SL Chem

Part 1 – Scientific Numbers

Information: Qualitative vs. Quantitative

The following observations are qualitative.

The building is really tall.
It takes a long time for me to ride my bike to the store.
I live really far away.

The following observations are quantitative.

The river is 31.5 m deep.
The cheese costs $4.25 per pound.
It is 75° F outside today.

Critical Thinking Questions

1. What is the difference between qualitative and quantitative observations? (Your answers should reveal an understanding of the definitions for qualitative and quantitative.)

2. Write an example of a quantitative observation that you may make at home or at school.

3. Why are instruments such as rulers, scales (balances), thermometers, etc. necessary?

Information: Units

The following tables contain common metric (SI) units and their prefixes.

Table 1: metric base units

Quantity	Unit	Unit Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K
Volume	Liter	L
Amount of substance	mole	mol

Table 2: prefixes for metric base units.

Prefix	Symbol	Meaning
Mega	M	million
Kilo	k	thousand
Deci	d	tenth
Centi	c	hundredth
Milli	m	thousandth
Micro	µ	millionth
Nano	n	billionth
Pico	p	trillionth

Note the following examples:

- "milli" means thousandth so a milliliter (symbol: mL) is one thousandth of a Liter and it takes one thousand mL to make one L.
- "Mega" means million so "Megagram" (Mg) means one million grams NOT one millionth of a gram. One millionth of a gram would be represented by the microgram (µg). It takes one million micrograms to equal one gram and it takes one million grams to equal one Megagram.
- One cm is equal to 0.01 m because one cm is "one hundredth of a meter" and 0.01 m is the expression for "one hundredth of a meter"

Critical Thinking Questions

4. How many milligrams are there in one kilogram?

5. How many meters are in 21.5 km?

6. Is it possible to answer this question: How many mg are in one km? Explain.

7. What is the difference between a Mm and a mm? Which is larger one Mm or one mm?

Information: Scientific Notation

"**Scientific notation**" is used to make very large or very small numbers easier to handle. For example the number 45,000,000,000,000,000 can be written as "4.5×10^{16}". The "16" tells you that there are sixteen decimal places between the right side of the four and the end of the number.

Another example: $2.641 \times 10^{12} = 2{,}641{,}000{,}000{,}000$ → the "12" tells you that there are 12 decimal places between the right side of the 2 and the end of the number.

Very small numbers are written with negative exponents. For example, 0.00000000000000378 can be written as 3.78×10^{-15}. The "-15" tells you that there are 15 decimal places between the right side of the 3 and the end of the number.

Another example: $7.45 \times 10^{-8} = 0.0000000745$ → the "-8" tells you that there are 8 decimal places between the right side of the 7 and the end of the number.

In both very large and very small numbers, the exponent tells you how many decimal points are between the right side of the first digit and the end of the number. If the exponent is positive, the decimal places are to the right of the number. If the exponent is negative, the decimal places are to the left of the number.

Critical Thinking Questions

8. Two of the following six numbers are written incorrectly. Circle the two that are incorrect.

   a) 3.57×10^{-8} b) 4.23×10^{-2} c) 75.3×10^{2} d) 2.92×10^{9} e) 0.000354×10^{4} f) 9.1×10^{4}

   What do you think is wrong about the two numbers you circled?

9. Write the following numbers in scientific notation:

   a) 25,310,000,000,000,000 = ______________ b) 0.000000003018 = ______________

10. Write the following scientific numbers in regular notation:

    a) 8.41×10^{-7} = ______________ b) 3.215×10^{8} = ______________

Information: Multiplying and Dividing Using Scientific Notation

When you multiply two numbers in scientific notation, you must add their exponents. Here are two examples. Make sure you understand each step:

$$(4.5\times10^{12}) \times (3.2\times10^{36}) = (4.5)(3.2) \times 10^{12+36} = 14.4\times10^{44} \rightarrow 1.44\times10^{45}$$

$$(5.9\times10^{9}) \times (6.3\times10^{-5}) = (5.9)(6.3) \times 10^{9+(-5)} = 37.17\times10^{4} \rightarrow 3.717\times10^{5}$$

