1. Explain the shape of the graph.

The graph is curvy, with a higher bit at the end and a rather aesthetically pleasing slope downwards towards a pretty flat straight bit. The actual graph itself consists of 2 straight lines meeting at the lower left hand corner of the graph and moving away at a 90° angle. Each line has an arrow head on the end.
Unit I Reading – Graphical Methods

One of the most effective tools for the visual evaluation of data is a graph. The investigator is usually interested in a quantitative graph that shows the relationship between two variables in the form of a curve.

For the relationship \( y = f(x) \), \( x \) is the independent variable and \( y \) is the dependent variable. The rectangular coordinate system is convenient for graphing data, with the values of the dependent variable \( y \) being plotted along the vertical axis and the values of the independent variable \( x \) plotted along the horizontal axis.

Positive values of the dependent variable are traditionally plotted above the origin and positive values of the independent variables to the right of the origin. This convention is not always adhered to in physics, and thus the positive direction along the axes will be indicated by the direction the arrow heads point.

The choice of dependent and independent variables is determined by the experimental approach or the character of the data. Generally, the independent variable is the one over which the experimenter has complete control; the dependent variable is the one that responds to changes in the independent variable. An example of this choice might be as follows. In an experiment where a given amount of gas expands when heated at a constant pressure, the relationship between these variables, \( V \) and \( T \), may be graphically represented as follows:

By established convention it is proper to plot \( V = f(T) \) rather than \( T = f(V) \), since the experimenter can directly control the temperature of the gas, but the volume can only be changed by changing the temperature.
Curve Fitting

When checking a law or determining a functional relationship, there is good reason to believe that a uniform curve or straight line will result. The process of matching an equation to a curve is called curve fitting. The desired empirical formula, assuming good data, can usually be determined by inspection. There are other mathematical methods of curve fitting, however, they are very complex and will not be considered here. Curve fitting by inspection requires an assumption that the curve represents a linear or simple power function.

If data plotted on rectangular coordinates yields a straight line, the function \( y = f(x) \) is said to be linear and the line on the graph could be represented algebraically by the slope-intercept form:
\[
y = mx + b,
\]
where \( m \) is the slope and \( b \) is y-intercept.

Consider the following graph of velocity vs. time:

![Graph of velocity vs. time]

The curve is a straight line, indicating that \( v = f(t) \) is a linear relationship. Therefore,
\[
v = mt + b,
\]
where slope \( m = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} \).

From the graph,
\[
m = \frac{8.0 \text{ m/s}}{10.0 \text{ s}} = 0.80 \text{ m/s}^2.
\]

The curve intercepts the v-axis at \( v = 2.0 \text{ m/s} \). This indicates that the velocity was 2.0 m/s when the first measurement was taken; that is, when \( t = 0 \). Thus, \( b = v_0 = 2.0 \text{ m/s} \).

The general equation, \( v = mt + b \), can then be rewritten as
\[
v = (0.80 \text{ m/s}^2)t + 2.0 \text{ m/s}.
\]
Consider the following graph of pressure vs. volume:

\[ P = m \left( \frac{1}{V} \right) + b, \]

where \( b = 0 \). Therefore; \( P = \frac{m}{V} \); when rearranged, this yields \( PV = \text{constant} \), which is known as Boyle's law.
Consider the following graph of distance vs. time:

![Graph of distance vs. time](image)

The curve appears to be a top-opening parabola. This function suggests that a test plot be made of \( d \) vs. \( t^2 \). The resulting graph is shown below:

![Graph of \( d \) vs. \( t^2 \)](image)

Since the plot of \( d \) vs. \( t^2 \) is linear, 
\[
   d = mt^2 + b.
\]

The slope, \( m \), is calculated by
\[
   m = \frac{\Delta d}{\Delta t^2} = \frac{0.80 \text{m}}{0.50 \text{s}^2} = 1.6 \text{ m/s}^2
\]

Since the curve passes through the origin, \( b = 0 \). The mathematical expression that describes the motion of the object is
\[
   d = (1.6 \text{ m/s}^2)t^2.
\]
Consider the following graph of distance vs. height:

The curve appears to be a side-opening parabola. This function suggests that a test plot be made of $d^2$ vs. $h$. The resulting graph is shown on the following page.

