

Experiment 2: Motion With Constant Acceleration

Graphing Motion

All kinds of motion are based on 4 fundamental variables: *position*, *velocity*, *acceleration*, and *time*. In this lab we will explore these variables and how they relate to each other.

1. Obtain a marble (or ball bearing), a track, track supports, a meter stick, masking tape, and a stopwatch.

2. Using these materials, set up an apparatus so that the marble appears to travel with *constant speed* over the length of the track, i.e., it is not slowing down or speeding up (once you get it going). Describe how you accomplished this.

3. Describe how you could check to see if speed is constant:

4. Make a hypothesis (an educated guess) about the shape of the graph for distance traveled vs. elapsed time for the marble at *constant speed*. "Distance traveled" means the distance from start to point X, and "elapsed time" means the time from start to that same point X (E.g, "it took 3.2 seconds to travel from 0 to 2.5m"). Sketch the graph below. So we are all consistent, put time on the horizontal axis and distance on the vertical. We will discuss the graph to clarify any questions before we go on.



5. Now angle the track so the marble accelerates. For the acceleration to be constant, the track will need to be as straight as possible. Try for a slope that is gentle enough that you'll be able to time it accurately—at least 4 seconds from start to finish is recommended. Practice until you are sure the motion and your measurements are repeatable.

6. Now make a hypothesis about the shape of the distance vs. time graph for the marble at *constant acceleration*. Draw this graph overlaid on the one in step #4.

7. We will now design an experiment to verify or refute your hypothesis on the shape of the *constant acceleration* graph. Answer these questions to help get you started:

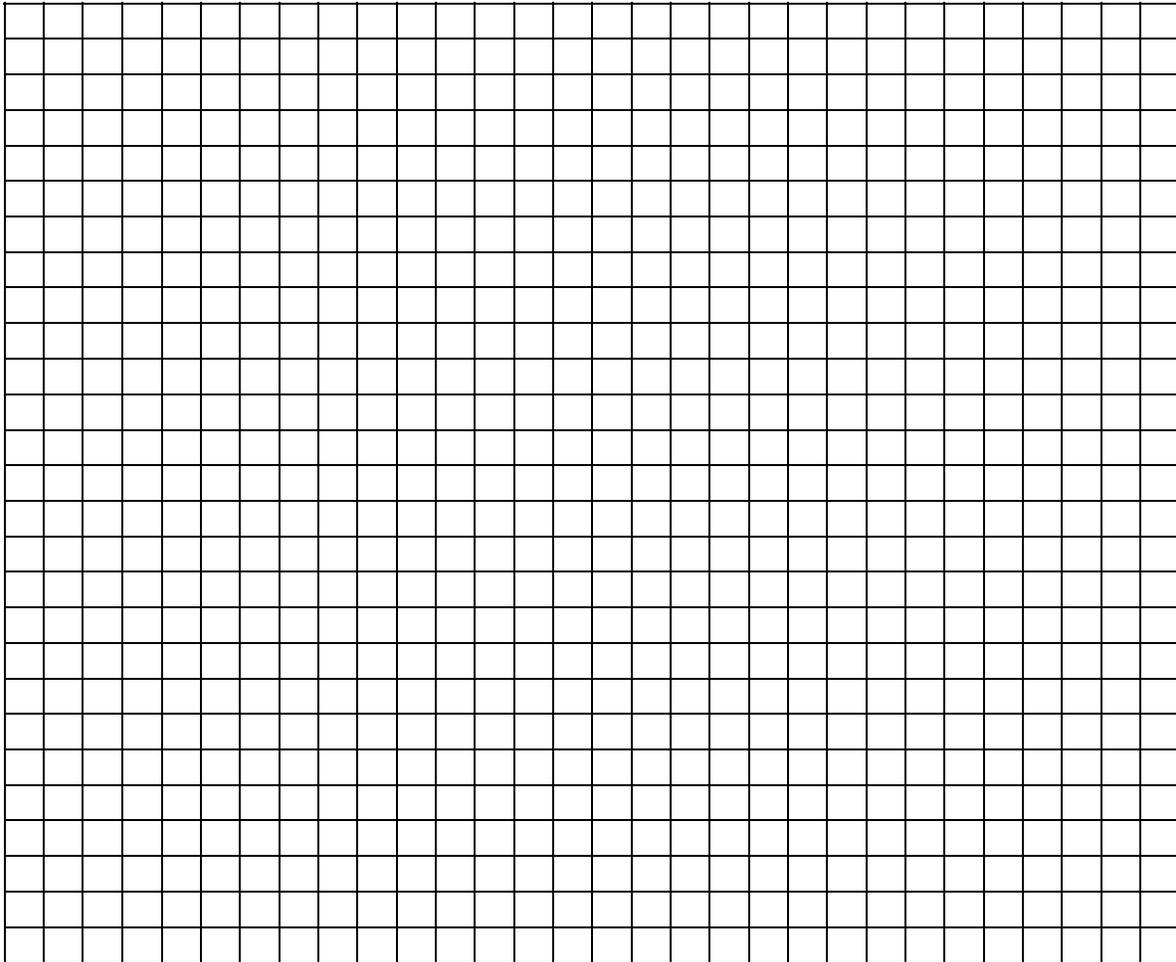
- Is it easier to measure the time at predetermined distances, or vice-versa?
- Given what you decided just above, which variable (distance or time) is the independent variable (the one you control):

