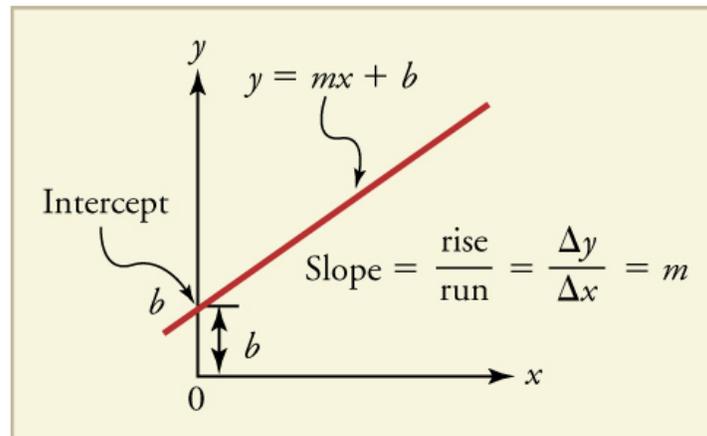


**Graphical Analysis of Motion Lab****Introduction**

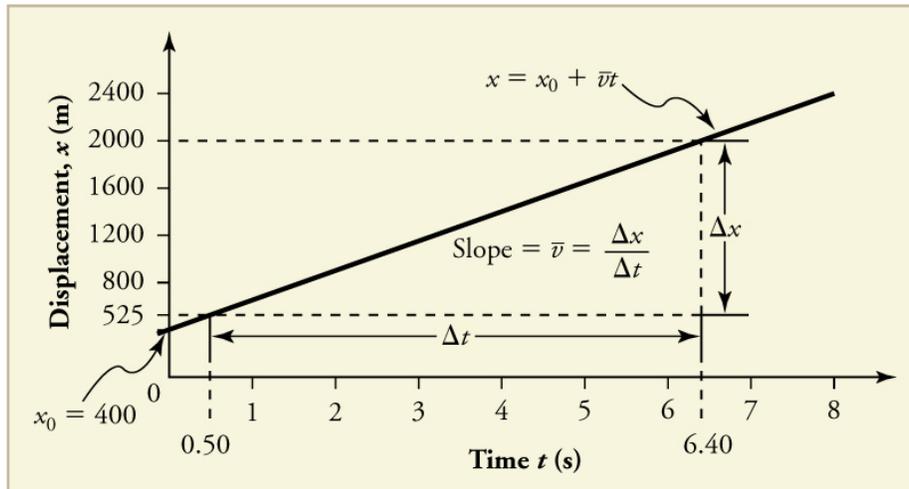
A graph, like a picture, is worth a thousand words. Graphs not only contain numerical information; they also reveal relationships between physical quantities. You can use graphs of displacement, velocity, and acceleration versus time to illustrate one-dimensional kinematics.

**A Little Bit on Dependent and Independent Variables**

When two physical quantities are plotted against one another in such a graph, the horizontal axis is usually considered to be an *independent variable* and the vertical axis a *dependent variable*. If we call the horizontal axis the *x*-axis and the vertical axis the *y*-axis, as in Figure 1, a straight-line graph has the general form:  $y = mx + b$ .

**Graph of Displacement v. Time ( $a = 0$ , so  $v$  is constant)**

Time is usually an independent variable that other quantities, such as displacement, depend upon. A graph of displacement versus time would, thus, have  $x$  on the vertical axis and  $t$  on the horizontal axis. Below is just such a straight-line graph. It shows a graph of displacement versus time for a jet-powered car on a very flat dry lake bed in Nevada.

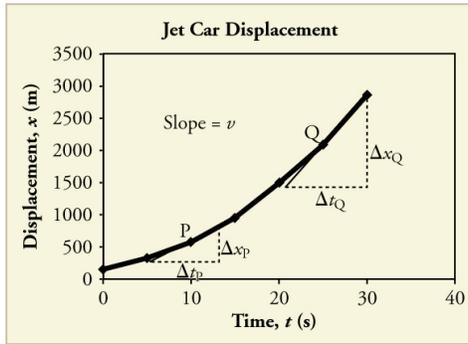


Using the relationship between dependent and independent variables, we see that the slope in the graph above is average velocity,  $v_{av}$  or:  $\text{slope} = \Delta x / \Delta t = v_{av}$ .

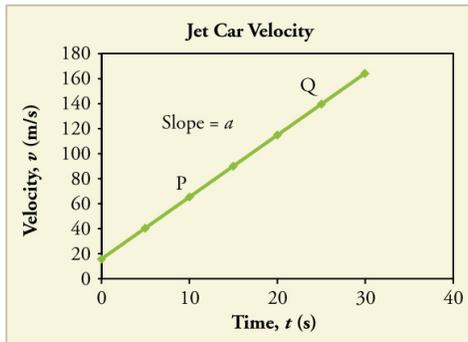
Similarly, the slope of a velocity vs. time graph is equivalent to the average acceleration.

### Graph of Motion when $a = \text{constant}$ but $a \neq 0$

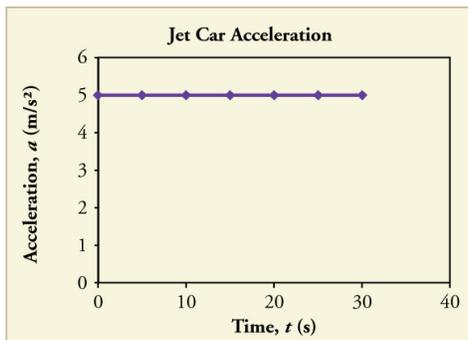
The graphs below represent the motion of the jet-powered car as it accelerates toward its top speed, but only during the time when its acceleration is constant. Time starts at zero for this motion (as if measured with a stopwatch), and the displacement and velocity are initially 200 m and 15 m/s, respectively.



