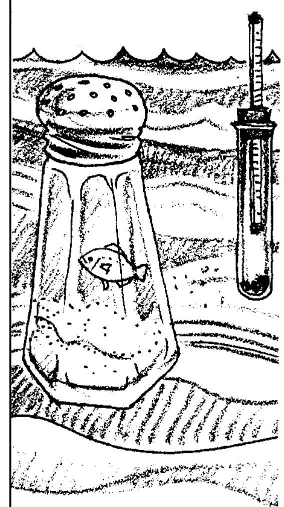
The Determination of Salinity - Hydrometer Method

Key Concepts

1. Warm water is less dense that cold water, fresh water is less dense that salt water.
2. The density (the mass per unit volume) of a water sample is affected by the salinity and temperature.
3. For a given sample of water, a hydrometer is an instrument used to measure density, and a thermometer is used to measure temperature.
4. It is possible to determine the salinity of a water sample once the density and the temperature of a sample have been measured.



Background

Since the salty taste is the most obvious difference between fresh water and salt water, the determination of salinity is a good place to begin a look at the things that make salt water "salty". It is possible to determine the amount of dissolved salts and minerals (salinity) of a sample without performing chemical tests or evaporation. If water density and temperature are measured, salinity can easily be determined. The hydrometer is a standard tool for the measurement of water density. The higher the hydrometer floats in a sample of water, the more dense the sample is. Density is the mass per unit volume of a water sample. The density of a sample is in turn affected by the salinity, or amount of dissolved salts and minerals present, as well as the temperature. Salty water is more dense than fresh water, and warm water is less dense than cold water. So once the variables of density and temperature are measured, salinity can be determined.

Materials

For each lab group of 2-3 students:

- a hydrometer
- a Celsius thermometer
- two 450 ml salt water samples with different salinities
- 500 ml graduated cylinder
- copy of each chart: Density-water temperature, Salinity-corrected density temperature

Teaching Hints

"The Determination of Salinity - Hydrometer Method" introduces students to the measurement of salinity through the use of commercial hydrometers. This activity is best performed by small groups. The number of students working in a group depends upon the number of thermometers and hydrometers available. Hydrometers are available in aquarium shops for a reasonable sum. They are also used during the process of making wine, and, as such, can be purchased from winery supply stores. If you can only obtain one or two hydrometers, you may choose to set this lab up as a station while students do another assignment.

Ideally, you will obtain two water samples using a water sampling device such as a Van Dorn bottle. One sample should come from one meter below the surface and the second should come from the bottom. If you cannot obtain the samples in this manner, you can still use the activity by making your own salt water. For example, the top sample can be made by dissolving 29 grams of table salt (sodium chloride) or rock salt in enough water to make 1000 grams of saltwater. The bottom sample can be made by dissolving 31 grams of salt in enough water to make 1000 grams of saltwater.

Hydrometers are fragile. Caution your students and demonstrate their care and handling. Provide any assistance necessary during the investigation. Circulate between groups to be sure everyone understands the procedure. Allow time for clean up. After the activity is completed, plan to spend time in a discussion of the results and their interpretation while providing answers to the questions found within the activity.

Part II uses the data gathered in Part I, but treats it in a slightly different manner. The two approaches may give slightly different results. This situation can provide an opportunity for a discussion of precision - just how precise do you need to be in determining salinity? The answer, of course, depends upon what you plan to do with the data once you have it in hand.

Key Words

buoyancy - the power of a fluid to push upward or keep afloat a body immersed in it

density - the amount of matter (mass) per unit volume

hydrometer - instrument for measuring specific gravity (density) of a liquid, commonly consisting of a graduated tube weighted to float upright in the liquid whose specific gravity is being measured

parts per thousand (‰) - in this case, the units used to express salinity

salinity - a measure of the salt concentration in a solution

Answer Key

Part I

Interpretation and Analysis

1. The salinity estimates will most likely not be exactly the same.
2. There are many sources of error including, but not limited to:
    a. differences between hydrometers
    b. errors in reading hydrometers
    c. errors in recording hydrometer readings on paper
    d. errors in recording hydrometer readings on board
    e. differences between thermometers
    f. errors in reading thermometers
    g. errors in recording temperature, etc.

