How Dense is SALT WATER?

Focus Question
What is the relationship between density and salinity?

ACTIVITY

Activity Overview

Fresh water from the Mississippi River pours into the salty ocean water in the Gulf of Mexico. More than 152,400 cubic meters (m^3) of fresh water are poured every second. This is about equal to the volume of water in 152 Olympic size swimming pools. The interaction of salt water and fresh water affects Louisiana's coastal wetlands as well as aquatic life in the Gulf of Mexico. Due to differences in densities, fresh water and salt water do not easily mix but instead form layers. As a result of human activities such as the construction of navigational canals, these layers of salt water have been moving inland from the ocean toward freshwater environments in a process called saltwater intrusion. Saltwater intrusion increases the level of salt in the waters upstream and affects the health of animals and plants not adapted to salt water. These effects have given scientists cause for concern.

In this activity, you will perform an experiment to explore the relationship between mass, density, and salinity. You will measure the salinity of four saltwater solutions of increasing strength using a conductivity sensor connected to a TI CBL 2™ or Vernier LabPro and a TI-73 Explorer™. You will find the density of each solution by measuring its mass and volume. Density is mass divided by volume.

How does the density of fresh water and salt water compare? What is the relationship between density and salinity? What is the relationship between mass and density?

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Part A — Measure Salinity

Procedure

1 Label your cups.
Your teacher has prepared 4 solutions that are labeled 1, 2, 3, and 4. Label four cups C1, C2, C3, and C4.

2 Dilute the solutions.
You are going to determine the salinity of each solution using a conductivity sensor. However, the salinity may be greater than the range of the conductivity sensor, so you will dilute the solutions to 1/10 their original strength before making measurements. The "C" in the labels of your cups stands for "cup."

a. Measure 20 mL of Solution 1 using a graduated cylinder and add it to Cup C1.
b. Measure 20 mL of Solution 2 using a graduated cylinder and add it to Cup C2.
c. Measure 20 mL of Solution 3 using a graduated cylinder and add it to Cup C3.
d. Measure 20 mL of Solution 4 using a graduated cylinder and add it to Cup C4.
e. Measure 180 mL of distilled water, add it to each cup, and stir.

3 Reset the TI-73 Explorer™.

a. Turn on the TI-73 Explorer™.
b. Press [2nd] [MEM] [7] [1] [2] to reset all RAM.

4 Connect the conductivity sensor to the CBL 2™or Vernier LabPro and TI-73 Explorer™.

a. Plug the conductivity sensor into Channel 1 of the CBL 2™ or Vernier LabPro.
b. Use the link cable to connect the TI-73 Explorer™ to the interface.
c. Firmly press in the cable ends.
d. Move the switch on the conductivity sensor to the 0–20,000 (µs) range.

5 Set up the TI-73 Explorer™.

a. Start the DATAMATE application. (For instructions on DATAMATE see Appendix A.)
b. Press [CLEAR] to reset the program.

6 Set up the TI-73 Explorer™ for data collection.

a. Select SETUP from the MAIN SCREEN by pressing [1].
b. If the TI-73 displays a Conductivity Probe in units of mg/L in Channel 1, then skip to Step 6.c. If not, continue with this step to set up the sensors manually.
   - Press [ENTER] to select CH1.
   - Select CONDUCTIVITY from the SELECT SENSOR MENU. Use the arrow keys ([▲], [▼]) to move the cursor next to CONDUCTIVITY and press [ENTER].
   - Select CONDUCT 10000 (MG/L).

Materials*

- TI-73 Explorer™
- TI CBL 2™ or Vernier LabPro
- TI-73 DataMate
- Conductivity sensor
- Balance
- Graduated cylinder
- Saltwater solutions (prepared by teacher)
- Distilled water
- Cups
- Medicine dropper

TI-73 Explorer™

Conductivity Sensor

* This activity has been written for the TI-73 Explorer™ but you can easily substitute the TI-83 or TI-83 Plus. Also see Appendix A for steps on how to transfer DataMate to your graphing device and how to use DataMate for data collection.