dependent variable (the one you measure):
- How many distance-time data points are needed to be reasonably certain about the graph shape (remembering there will be considerable error in every measurement)?
- What factors might be confounding variables in your experiment? And, what can be done to control or minimize these to ensure measurement accuracy?
- What data can you use for the starting point (by logic)? Would this point have error like the other measurements?

8. Before you go on, discuss these questions with your lab partners.

9. Based on steps 7 and 8, develop a procedure to test your hypothesis in step 6. Briefly describe the plan for your experiment:

10. Perform the experiment and make a neat data table of your results. Then plot the data (remember the tips for clear graphs from the Lab Manual). Like step 4, put time on the horizontal axis and distance on the vertical axis. So we are all consistent, use *cm* for distance. Keep your apparatus set up until step 12.



11. Now examine the graph. It will probably have some "rough spots" and/or "holes."
As needed, take some more data points to help refine the shape of the graph.

12. Look back to step #5/7 and state whether your hypothesis is supported or not supported. (It is perfectly ok if the hypothesis is not supported!)

13. Think about confounding variables again--what effects do you think they had?

Modeling Motion

One of the goals of science is to be able to describe phenomena with simple, accurate, and usable models. In physics these models often take the form of equations. In this part we are going to try to write the equation for the graph in part one.

Straight-line graphs have the equation

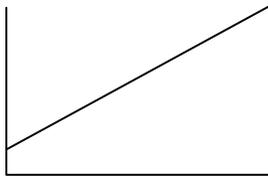
$$y = k(x) + a,$$

where k and a are constants. If $a = 0$, y is said to be *directly proportional* to x . For example, the distance traveled by a car going 60 miles/hour in a time of 2.5 hours is

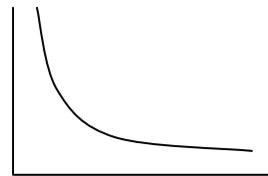
$$d = 60 \frac{\text{miles}}{\text{hour}} (2.5 \text{ hour}) = 150 \text{ miles}.$$

If the graph is a straight line, we can find the *slope*, k , by computing the *rise over run*, and the *y-intercept*, a , by finding the value of y when x is zero. But if the graph is *not* straight, we have to do some figuring to get the equation. There are a few techniques to do this, probably invented by physicists a long time ago to develop the formulas in your textbook. We're going to do the same thing.

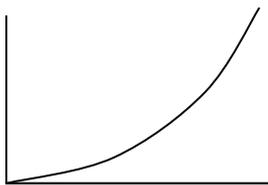
1. Take an educated guess about the form of the equation. Some common ones are shown below. Which do you think is most likely to describe the graph in Lab 2.1?