    It might be helpful to point out to your students that what we see here is two large classes of variation: one group is due to errors within the equipment, the second is due to experimenter errors.

3. Answers depend upon the experimental results.
4. It is possible, but unlikely, that the average is exactly the same as one of the estimates.
5. Answer depends upon the experimental results.
6. Answer depends upon the experimental results, most likely the answer is yes.
7. Conditions that might help account for a range in salinities include differences in rainfall, river outflow, differences in evaporation and differences in rate and degree of mixing.
8. Lowest salinities would be found in areas with high rainfalls and large river outflows.
9. Highest salinities would be found in areas with high evaporation rates and low rainfalls and low river outflows or where seawater has settled in a layer below fresher water.

Part II

Interpretation and Analysis

1. The answers will vary, but generally students find the graph method the easier to use.
2. The densities determined using the two techniques will probably not be exactly the same.
3. Answers will depend upon experimental results.

4. Since the charts were the original source of data, they should be more accurate. Changing the charts to graphs introduces the possibility of errors in recording, interpretation, etc.
5. The charts should be used when a high degree of certainty is required. They are more cumbersome to use, but provide more accurate information. The graph would be used for routine salinity determinations where great precision is not required. If the salinity determination was going to be used to make important management decisions, the charts would be preferred.

Density - Water Temperature Chart

Water Temperature 0° C - 9° C

Observed density	0° Diff.	1° Diff.	2° Diff.	3° Diff.	4° Diff.	5° Diff.	6° Diff.	7° Diff.	8° Diff.	9° Diff.	Observed density
1.0000	-3	-4	-5	-5	-6	-6	-6	-6	-6	-5	1.0000
1.0010	-4	-5	-6	-6	-6	-6	-6	-6	-6	-5	1.0010
1.0020	-4	-5	-6	-6	-7	-7	-6	-6	-6	-6	1.0020
1.0030	-5	-6	-6	-7	-7	-7	-7	-6	-6	-6	1.0030
1.0040	-5	-6	-7	-7	-7	-7	-7	-7	-6	-6	1.0040
1.0050	-6	-7	-7	-7	-8	-7	-7	-7	-7	-6	1.0050
1.0060	-6	-7	-8	-8	-8	-8	-8	-7	-7	-6	1.0060
1.0070	-7	-7	-8	-8	-8	-8	-8	-7	-7	-6	1.0070
1.0080	-7	-8	-8	-8	-8	-8	-8	-8	-7	-7	1.0080
1.0090	-8	-8	-9	-9	-9	-9	-8	-8	-7	-7	1.0090
1.0100	-8	-9	-9	-9	-9	-9	-9	-8	-8	-7	1.0100
1.0100	-9	-9	-10	-10	-9	-9	-9	-8	-8	-7	1.0100
1.0120	-9	-10	-10	-10	-10	-10	-9	-9	-8	-7	1.0120
1.0130	-10	-10	-10	-10	-10	-10	-9	-9	-8	-7	1.0130
1.0140	-10	-11	-11	-11	-10	-10	-10	-9	-8	-7	1.0140
1.0150	-11	-11	-11	-11	-10	-10	-10	-9	-9	-8	1.0150
1.0160	-11	-11	-12	-11	-11	-11	-10	-10	-9	-8	1.0160
1.0170	-12	-12	-12	-12	-11	-11	-11	-10	-9	-8	1.0170
1.0180	-12	-12	-12	-12	-11	-11	-11	-10	-9	-8	1.0180
1.0190	-13	-13	-13	-13	-12	-12	-11	-10	-9	-8	1.0190
1.0200	-13	-13	-13	-13	-12	-12	-11	-11	-10	-9	1.0200
1.0210	-14	-14	-14	-13	-12	-12	-12	-11	-10	-9	1.0210
1.0220	-14	-14	-14	-14	-13	-13	-12	-11	-10	-9	1.0220
1.0230	-15	-15	-14	-14	-13	-13	-12	-11	-10	-9	1.0230
1.0240	-15	-15	-15	-14	-13	-13	-13	-12	-10	-9	1.0240
1.0250	-16	-15	-15	-15	-13	-13	-13	-12	-11	-9	1.0250
1.0260	-16	-16	-16	-15	-14	-14	-13	-12	-11	-10	1.0260
1.0270	-17	-16	-16	-15	-14	-14	-13	-12	-11	-10	1.0270
1.0280	-17	-17	-16	-16	-14	-14	-13	-12	-11	-10	1.0280
1.0290	-18	-17	-17	-16	-15	-15	-14	-13	-12	-10	1.0290
1.0300	-18	-18	-17	-17	-15	-15	-14	-13	-12	-10	1.0300
1.0310	-19	-18	-18	-17	-15	-15	-14	-13	-12	-10	1.0310