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c. Select MODE. Use the arrow keys ([▲], [▼]) to move the cursor next to MODE and press [ENTER].
d. Press [5] to select SELECTED EVENTS.
e. Press [1] to select OK and return to the MAIN SCREEN.

7 Collect your data.

a. Line up the four cups labeled C1, C2, C3, and C4.
b. Press [2] on the TI-73 Explorer™ to begin data collection.
c. Place the sensor in Cup C1 and press [ENTER].
d. Rinse the sensor in distilled water.
e. Place the sensor in Cup C2 and press [ENTER].
f. Rinse the sensor in distilled water.
g. Place the sensor in Cup C3 and press [ENTER].
h. Rinse the sensor in distilled water.
i. Place the sensor in Cup C4 and press [ENTER].
j. Press [STO▸] to stop the data collection.
k. Press [ENTER] to return to the MAIN SCREEN.
l. Press [6] to QUIT the DATAMATE program.
m. Press [ENTER].

Part B — Label your data on the TI-73 Explorer™.

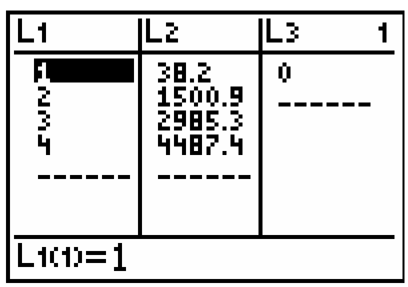
Procedure

1 Name your lists.

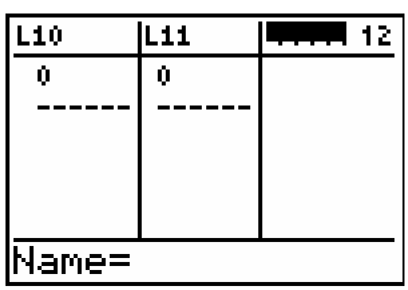
a. Press [LIST] to open the list editor.

Note: The cup numbers will be shown in L1 and the conductivity, or salinity data of the diluted solutions will appear in L2.

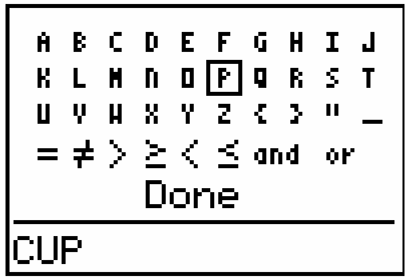
The numbers shown here represent sample values.



b. Press [◂] to move the cursor to the first available unnamed list.



c. You will name the list *CUP*. To do that press [2nd] [TEXT] C [ENTER] U [ENTER] P [ENTER] DONE [ENTER].



d. Press [ENTER].

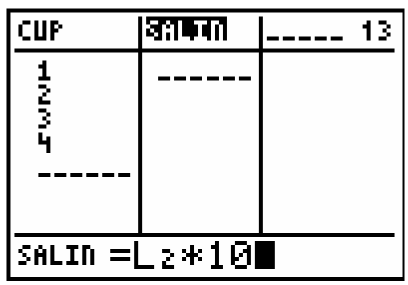
e. Enter 1, 2, 3, and 4 in the CUP list, pressing [ENTER] after each number.

f. Use [▶] and [▲] to move the cursor to L13, or the next unnamed list.

g. Name this list SALIN (stands for salinity). To do that press [2nd] [TEXT] S [ENTER] A [ENTER] L [ENTER] I [ENTER] N [ENTER] DONE [ENTER] [ENTER].

2 **Find the actual (non-diluted) salinity of the solutions.**
Note: In Part A, Step 2 you diluted the solutions to 1/10 their original strength. To obtain the actual salinity value, you will multiply the measured values by 10.

a. Use [▶] and [▲] to move the cursor to SALIN.



b. Press 2nd STAT L2 [×] 10 [ENTER] to calculate the actual salinity of each solution.

