Mathematical Journeys I

Lab 7
Faculty Notes

Water Quality, pH, and Acid Rain

This laboratory will help students better understand the meaning of pH and the effects of acid rain on bodies of water. It is written at the college algebra or precalculus level. Students will need to use mathematics topics such as logarithms, exponential functions, percent, ratio and proportions, solving linear equations, statistics, linear regression, and interpolation.

Following is information that you may find helpful while doing the lab. This information is set up in two parts: Part One – overview of the Lab and Handouts and Part Two – Selected Answers.

A class period should be devoted to discussing the bibliotechnology research, taking Handout 1: Warm-Up Quiz, and explaining pH, acid rain, and dilutions. Handout 2: Guide for Serial Dilution and pH Experiment (creating the dilutions, gathering the pH data, and measuring the unknown dilution) can be completed in an additional 50-minute class period. The data analysis and the written report for the experiment will require either out-of-class time or another class period.

When beginning the model development for the water site, a portion of a class period should be devoted to reviewing the scientific method and pH. After this, the majority of the student work will be completed outside of class. Class time should be set aside at the end of the project for the thesis defense. The amount of time needed depends on the projected length of each presentation and the number of presentations.

Part One

Overview of the Lab and Handouts

Introduction

This information should give the students an idea of where they are headed and what is needed to complete the technology problem. You will probably have to spend a few minutes answering questions and setting the stage for what is to come.

Technology Problem

One of the many tasks a water quality technician performs is to accurately track the quality of the water in a specific body of water. The actual tests run depend upon how the water is to be used. Water can be tested for pollutants, amount of oxygen, presence of bacteria, and numerous other substances. In this lab, the students are measuring only the pH of the water over a specified time frame.

Various bodies of water can be selected for this project – a small stream, a lake, a swimming pool, a river. The main criterion for the water is that it be easily accessible over the length of the data collection period. Of course, the safety of students while collecting data is of utmost concern.

Bibliotechnology Research

The research performed by the student will provide the vocabulary and concepts needed to get started. Suggested answers to the posed questions are included at the end of the Faculty Notes.

Mathematics Tools

It is important that students have the prerequisite skills to be successful. Handout 3: Warm-Up Quiz will ensure that the students have the math skills necessary to start the project. It can be done as an individual or as a group quiz. You will have to review or teach linear regression, logarithms, and exponentials before the quiz.

Model Portfolio

It is important that the students keep a complete and accurate record of all activities associated with the lab. You may want to meet with each student and set up regular checkpoints to review the materials in the model portfolio.

Model Development

Section I Serial dilution and pH

The Serial Dilution and pH Experiment will provide practice for students in using the pH probe and in writing a formal technical report. To give students further guidance in writing their reports, distribute both Handout 2: Guide for Serial Dilution and pH Experiment as well as Handout 3: Grading Rubric for Serial Dilution and pH. After you have graded the experiment, you will probably have to spend some time on the scientific method to be sure students are ready for the technology problem.

You may want to check your students' understanding of the serial-dilution experiment when they have completed it. Handout 4: Post-Activity Individual Quiz is included in these materials. It has been written as an individual, not a group quiz. The quiz is designed to ensure accountability of each group member for the material covered in the experiment. Students should be able to complete the quiz in 15 to 20 minutes.

Note: Since pH probes, serial dilutions, and the general idea of pH may be unfamiliar, it is recommended that you seek the advice and assistance of a chemistry teacher when doing this lab. Following are some comments for implementing Handout 2: Guide for Serial Dilution and pH Experiment. The comments are directly keyed to the handout in Part Two of the Faculty Notes.

Part A Purpose

The purpose of the experiment on serial dilution and pH is to allow students to gain experience with a pH probe, to learn how to analyze logarithmic data, and to practice writing a formal lab report.

In this experiment, students will take known dilutions of vinegar in water, measure the pH of these dilutions, develop a logarithmic model showing the relationship between percent dilution and pH, and use this model to determine the percent dilution of an unknown solution from a pH reading.

Part B Experiment

1) Materials and tools

You can find pH probes in your chemistry and/or biology departments. Also, Texas Instruments Inc. has pH probes available for the TI-83 Plus™. Distilled water gives much better results than does tap water. Impurities in tap water can interact with the vinegar and affect the readings.