				Density - Water Temperature Chart					
Observed				Water Temperature 10° C - 18° C					Observed
density	10°	11°	12°	13°	14°	15°	16°	17°	18°	density
	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	
1.0000	-5	-4	-2	-2	-1	0	1	3	4	1.0000
1.0010	-5	-4	-3	-2	-1	0	1	3	4	1.0010
1.0020	-5	-4	-3	-2	-1	0	1	3	5	1.0020
1.0030	-5	-4	-3	-2	-1	0	1	3	5	1.0030
1.0040	-5	-4	-3	-2	-1	0	1	3	5	1.0040
1.0050	-5	-5	-4	-3	-1	0	1	3	5	1.0050
1.0060	-6	-5	-4	-3	-1	0	2	3	5	1.0060
1.0070	-6	-5	-4	-3	-1	0	2	3	5	1.0070
1.0080	-6	-5	-4	-3	-1	0	2	3	5	1.0080
1.0090	-6	-5	-4	-3	-1	0	2	3	5	1.0090
1.0100	-6	-5	-4	-3	-1	0	2	3	5	1.0100
1.0100	-6	-5	-4	-3	-1	0	2	3	5	1.0100
1.0120	-6	-5	-4	-3	-1	0	2	3	5	1.0120
1.0130	-6	-5	-4	-3	-2	0	2	3	5	1.0130
1.0140	-7	-6	-4	-3	-2	0	2	3	5	1.0140
1.0150	-7	-6	-4	-3	-2	0	2	3	5	1.0150
1.0160	-7	-6	-4	-3	-2	0	2	4	6	1.0160
1.0170	-7	-6	-5	-3	-2	0	/ 2	4	6	1.0170
1.0180	-7	-6	-5	-3	-2	0	2	4	6	1.0180
1.0190	-7	-6	-5	-3	-2	0	2	4	6	1.0190
1.0200	-7	-6	-5	-3	-2	0	2	4	6	1.0200
1.0210	-8	-6	-5	-3	-2	0	2	4	6	1.0210
1.0220	-8	-6	-5	-3	-2	0	2	4	6	1.0220
1.0230	-8	-6	-5	-3	-2	0	2	4	6	1.0230
1.0240	-8	-7	-5	-3	-2	0	2	4	6	1.0240
1.0250	-8	-7	-5	-4	-2	0	2	4	6	1.0250
1.0260	-8	-7	-5	-4	-2	0	2	4	6	1.0260
1.0270	-8	-7	-5	-4	-2	0	2	4	6	1.0270
1.0280	-9	-7	-5	-4	-2	0	2	4	6	1.0280
1.0290	-9	-7	-5	-4	-2	0	2	4	6	1.0290
1.0300	-9	-7	-6	-4	-2	0	2	4	6	1.0300
1.0310	-9	-7	-6	-4	-2	0	2	4	7	1.0310

