

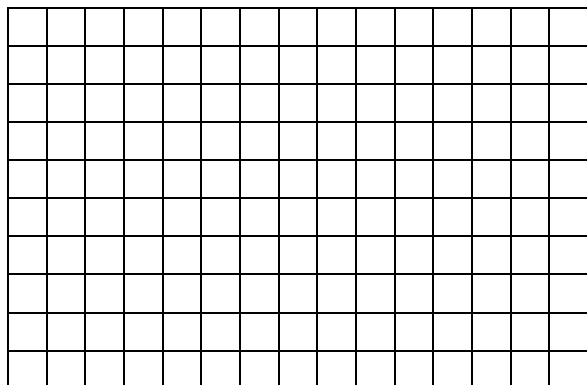
Introduction to Graphing Functions

What is a graph? A graph represents specific numerical values as well as a general pattern. Scientific graphs are used to show general patterns, to represent experimental data in a way that is easy to read, to find numerical values of quantities, to make predictions about quantities not shown based on trends, to help determine an equation that describes a phenomenon and to solve equations.

Important Graph Terminology:

- **Grid:** lined pattern on which a graph is drawn
- **Axes:** heavier intersecting lines
- **Abscissa:** horizontal or x-axis; the independent variable is plotted here
- **Ordinate:** vertical or y-axis; the dependent variable is plotted here
- **Scale:** set of numbers that are distributed uniformly (equally spaced) along the axes
(Note: the scale does not have to be the same for the horizontal and vertical axes)
- **Independent variable:** variable determined by the experimenter (controlled or manipulated)
- **Dependent variable:** variable measured; value results from the value of the independent variable (this variable “depends” on the independent variable’s value)
- **Origin:** point where the axes intersect

Practice: Draw a set of perpendicular axes *in the center of* the grid below. Label the independent and dependent variable locations. Label the origin. Label the axes with x and y.



Plotting Points: To graph data points, which are usually expressed using ordered pairs (x,y) , start at the origin $(0,0)$ and simply move in the horizontal direction x units, then from that point, move in the vertical direction y units. Mark the point of the final destination and no points in between.

For example, to plot the ordered pair $(-3, 4)$, put your pencil at the origin $(0, 0)$, then go left 3, then up 4. Mark the point there, and label with the ordered pair $(-3, 4)$. *Do not mark any other points along the way.*

You try! Plot the following ordered pairs on the graph above:

1. $(2, -3)$
2. $(0, -4)$
3. $(-5, -1)$
4. $(3, 0)$
5. $(5, -2)$

Note: Sometimes, you will not be given ordered pairs. Instead, you will be given tables of data. Determine which variable is independent (x) and which is dependent (y), and then plot the data as each independent x along with the corresponding dependent y like you would with an ordered pair.

Elements of a Good Graph:

1. The graph is *easy to plot* and *easy to read*.
 2. The *axes are clearly labeled* so that the reader is able to see exactly what is plotted and its value. This labeling includes the units for which each value is expressed.
 3. To the left of a vertical axis and beneath the horizontal axis, *there is enough room for numbers and labels* without crowding. This means the axes are not at the edge of the grid (or graph paper) but well enough inside so that there is room to write.
 4. *Scales are uniform* (equally spaced). Scale numbers should be “round” numbers, like 20, 50, 100, rather than 17 or 224. The scaling does not have to start at 0, but it should be clear what the starting value is.
 5. Scales are selected so that the *graph covers as much of the page as possible*. Spread out scaling so that when data points are graphed, they are set far enough apart so that they can be read.
 6. *Plotted points can be easily seen*. If two or more data sets are plotted on the same graph, use different symbols for each data set (i.e., use dots for one data set, X’s for another, and + for another, so they look different).
 7. The *straight line or curve is drawn smoothly among the points* rather than as a zigzag line that passes through each point. The line or curve does not have to touch each point. You can use a “line of best fit” which shows the trend in the data, but does not have to touch even one point as long as it shows the general pattern of the data.
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Plotting a Graph: Use this guide as a checklist when creating your graphs.