2) Procedure

For Procedure Step 2a:

Whether you or the students perform the pH probe calibration depends on class time available and how many pH probes you have. If you have only one probe or limited class time, have the students prepare the dilution, and you can collect and disseminate the data.

The pH probe should contain an internal temperature probe that will adjust the pH reading to take into account differences in water temperature. However, it is suggested that you take your readings with all dilutions at room temperature.

Measure the pH of 0% vinegar, i.e. the water, and 100% vinegar. These will give you asymptotic values on your graph and for your model. A problem will arise if you use 0% in your logarithmic regression. You can replace 0% with some very small value, such as 10^{-6}, and it should work. Whether you want to exclude 0% and 100% values and keep them as a check on the student models is up to you.

For Procedure Step 2d:

It is easiest to prepare dilutions using simple percentages such as 10%, 20%, 25%, etc. In this way, there should be 5 to 15 different dilutions that are created. The markings of the graduated cylinder will affect the number of dilutions you can realistically prepare.

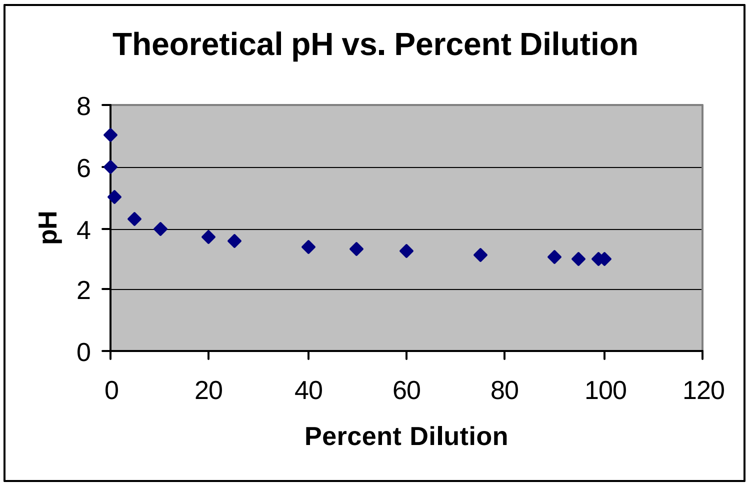
3) Data representation

The following are experimental pH values for various dilutions of pH 3 vinegar in pH 7 water. Your class values should be similar in form. Most water is not at pH 7, and the vinegar may vary in pH. A very important thing to realize is that a pH of 3 means a hydrogen ion concentration of 1 in 1000. A pH of 7 means a concentration of 1 in 10,000,000. It takes a lot of pH 7 stuff to counteract a little pH 3 stuff!!! The value of your acid, i.e. the vinegar, will dominate most of the data. Only at low concentrations will you notice the difference, and then the pH of your water will dominate. You should see this in your data.

Table 1

Percent Vinegar	Experimental pH Values
0	7.000
0.1	5.959
1	4.996
5	4.300
10	3.990
20	3.699
25	3.602
40	3.398
50	3.301
60	3.222
75	3.125
90	3.042
95	3.022
99	3.004
100	3.000

The following is a graph of the data in Table 1 on the previous page. Recall that this graph is based on dilutions of pH 3 vinegar and pH 7 water.



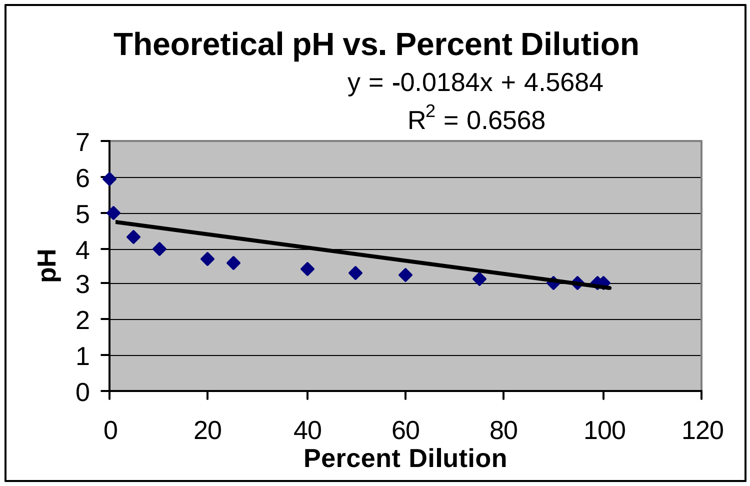
Below is the authors' data with water at pH 5.88 and white wine vinegar at pH 2.34.