Since the graph of $d^2$ vs. $h$ is linear the expression is

$$d^2 = mh + b.$$

The slope, $m$, is calculated by

$$m = \frac{\Delta d^2}{\Delta h} = \frac{2.5\text{cm}^2}{5.0\text{ cm}} = 0.50\text{ cm}.$$

Since the curve passes through the origin, $b = 0$. The mathematical expression is then

$$d^2 = (0.50 \text{ cm})h.$$
Making a Graph with Graphical Analysis

A. Initial Set-Up

- Plot Data in X and Y columns
- Change the X and Y column headings by double clicking on the letters in the X and Y column.
- Make sure you include the specific **Variable name and units** for both the X and Y columns

B. If the Graph is NOT Linear.....

- Go to DATA and pull down to NEW CALCULATED COLUMN.
- Replace ‘Calculated Column’ with what will be plotted (example: time^2). Make sure you include the new units in the units location (example: sec^2)
- In the EQUATION section, use the pull down from VARIABLE section. This will put that variable in the EQUATION, then put what you want to do with that variable. (example: “time”^2)
- This will add a new column on the data table

C. Changing Your X and Y Axis on the Graph

- Make new plot by ‘left click’ on the label of the axis you are changing
- Repeat the above steps B and C until graph is linear (straight line with + slope)

D. Writing Out Your Equation In y=mx +b Format:

- Click on 2nd to last icon to display slope, y-int, and correlation.
- Write equation in the y = mx + b format but use actual symbols that represent the variables. **Include units for slope and y-int.**
- Type in your group member names and **equation** in the notes area on the graph.
- You can then copy and paste your graph directly into a Word document for your Lab Write Up
Graphing, Data Tables and Math Skills Review Worksheet

1. The mass values of specified volumes of pure gold nuggets are given in the table below.

<table>
<thead>
<tr>
<th>Volume (cm$^3$)</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>19.4</td>
</tr>
<tr>
<td>2.0</td>
<td>38.6</td>
</tr>
<tr>
<td>3.0</td>
<td>58.1</td>
</tr>
<tr>
<td>4.0</td>
<td>77.4</td>
</tr>
<tr>
<td>5.0</td>
<td>96.5</td>
</tr>
</tbody>
</table>

A. Plot mass v. Volume from the values given in the table and draw the curve that best fits the point.

B. Describe the resulting curve.

C. According to the graph, what type of relationship exists between the mass and the volume of the pure gold nuggets?

D. Write the mathematical equation in the $y = mx+b$ format showing the mass as a function of volume. (your slope and y-intercept should have a # and unit!)

F. Write a word interpretation for the slope of the line specific to this graph information.

2. Give the name for each of the following multiples of the unit meter. Ex. 1/100 m = one one hundredth of a meter (1 kilometer)

   A. 1/1000 m =
   
   B. 1000 m =
3. What conversion factor would you use to convert 1.8 hours to minutes? Calculate how many minutes are in 1.8 hours using dimensional analysis. Show your work!

4. How do you find the slope of a linear graph. What is the “formula”?

5. What type of relationship is shown in the graph below? Give the general equation for this relationship.

6. You are cracking a code and have discovered the following conversion factors:

   1.23 longs = 23 mediums and 74.5 mediums = 645 shorts

   A. 1 long equals how many shorts? (show all of your work!)
UNIT I Worksheet 1: GRAPHING PRACTICE

For each data set below, determine the mathematical expression. To do this, first graph the original data. Assume the 1st column in each set of values to be the independent variable and the 2nd column the dependent variable. Then taking clues from the shape of the first graph, modify the data so that the modified data will plot as a straight line. Using the slope and y-intercept of the stright-line graph, write an appropriate mathematical expression for the relationship between the variables. Be sure to include units!