DENSITY AT 15°C. - SALINITY IN PARTS PER 1,000 (PAGE 1 - FOR DENSITIES FROM 0.9991 - 1.0165)									
Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
0.9991	0.0	1.0026	4.5	1.0061	9.0	1.0096	13.6	1.0131	18.2
0.9992	0.0	1.0027	4.6	1.0062	9.2	1.0097	13.7	1.0132	18.3
0.9993	0.1	1.0028	4.7	1.0063	9.3	1.0098	13.9	1.0133	18.4
0.9994	0.3	1.0029	4.8	1.0064	9.4	1.0099	14.0	1.0134	18.6
0.9995	0.4	1.0030	5.0	1.0065	9.6	1.0100	14.1	1.0135	18.7
0.9996	0.5	1.0031	5.1	1.0066	9.7	1.0101	14.2	1.0136	18.8
0.9997	0.7	1.0032	5.2	1.0067	9.8	1.0102	14.4	1.0137	19.0
0.9998	0.8	1.0033	5.4	1.0068	9.9	1.0103	14.5	1.0138	19.1
0.9999	0.9	1.0034	5.5	1.0069	10.1	1.0104	14.6	1.0139	19.2
1.0000	1.1	1.0035	5.6	1.0070	10.2	1.0105	14.8	1.0140	19.4
1.0001	1.2	1.0036	5.8	1.0071	10.3	1.0106	14.9	1.0141	19.5
1.0002	1.3	1.0037	5.9	1.0072	10.5	1.0107	15.0	1.0142	19.6
1.0003	1.4	1.0038	6.0	1.0073	10.6	1.0108	15.2	1.0143	19.7
1.0004	1.6	1.0039	6.2	1.0074	10.7	1.0109	15.3	1.0144	19.9
1.0005	1.7	1.0040	6.3	1.0075	10.8	1.0110	15.4	1.0145	20.0
1.0006	1.8	1.0041	6.4	1.0076	11.0	1.0111	15.6	1.0146	20.1
1.0007	2.0	1.0042	6.6	1.0077	11.1	1.0112	15.7	1.0147	20.3
1.0008	2.1	1.0043	6.7	1.0078	11.2	1.0113	15.8	1.0148	20.4
1.0009	2.2	1.0044	6.8	1.0079	11.4	1.0114	16.0	1.0149	20.5
1.0010	2.4	1.0045	7.0	1.0080	11.5	1.0115	16.1	1.0150	20.6
1.0011	2.5	1.0046	7.1	1.0081	11.6	1.0116	16.2	1.0151	20.8
1.0012	2.6	1.0047	7.2	1.0082	11.8	1.0117	16.3	1.0152	20.9
1.0013	2.8	1.0048	7.3	1.0083	11.9	1.0118	16.5	1.0153	21.0
1.0014	2.9	1.0049	7.5	1.0084	12.0	1.0119	16.6	1.0154	21.2
1.0015	3.0	1.0050	7.5	1.0085	12.2	1.0120	16.7	1.0155	21.3
1.0016	3.2	1.0051	7.7	1.0086	12.3	1.0121	16.9	1.0156	21.4
1.0017	3.3	1.0052	7.9	1.0087	12.4	1.0122	17.0	1.0157	21.6
1.0018	3.4	1.0053	8.0	1.0088	12.6	1.0123	17.1	1.0158	21.7
1.0019	3.5	1.0054	8.1	1.0089	12.7	1.0124	17.3	1.0159	21.8
1.0020	3.7	1.0055	8.2	1.0090	12.8	1.0125	17.4	1.0160	22.0
1.0021	3.8	1.0056	8.4	1.0091	12.9	1.0126	17.5	1.0161	22.1
1.0022	3.9	1.0057	8.5	1.0092	13.1	1.0127	17.6	1.0162	22.2
1.0023	4.1	1.0058	8.6	1.0093	13.2	1.0128	17.8	1.0163	22.4
1.0024	4.2	1.0059	8.8	1.0094	13.3	1.0129	17.9	1.0164	22.5
1.0025	4.3	1.0060	8.9	1.0095	13.5	1.0130	18.0	1.0165	22.6