When you divide two numbers, you must subtract denominator's exponent from the numerator's exponent. Here are two examples. Make sure you understand each step:

$$\frac{2.8\times10^{14}}{3.2\times10^{7}} = \frac{2.8}{3.2}\times10^{14-7} = 0.875\times10^{7} = 8.75\times10^{6}$$

$$\frac{5.7\times10^{19}}{3.1\times10^{-9}} = \frac{5.7}{3.1}\times10^{19-(-9)} = 1.84\times10^{19+9} = 1.84\times10^{28}$$

Critical Thinking Questions

11. Solve the following problems.

a) $(4.6x10^{34})(7.9x10^{-21}) =$

b) $(1.24x10^{12})(3.31x10^{20}) =$

12. Solve the following problems.

a) $\frac{8.4x10^{-5}}{4.1x10^{17}} =$

b) $\frac{5.4x10^{32}}{7.3x10^{14}} =$

Information: Adding and Subtracting Using Scientific Notation

Whenever you add or subtract two numbers in scientific notation, you must make sure that they have the same exponents. Your answer will them have the same exponent as the numbers you add or subtract. Here are some examples. Make sure you understand each step:

$4.2x10^{6} + 3.1x10^{5}$ → make exponents the same, either a 5 or 6 → $42x10^{5} + 3.1x10^{5} = 45.1x10^{5} = 4.51x10^{6}$

$7.3x10^{-7} - 2.0x10^{-8}$ → make exponents the same, either -7 or -8 → $73x10^{-8} - 2.0x10^{-8} = 71x10^{-8} = 7.1x10^{-7}$

Critical Thinking Questions

13. Solve the following problems.

a) $4.25x10^{13} + 2.10x10^{14} =$

b) $6.4x10^{-18} - 3x10^{-19} =$

c) $3.1x10^{-34} + 2.2x10^{-33} =$

Scientific Notation

Introduction:

Scientific notation is a shorthand way to express large or tiny numbers. Since you will need to do calculations throughout the year WITHOUT A CALCULATOR, we will consider anything over 1000 to be a large number. Writing these numbers in scientific notation will help you do your calculations much quicker and easier and will help prevent mistakes in conversions from one unit to another. Like the metric system, scientific notation is based on factors of 10. A large number written in scientific notation looks like this:

$$1.23 \times 10^{11}$$

The number before the x (1.23) is called the coefficient. The coefficient must be greater than 1 and less than 10. The number after the x is the base number and is always 10. The number in superscript (11) is the exponent.

Part I: Writing Numbers in Scientific Notation

To write a large number in scientific notation, put a decimal after the first digit. Count the number of digits after the decimal you just wrote in. This will be the exponent. Drop any zeros so that the coefficient contains as few digits as possible.

Example: 123,000,000,000

Step 1: Place a decimal after the first digit. 1.23000000000

Step 2: Count the digits after the decimal...there are 11.

Step 3: Drop the zeros and write in the exponent. 1.23×10^{11}

Writing tiny numbers in scientific notation is similar. The only difference is the decimal is moved to the left and the exponent is a negative. A tiny number written in scientific notation looks like this:

$$4.26 \times 10^{-8}$$

To write a tiny number in scientific notation, move the decimal after the first digit that is not a zero. Count the number of digits before the decimal you just wrote in. This will be the exponent as a negative. Drop any zeros before or after the decimal.

Example: .0000000426

Step 1: 00000004.26

Step 2: Count the digits before the decimal...there are 8.

Step 3: Drop the zeros and write in the exponent as a negative. 4.26×10^{-8}

Part II: Adding and Subtracting Numbers in Scientific Notation

To add or subtract two numbers with exponents, the exponents must be the same. You can do this by moving the decimal one way or another to get the exponents the same. Once the exponents are the same, add (if it's an addition problem) or subtract (if it's a subtraction problem) the coefficients just as you would any regular addition problem (review the previous section about decimals if you need to). The exponent will stay the same. Make sure your answer has only one digit before the decimal – you may need to change the exponent of the answer.