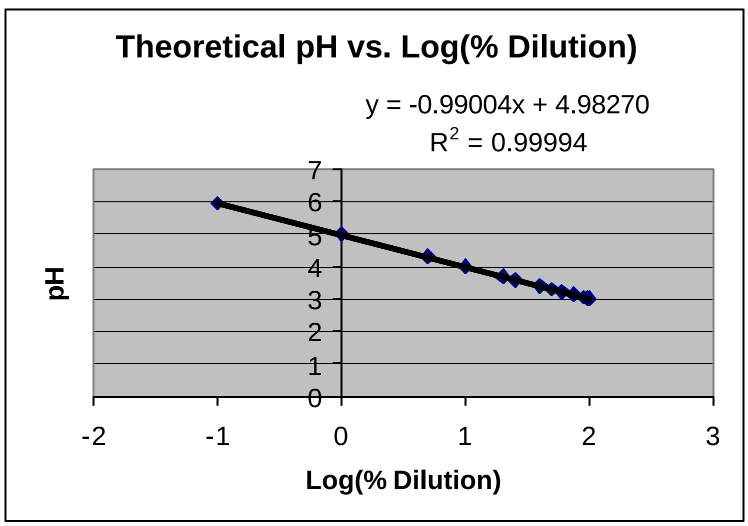
Table 2

% Dilution	Log(% Dilution)	pH
0		5.88
25	1.3979	2.63
35	1.5441	2.58
50	1.6990	2.48
60	1.7782	2.44
75	1.8751	2.4
100	2.0000	2.34

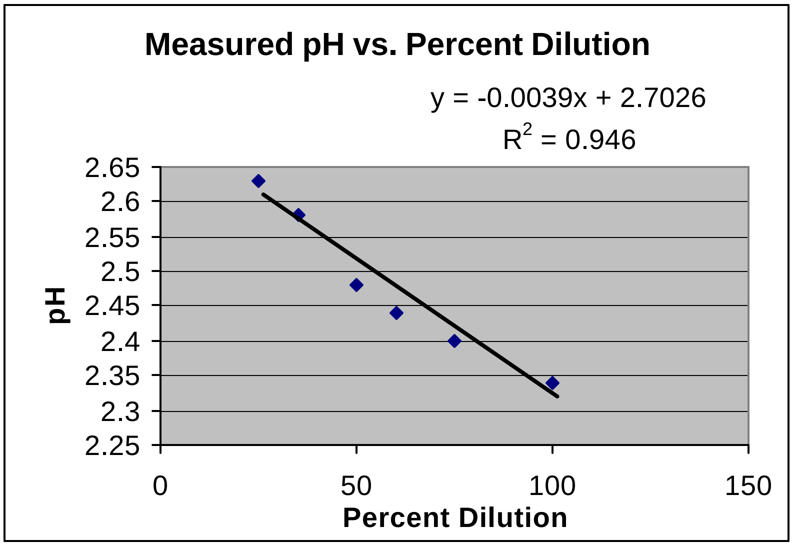
4) Data Analysis

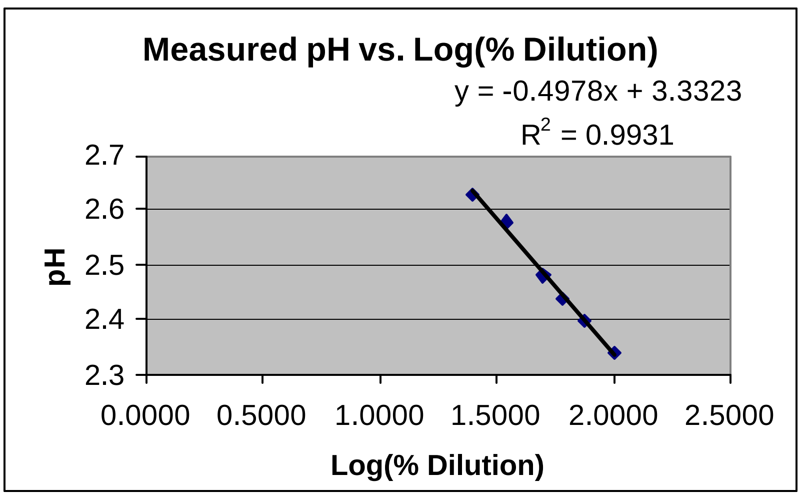
Below is the analysis for water at pH 7 and vinegar at pH 3. The 0% datum is excluded in the analysis. The data should be logarithmic of the form pH = $-1*\log_{10}$ (Percent Dilution) + 5. Clearly, the linear fit is not very good.