<table>
<thead>
<tr>
<th>Data set 1 Volume and Pressure</th>
<th>Data set 2 Time and Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V \text{ (m}^3)</td>
<td>( P \text{ (pa)} )</td>
</tr>
<tr>
<td>.1</td>
<td>40</td>
</tr>
<tr>
<td>.5</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>.8</td>
</tr>
<tr>
<td>8</td>
<td>.5</td>
</tr>
<tr>
<td>10</td>
<td>.4</td>
</tr>
</tbody>
</table>

Mathematical expression #1

Mathematical expression #2

<table>
<thead>
<tr>
<th>Data set 3 Age and Weight</th>
<th>Data set 4 Time and Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A \text{ (months)} )</td>
<td>( W \text{ (lbs)} )</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>9.4</td>
</tr>
<tr>
<td>3</td>
<td>10.5</td>
</tr>
<tr>
<td>4</td>
<td>12.0</td>
</tr>
<tr>
<td>5</td>
<td>13.0</td>
</tr>
<tr>
<td>6</td>
<td>14.3</td>
</tr>
<tr>
<td>7</td>
<td>15.2</td>
</tr>
<tr>
<td>8</td>
<td>16.7</td>
</tr>
</tbody>
</table>

Mathematical expression #3

Mathematical expression #4
Pendulum Lab Example Lab Write Up
(This is only an EXAMPLE...this will not be identical to your write up!)

Pendulum Lab

**Purpose:** to determine the graphical and mathematical relationship between the color string and the period of a pendulum.

**Set-Up:** See attached

**Procedure:**
- Independent variable – color of string
- Dependent variable – period of the pendulum
- To change the independent variable we changed the color of the string but kept all other variables constant (length, amplitude, mass)
- To measure the dependent variable we timed how long it took for the pendulum to swing over and back.

**Data Table**

<table>
<thead>
<tr>
<th>Color string</th>
<th>Period Trial 1 (sec)</th>
<th>Period Trial 2 (sec)</th>
<th>Period Trial 3 (sec)</th>
<th>Period Average (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>1.2</td>
<td>1.1</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Red</td>
<td>1.3</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Green</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Yellow</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Black</td>
<td>1.2</td>
<td>1.1</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>White</td>
<td>1.2</td>
<td>1.3</td>
<td>1.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Period Average = (Trial 1 + Trial 2 + Trial 3) / 3

**Graph:** See attached

**Conclusion:** In this lab we found that there was no relation between the color of string and the period of a pendulum.

General Equation: Period = 0 (color) + initial Period

No new terms were involved

Slope represents the period of the pendulum/color

Y-int. represents the initial period

**PSOE:**
- Might not have kept the length of the string constant
- Might not have kept the amplitude constant
- Might not have kept the mass constant
- Might have been an error in timing
Worksheet 2- Review Concepts
(a.k.a … you should already know how to do all of this!)

1. Convert the following.
   a) 34 mm = _________ m
   b) 5.3 m = __________cm
   c) 9.2 m = ___________km
   d) 1.45 mm = _________ cm

2. Put the following number in scientific notation
   300000000 = __________________

3. Calculate the following
   a) \((3 \times 10^3)(4 \times 10^7) / 8 \times 10^{-5} = \) ________________
   b) 47 seconds = _____________ years

4. For each of the equations, solve for x
   A) \(w = fx\)  B) \(g = f/x\)  C) \(n = x/y\)
   D) \(d = ax^2/2\)  E) \(bx = 2ac/4\)  F) \(a/x = b/c\)
Graphing and Data Table Review: Part 2 Worksheet

1. Based on the correlation box for the position (m) vs. time (sec) graph below, what is the correct mathematical formula in \(y=mx+b\) form?

   \[ m \text{ (Slope): 0.1000 meters/seconds} \]
   \[ b \text{ (Y-Intercept): 0.05000 meters} \]
   \[ \text{Correlation: 1.000} \]

   A. \(Y = 0.1000m/\text{s} \times \text{time} + 0.5m\)
   B. \(\text{Position} = 0.1000m/\text{s} \times \text{time} + 0.5m\)
   C. \(\text{Position} = 0.1000m/\text{s} \times \text{x} + 0.5m\)
   D. None of these

2. Which of the following is equal to 86.2 cm

   A. 8.2 m
   B. .862 mm
   C. 8.62 \times 10^{-4} km
   D. 862 dm

3. Chris P. Bacon has a problem to do involving time, distance and velocity, but he has forgotten the formula. The question asks him for a measurement in seconds, but the numbers are given to him have units of m/s for velocity and km for distance. What could Chris do to get the answer in seconds?

