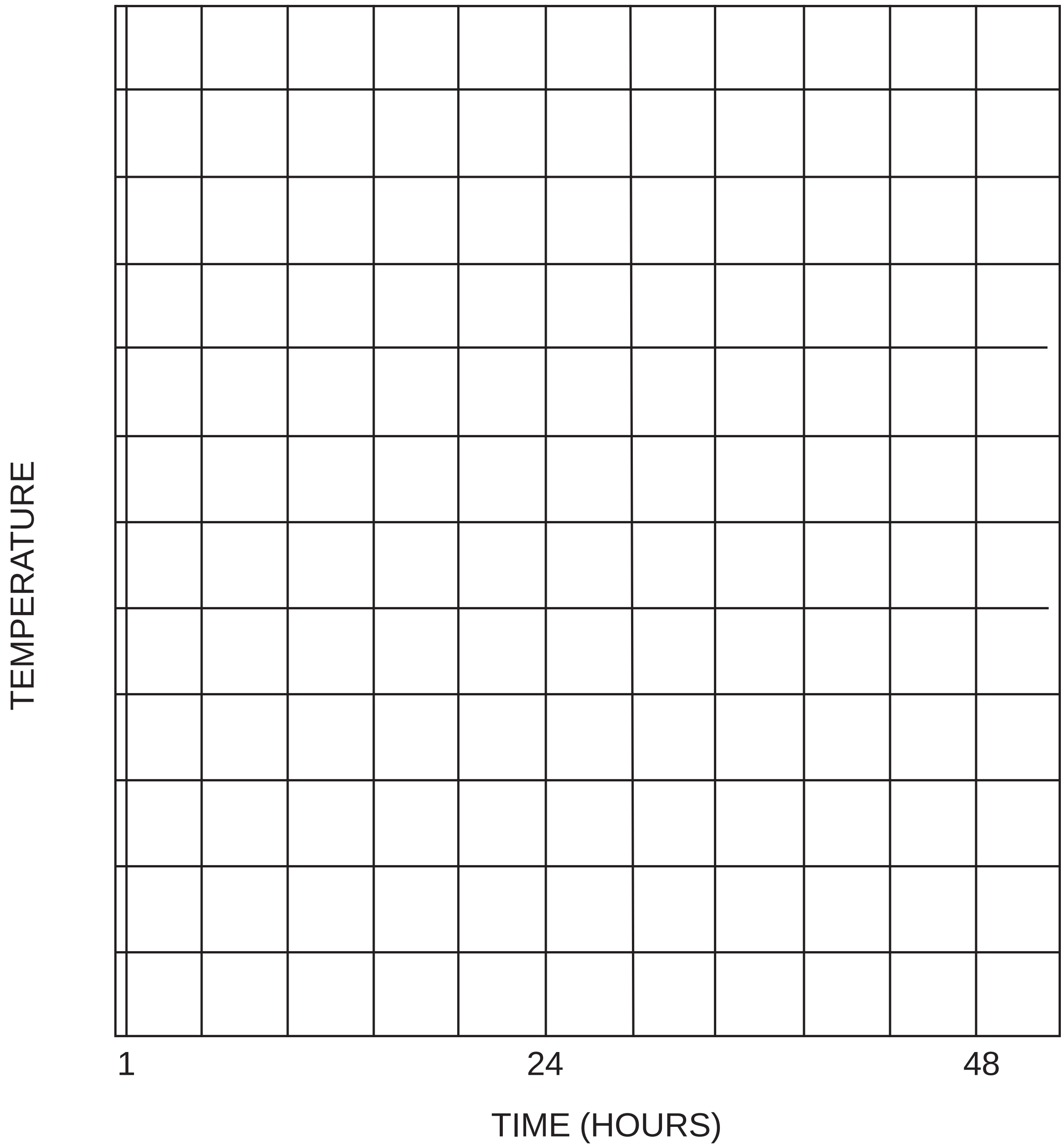
Activity #1 - Making “Icebergs”

data records:

	Starting Salt/H_2O Content:	Record Your Observations Below:					
		1hr.		24 hrs.		48 hrs.	
Jar		temp	notes	temp	notes	temp	notes
A							
B							
C							
D							

Activity #1 - Making “Icebergs”

GRAPH OF TEMPERATURE DATA



Key: (color in the squares to match each of your 4 lines)

Solution A ☐ Solution C ☐

Solution B ☐ Solution D ☐

Activity #2 - A Model Iceberg

Concepts # 3, 4, 5

#3 Fresh water separates from salt water and freezes.
#4 Ice is less dense than liquid water, causing it to float.
#5 More of an iceberg is found below the water level than above.

Objective:

Students will observe a model of an iceberg in simulated seawater, drawing inferences of the dangers to ships.

Materials:

- balloon
- water
- freezer
- bucket
- ruler
- plastic container
- kosher salt in solution of 35 g per 1 liter of water (35 o/oo)

Procedures:

1. Fill a round balloon with tap water and tie it off. Place in a container.
2. Place the container with the balloon in a freezer overnight.
3. Remove the rubber from the frozen balloon and place it into a saltwater filled bucket.
4. Measure the height of the iceberg top to bottom.
5. Measure the height of the iceberg above the water line.
6. Subtract the number above the water from the total length.
7. Determine a percentage of the ice above and below the water.(# on top/total length = decimal x 100 = %)
8. Make a drawing of your iceberg labeling the % above and the % below the water level.

Evaluation:

- Why would an iceberg be dangerous if it floats into the shipping lanes?
- What could be done with floating icebergs?
- What are icebergs made of?

Activity #3 - Testing for Conductivity

Concepts # 12, 13, 17

#12 Liquids with dissolved salts (ions) conduct electricity.
#13 Solids with metals conduct electricity.
#17 Fresh and salt water have different properties.

Objective:

Students will test the conductivity of selected liquids and solids.

Materials:

- copper wire
- scissors
- sandpaper
- 5 watt flashlight bulb and holder
- 9 volt battery
- stirring rod
- 5 petri dishes
- distilled water
- ethyl alcohol
- vegetable oil
- detergent
- kosher salt
- small pieces of: wood, aluminum foil, rubber, cardboard, plastic, brass, aluminum rod

Procedures:

1. Set up materials as shown in the diagram.
2. Remove 5 cm of insulation from both ends of each wire.
3. Sand the wire with sandpaper until it is bright.
4. Wrap the end of one wire around the screw of the bulb holder.
5. Attach a second wire to the other screw.
6. Take the loose end of the second wire and attach it to the battery.
7. Attach the third wire to the other terminal of the battery.
8. Test the circuit by touching the two free ends of the wires together. If your circuit is complete the light bulb will burn bright.
9. Place about 1 tbsp. of distilled water in two petri dishes and 1 tbsp. of the other liquids in separate petri dishes.
10. Add ¼ tsp. salt at a time to one dish of distilled water until you reach 2 tsps. (Stir the salt water well after each addition). After each addition test the salt water solution. Record the data after each addition.
11. Predict if each item will or will not conduct electricity before testing. Write the predictions in the table.
12. Test each item and record the observations in the table. (Make sure to sand the wires so they are bright after each test).

Evaluation:

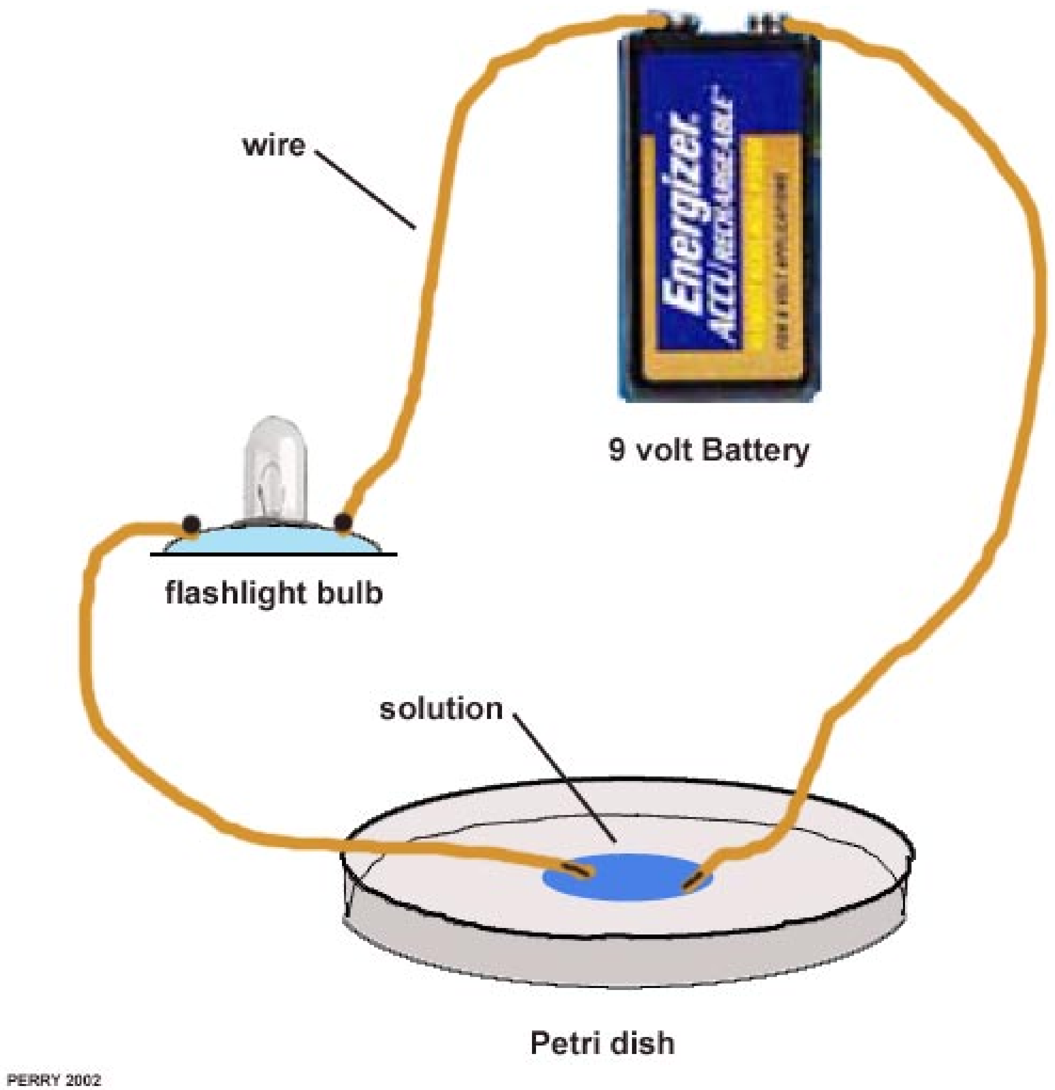
➢Which salt water solution was the best conductor of electricity? (The salt solution with 1¼ - 1½ tsp. salt dissolved.)

➢Which items were conductive? (Aluminum foil, brass, aluminum rod, salt water)

➢What kinds of bonds do compounds that conduct electricity have? (ionic bonds; these dissolve in water to form charged ions).

➢Oceanographers use conductivity meters to determine the salinity of seawater. Explain how this is possible. (Salinity is a measure of the amount of dissolved ions; conductivity increases as the amount of dissolved ions increases.

➢What conducts electricity?



Activity #3 - Conductivity Data Chart

Materials tested		Prediction of Conductivity	Observed Conductivity
Distilled water			
Ethyl Alcohol			
Vegetable Oil			
Detergent			
Rubber			
Aluminum Foil			
Aluminum Rod			
Cardboard			
Brass Rod			
Plastic			
Wood			
Salt Water	¼ tsp.		
	½ tsp.		
	1 tsp.		
	1 ¼ tsp.		
	2 tsp.		

