Graphs of Motion

Motion graphs are an important tool used to show the relationships between position, speed, and time. For example, meteorologists use graphs to show the motion of hurricanes and other storms. A graph can show the location and speed of a storm at different points in time. The graph can be used to help predict the path of the storm and the time when it will reach a certain location.

The position vs. time graph

Recording data Imagine you are helping a friend who is training for a track meet. She wants to know if she is running at a constant speed. You mark the track every 50 meters. Then you measure her time at each mark as she runs. This is position vs. time data because it tells you her position at different points in time. She is at 50 meters after 10 seconds, 100 meters after 20 seconds, and so on.

Graphing the data

To graph the data, you put position on the vertical (y) axis and time on the horizontal (x) axis. Each row of the data table makes one point on the graph. Notice the graph goes over 10 seconds and up 50 meters between each point. This makes the points fall exactly in a straight line. The straight line tells you the runner moves the same distance during each equal time period. *An object moving at a constant speed always creates a position vs. time graph that is a straight line.*

Calculating speed

The data shows that your friend took 10 seconds to run each 50-meter segment. Because the time was the same for each segment, you know her speed was the same for each segment. You can use the formula $v = d/t$ to calculate the speed. Dividing 50 meters by 10 seconds tells you her speed was 5 meters per second.

Graphs show relationships between variables

Physical science is all about relationships between variables. Think about rolling a car down a ramp. You suspect that steeper angles on the ramp will make the car go faster. How do you find out if your suspicion is correct? You need to know the relationship between the variables *angle* and *speed*.

Patterns on a graph show relationships

A good way to show a relationship between two variables is to use a **graph**. A graph shows one variable on the vertical (or y) axis and a second variable on the horizontal (or x) axis. Each axis is marked with the range of values the variable has.

Recognizing a relationship from a graph

The relationship between variables may be strong, weak, or no relationship at all. In a strong relationship, large changes in one variable make similarly large changes in the other variable.

graph - a mathematical diagram showing one variable on the vertical (y) axis and the second variable on the horizontal (x) axis.

independent variable - in an experiment, a variable that is changed by the experimenter and/or causes changes in the dependent variable.

dependent variable - in an experiment, a variable that responds to changes in the independent variable.

4 steps to making a graph

Step 1: Choose which will be the dependent and independent variables. The dependent variable axis and the independent variable goes on the x-axis.

Step 2: Make a scale for each axis by counting boxes to fit your largest value. Count by multiples of 1, 2, 5, or 10.

Step 3: Plot each point by finding the x-value and drawing a line upward until you get to the corresponding y-value.

Step 4: Draw a smooth curve that shows the pattern of the points. Do not just connect the dots with straight lines.

Designing a graph: Dependent and independent variables

What to put on the *x*- and *y*-axes

To a scientist, a graph is a language that shows the relationship between two variables. Graphs are drawn a certain way, just like words are spelled a certain way. The first rule in drawing a proper graph is to choose which variable to put on which axis.

The independent variable

Graphs are usually made to show a cause and effect relationship between two variables. A graph makes it easy to see if changes in one variable *cause* changes in the other variable (the *effect*). The variable that causes the change is called the **independent variable**. In an experiment, this is the variable that the experimenter is free to change. *By agreement among scientists, the independent variable goes on the* x-*axis*. In the example below, mass is the independent variable, so mass goes on the *x*-axis (horizontal).

The **dependent variable** shows the effect of changes in the independent variable. *The dependent variable goes on the* y-*axis*. In the example, temperature is the dependent variable and therefore goes on the *y*-axis (vertical).

If time is a variable

Like many rules, there are important exceptions. Time is an exception to the rule about which variable goes on which axis. *When time is one of the variables on a graph it usually goes on the* x-*axis*. This is true even though you may not think of time as an independent variable.

Reading a graph

Using a graph to make a prediction

Suppose you measure the speed of a car at four places on a ramp. Can you figure out the speed at other places without having to actually measure it? As long as the ramp and car are set up the same, the answer is yes! A graph can give you an accurate answer even without doing the experiment. Look at the example below to see how. The students doing the experiment measured the speed of the car at 20, 40, 60, and 80 cm. They want to know the speed at 50 cm.

Large graphs are more precise

For this example, the graph predicts the speed to be 76 cm/s. You will get the best predictions when the graph is big enough to show precise measurements. That's why you should draw your graphs so they fill as much of the graph paper as possible.

A graph is a form of a model

A graph is a simple form of a model. Remember, a model is a relationship that connects two or more variables. Scientists use models to make and test predictions.

slope - the ratio of the rise (vertical change) to the run (horizontal change) of a line on a graph.

Comparing speeds

You can use position vs. time graphs to quickly compare the speeds of different objects.

A steeper line on a position vs. time graph means a faster speed.

Calculating slope

The "steepness" of a line is called its *slope*. The **slope** is the ratio of the "rise" (vertical change) to the "run" (horizontal change). The diagram below shows you how to calculate the slope of a line. Visualize a triangle with the slope as the hypotenuse. The rise is equal to the height of the triangle. The run is equal to the length along the base of the triangle. Here, the *x*-values represent time and the *y*-values represent position. The slope of a position vs. time graph is therefore a distance divided by a time, which equals speed. The units for the speed are the units for the rise (meters) divided by the units for the run (seconds), meters per second, or m/s.

Constant speed on a speed vs. time graph

The speed vs. time graph has speed on the *y*-axis and time on the *x*-axis. The bottom graph in Figure 3.13 shows the speed vs. time for the runner. The top graph shows the position vs. time. Can you see the relationship between the two graphs? The blue runner has a speed of 5 m/s. The speed vs. time graph shows a horizontal line at 5 m/s for the entire time. On a speed vs. time graph, constant speed is shown with a straight horizontal line. At any point in time between 0 and 60 seconds the line tells you the speed is 5 m/s.

Another example The red runner's line on the position vs. time graph has a less steep slope. That means her speed is lower. You can see this immediately on the speed vs. time graph. The red runner shows a line at 4 m/s for the whole time.

Calculating distance

A speed vs. time graph can also be used to find the *distance* the object has traveled. Remember, distance is equal to speed multiplied by time. Suppose we draw a rectangle on the speed vs. time graph between the *x*-axis and the line showing the speed. The area of the rectangle (shown below) is equal to its length times its height. On the graph, the length is equal to the time and the height is equal to the speed. Therefore, the area of the graph is the speed multiplied by the time. This is the distance the runner traveled.