1. Give the graph a **unique title** to show what it represents. This should be stated briefly but with enough description so that it is clear what the graph is showing.
 - a. Title should identify the variables measured.
 - b. Title is usually placed at the top center of the graph.
(For example: Number of Students vs. Number of Textbooks would be an appropriate title)
2. **Axis number spacing (scale) should be uniform.** This means, *use the same difference between each number*. For example, 0, 5, 10, 15, There is a difference of 5 between each number. Do not use non-uniform scaling, such as 0, 5, 9, 16, By doing this, your graph will be harder to read and interpret.
 - a. **Rule of 1-2-5:** most convenient scales count by 1, 2, or 5. However, depending on the data, it may be appropriate to count by larger numbers, such as 100, or even 5,000 to make the data fit the grid you are using.
 - b. **Determine the range of numbers** to be plotted on the axis (highest number minus lowest number).
 - c. **Determine how much space** (how many squares) you have. Divide the range by the number of squares and *round up* to a nice value (1, 2, 5, 10, 20, etc...) to determine an appropriate scaling.
 - d. **Determine the smallest value** of the range and start below that value so the first point does not run into the other axis. Be sure this value is easy to use with all the divisions on the axis.
 - e. **All data should fit within the grid.** If not, readjust your scaling.
 - f. To plot fractions, find an estimate of the decimal equivalent and then plot.

Plotting a Graph (cont'd)

3. **Number each major division** along each axis. (Remember, you can use different scaling on each axis that is appropriate for the data given for that axis variable).
 4. **Label the axes** to identify the variable and the units for which it is measured.
 5. **Plot the data.** To do so, verify that the highest and lowest values will fit on the grid. If not, change the scaling so all will fit. Mark each point clearly so they will show up after the line is drawn.
 6. **Connect points with a smooth curve**, not just connecting dots. This curve should be as close to as many points as possible, but it does not have to touch them all.
 7. If more than one curve is drawn, place a legend in one corner identifying each curve. You can use different colors, or dashed lines, to differentiate the curves.
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Practice 1: Say you want to establish a horizontal axis that is suitable for plotting the following numbers: 20.5, 39.7, 61.0, 92.8, 116.9

1. Find the range to be plotted. This is the highest value – the lowest value. (Did you get 96.4?)
 2. Say you have 13 squares to the right of the origin to work with. What divisions will be appropriate to fit all the data in your range? (Take 96.4 and divide by 13 to get 7.4).
 3. If your divisions are not nice round numbers, such as 1, 2, 5, 10, 20, etc..., think of an appropriate number to use for each division so that all data will be included.

(If you use 1, 2, or 5, the data will not all fit. So, the best division amount is 10).
 4. Draw a horizontal line and label the zero point. Draw thirteen divisions to the right to represent the squares you have to work with. Label each division value (0, 10, 20, ...). Mark a point on the line where each of the numbers you are plotting will fall (estimate if the data is between divisions).
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Practice 2: Say you want to establish a vertical axis that is suitable for plotting the following numbers: 0.00054, 0.000824, 0.001075, 0.001291, 0.003472, 0.009876, 0.013940

1. Convert each number to exponential notation so each is expressed as the same power of 10. (For example, 0.00054 can be written as 5.4×10^{-4} , and then 0.001291 can be written as 12.91×10^{-4}).
2. What should be the lowest value for your scale?
3. What is the range of values (calculate this without the 10^{-4})?
4. Say you have 20 grid squares to the right of the origin to work with. What divisions will be appropriate to fit all of the data in your range?

5. If your divisions are not nice round numbers, think of the most suitable round number to use to fit all of the data, including a value smaller than the smallest data value.
 6. Draw a vertical line, mark the zero point. Draw in each division (above, since all numbers are positive), labeling with the division values. Mark on the line where each of the numbers you are plotting will fall (estimate if the data is between divisions).
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Practice 3: Say you want to establish a horizontal axis that is suitable for plotting the following masses expressed in kilograms: 4,750,000; 6,040,000; 6,980,000; 7,840,000; 9,310,000.