   A. Multiply by the km by m/s, then multiply by 1000
   B. Divide the km by m/s, then multiply by 1000
   C. Divide the km by m/s then divide by 1000
   D. Multiply the km by m/s, then divide by 1000

4. What is the slope of this graph?

   A. 0.25 m/s²
   B. 0.4 m/s²
   C. 2.5 m/s²
   D. 4.0 m/s²

5. What is the mathematical equation for this graph?

   Which formula is equivalent to \(D = \frac{m}{v}\)

   A. \(V = \frac{m}{d}\)
   B. \(V = Dm\)
   C. \(V = \frac{mD}{V}\)
   D. \(V = D/m\)
Worksheet 2a

1. For a driver, the time between seeing a stoplight and stepping on the brakes is called reaction time. The distance traveled during this time is called reaction distance. Reaction time and distance for a driver depends linearly on speed.
   a. Would the graph of reaction distance versus speed have a positive or negative slope?

   b. A driver who is distracted has a longer reaction distance compared to one who is not. Would the graph of reaction distance versus speed for a distracted driver have a larger or smaller slope than for a normal driver? Explain.

2. During a laboratory experiment, the temperature of gas in a balloon is varied and the volume of the balloon is measured. Which quantity is the dependent variable? Which quantity is the independent variable?

3. The graph below shows the masses of three substances for volumes between 0 and 60 cm$^3$
   a. What is the mass of 30 cm$^3$ of each substance?

   b. If you had 100 grams of each substance, what would be their volumes?

   c. In one or two sentences, describe the meaning of the slopes of the lines on this graph

   d. What is the y-intercept of each line? What does it mean?
4. During a class demonstration, a physics instructor placed a mass on a horizontal table that was nearly frictionless. The instructor then applied various horizontal forces to the mass and measured the distance it traveled in 5 seconds for each force applied. The results of the experiment are shown in the table below.

<table>
<thead>
<tr>
<th>Force (N)</th>
<th>Distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>49</td>
</tr>
<tr>
<td>15</td>
<td>75</td>
</tr>
<tr>
<td>20</td>
<td>99</td>
</tr>
<tr>
<td>25</td>
<td>120</td>
</tr>
<tr>
<td>30</td>
<td>145</td>
</tr>
</tbody>
</table>

a. Plot the values given in the table and draw the curve that best fits all points.

b. Describe the resulting curve.

c. Use the graph to write an equation relating the distance to the force.

d. What is the constant in the equation? Find its units.

e. Predict the distance traveled when a 22.0 Newton force is exerted on an object for 5 seconds.

5. The physics instructor from the previous problem changed the procedure. The mass was varied while the force remained constant. Time and distance were measured, and the acceleration of each mass was calculated. The results of the experiment are shown below.

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Acceleration (m/s^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>12.0</td>
</tr>
<tr>
<td>2.0</td>
<td>5.9</td>
</tr>
<tr>
<td>3.0</td>
<td>4.1</td>
</tr>
<tr>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>5.0</td>
<td>2.5</td>
</tr>
<tr>
<td>6.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

a. Plot the values given in the table and draw the curve that best fits all points.

b. Describe the resulting curve.

c. According to the graph, what is the relationship between mass and acceleration produced by a constant force?

d. What is the equation relating acceleration to mass given by data in the graph?

e. Find the units of the constant in the equation.

f. Predict the acceleration of an 8.0 kg mass.
Unit I – Wkst 3a

In a biology experiment the number of yeast cells is determined after 24 hours of culture at different temperatures.

a) Identify the independent and dependent variables in the experiment.

b) Draw the graph of the following data. Label your axes. Write the mathematical equation that best fits the graph.