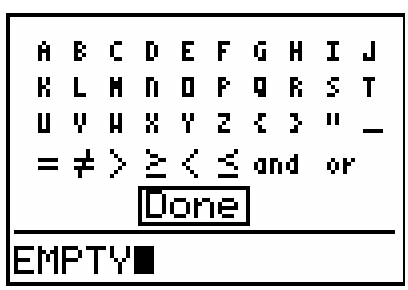
Part C — Measure Density

Density is mass divided by volume. To find the mass of each solution you will subtract the mass of the empty cup from the mass of the cup filled with the solution.

Procedure

1 **Name your lists.**

a. Use [▶] and [▲] to move the cursor to L14, or the next unnamed list.



b. Name this list EMPTY. To do that press [2nd] [TEXT] E [ENTER] M [ENTER] P [ENTER] T [ENTER] Y [ENTER] DONE [ENTER] [ENTER].

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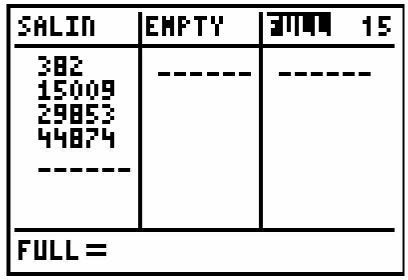
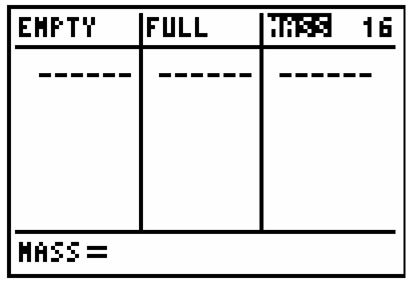
c. Use [▶] and [▲] to move the cursor to L15, or the next unnamed list.

d. Name this list FULL. To do that press [2nd] [TEXT] F [ENTER] U [ENTER] L [ENTER] L [ENTER] DONE [ENTER] [ENTER].



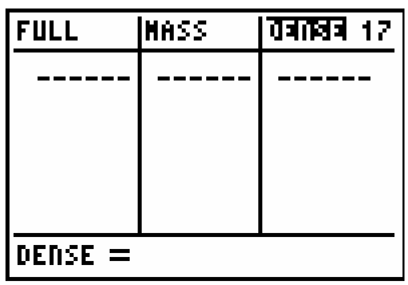
e. Use [▶] and [▲] to move the cursor to L16, or the next unnamed list.

f. Name this list MASS. To do that press [2nd] [TEXT] M [ENTER] A [ENTER] S [ENTER] S [ENTER] DONE [ENTER] [ENTER].



g. Use [▶] and [▲] to move the cursor to L17, or the next unnamed list.

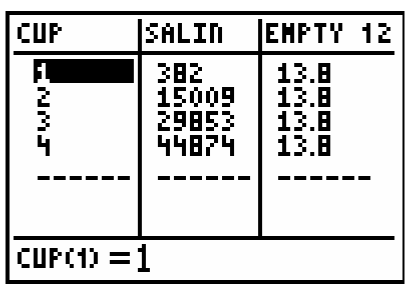
h. Name this list DENSE (stands for density). To do that press [2nd] [TEXT] D [ENTER] E [ENTER] N [ENTER] S [ENTER] E [ENTER] DONE [ENTER] [ENTER].



2 Measure mass and volume.

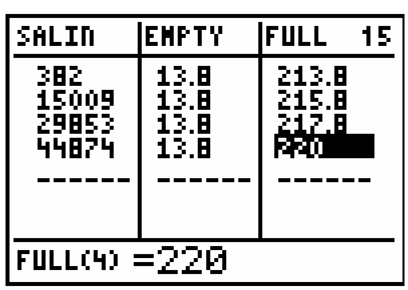
a. Empty your cups. Rinse the cups with tap water and dry them using paper towels.

b. Measure the mass of each empty cup and record the values in the EMPTY list on the TI-73 Explorer™, pressing [ENTER] after each number.



c. Using a graduated cylinder, measure 200 mL of Solution 1 and add it to Cup 1. *Note: Make sure you use the solution your teacher prepared and not your diluted solution.*

d. Measure the mass of Cup 1 with Solution 1 added. Record the mass in the FULL list.



e. Repeat Steps 2.c. and d. for Cups 2, 3, and 4 and Solutions 2, 3, and 4.