	DENSITY AT 15°C. - SALINITY IN PARTS PER 1,000 (PAGE 2 - FOR DENSITIES FROM 1.0166 - 1.0320)								
Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
1.0166	22.7	1.0201	27.3	1.0236	31.9	1.0271	36.4	1.0306	41.0
1.0167	22.9	1.0202	27.4	1.0237	32.0	1.0272	36.6	1.0307	41.1
1.0168	23.0	1.0203	27.6	1.0238	32.1	1.0273	36.7	1.0308	41.2
1.0169	23.1	1.0204	27.7	1.0239	32.3	1.0274	36.8	1.0309	41.4
1.0170	23.3	1.0205	27.8	1.0240	32.4	1.0275	37.0	1.0310	41.5
1.0171	23.4	1.0206	28.0	1.0241	32.5	1.0276	37.1	1.0311	41.6
1.0172	23.5	1.0207	28.1	1.0242	32.7	1.0277	37.2	1.0312	41.8
1.0173	23.7	1.0208	28.2	1.0243	32.8	1.0278	37.3	1.0313	41.9
1.0174	23.8	1.0209	28.4	1.0244	32.9	1.0279	37.5	1.0314	42.0
1.0175	23.9	1.0210	28.5	1.0245	33.0	1.0280	37.6	1.0315	42.1
1.0176	24.0	1.0211	28.6	1.0246	33.2	1.0281	37.7	1.0316	42.3
1.0177	24.2	1.0212	28.8	1.0247	33.3	1.0282	37.9	1.0317	42.4
1.0178	24.3	1.0213	28.9	1.0248	33.4	1.0283	38.0	1.0318	42.5
1.0179	24.4	1.0214	29.0	1.0249	33.6	1.0284	38.1	1.0319	42.7
1.0180	24.6	1.0215	29.1	1.0250	33.7	1.0285	38.2	1.0320	42.8
1.0181	24.7	1.0216	29.3	1.0251	33.8	1.0286	38.4		
1.0182	24.8	1.0217	29.4	1.0252	34.0	1.0287	38.5		
1.0183	25.0	1.0218	29.5	1.0253	34.1	1.0288	38.6		
1.0184	25.1	1.0219	29.7	1.0254	34.2	1.0289	38.8		
1.0185	25.2	1.0220	29.8	1.0255	34.4	1.0290	38.9		
1.0186	25.4	1.0221	29.9	1.0256	34.5	1.0291	39.0		
1.0187	25.5	1.0222	30.0	1.0257	34.6	1.0292	39.2		
1.0188	25.6	1.0223	30.2	1.0258	34.7	1.0293	39.3		
1.0189	25.8	1.0224	30.3	1.0259	34.9	1.0294	39.4		
1.0190	25.9	1.0225	30.4	1.0260	35.0	1.0295	39.6		
1.0191	26.0	1.0226	30.6	1.0261	35.1	1.0296	39.7		
1.0192	26.1	1.0227	30.7	1.0262	35.3	1.0297	39.8		
1.0193	26.3	1.0228	30.8	1.0263	35.4	1.0298	39.9		
1.0194	26.4	1.0229	31.0	1.0264	35.5	1.0299	40.1		
1.0195	26.5	1.0230	31.1	1.0265	35.6	1.0300	40.2		
1.1096	26.7	1.0231	31.2	1.0266	35.8	1.0301	40.3		
1.0197	26.8	1.0232	31.4	1.0267	35.9	1.0302	40.4		
1.0198	26.9	1.0233	31.5	1.0268	36.0	1.0303	40.6		
1.0199	27.1	1.0234	31.6	1.0269	36.2	1.0304	40.7		
1.0200	27.2	1.0235	31.8	1.0270	36.3	1.0305	40.8		

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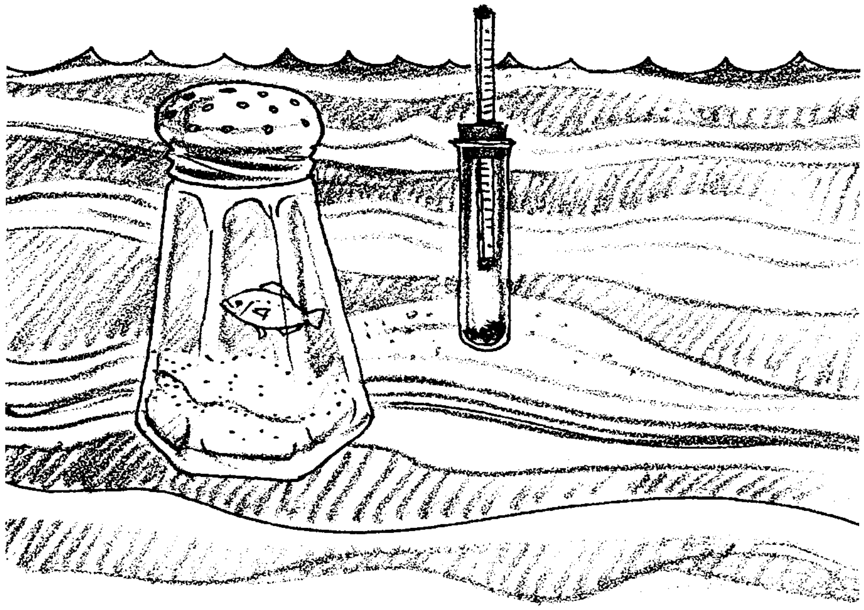