Example: $1.35 \times 10^{6} + 3.72 \times 10^{5} = ?$

Step 1: Make sure both exponents are the same. It's usually easier to go with the larger exponent so you don't have to change the exponent in your answer, so let's make both exponents 6 for this problem.

$$3.72 \times 10^{5} \rightarrow .372 \times 10^{6}$$

Step 2: Add the coefficients just as you would regular decimals. Remember to line up the decimals.

$$\begin{array}{r} 1.35 \\ +\ .372 \\ \hline 1.722 \end{array}$$

Step 3: Write your answer including the exponent, which is the same as what you started with.

$$1.722 \times 10^{6}$$

Part III: Multiplying and Dividing Numbers in Scientific Notation

To multiply exponents, multiply the coefficients just as you would regular decimals. Then add the exponents to each other. The exponents DO NOT have to be the same.

Example: $1.35 \times 10^6 \quad X \quad 3.72 \times 10^5 = ?$

Step 1: Multiply the coefficients.

```
  1.35
x 3.72
   270
  9450
 40500
 50220  → 5.022
```

Step 2: Add the exponents.

$$5 + 6 = 11$$

Step 3: Write your final answer.

$$5.022 \times 10^{11}$$

To divide exponents, divide the coefficients just as you would regular decimals, then subtract the exponents. In some cases, you may end up with a negative exponent.

Example: $5.635 \times 10^3 \; / \; 2.45 \times 10^6 = ?$

Step 1: Divide the coefficients.

$$5.635 / 3.45 = 2.3$$

Step 2: Subtract the exponents.

$$3 - 6 = -3$$

Step 3: Write your final answer.

$$2.3 \times 10^{-3}$$

Practice: Remember to show all your work, include units if given, and NO CALCULATORS!

Write the following numbers in scientific notation:

1. 145,000,000,000 = ____________________
2. 13 million = ____________________
3. 435 billion = ____________________
4. .000348 = ____________________
5. 24 thousand = ____________________

Complete the following calculations:

6. $4.67 \times 10^4 + 323 \times 10^3 =$ ____________________
7. $7.89 \times 10^{-6} + 2.35 \times 10^{-8} =$ ____________________
8. $2.9 \times 10^{11} - 3.7 \times 10^{13} =$ ____________________
9. $1.278 \times 10^{-13} - 1.021 \times 10^{-10} =$ ____________________
10. three hundred thousand plus forty-seven thousand = ____________________
11. 13 million minus 11 thousand = ____________________
12. $1.32 \times 10^8 \text{ X } 2.34 \times 10^4 =$ ____________________
13. $3.78 \times 10^3 \text{ X } 2.9 \times 10^2 =$ ____________________
14. three million times eighteen thousand = ____________________
15. one thousandth of seven thousand = ____________________
16. eight ten-thousandths of thirty-five million= ____________________
17. $3.45 \times 10^9 / 2.6 \times 10^3 =$ ____________________
18. $1.98 \times 10^{-4} / 1.72 \times 10^{-6} =$ ____________________
19. twelve thousand divided by four thousand = ____________________

Part 2 – Significant Figures

Information: Significant Figures

We saw in the last ChemQuest that scientific notation can be a very nice way of getting rid of unnecessary zeros in a number. For example, consider how convenient it is to write the following numbers:

$$32{,}450{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000 = 3.245 \times 10^{34}$$
$$0.000000000000000127 = 1.27 \times 10^{-16}$$

There are a whole lot of zeros in the above numbers that are not really needed. As another example, consider the affect of changing units:

21,500 meters = 21.5 kilometers
0.00582 meters = 5.82 millimeters

Notice that the zeros in "21,500 meters" and in "0.00582 meters" are not really needed when the units change. Taking these examples into account, we can introduce three general rules:

1. Zeros at the beginning of a number are never *significant* (important).
2. Zeros at the end of a number are not significant unless... (you'll find out later)
3. Zeros that are between two nonzero numbers are always significant.

Therefore, the number 21,500 has *three* significant figures: only three of the digits are important—the two, the one, and the five. The number 10,210 has four significant figures because only the zero at the end is considered not significant. All of the digits in the number 10,005 are significant because the zeros are in between two nonzero numbers (Rule #3).

Critical Thinking Questions

1. Verify that each of the following numbers contains <u>four</u> significant figures. Circle the digits that are significant.

   a) 0.00004182 b) 494,100,000 c) 32,010,000,000 d) 0.00003002

2. How many significant figures are in each of the following numbers?

   _____ a) 0.000015045 _____ b) 4,600,000 _____ c) 2406

   _____ d) 0.000005 _____ e) 0.0300001 _____ f) 12,000

Information: The Exception to Rule #2

There is one exception to the second rule. Consider the following measured values.