The authors' data from Table 2 gave the following scatter plots and models. The 0% datum is excluded from the analysis. The log model comes out as pH = $-0.4978*\log_{10}$(Percent Dilution) + 3.3323.





5) Analysis questions

a) For example, a 200 ml, 25% dilution of vinegar in distilled water contains 50 ml of vinegar and 150 ml of distilled water.
b) Using the author's data and regression line to evaluate the pH of a 47% dilution, we obtain pH = $-0.4978*\log_{10}(47) + 3.3323 = 2.50$.
c) Using the author's data, if the pH is 3, then the percent dilution can be found as follows $3 = -0.4978*\log_{10}$(Percent Dilution) + 3.3323 gives Percent Dilution = 4.65% or 5%.

Section II Monitoring acidity for your water site

At this time, students will be able to apply the research and knowledge they've gained from the previous lab activities. Handout 3: The Grading Rubric for Water Quality, pH, and Acid Rain, should be given to the students as a guide for writing their reports. Handout 6: Oral Presentation Evaluation form may also be given out before the thesis defense so that the students may better prepare for it.

For this part of the lab, students will use mathematics topics such as data collection, mean, standard deviation, range, logarithms, and regression analysis.

You can find pH probes in your chemistry and/or biology departments. Also, Texas Instruments Inc. has pH probes available for the CBL™. Temperature affects hydrogen ion activity, which in turn, affects the pH. The pH probe will adjust to temperature variation as long as the variation is within a reasonable range.

Possible answers to the analysis questions are included in the Answer Section.

Lab Extensions

Below are some possible options to extend the laboratory. A web search on any of these topics will provide sufficient information for a professor to gauge the accuracy of a report. A mathematics professor may want to involve a chemistry or biology professor in the evaluation of the project, especially during the thesis defense.

1) Determine the level of pH in the major soil types in your area, and determine which crops would grow best at these pH levels.

2) Determine the level of pH of household chemicals, for example cleaning supplies, paint, oil, and toiletry items. Correlate pH level with disposal methods allowed by your municipality.

3) Determine the level of pH of various foods in your diet. Is pH critical to the absorption level of vitamins, minerals, and nutrients? Explain.

4) Investigate the consequences of pH on pesticide effectiveness. Does pH level affect the disposal methods or environmental effects of the pesticide?

5) Find and visit local companies that measure pH or study acid rain. Report on your findings, such as the tests or studies these companies perform and the mathematics and science they use in their work.

Handout 1: Warm-Up Quiz

1) How much water should you add to dilute 100 ml of 20% acid to get a solution that is 16% acid?

A. 80 ml B. 25 ml C. 56 ml D. 32 ml

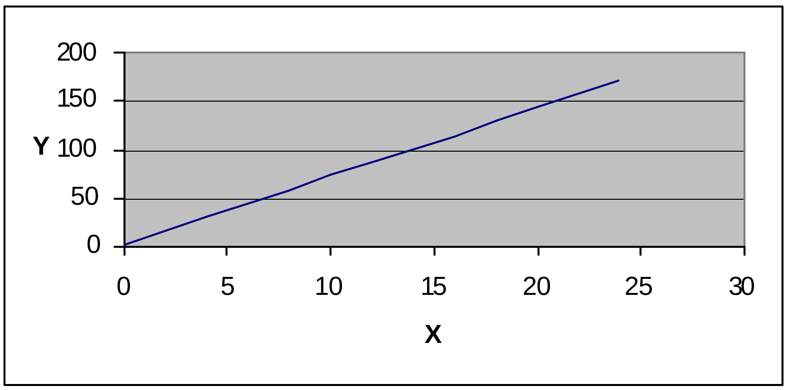
2) If y = 3.2x + 4.8, what is x when y = 7?