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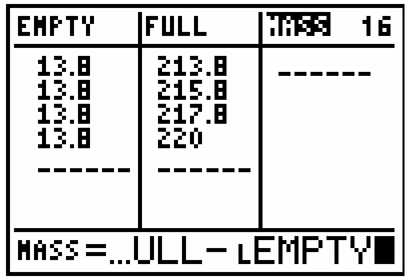
3 Find the mass of the solutions.

Subtract the mass of the empty cups from the mass of the cups filled with solution.

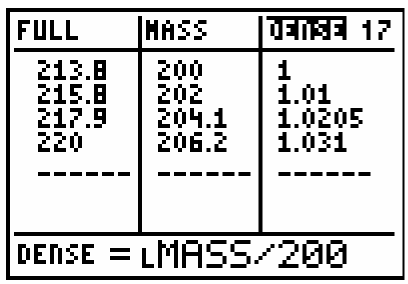
a. Use [▶] and [▲] to move the cursor to MASS.
b. Press [2nd] [STAT].
c. Use [▼] to move the cursor to FULL and press [ENTER].
d. Press [−].
e. Press [2nd] [STAT].
f. Use [▼] to move the cursor to EMPTY and press [ENTER].
g. Enter.



4 Find the density.

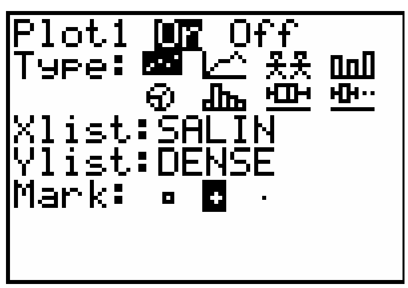
Divide the mass of the solution by volume.

a. Use [▶] and [▲] to move the cursor to DENSITY.
b. Press [2nd] [STAT].
c. Use [▼] to move the cursor to MASS and press [ENTER].
d. Press [÷].
e. Enter 200.
f. Press [ENTER].



5 Graph your salinity and density data.

a. Press [2nd] [PLOT].
b. Press [1] to define Plot1.
c. Turn Plot1 on by pressing [ENTER].
d. Press [▼] [ENTER] to select SCATTER GRAPH (⋰).
e. Set the Xlist. Press [STAT] and use [▼] to move the cursor to SALIN.
f. Press [ENTER] to set Salinity as the X-axis.
g. Set the Ylist. Press [STAT] and use [▼] to move the cursor to DENSE.
h. Press [ENTER] to set Density as the Y-axis.
i. Press [▶] [ENTER].
j. Press [GRAPH] to see the plot.
k. Press [ZOOM] [7] to adjust the scale on your graph.
l. Press [TRACE] to scroll through the graph.



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Data Analysis

1 Draw a sketch of the graph created by your graphing device in your journal. Title the graph *Density and Salinity*. Label the X-axis *Salinity (mg/L)* and the Y-axis *Density (g/mL)*.

Use the left and right arrow keys ([◄], [►]) to move the cursor along a curve. The conductivity (x) and density (y) values of each data point are displayed below the graph.

2 What is the density of distilled water?

3 Which solution had the greatest salinity?

4 What was the density of the solution with the greatest salinity?

5 What happens to the density of a solution when its salinity increases?

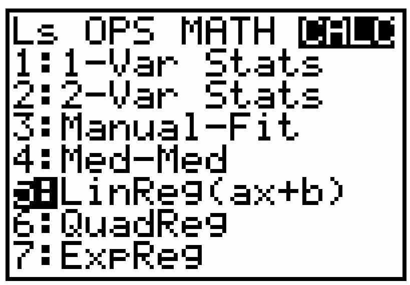
Part D — Best-Fit Line of Salinity and Density

A best-fit line is a line that passes as near to as many of the data points as possible. Once drawn, the best-fit line can be used to determine the density or the salinity of unknown samples.