It is **1200 miles** from my town to Atlanta.

It is **1200.0 miles** from my town to Atlanta.

The quantity "1200.0 miles" is more precise than "1200 miles". The decimal point in the quantity "1200.0 miles" means that it was measured very precisely—right down to a tenth of a mile. Therefore, the complete version of Rule #2 is as follows:

Rule #2: Zeros at the end of a number are not significant **unless there is a decimal point in the number.** A decimal point anywhere in the number makes zeros at the end of a number significant.

Not significant because these are at the beginning of the number!

0.0000007290

This zero is significant because it is at the end of the number and there is a decimal point in the number.

Critical Thinking Questions

3. Verify that each of the following numbers contains five significant figures. Circle the digits that are significant.

a) 0.00030200 b) 200.00 c) 2300.0 d) 0.000032000

4. How many significant figures are there in each of the following numbers?

______ a) 0.000201000 ______ b) 23,001,000 ______ c) 0.0300

______ d) 24,000,410 ______ e) 2400.100 ______ f) 0.000021

Information: Rounding Numbers

In numerical problems, it is often necessary to round numbers to the appropriate number of significant figures. Consider the following examples in which each number is rounded so that each of them contains 4 significant figures. Study each example and make sure you understand why they were rounded as they were:

42,008,000 → 42,010,000
12,562,425,217 → 12,560,000,000
0.00017837901 → 0.0001784
120 → 120.0

Critical Thinking Questions

5. Round the following numbers so that they contain 3 significant figures.

a) 173,792 b) 0.0025021 c) 0.0003192 d) 30

______ ______ ______ ______

6. Round the following numbers so that they contain 4 significant figures:

a) 249,441 ______ b) 0.00250122 ______ c) 12,049,002 ______ d) 0.00200210 ______

Information: Multiplying and Dividing

When you divide 456 by 13 you get 35.0769230769… How should we round such a number? The concept of significant figures has the answer. When multiplying and dividing numbers, you need to round your answers to the correct number of significant figures. To round correctly, follow these simple steps:

1) Count the number of significant figures in each number.
2) Round your answer to the least number of significant figures.

Here's an example:

$$\frac{4560}{14} = 325.714285714 = 330$$

4560: 3 significant figures

14: 2 significant figures

330: Final rounded answer should have only 2 significant figures since 2 is the least number of significant figures in this problem.

Here's another example:

$$13.1 \times 1.2039 = 15.77109 = 15.8$$

13.1: 3 significant figures

1.2039: 5 significant figures

15.8: Final rounded answer should have 3 significant figures since 3 is the least number of significant figures in this problem.

Critical Thinking Questions

7. Solve the following problems. Make sure your answers are in the correct number of significant figures.

a) (12.470)(270) = ______ b) 36,000/1245 = ______

c) (310.0)(12) = ______ d) 129.6/3 = ______

e) (125)(1.4452) = ______ f) 6000/2.53 = ______

Information: Rounding to a Decimal Place

As you will soon discover, sometimes it is necessary to round to a decimal place. Recall the names of the decimal places:

175,398.426

1	7	5	3	9	8	4	2	6
The hundred thousands place	The ten thousands place	The thousands place	The hundreds place	The tens place	The ones place	The tenths place	The hundredths place	The thousandths place

If we rounded the above number to the hundreds place, that means that there can be no significant figures to the right of the hundreds place. Thus, "175,400" is the above number rounded to the hundreds place. If we rounded to the tenths place we would get 175,398.4. If we rounded to the thousands place we would get 175,000.

Critical Thinking Questions

8. Round the following numbers to the tens place.

   a) 134,123,018 = ______________ b) 23,190.109 = ______________

   c) 439.1931 = ______________ d) 2948.2 = ______________

Information: Adding and Subtracting

Did you know that 30,000 plus 1 does not always equal 30,001? In fact, usually 30,000 + 1 = 30,000! I know you are finding this hard to believe, but let me explain...