1. Convert each number to exponential notation so each is expressed as the same power of 10 (for example, $4,750,000 = 4.75 \times 10^6$).
 2. What should be the lowest value for your scale?
 3. What is the range of values (calculate this without the 10^6).
 4. Say you have 7 grid squares from the origin to work with. What divisions will be appropriate to fit all of the data in your range?
 5. If your divisions are not nice round numbers, think of the most suitable round number to use to fit all of the data, including a value smaller than the smallest data value.
 6. Draw a horizontal line, mark the zero point. Draw in each division (to the right, since all numbers are positive), labeling with the division values. Mark on the line where each of the numbers you are plotting will fall (estimate if the data is between divisions).
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Practice 4: Say you want to establish a vertical axis that is suitable for plotting the following temperature values: 100, 73, 52, 25, 0, -30, -48, -79, and -94°C .

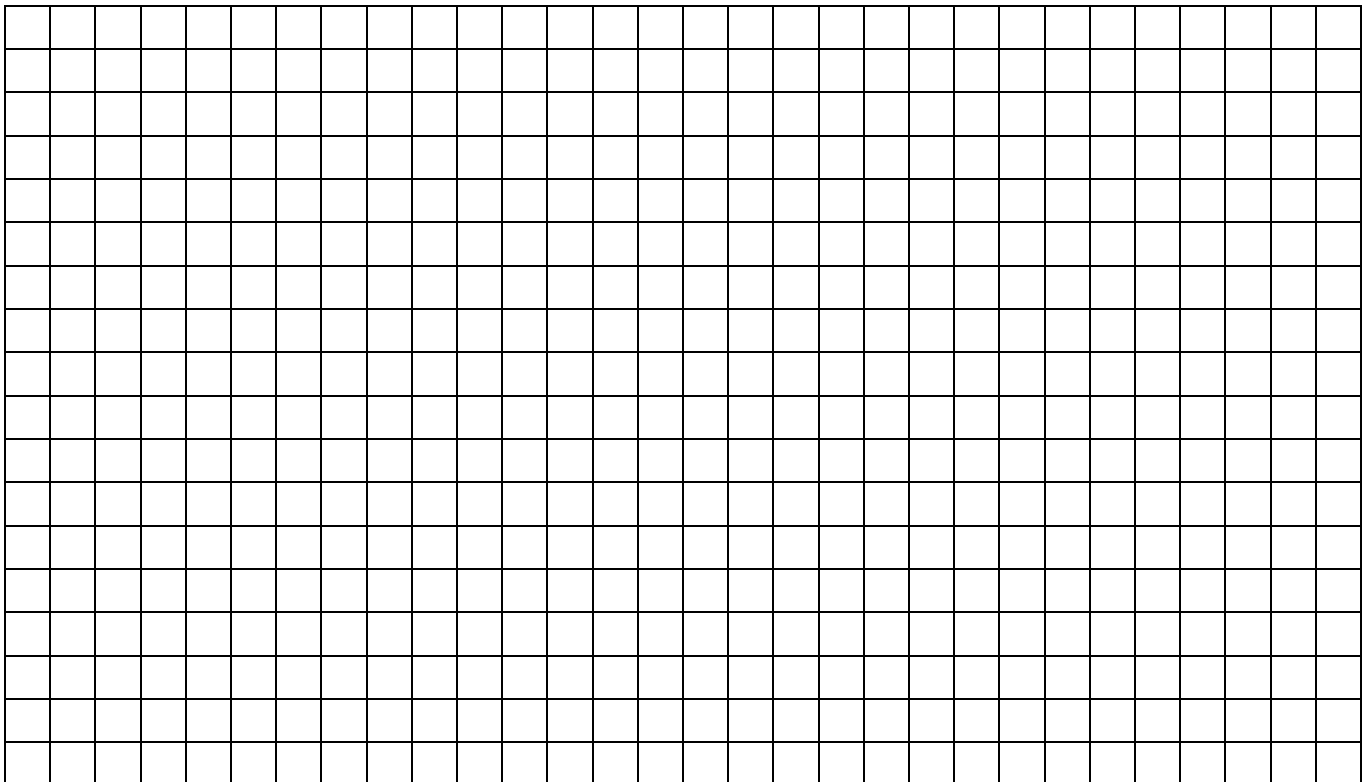
1. What is different about the data than the previous examples? How will you modify your scaling and where you draw your axes to accommodate this?
2. Say your graph paper has a total of 20 squares across by 10 squares vertically, and you want to draw the axes in the exact middle of the page. Where is the horizontal axis to be located? Where is the vertical axis to be located?
3. How many squares do you have to work with to establish your vertical axis?
4. What is the range of values? (Remember, $a - (-b) = a + b$).