A. 0.6785 B. 0.6275 C. 0.6845 D. 0.6875

3) Find the linear regression for (1, -1.7), (3, 2.9), (4, 5.2), (5, 7.5), (8, 14.4).

A. y = 3.2x - 4 B. y = 2.3x + 4 C. y = 2.4x - 3 D. y = 2.3x - 4

4) From the graph below, what is the approximate value for y if x is 11?



5) Using the same graph, what is the value of x when y = 120?

A. 17 B. 15 C. 21 D. 19

6) Find $\log_{10}(17.5)$.

A. 2.862 B. 4.183 C. 1.243 D. 306.25

7) If $y = -0.5 \log_{10}(x) + 3$, find x if y = 2.2.

A. 21.2 B. 39.8 C. 31.8 D. 54.5

Handout 2: Guide for Serial Dilution and pH Experiment

Part A Purpose

The purpose of this experiment is to learn how to use a pH probe, to learn how to analyze logarithmic data, and to practice writing a formal technical report.

In this experiment, you will take known dilutions of vinegar in water, measure the pH of these dilutions, develop a logarithmic model showing the relationship between percent dilution and pH, and use this model to determine the percent dilution of an unknown solution from your pH reading.

Part B Experiment

1) Materials and Tools
   White wine vinegar, pH probe, distilled water, graduated cylinder, beakers or plastic cups, paper towels, learning technology such as Excel™ or TI-83™ graphing calculator.

2) Procedure
   a) Calibrate the pH probe according to the instructions included with the probe.
   b) Measure and record the pH of the water to be used in the dilutions.
   c) Measure and record the pH of undiluted vinegar.
   d) Set up serial dilutions using vinegar, water, the graduated cylinder, and a cup or beaker.
   e) Each group will create a solution of vinegar and water with the percent dilution assigned by the teacher.
   f) Record the percentage of dilution for each group in the class.
   g) Measure and record the pH of your group's dilution. Report this pH to the class.

3) Data representation
   a) Using values from the calibration process, create a table comparing the standard values with the measured values from your pH probe.
   b) Make a data table that includes the percent dilution, $\log_{10}$ (percent dilution), and measured pH for each group's solution.
   c) Create a scatter plot of pH vs. percent dilution.
   d) Create a scatter plot of pH vs. $\log_{10}$ of the percent dilution.

4) Data analysis
   a) Calculate the percent error in the calibration data.
   b) Determine the linear regression for the pH vs. percent dilution data. State the equation of the line and the correlation coefficient.
   c) Determine the linear regression for the pH vs. $\log_{10}$ of the percent dilution data. State the equation of the line and the correlation coefficient.
   d) Determine which of the two regression equations is the better fit. Explain your choice.
   e) Calculate the percent vinegar in your unknown dilution using your selected regression line. How many ml of vinegar were in your dilution? Show your work.

5) Analysis Questions

a) Show the calculations used to determine the amount of water and vinegar needed to create the assigned dilution.
b) Using your selected regression line, what would the pH be for a 47% dilution? (Round to the nearest hundredth.)
c) Using your selected regression line, what would the percent dilution be for a pH of 5.2? (Round to the nearest percent.)

6) Conclusions

State any discoveries made by your group during the lab. Also state sources of error and methods used to minimize error.

7) Report

Follow a standard experiment report format and include Purpose, Procedure, Data Representation, Data Analysis, Analysis, and Conclusion as defined by the tasks you performed in the experiment.