Recall that zeros in a number are not always important, or *significant*. Knowing this makes a big difference in how we add and subtract. For example, consider a swimming pool that can hold 30,000 gallons of water. If I fill the pool to the maximum fill line and then go and fill an empty one gallon milk jug with water and add it to the pool, do I then have exactly 30,001 gallons of water in the pool? Of course not. I had approximately 30,000 gallons before and after I added the additional gallon because "30,000 gallons" is not a very precise measurement. So we see that sometimes 30,000 + 1 = 30,000!

Rounding numbers when adding and subtracting is different from multiplying and dividing. In adding and subtracting you round to the <u>least specific decimal place</u> of any number in the problem.

Example #1: Adding

$$\begin{array}{r} 350.04 \\ +720 \\ \hline 1070.04 \\ \downarrow \\ 1070 \end{array}$$

The hundredths place contains a significant figure.

The tens place contains a significant figure.

The answer gets rounded to the *least* specific place that has a significant figure. In this case, the tens place is less specific than the hundredths place, so the answer is rounded to the tens place.

Example #2: Subtracting

$$\begin{array}{r} 7000 \\ -1770 \\ \hline 5230 \\ \downarrow \\ 5000 \end{array}$$

The tens place contains a significant figure.

The thousands place contains a significant figure.

The answer gets rounded to the *least* specific place that has a significant figure. In this case, the thousands place is less specific than the tens place, so the answer gets rounded to the thousands place.

Critical Thinking Questions

9. a) 24.28 + 12.5 = ________________ b) 120,000 + 420 = ________________

   c) 140,100 – 1422 = ________________ d) 2.24 – 0.4101 = ________________

   e) 12,470 + 2200.44 = ________________ f) 450 – 12.8 = ________________

10. The following are problems involving multiplication, dividing, adding, and subtracting. Be careful of the different rules you need to follow!

    a) 245.4/120 = ________________ b) 12,310 + 23.5 = ________________

    c) (31,900)(4) = ________________ d) (320.0)(145,712) = ________________

    e) 1420 – 34 = ________________ f) 4129 + 200 = ________________

Part 3 – Graphing

Graphing Exercise

Graphs are a useful tool for displaying scientific data because they show relationships among variables in a compact, visual form. You may have used *x-y* graphs, or Cartesian graphs, in your math classes.

There are four basic steps to constructing a graph from data in the chemistry lab. These basic steps are (1) determining the independent variable, (2) scaling the axes, (3) plotting the data, and (4) titling your graph.

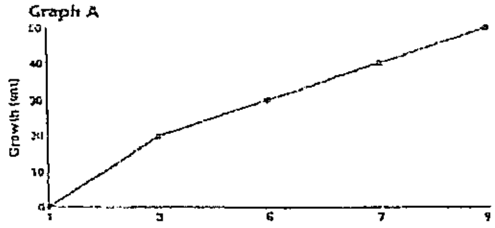
DETERMINING THE INDEPENDENT VARIABLE

In an experiment, the **independent variable** is the property that is under control and can be varied. The **dependent variable** is the property that is measured, observed, counted or found. The dependent variable changes when the independent variable changes. Here we will be plotting data on an *x-y* graph, or Cartesian graph. The independent variable is usually assigned to be the *x* value, and the dependent variable is usually assigned to be the *y* value.

SCALING THE AXES

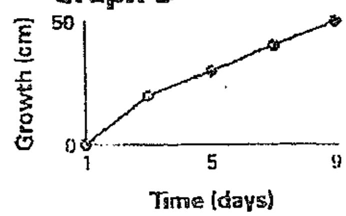
When preparing a graph, the scale of the axes should be chosen to include all data points and to allow as much room as possible on both axes. Each axis should be evenly divided with plenty of space between divisions, making the graph easy to read and understand. The divisions should be labeled in multiples units of 1, 2, 5, or 10. Each axis should also be labeled with a description of what it represents and the units of measurement.

Graph A



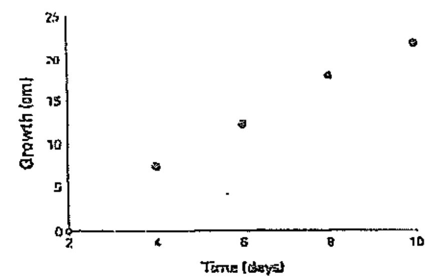
Graph A has well-spaced dimensions that are easy to read. Graph B, in the next column, shows the same data, but there are too few divisions on the *y*-axis to allow for easy interpretation.