Salts make sea water different from fresh water. The concentrations of the salts affect everything that comes in contact with sea water. Living organisms have to deal with this salinity. To measure the salinity of sea water, oceanographers have developed several techniques. People observed that the saltier the water, the higher something floats in it. Marine scientists use this buoyancy (flotation) information to determine salinity rapidly, with an instrument called a hydrometer. One type of hydrometer is a weighted glass cylinder with a thin glass tube at the top. The thin tube contains a printed scale (see diagram). The higher the salinity, the higher the tube floats and the larger the number that lines up with the water's surface. Pure water at 4°C is given a density of 1.0000. In this activity you will use a hydrometer and thermometer to determine the salinity of salt water samples.

Materials

- Salt water solutions
- Thermometer °C
- Hydrometer
- Density- water temperature chart
- Salinity - corrected density chart
- Temperature / salinity graph
- 500 ml graduated cylinder

Part I

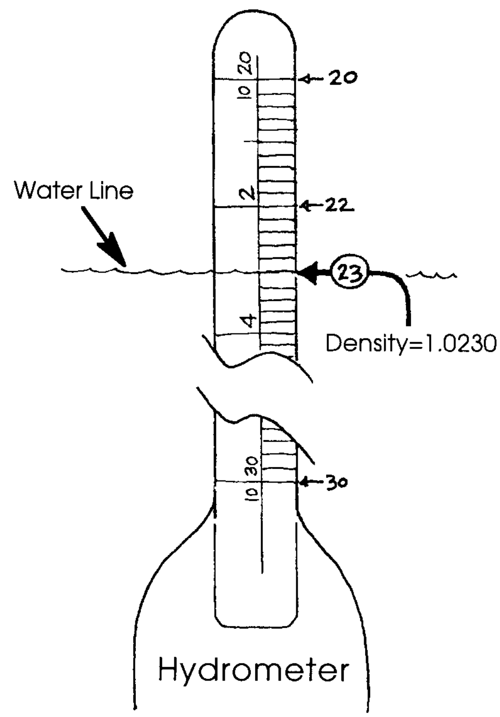
Procedure:

1. Fill graduated cylinder with 450 ml of your salt water sample.

2. Record water temperature with centigrade thermometer.

3. Using the hydrometer, measure the density of your sample. The diagram to the right will help you read the hydrometer.

   Record the density________________



4. Correct density using density-water temperature chart and record.

   Example: density = 1.0230   water temperature = 10°

   Find 1.0230 under "Observed density" on the Density-Water Temperature Chart.

   Move across to the column marked "10°" under "Temperature of water in jar".

   Read: -8. The -8 is the correction factor and is really -.0008.

   Thus:

   1.0230
   -.0008
   1.0222 = the corrected density reading

   Record the corrected density for your sample.

5. Read salinity from salinity-corrected density chart and record.

   Example: Find 1.0222 in the density column.

   Read 30.0 in the salinity column to the right of the density 1.0222.

   Record the salinity for your sample ________‰.

6. RECORD YOUR SALINITY ON THE BLACKBOARD as directed by your teacher.

   Repeat the above steps for each salt solution provided.

Interpretation and Analysis

1. Look at the salinity determinations for salt solution number 1. Are all of the salinity estimates for a particular solution the same?

2. If you see differences in the estimates, list three possible sources of this variation.
   a.

   b.

   c.

3. Scientists have found that they can obtain more accurate results if they repeat a procedure several times and take an average. The average figure that they obtain has a better chance of being the real (correct) figure than does any of the individual figures.