5. What divisions will you use so that they are nice round numbers and will fit all of your data?

6. Draw a vertical line and mark the zero point and all available squares. Mark each division on the vertical line in both directions, labeling with the division values. Mark on the line where each of the numbers you are plotting will fall (estimate if the data is between divisions).

Practice 5: Construct a graph of the following data, which relates the density of water in g/cm^3 to the temperature, in degrees Celsius. Draw a best-fit curve (or straight line) for the points. Be sure to use all elements of a good graph from the list above.

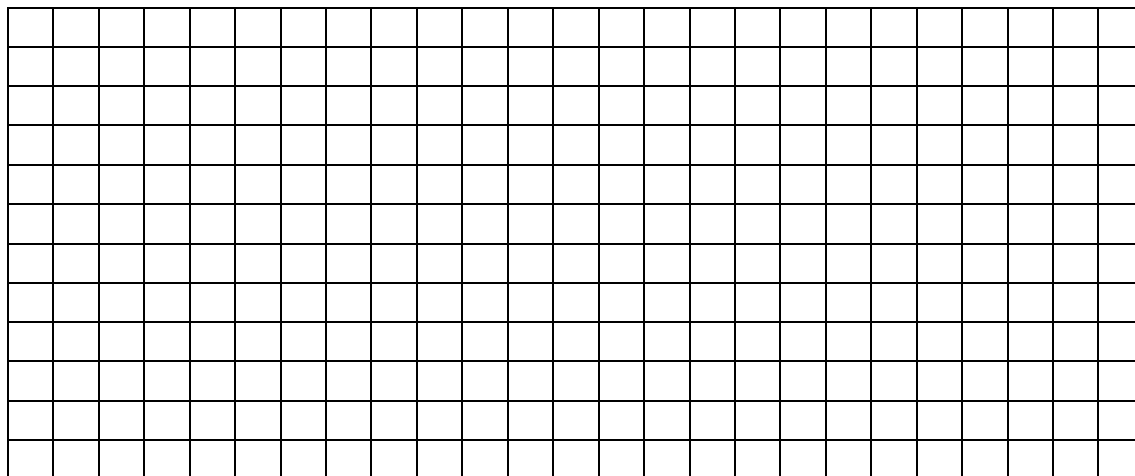
| Temperature, $^{\circ}C$ (Indep. Variable) | Density of Water, g/cm^3 (Dep. Variable) |
|---|---|
| 0 | 0.9998 |
| 10 | 0.9997 |
| 20 | 0.9982 |
| 30 | 0.9957 |
| 40 | 0.9922 |
| 50 | 0.9880 |
| 60 | 0.9832 |
| 70 | 0.9778 |
| 80 | 0.9712 |
| 90 | 0.9654 |
| 100 | 0.9584 |



Practice 6: A student is making a measurement of the solubility of a salt in a NaCl (sodium chloride) solution. The following data are collected experimentally:

| NaCl concentration, M (Indep. Variable) | Solubility of Second Salt, g/L (Dep. Variable) |
|--|---|
| 0.05 | 1.7×10^{-6} |
| 0.025 | 9.5×10^{-7} |
| 0.0125 | 5.1×10^{-7} |
| 0.00625 | 2.9×10^{-7} |