Graph B

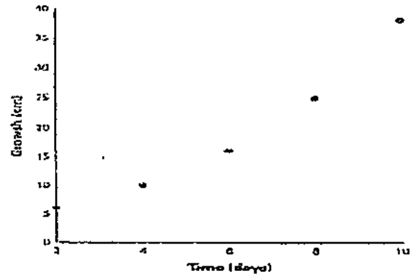


PLOTTING THE DATA

If the plotted data points roughly form a straight line, use a transparent ruler to draw a line that best represents the data points. This is known as a best-fit line.



If the points do not form a straight line but appear to form a curve, lightly sketch the curve with a pencil, connecting all the data points. After you have sketched a suitable curve, draw over it darkly with a pen or colored pencil.



TITLING THE GRAPH

It is important to add a title to the top of your graph, so that anyone looking at the graph can easily identify its purpose. Choose a title that is brief and descriptive of the data.

EXAMPLE 1 – Tickets vs Dollars

Your school is putting on a play. To raise money for the event, tickets for the play are being sold for $3.00 each. The chart below shows how much money will be made from selling certain numbers of tickets. Construct a graph of the data.

Number of tickets sold	Amount of money collected
5	$15
15	$45
25	$75
40	$120
45	$135

Step 1
Determine the independent variable

In this example, the amount of money collected depends on the number of tickets sold.
Independent variable (x) is number of tickets sold
Dependent variable (y) is the amount collected

Step 2
Scale the axes

When choosing the scales for the axes, consider what you want the graph to show and how it will be used. For this example, you want to be able to easily determine the amount of money made from selling different numbers of tickets, not just those given as data points. Therefore, you should choose a scale that is large enough that you can easily find the values between your data points.

Decide how many divisions are needed on the *x*-axis. Since you want to be able to easily determine the amount of money made for any number of tickets sold, you should choose a large number of divisions, such as 10.

Divide the largest value from the data table for the independent variable by the number of divisions chosen. For this example, 45 is the largest value for the independent variable, and 10 is the number of divisions chosen.

$$\frac{45}{10} = 4.5$$

Find the closest whole number value that is a multiple of 1, 2, 5, or 10. Five is the closest whole value to 4.5, so the divisions on the *x*-axis should be labeled in intervals of 5.

Now determine the scale for the dependent variable.

a. Decide how many divisions are needed on the *y*-axis.
b. Divide the largest value from the data table for the dependent variable by the number of divisions you have chosen.
c. Find the closest whole-number value that is a multiple of 1, 2, 5, or 10.

There is no one correct answer. Good choices would be five divisions of $25 each or 10 divisions of $15.

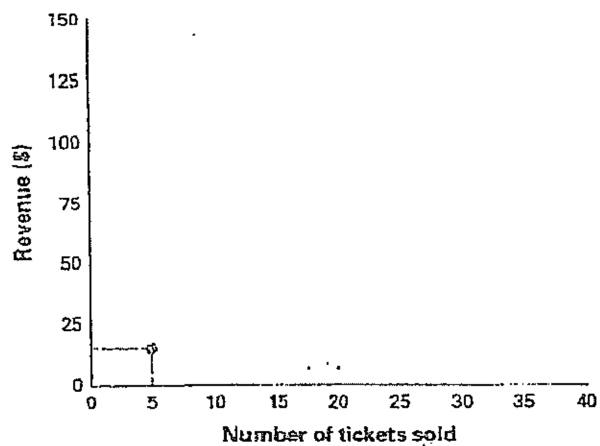
There are two different methods for drawing the axes. The first method used grid or graph paper with evenly spaced horizontal and vertical lines that make drawing the axes and marking the divisions easy. To draw the *x*-axis, choose a horizontal line and trace over it with a dark pencil or pen. Write in the number values for the divisions. For the *y*-axis, choose the vertical line that crosses at the zero point or at the lowest division. Trace over this line, and mark the divisions. Be sure to title each line and label the units of measurement.

The second method for drawing a graph involves a ruler and plain paper. THIS METHOD WILL NOT BE USED IN CHEMISTRY CLASS.

Step 3
Plot the data

Plot the data on the graph by carefully locating the x and y coordinates and marking the corresponding point on the graph.