Handout 3: Grading Rubric for Serial Dilution and pH

Grade	
	Format (10%) • Project has a cover page that includes: project title, date submitted, names of group members. • Spelling/grammar/punctuation are correct. • Format of work is easy to read and follow. • Sketches of equipment, setup, etc. are labeled. • Work is neat and legible (neatly typed, only front sides of paper used, no stray marks, tears, crossing out). • Responses to questions are listed sequentially.
	Data Representation and Calculations (30%) • Calculations for your group's serial dilution are included. • Original data sheets are included. • Data table of standard values used in calibration vs. pH-probe values is included. • Data table for pH-probe values vs. percent dilution is included. • Scatter plot of pH vs. percent dilution is shown. • Scatter plot of pH vs. $\log_{10}$(percent dilution) is shown.
	Data Analysis (30%) • Percent error in calibration is calculated. • Linear regression equations and correlation coefficients are listed. • Percent vinegar in unknown solution is stated and calculation is included.
	Analysis and Conclusions (30%) • Answers to *Analysis* questions are clearly stated in narrative form using complete sentences so that the reader does not need to refer to the original questions. • Clear reasoning and logic are present in the *Analysis* answers and conclusions. • Conclusions are supported with reasons, by examples, or using data from the group's work. • Additional discoveries made during the activity are stated. • Methods or techniques used to minimize error are mentioned. • Types of errors that occurred and their possible sources are stated.
	Total Grade

Handout 4: Post Activity Individual Quiz – Serial Dilution

Name: ____

1) Suppose you want 300 ml of a 70% solution of vinegar in water. Show the calculations needed to determine the amount of water and vinegar to be used to create the solution.

2) Given the following data, use learning technology such as the TI-83™ graphing calculator or Excel™ software to calculate the regression line and the correlation coefficient.
(0.8, 3.2), (0.15, 11), (0.25, 7.8), (0.7, 4.1), (0.1, 12), (0.2, 8.7)

3) If pH = $-1 * \log_{10}$(Percent Dilution) + 5,

   a) Find the pH if the percent dilution is 15%. (Round to the nearest tenth.)
   b) Find the percent dilution if the pH is 3.3. (Round to the nearest percent.)

4) You measure the pH of Liquid Plumber to be 11.7. If the standard pH value for Liquid Plumber is 12.5, what is the percent error in your measurement, to the nearest tenth?

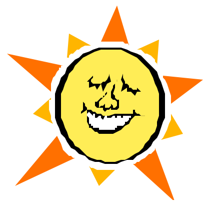
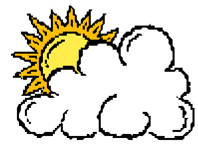
Handout 5: Grading Rubric for Water Quality, pH, and Acid Rain

Grade	
	Format (15%) • Project has a cover page that includes: project title, date submitted, names of group members. • Spelling/grammar/punctuation are correct. • Format of work is easy to read and follow. • Sketches of equipment, setup, etc. are labeled. • Work is neat and legible (neatly typed, only front sides of paper used, no stray marks, tears, crossing out). • Responses to questions are listed sequentially.
	Data Presentation and Calculations (40%) • Original data sheets are included. • Data tables are computer generated, contain appropriate titles, and use proper units. • Sample calculations are shown. • Variables are clearly defined. • Calculation steps are logical and correct. • Answers are labeled with appropriate units. • Graphs are done on graph paper or computer. • All graphs are labeled and have descriptive titles. • Results are checked for reasonableness.
	Method/Conclusions/Analysis (45%) • A summary, with bibliography, of the research leading to your hypothesis is included. • The plan used to perform the experiment and collect the data is clear and well-documented. • Answers to *Analysis* questions are stated in narrative form using complete sentences, so that the reader does not need to refer to the original questions. • Clear reasoning and logic are present in the *Analysis* answers, conclusions, and throughout the project. • Conclusions are supported with reasons, by examples, or using data from the group's work. • Additional discoveries made during the activity are stated. • Methods or techniques used to minimize error are mentioned. • Types of errors that occurred and their possible sources are stated.
	Total Grade

Handout 6: Oral Presentation Evaluation

Speaker's Name: ____

Project Title: ____

Please rate the presentation on a scale of 10 (highest) to 1 (lowest)										
	10	9	8	7	6	5	4	3	2	1
Content and Organization										
Clear Beginning, Middle, End										
Logical, Easy to Follow										
Complete										
Reasonable Technical Results										
Communication Skills										
Looks at Audience										
Stands Straight										
Appropriate Gestures										
Loud and Clear										
Visual Aids										
Visible, Professional Visuals										
Follow-up										
Answers Questions										

Please write your comments or reactions: _________________________________

____

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Part Two

Selected Answers

Bibliotechnology Research

1) pH

Web sites

- http://www.miamisci.org/ph/
- http://www.ph-measurement.co.uk/

a) What is it?