1 **Draw a best-fit line.**

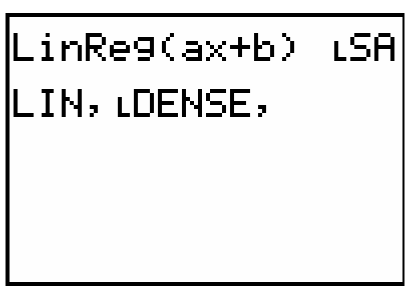
a. Turn off Plot1. Press [2nd] [PLOT] [ENTER] [►] [ENTER].

b. Press [2nd] [STAT] [◄] to move the cursor to the CALC MENU.



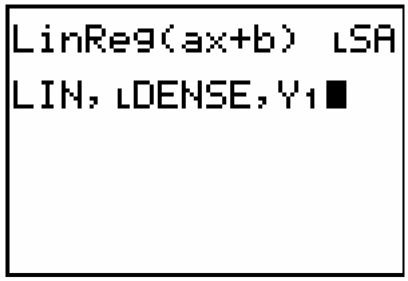
c. Press [5] to select LinReg(ax + b).

d. Press [2nd] [STAT] SALIN [,] [2nd] [STAT] DENSE [,] to select SALIN and DENSE.



e. Press [2nd] [VARS] [2] to select Y-Vars.

f. Press [1] or [ENTER] to select Y1.



g. Press [ENTER] to find the best-fit line.

h. Press [GRAPH] to see the graph of the best-fit line.

i. Press [ZOOM] [7] to adjust the scale on your graph.

j. Press [TRACE] to scroll through the graph.

Data Analysis

1 You can use the best-fit line to determine the density if you know the salinity of a solution. To do this, mark the given salinity on your graph, draw a vertical line to the point where this line meets the best-fit line, and read the density value on the Y-axis. Based on your graph and the best-fit line, what is the density if the salinity is 10,000 mg/L?

2 Describe how you would use your graph to find the salinity of a solution if you knew its density.

3 Based on your best-fit line graph, estimate the salinity of a solution with a density of 1.015 g/mL.

4 Measurements taken from a freshwater stream found a density of 1.005 g/mL. Based on this information and your graph, did this stream have salinity? If yes, what was the salinity of the stream?

5 The salinity of an ocean water sample was 35,000 mg/L. Based on your graph, what would the density of the sample be? *Hint: You may have to extend your best-fit line.*

6 Compare the density of the saltwater sample from Question 5 with the freshwater sample from Question 4.

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Part E — Best-Fit Line of Mass and Density

1 Draw a best-fit line.

a. Turn off Plot1. Press [2nd] [PLOT][ENTER] [▸] [ENTER].
b. Press [2nd] [STAT] [◂] to move the cursor to the CALC MENU.
c. Press [5] to select LinReg(ax + b).
d. Press [2nd] [STAT] MASS [,] [2nd] [STAT] DENSE [,] to select MASS and DENSE.
e. Press [2nd] [VARS] [2] to select Y-Vars.
f. Press [1] or [ENTER] to select Y1.
g. Press [ENTER] to find the best-fit line.
h. Press [GRAPH] to see the graph of the best-fit line.
i. Press [ZOOM] [7] to adjust the scale on your graph.
j. Press [TRACE] to scroll through the graph.

Data Analysis

1 In this experiment, the volume of solution was always 200 mL. Based on your graph, how did density change as mass increased when the volume was constant?

2 If fresh water and salt water have the same volume, which liquid would be heavier (greater mass)? *Hint: mass = density x volume.*

3 When fresh water pours into salt water in coastal Louisiana they form layers. Based on your answer from Question 2, would salt water be the bottom or the top layer? Explain.

4 Saltwater intrusions occur when salt water enters freshwater areas. Based on this information and the research article, which would be impacted first by saltwater intrusion, organisms that dwell on the bottom or on the surface? Explain.