<table>
<thead>
<tr>
<th>No. of yeast cells</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>55</td>
<td>30</td>
</tr>
</tbody>
</table>
Unit 1 – Wkst 3b

For each of the following:

1) State the type of relationship suggested by each graph.

2) Write the general equation you would obtain after you modified the data to produce a linear graph that passes through the origin. Use ‘k’ to represent the slope.

a) 

\[ P \quad V \]

b) 

\[ v \quad t \]

c) 

\[ L \quad T \]

d) 

\[ x \quad t \]
1. The following data are based on charges for membership in a CD purchasing club.

<table>
<thead>
<tr>
<th>Compact Discs</th>
<th>Cost (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>20.0</td>
</tr>
<tr>
<td>2</td>
<td>40.0</td>
</tr>
<tr>
<td>3</td>
<td>60.0</td>
</tr>
<tr>
<td>4</td>
<td>80.0</td>
</tr>
<tr>
<td>5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Statistics:

<table>
<thead>
<tr>
<th>Data Set 1</th>
<th>Slope</th>
<th>Y Intercept</th>
<th>C.O.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.3±0.246</td>
<td>4.00±1.38</td>
<td>0.998</td>
<td></td>
</tr>
</tbody>
</table>

a. What are the units of slope for this graph?

b. What is the average price of a compact disc?

c. What is the mathematical equation that states the relationship described by the graph?

2. From your pendulum experiment, what factor(s) affect the period of a pendulum

b. List some methods used that allow you to collect good data
3. The graph below shows the relationship between scores on the SAT exam and the number of years students study science.

![Graph showing the relationship between SAT scores and science class years]

<table>
<thead>
<tr>
<th>Science Classes (Years)</th>
<th>SAT Score (Points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1.00</td>
<td>200</td>
</tr>
<tr>
<td>2.00</td>
<td>400</td>
</tr>
<tr>
<td>3.00</td>
<td>600</td>
</tr>
<tr>
<td>4.00</td>
<td>800</td>
</tr>
<tr>
<td>5.00</td>
<td>1.00E+03</td>
</tr>
</tbody>
</table>

Statistics:  
Data Set 1  
Slope: 150±0.00  
Y Intercept: 500±0.00  
C.O.R.: 1.00

(a) What is the mathematical equation that states the relationship described by the graph?

(b) Write a clear, English sentence that describes the meaning of the slope.

(c) What would be the SAT score of a student who took seven science classes?

4. A student performed an experiment with a metal sphere. The student shot the sphere from a slingshot and measured its maximum height. Six different trials were performed with the sphere being shot at a different angle from the horizontal for each trial.

(a) What is the relationship being studied?

(b) What is the independent variable in this experiment?

(c) What is the dependent variable in this experiment?

(d) What variable must be held constant throughout this experiment?
5. a. What type of relationship does this graph suggest?

b. What variables would you plot to linearize the data?

6. Below is a graph of the relationship between scholarship awards and the effort students exerted trying to win scholarships.

   a. Write the mathematical equation that states the relationship described by the graph.

   b. What does the y-intercept illustrate?

   c. Using the mathematical model, how many applications would be needed to earn $8000?
7. For each of the following relationships:
   • Write what method should be used to linearize the data.
   • Write the mathematical equation that would describe the straight line produced.
   • Draw a graph which visually represents the relationship.

   a. Hyperbolic (Inverse)

   b. Top Opening Parabola

   c. Side Opening Parabola
Calculation Answers for Unit 1 Packet
Since you have the answers to these questions, your teacher will be looking for the work as you how you got to the answers to receive credit. Be sure to ALWAYS show ALL of your work for ANY calculations!!

**Graphing, Data Tables and Math Skills Review Worksheet**

1d. 19.3 g/cm³
3. 108 min
6. 161.9 short

**Worksheet 2- Review Concepts**

1a. .034 m
1b. 530 cm
1c. .0092 km
1d. .145 cm
2. 3 x 10⁸
3a. 1.5 x 10¹⁵
3b. 1.5 x 10⁻⁶ years

**Worksheet 2a**

4e. 106 cm

**Review Worksheet**

1b. 10.3 cost/CD
3c. 1550 points
6c. 16 applications