The term pH derives from a combination of p for "power" and H for Hydrogen. pH represents the "activity" of hydrogen ions in a solution at a given temperature. The mathematical definition is $pH = -\log_{10}(a_{H^+})$ where a_{H^+} is the activity of the hydrogen atoms. Activity is usually related directly to the concentration of hydrogen atoms, but is not exactly the same. In water, pH ranges from 0 to 14, with 7 being neutral.

b) What methods/materials are used to determine it?

Litmus paper, pH meters

c) Identify five common household items and look up their pH values.

Answers will vary. Here are some samples. These values have been rounded.

pH	Household or common item
1	Car battery acid
2	Lemon juice, Coca Cola, cranberry juice
3	Vinegar, Pepsi, applesauce
4	Oranges, Powerade, Lip Gloss
5	Lemon Cleaner, Pez
6	Pledge, shampoo, mouth spray, antibacterial gel
7	Contact solution, Scope, pure de-ionized water
8	Tic Tacs, baking soda, deodorant
9	Mr. Clean, toothpaste, Pine Sol
10	Fantastik, window cleaner
11	Comet, clear ammonia
12	Clorox bleach, cloudy ammonia
13	Cascade, Ajax
14	Easy Off Oven Cleaner, Drano, Liquid Plumber

2) Scientific method

Web sites

- http://teacher.nsrl.rochester.edu/phy_labs/AppendixE/AppendixE.html
- http://www.hobart.k12.in.us/jkousen/Sci_Meth/pmethod.htm
- http://teach.valdosta.edu/whuitt/materials/scientific_method.htm
- http://phyun5.ucr.edu/~wudka/Physics7/Notes_www/node6.html

The scientific method is a process designed, to paraphrase Feynman, "not to fool yourself". The method is usually thought of as a multi-step process.

3) Acid rain

Acid rain is actually acid deposition as a result of emissions into the atmosphere. Acid deposition was first identified in the 17^{th} century, when scientists discovered its effects on vegetation and people. Sulfur dioxide emissions are responsible for more than half of existing acid rain. These emissions are primarily a result of burning fossil fuels such as coal and of smelting ores to obtain pure metals. To a much lesser degree, there are also natural sources of sulfur dioxide emissions from volcanic eruptions and organic decay.

Nitrogen oxide emissions are the second major cause of acid rain. These emissions occur primarily from combustion of oil, coal, or gas. Other factors leading to nitrogen oxide emissions are bacterial action in the soil, forest fires, volcanic activity, and lightning.

Atmospheric carbon dioxide is primarily responsible for the slight acidity of natural rainwater. Nitrogen oxides and sulfur dioxide have a greater effect on the pH of rainwater, however, because they are more soluble than carbon dioxide.

Web sites

- http://www.ns.ec.gc.ca/msc/as/as_acid.html
- http://www.ec.gc.ca/acidrain/
- http://www.ns.ec.gc.ca/msc/as/acidfaq.html
- http://www.soton.ac.uk/~engenvir/environment/air/acid.home.html
- http://www.acidrain.org/
- http://olp.swlauriersb.qc.ca/webquest/rainwq.htm

4) Serial dilution

Web sites

- http://www.woodrow.org/teachers/bi/1993/serial.html
- http://www.brooklyn.cuny.edu/bc/ahp/MBG/MBG4/Dilution.html

Serial dilution involves diluting a substance through a series of specific steps. Typically, the dilutions go down by a factor of 10 or 100 or 1000. For example, if you add 1 ml of substance to 99 ml of sterile solution, you get a 1% dilution of the substance. The next step would be to take 1 ml of this newly diluted solution and add it again to 99 ml of sterile solution. The final dilution would then be 1% * 1% = 0.01 * 0.01 =0.0001, which is 1 in 10,000 or 0.01%. The series of steps is repeated until a dilution of the desired proportion is created.

5) Linear regression

Web sites

- http://www.mste.uiuc.edu/patel/amar430/intro.html
- http://infoweb.magi.com/~timusk/linhyd.html
- http://www.equis.com/free/taaz/linearegression.html
- http://www.math.csusb.edu/faculty/stanton/m262/regress/regress.html

Linear regression is a standard method for determining the linear relationship between paired data points.