Activity #4 - Making and Using a Hydrometer

Concepts # 7, 8, 10, 11

#7 Water with the most dissolved salt tends to form the bottom layer (most dense).
#8 Water with the least dissolved salt usually forms the top layer.
#10 Salt content of water is measured in grams of salt per kilogram of seawater (g/kg), expressed as parts per thousand (o/oo, or ppt).
#11 A hydrometer is a tool used to determine density (and, with temperature, salinity) of a water sample.

Objective:

Students will build a hydrometer to measure the densities of fresh and salt water samples.

Materials:

- distilled water (1 gal)
- 100 ml graduated cylinder
- clay (modeling)
- fine-tip permanent marking pen
- straw
- thermometer
- water samples
- temperature-density-salinity conversion graph
- laboratory balance or scale
- salt
- real hydrometer (for optional part II)

"Unknown" test solutions (to be mixed ahead of time) :

A. 33 grams salt to 1000 ml water at room temperature
B. 34 grams salt to 1000 ml water at room temperature
C. 34 grams salt to 1000 ml water at 10^{O}C (keep in refrig. overnight and remove 1 or hours before using)
D. 35 grams salt to 1000 ml water at room temperature

Procedures:

Part I **- making and using your own hydrometer.**

1. Press a small ball of clay into one end of a straw to form a plug. This straw will become a hydrometer.
2. Add fresh water to a graduated cylinder to the 100 ml line. [Note: in this investigation you will make all your readings on your hydrometer. The graduation lines on the cylinder are not used as data].
3. Put the hydrometer (straw) in the fresh water. Remove or add clay until the hydrometer floats with just the upper (approx. 1") tip exposed to the air, the rest underwater.
4. Carefully make a small horizontal line to mark the point where the surface of the water meets the straw with a permanent marker and label it "0" because no salt has been added to the water yet.
5. Remove the hydrometer. Add 1 gram of salt to the cylinder water. Dissolve all salt. Replace the hydrometer.
6. Make a line where the straw meets the water line and label it "10" (because 1 g of salt was added to 100 ml of water to make a solution with a salinity of 10 o/oo).

7. Remove the hydrometer. Add 1 more gram of salt to the cylinder water. Dissolve all salt. Replace the hydrometer.
8. Make a line where the straw meets the water line and label it “20” (because a total of 2g of salt was added to 100 ml of water to make a solution with a salinity of 20 o/oo).
9. Remove the hydrometer. Add 1 more gram of salt to the cylinder water. Dissolve all salt. Replace the hydrometer.
10. Again, make a line where the straw meets the water line and label it “30.”
11. For your data observations, write a statement about the scale created on the straw.
12. Use your hydrometer to test the unknown salt solutions prepared by your teacher. Write down the salinity of each. You will estimate if the water comes between your lines.

Part II **- using a real hydrometer (if available) to determine salinity**

1. Fill the graduated cylinder with water sample “A”
2. Record water temperature and density.
3. Use the temperature-density-salinity conversion graph to find the salinity.
4. Repeat the above procedure with samples “B,” “C” and “D.”

Evaluation:

➢ How did the salinity recordings you made with your straw hydrometer compare with the salinity you measured with the commercial hydrometer for solutions A, B, C and D?

➢ Which would be the surface water? __(**A**)______. Which would be the bottom sample? __(**C**)______.

➢ Which solution was the saltiest? (The bottom sample will be more saline)

➢ The range of salinity in seawater is between 25 ppt. (parts per thousand) to 40 ppt. Did any of the samples fall in this range? (All should fall within the given range.)

➢ What are two conditions that might account for this range in ocean salinities? (Many things can help explain the range in salinities: fresh water inflows, rain water, evaporation, mixing, etc.)