To plot the first set of coordinates (5,15), start from zero and move 5 units to the right along the x-axis. From that point, move up the y-axis 15 units. Mark that location with a dot.



To plot the next point (15, 45), again start from zero and move 15 units to the right along the x-axis. From that point, move 45 units up the y-axis. Mark that point on the graph. When you have plotted all the points, draw the line, or curve, that best fits the data.

Step 4
Title the graph

Choose an appropriate title for the graph, such as **Money Collected vs Number of Tickets Sold.**

Reading Graphs

Being able to read a graph is a very important skill. Many fields of endeavor, including science, politics, and economics often use graphs to quickly and effectively relate a large amount of information.

Look at the graph on the right and answer the questions.

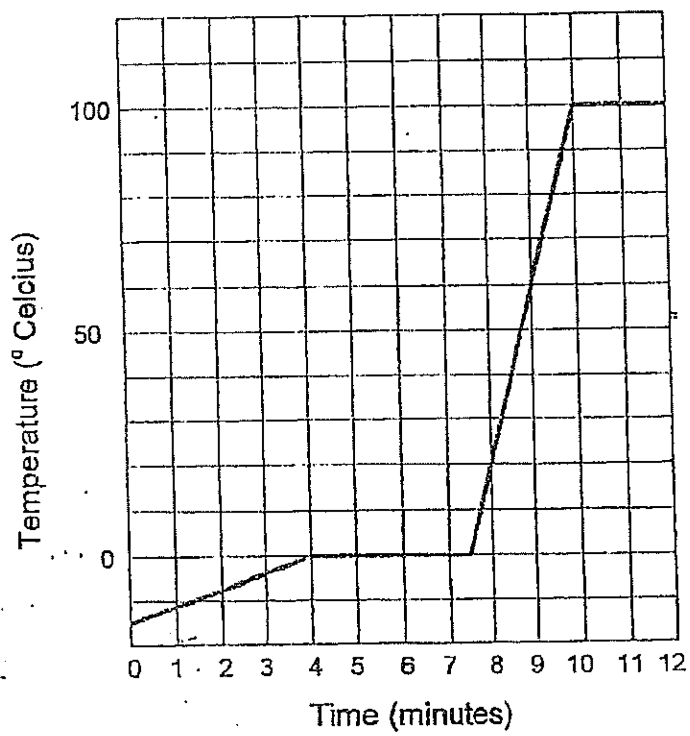
1. What is the label on the x-axis?

   ...the y-axis?

2. What units are used to describe these labels?

   ...x ...y

3. Describe in detail what you think the experimenter did to get the data for this graph.



4. Over what time interval(s) does the temperature remain constant? Include units.

5. Over what time interval(s) is the temperature rising? Include units.

6. What is the temperature of the water after four minutes? Include units.

7. At what time is the temperature 10°C? Include units.

Creating Graphs

All good graphs have several items in common. All good graphs...

1. have a title at the top.
2. have axes that are labeled, with proper units.
3. are neat, and easy to read.
4. use most of the available space.

Time	Total Distance Bicycled (km)
8:00 a.m.	0
9:00 a.m.	12
10:00 a.m.	23
11:00 a.m.	33
noon	42
1:00 p.m.	50
2:00 p.m.	57
3:00 p.m.	63
4:00 p.m.	68

Using the table on the previous page, prepare a graph that illustrates this data about a bicycle trip.

a. How would you expect the graph to look if data were available for 5 and 6 p.m.? Then, identify one factor that might cause the graph NOT to look like this.

b. Use your graph to estimate the total distance traveled by 10:30 a.m. Can you be absolutely certain of this value? Why or why not?

c. Compare the distance traveled during the first hour of the trip with the distance traveled during the last hour of the trip. Suggest a possible explanation for the difference. How is this difference illustrated on the graph?

Dimensional Analysis

Introduction

Dimensional analysis is a way to convert a quantity given in one unit to an equal quantity of another unit by lining up all the known values and multiplying. It is sometimes called factor-labeling. The best way to start a factor-labeling problem is by using what you already know. In some cases you may use more steps than a classmate to find the same answer, but it doesn't matter. Use what you know, even if the problem goes all the way across the page!