6) Water quality and water quality standards

Web sites

- http://www.epa.gov/safewater/mcl.html
- http://www.epa.gov/ow/
- http://www.nalusda.gov/wqic/
- http://water.usgs.gov/owq/
- http://www.bae.ncsu.edu/bae/programs/extension/wqg/
- http://www.epa.gov/owow/monitoring/
- http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/index3.html

There are numerous web sites about water quality and its effects. To find the regulations on water quality in your area, contact the water utility supplier, the state water quality agency, or your agricultural extension agency.

Mathematics Tools

Warm-Up Quiz Solutions

1) B. 25 ml

2) D. 0.6875

3) D. y = 2.3x – 4

4) B. 80

5) A. 17

6) C. 1.243

7) B. 39.8

Section I Serial dilution and pH

Post Activity Individual Quiz – Serial Dilution and pH - Solutions

1) 210 mL of vinegar
   90 mL of water

2) $y = -11.324x + 11.952$
   correlation = - .9617

3. a) At 15% dilution, the pH is 3.8.
   b) With a pH of 3.3, the dilution should be 50%.

4) Your measurement is 6.4% below the actual pH.

Section II Monitoring acidity for your water site

1) According to your state guidelines, what is the acceptable range of pH values for drinking water? Does the pH for your water source fall within this range?

   From the North Carolina Public Water System Monitoring Requirements, pH must be within the range 6.5 – 8.5. Most states will be similar.

2) Did any of the special conditions present during data collection affect the pH value?

   Answers will vary. Conditions such as changes in temperature, droughts, heavy rains, etc. may affect the pH.

3) What range of pH is required for most aquatic life? Were any of your data points outside this range?

For aquatic life, the following table should help.

Effects of pH Range on Aquatic Species

pH	Effect on Aquatic Species
3.0-3.5	Unlikely that fish can survive for more than a few hours in this range although some plant and invertebrates can be found at pH levels this low.
3.5-4.0	Known to be lethal to all salmonids (salmon, trout, and other similar fish).
4.0-4.5	All fish, most frogs and insects are not present.
4.5-5.0	Mayfly and many other insect species are not found. Most fish eggs will not hatch.
5.0-5.5	Bottom-dwelling decomposing bacteria begin to die off. Leaf litter and dead plant and animal materials begin to accumulate. Plankton begin to disappear.
6.0-6.5	Freshwater shrimp are not present.
6.5-8.5	Optimal for most organisms.
8.5-9.0	Unlikely to be harmful to fish, but indirect effects from chemical changes in the water may occur.
9.0-10.5	Harmful to perch and salmonids if prolonged exposure.
10.5-11.0	Prolonged exposure is lethal to carp and perch.
11.0-11.5	Lethal to all species of fish.

This information is taken in part from the LaMotte Company's The Monitor's Handbook, 1992.

4) What are the sources of the precursors to the acids that form acid rain?

Acid rain results from emissions of sulfur dioxide, nitrogen oxides, and ammonia. The primary source is sulfur dioxide, which results from burning fossil fuels such as coal. The second largest source is nitrous oxide, a by-product of combustion. A much smaller factor is ammonia, produced by livestock and agricultural enterprises involving manure. The composition of acid rain differs from region to region.

5) What are some of the environmental effects of acid deposition?

Acid deposition affects the environment in many different ways. It affects all living organisms- marine life, animal life, and plant life both on land and in the water. Acid deposition also has socioeconomic consequences on businesses and industries that depend on marine life, forestry, or agriculture. In addition, acid rain may affect the materials or covering of structures that are exposed to the elements such as buildings, sculptures, cars, etc.

6) State at least three other tests that are typically run on drinking water.

Other frequently tested substances and their levels are:

Substance	Action Level	Comment
Lead	0.015 mg/L or 15 micrograms/L	Action must be taken if this limit is exceeded in more than 10% of tap water samples during a monitoring period.
Copper	1.3 mg/L	Action must be taken if this limit is exceeded in more than 10% of tap water samples during a monitoring period.
Arsenic	0.05 mg/L or 50 micrograms/L	If any sample exceeds this maximum contaminant level action must be taken.
Fluoride	4.0 mg/L	If any sample exceeds this maximum contaminant level action must be taken.