➢ Where would you expect the lowest salinities to be found? (Lowest salinities would be found in areas with fresh water inflows, lots of rain, and low evaporation rates. Usually these conditions are more prevalent in the temperate zones.)

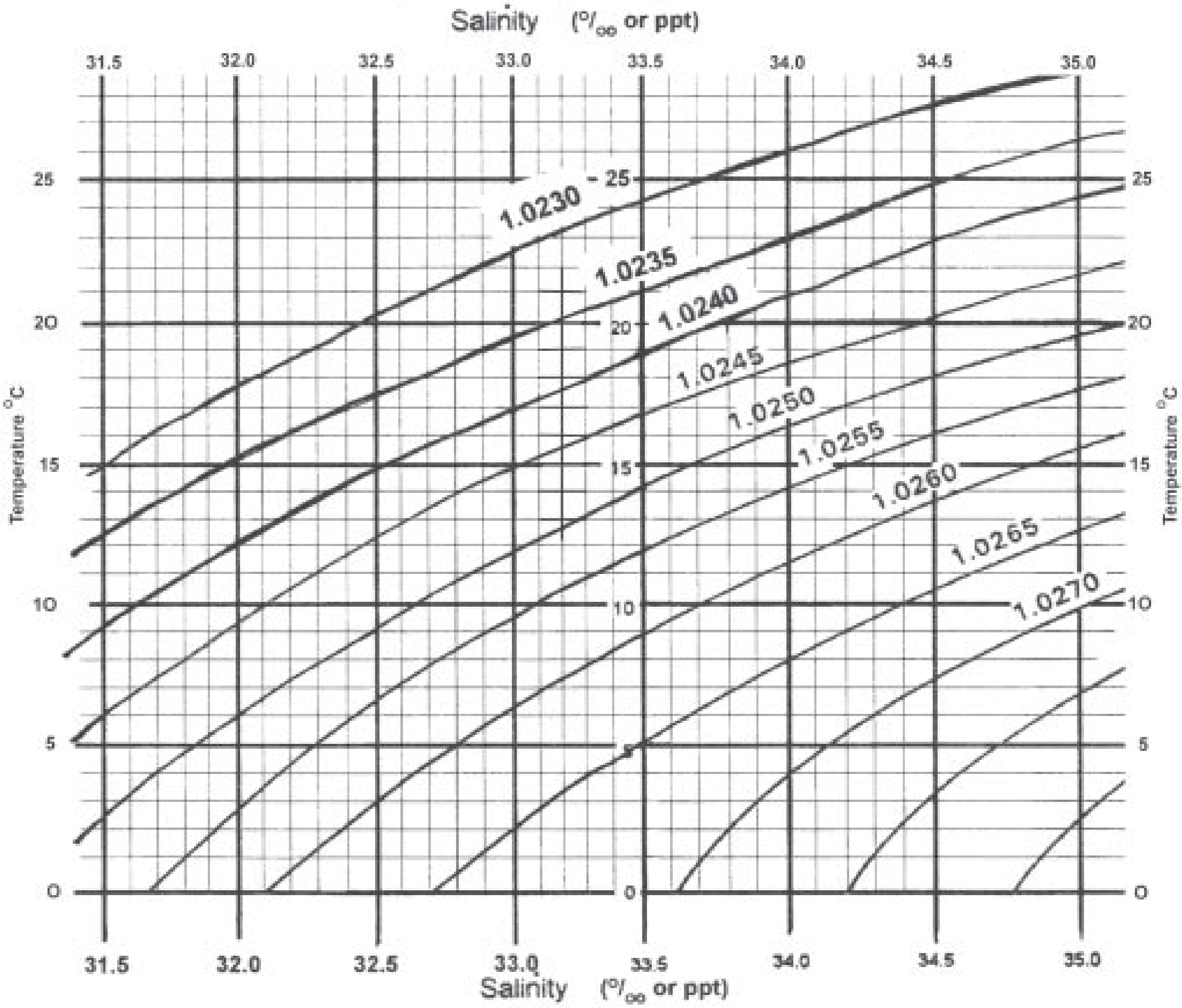
➢ Where would you expect the highest salinities to be found? (Highest salinities would be found in areas with low fresh water inflow, low rainfall, and high evaporation rates. Usually these conditions are more prevalent in tropical areas and enclosed seas.)