Calculate the average salinity for each of the salt solutions tested. (Hint: This is easy! Take all of the salinity estimates for a given solution and add them together. Divide this sum by the number of estimates. The answer is your average. In other words,

$$\frac{\text{sum of salinity estimates for solution X}}{\text{number of salinity estimates for solution X}} = \text{average salinity estimate for solution X)}$$

Please show your work in the space below:

4. Are any of the estimates on the board exactly the same as the calculated average?

5. Which solution was the saltiest?

6. The salinity of sea water ranges from about 25 parts salt per thousand parts of water (25 ‰) to about 35 parts per thousand (35 ‰). Did either or both solutions fall in this range? If yes, which one(s)?

7. What are two conditions that might help account for a range (from 25 ‰ to 35 ‰) in water salinities rather than a single uniform salinity?
   a.

   b.

8. Where would you expect the lowest salinities to be found? Explain.

9. Where would you expect the highest salinities to be found? Explain.

Part II

Using the density-water temperature chart and the salinity-corrected chart can be tedious. To make things a bit quicker scientists have developed a hydrometer-temperature graph which corrects for differences in temperature. Using this graph you will again determine the salinities that correspond to the hydrometer densities you discovered.

Procedure:

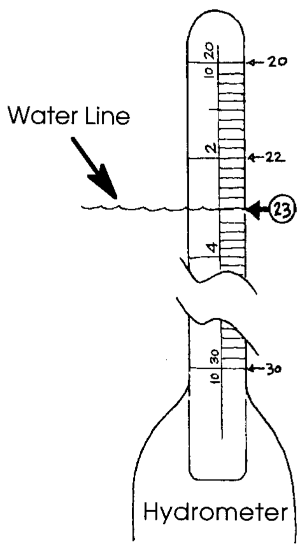
1. Use the hydrometer-temperature graph to read the salinity.

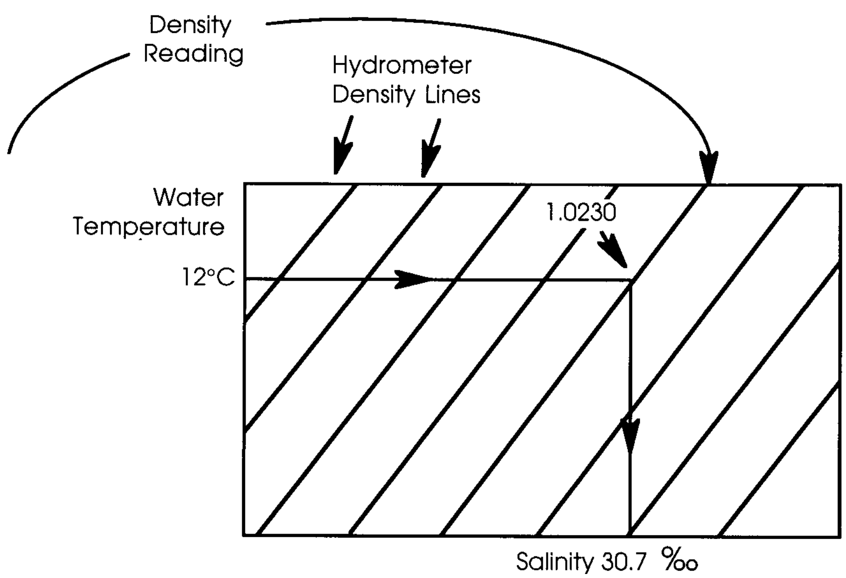
   EXAMPLE: To Find Salinity:

   a. Find correct water temperature on graph.

   b. Follow temperature line over until you meet correct hydrometer density line.

   c. From this point drop straight down and read off correct salinity of your sample in parts per thousand (‰).





Record your salinity:

Salinity for sample # ________is __________‰.

Interpretation and Analysis

1. Which method of determining salinity from density data did you find easier? Why?

2. Were the densities you determined using the charts exactly the same as those that you determined using the graph?

3. By what percentage does the graph salinity determination for the first sample differ from the chart salinity determination?

   (HINT: % difference = $\frac{\text{(chart salinity) - (graph salinity)}}{\text{chart salinity}} \times 100$)

   Please show your work in the space below:

4. The graph was constructed from the charts. Which do you think is more accurate? Why?

5. When might you want to use the chart method and when might it be most appropriate to use the graph method?