(a)



(b)



(c)

The graph of displacement versus time in Figure (a) is a curve rather than a straight line. The slope of the curve becomes steeper as time progresses, showing that the velocity is increasing over time. The slope at any point on a displacement-versus-time graph is the instantaneous velocity at that point. It is found by drawing a straight line tangent to the curve at the point of interest and taking the slope of this straight line. Tangent lines are shown for two points in Figure 3(a). If this is done at every point on the curve and the values are plotted against time, then the graph of velocity versus time shown in Figure (b) is obtained. Furthermore, the slope of the graph of velocity versus time is acceleration, which is shown in Figure (c).

Source: [Lumen Learning](#)

## Materials

Tennis ball  
Meter stick  
Vernier Video Analysis App  
Mobile Device

### Procedure: Set Up

1. Tape the meter stick to the wall. You will need this to set the scale for your video analysis.
2. Place the GoMotion Detector face up on the floor at the base of the meter stick.
3. Connect the GoMotion Detector to your laptop. Open Vernier Graphical Analysis.

### Procedure: Data Collection

1. Lab Partner One will hold the tennis ball with an outstretched arm, ready to drop the ball.
2. Lab Partner Two will stand six feet away, ready to record the motion of the falling ball on their mobile device. Your mobile device should be held landscape and should be able to capture the entire drop and bounce.
3. Lab Partner Three will collect data on their laptop.
4. Lab Partner Four will count down from 5 (4, 3, 2, 1). Lab Partner Two will begin recording on their mobile device when the countdown begins. Lab Partner Three will hit collect on their laptop when the countdown begins.
5. Lab Partner One will drop the ball and let it bounce once. It is ok if the ball hits the motion detector and bounces away. **Note: The ball must bounce perpendicular to the floor.**
6. Lab Partner Two and Three should stop recording after the ball has bounced away..

### Generating Your Graph: Vernier Video Analysis

1. AirDrop your video to your laptop.
2. Open the **Vernier Video Analysis App** on your laptop.
3. Use the meterstick to set the scale for your analysis.
4. Set the origin to the initial position of the tennis ball.
5. Fast forward to the point where the ball just starts to leave the hand of Lab Partner One.
6. Using the plotting tool to plot the position of the tennis ball as it falls to the ground. Stop your plotting when the ball hits the ground.

### Analyzing Your Graphs: Vernier Video Analysis

1. In the graph window, switch the axes to show y-position (y-axis) v. time (x-axis).
- 2. Describe the general shape of your graph.**
3. To apply a curve fit, click on the little graph in the lower left corner of the graph. In the dialogue box that appears, click **Apply Curve Fit** → **Quadratic** → **Apply**.
4. Record the values for the parameters a, b, and c. Export your graph and best fit line by clicking on the little piece of paper in the upper left corner. Make sure your graph has an appropriate title and appropriately labeled axes.
5. Now switch the axes to show y-velocity (y-axis) v. time (x-axis).
- 6. Describe the general shape of your graph.**

7. To apply a curve fit, click on the little graph in the lower left corner of the graph. In the dialogue box that appears, click **Apply Curve Fit** → **Linear** → **Apply**.
8. Record the values for the parameters  $m$  and  $b$ . Export your graph and best fit line by clicking on the little piece of paper in the upper left corner. Make sure your graph has an appropriate title and appropriately labeled axes.

### Insert Your Graphs: Vernier Video Analysis

Insert the images of your graphs below.

### Making Meaning of Your Data

This experiment represents two scenarios:

1. The tennis ball is moving with constant acceleration.
2. The tennis ball is in free fall. Free fall is any motion of a body where gravity is the only force acting upon the body. Air resistance is ignored.

For an object in free fall, its acceleration is called the **acceleration due to gravity**. This acceleration is represented by  $g$  and has a magnitude of  $9.8 \text{ m/sec}^2$ . Because objects accelerate toward the center of the earth, we usually write  $a_g = -9.8 \text{ m/sec}^2$ . This is a global average and your theoretical value.

1. For your quadratic curve fit analysis, look at the value for the **parameter a**. Consider the value  $2a$ . How does  $2a$  compare to the value  $a_g = -9.8 \text{ m/sec}^2$ ? Calculate the percent error, using the equation below.
2. For your linear curve fit analysis, look at the value for the **parameter m**. How does  $m$  compare to the value  $a_g = -9.8 \text{ m/sec}^2$ ? Calculate the percent error, using the equation below.

$$\% \text{ Error} = \left| \frac{\text{Theoretical Value} - \text{Experimental Value}}{\text{Theoretical Value}} \right| \times 100$$

	Vernier Video Analysis Value
Value of $2a$	
% error from $-9.8 \text{ m/sec}^2$	
Value of $m$	
% error from $-9.8 \text{ m/sec}^2$	

4. The curve for position  $v$  time for the tennis ball is quadratic. The curve for velocity  $v$  time for the tennis ball is linear. Predict the shape of the curve for acceleration  $v$  time. Sketch a graph and insert an image of that graph below.