Activity #4 - Making and Using a Hydrometer

Student Data Chart

	Part I Straw Hydrometer	Part II Commercial Hydrometer		
Sample	Salinity o/oo	Temp OC	Density g/cm3	Salinity o/oo
A				
B				
C				
D				

Temperature Density Salinity Conversion Chart



Place one finger on the SST line.
Use another finger to follow the density curve to the SST line.
Where the two intersect, go straight up or down to read salinity.

Record salinity values to one decimal place accuracy.

(a two part activity)

Activity # 5 - Layering of Water

Concepts # 6, 7, 8, 9

#6 Water mixes or forms layers due to the amount of salinity.
#7 Water with the most dissolved salt tends to form the bottom layer (most dense).
#8 Water with the least dissolved salt usually forms the top layer.
#9 Density differences between two volumes of water can prevent them from mixing.

Objective:

Students will investigate what happens when ocean water, fresh water and/or brackish water meet.

- - - - - Part I - - - - -

Materials for part I:

- 4 glass jars
- 2 siphons (clear plastic tubes)
- 1 gal. fresh water
- 1 gal. fresh water with green food coloring
- 1 gal. salt water with 1 cup of kosher salt
- 1 gal. salt water with 1 cup of kosher salt and green food coloring

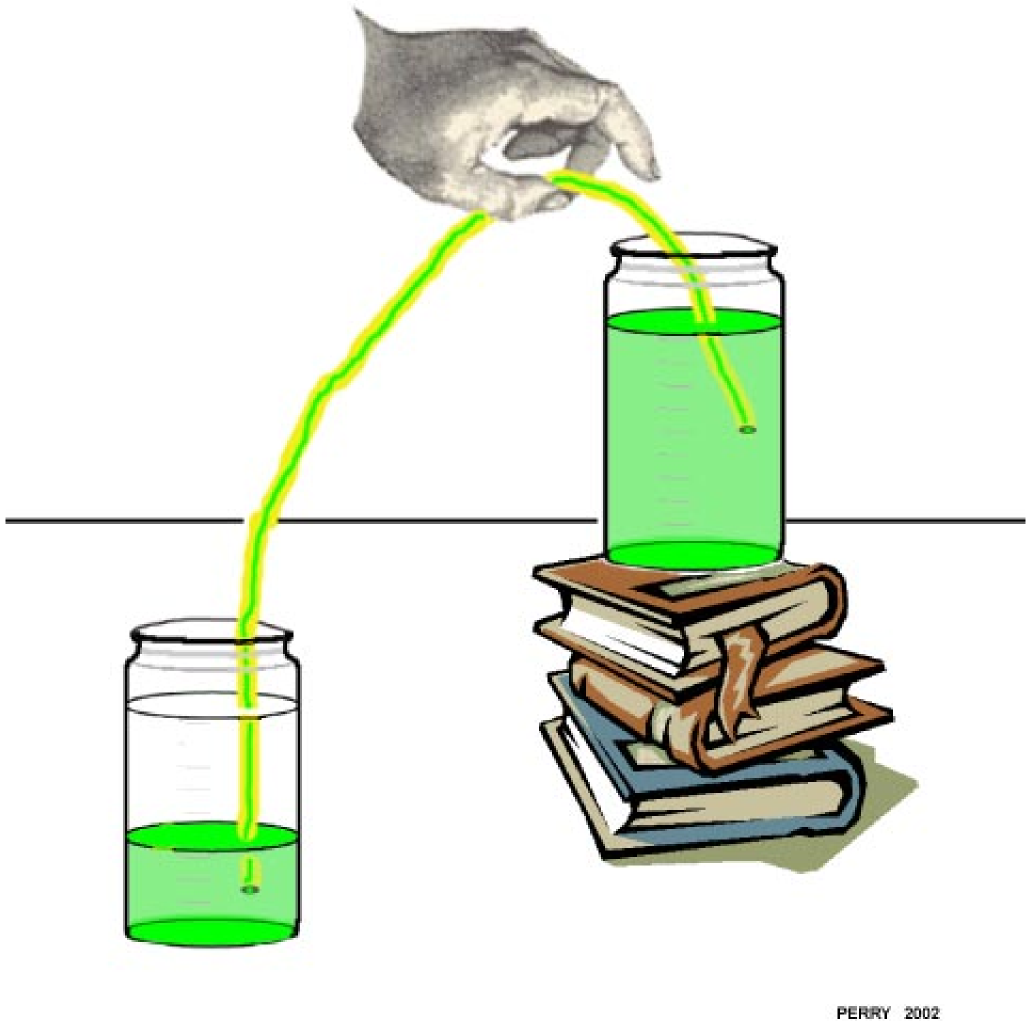
Procedures for part I:

1. Make the salt solutions the day before and allow to sit. Label each bottle.
2. Guide students to hypothesize regarding what could happen when salt water meets fresh water.
3. Fill one jar 1/3 full of clear fresh water. Fill a second jar with colored salt water. Start a siphon by filling a plastic tube with colored water and keeping the colored salt water solution jar higher than the fresh water jar. A colored salt solution layer will form on the bottom of the jar.
4. Fill one jar 1/3 full of clear salt water. Fill a siphon of the colored fresh water. Colored fresh water will layer at the top of the jar.
5. Record and discuss observations.

Evaluation for part I:

- How many layers formed? (2)
- Which layer is salty? (bottom)
- Are the layers completely separated? (no)
- What happened at the interface? (Mixing)
- Draw the results of the demonstration (Drawings here)

Activity #5 - Layering of Water



Siphoning colored salt water to bottom of freshwater jar.

- - - - - Part II - - - - -

Materials for part II:

- straw (clear plastic)
- clay
- eye droppers
- sheet of white paper
- towel
- waste cup
- 3 cups with solutions
- towel
- waste cup
- 3 cups with solutions
- kosher salt

Solutions

Ocean Water 500 ml water 120 ml salt 20 drops blue food coloring	Brackish Water 500 ml water 40 ml salt 20 drops red food coloring	River Water 500 ml water no salt 20 drops green food coloring

Dissolve salt completely (sitting overnight)

Procedures for part II:

1. Place the plastic straw into the clay at an angle. Put the straw half-way through the clay.
2. You will now hypothesize which solution is fresh (river), which is salty (ocean), which is brackish (mixture). This is done by placing small amounts of each solution into the straw. In the correct order three distinct layers will be produced.
3. Write your hypothesis for each possible combination of colored solutions before you start. Record your observations after each trial.
4. Test your hypothesis by using an eye dropper to fill 1/3 of the straw with each solution. Place the white paper behind the straw to observe the solutions. Record your observations.
5. Empty the straw by picking up the whole assembly (do not take the straw out of the clay) and shaking the solution into the waste cup. Try your next hypothesis. When finished with your trials answer these questions.

Evaluation for part II:

- ➢What is the order of the solutions that results with three distinct layers? (blue, red, green)
- ➢Why did this result happen in that order? (The highest density on the bottom, lowest density on the top, and the mixture between the two.)
- ➢In an estuary where the river meets the sea, where would the salinity of the water be the greatest? (near the bottom layer of the estuary)

Extensions:

- Visit an estuary and take salinity samples at different levels, places, and times of the day.
- Have a contest to see who can find out what kind of water they have in their jar. (The teacher fills the jars with 3 different kinds of solutions.) Students can not taste the water. They do some physical tests to determine which solution they have. Award prizes for right guesses. (Remember to label each jar with a # or letter and keep a record of the correct answers.)