In a dimensional analysis problem, start with your given value and unit and then work toward your desired unit by writing equal values side by side. Remember you want to cancel each of the intermediate units. To cancel a unit on the top part of the problem, you have to get the unit on the bottom. Likewise, to cancel a unit that appears on the bottom part of the problem, you have to write it in on the top.

Once you have the problem written out, multiply across the top and bottom and then divide the top by the bottom.

Example: 3 years = ? seconds

Step 1: Start with the value and unit you are given. There may or may not be a number on the bottom.

$$\left(\frac{3\text{ years}}{\quad}\right)$$

Step 2: Start writing in all the values you know, making sure you can cancel top and bottom. Since you have years on top right now, you need to put years on the bottom in the next segment. Keep going, canceling units as you go, until you end up with the unit you want (in this case seconds) on the top.

$$\left(\frac{3\text{ years}}{\quad}\right)\left(\frac{365\text{ days}}{1\text{ year}}\right)\left(\frac{24\text{ hours}}{1\text{ day}}\right)\left(\frac{60\text{ minutes}}{1\text{ hour}}\right)\left(\frac{60\text{ seconds}}{1\text{ minute}}\right)$$

Step 3: Multiply all the values across the top. Write in scientific notation if it's a large number. Write units on your answer.

$$3 \times 365 \times 24 \times 60 \times 60 = 9.46 \times 10^7 \text{ seconds}$$

Step 4: Multiply all the values across the bottom. Write in scientific notation if it's a large number. Write units on your answer if there are any. In this case everything was cancelled so there are no units.

$$1 \times 1 \times 1 \times 1 = 1$$

Step 5: Divide the top number by the bottom number. Remember to include units.

$$9.46 \times 10^7 \text{ seconds} / 1 = 9.46 \times 10^7 \text{ seconds}$$

Step 6: Review your answer to see if it makes sense. 9.46×10^7 is a really big number. Does it make sense for there to be a lot of seconds in three years? YES! If you had gotten a tiny number, then you would need to go back and check for mistakes.

In lots of APES problems, you will need to convert both the top and bottom unit. Don't panic! Just convert the top one first and then the bottom.

Example: 50 miles per hour = ? feet per second

Step 1: Start with the value and units you are given. In this case there is a unit on top and on bottom.

$$\left[\frac{50\text{ miles}}{1\text{ hour}}\right]$$

Step 2: Convert miles to feet first.

$$\left[\frac{\cancel{50}\text{ miles}}{1\text{ hour}}\right]\left[\frac{5280\text{ feet}}{\cancel{1}\text{ mile}}\right]$$

Step 3: Continue the problem by converting hours to seconds.

$$\left[\frac{\cancel{50}\text{ miles}}{\cancel{1}\text{ hour}}\right]\left[\frac{5280\text{ feet}}{\cancel{1}\text{ mile}}\right]\left[\frac{1\cancel{\text{h}}\text{our}}{\cancel{60}\text{ minutes}}\right]\left[\frac{\cancel{1}\text{ minute}}{60\text{ seconds}}\right]$$

Step 4: Multiply across the top and bottom. Divide the top by the bottom. Be sure to include units on each step. Use scientific notation for large numbers.

50 x 5280 feet x 1 x 1 = 264000 feet

1 x 1 x 60 x 60 seconds = 3600 seconds

264000 feet / 3600 seconds = 73.33 feet/second

<u>Practice</u>: Remember to show all your work, include units if given, and NO CALCULATORS! Use scientific notation when appropriate.

Conversions:

1 square mile = 640 acres

1 hectare (ha) = 2.47 acres

1 kwh (kilowatt-hour) = 3,413 BTUs (British Thermal Units)

1 barrel of oil = 159 liters

1 metric ton = 1000 kg

20. 134 miles = ______________________________ inches

21. 8.9×10^5 tons = ______________________________ ounces

22. 1.35 kilometers per second = ______________________________ miles per hour

23. A city that uses ten billion BTUs of energy each month is using how many kilowatt-hours of energy?

24. A 340 million square mile forest is how many hectares?

25. If one barrel of crude oil provides six million BTUs of energy, how many BTUs of energy will one liter of crude oil provide?

26. Fifty eight thousand kilograms of solid waste is equivalent to how many metric tons?