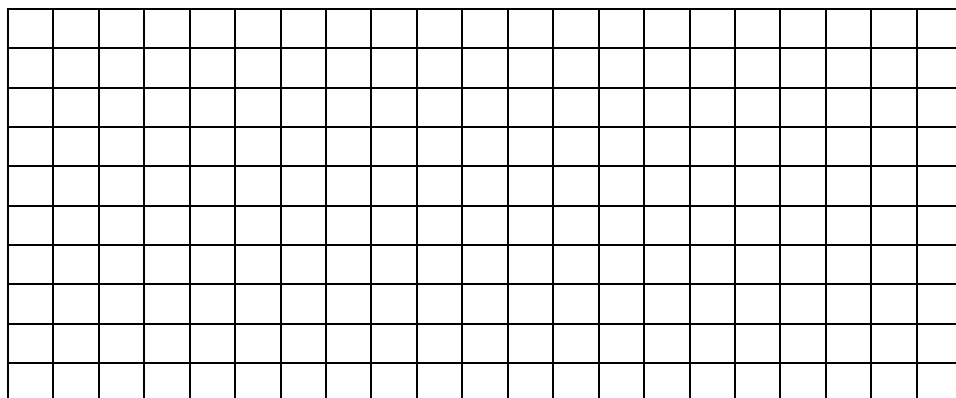
Create an appropriate graph, using all elements of a good graph from the list above:



Practice 7: A beaker was placed on a balance and different volumes of a liquid were poured into it. The mass of the beaker plus liquid was measured each time. The following data were collected:

| Mass, g (Dep. Variable) | Volume, mL (Indep. Variable) |
|----------------------------|---------------------------------|
| 192.8 | 8.23 |
| 204.0 | 0.34 |
| 219.6 | 6.45 |
| 236.5 | 5.59 |
| 246.3 | 3.68 |

Create an appropriate graph, using all elements of a good graph from the list above:



Answers to Introduction to Graphing Functions

Practice 2:

1. 5.4×10^{-4} ; 8.24×10^{-4} ; 10.75×10^{-4} ; 12.91×10^{-4} ; 34.72×10^{-4} ; 98.76×10^{-4} ; 139.40×10^{-4}
2. Could start at 0 or 5.
3. 134
4. 6.7
5. round up to 10

Practice 3:

1. 4.75×10^6 ; 6.04×10^6 ; 6.98×10^6 ; 7.84×10^6 ; 9.31×10^6
2. 4
3. 4.56
4. around 0.65
5. round up to 1

Practice 4:

1. There are positive and negative numbers in this set of data.
2. Horizontal at the 5th square; vertical at the 10th square.
3. 10 squares
4. 194 (that is, $100 - (-94) = 100 + 94 = 194$)
5. Every square is 20

Practice 5:

- Draw the Temperature for the horizontal axis and the Density of Water for the vertical axis.
- Place axes so the origin is near the lower left corner (since all values are positive).
- Scaling for the horizontal axis: start at 0 and mark every other square with a multiple of 10
- Scaling for the vertical axis: start at 0.9500, and count every other square in increments of 0.0100 (0.9500, 0.9600, 0.9700, etc...). Could also convert each to a power of ten (i.e., 99.98×10^2)

Practice 6:

- Draw the NaCl concentration for the horizontal axis and the Solubility of Second Salt for the vertical axis.
- Place axes so the origin is near the lower left corner (since all values are positive).
- Scaling for the horizontal axis: convert to a power of ten, such as 25×10^3 , then count by tens starting at 0 (if room, count every other square as 10)
- Scaling for the vertical axis: Count by 2's starting at 0 through 10

Practice 7:

- Draw the Mass for the vertical axis and the Volume for the horizontal axis.
- Place axes so the origin is near the lower left corner (since all values are positive)
- Scaling for the vertical: start at 190 and count by tens to 250
- Scaling for the horizontal axis: count by 2's from 0 to 10 (every other square to spread out)