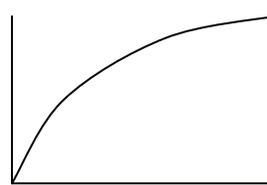
linear: $y = kx + a$



inverse: $y = k/x$



quadratic: $y = kx^2$



square-root: $y = kx^{1/2}$

2. Let's say the equation is

$$y = kx^{1/2}$$

3. Now imagine a new variable z which is equal to $x^{1/2}$

$$z = x^{1/2}$$

4. Then,

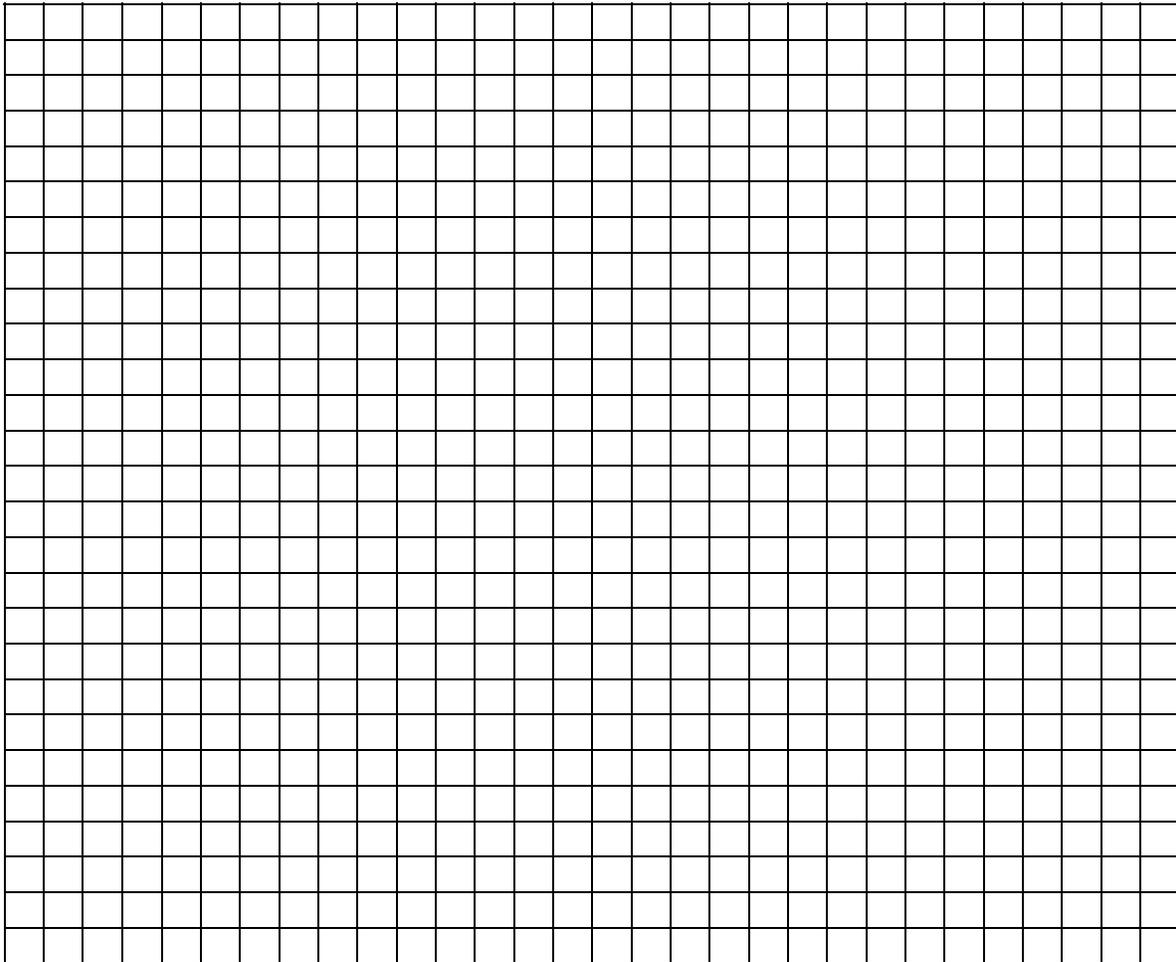
$$y = kz$$

5. Take all the x values, *find the square root of each* (thus making z values), and plot the data in the form of y versus z . Now the key step: if that graph turns out to be a straight line, we know two things:

- i. We were right in our original guess that $y = k x^{1/2}$
- ii. The "k" in $y = k x^{1/2}$ is the slope in the straight line graph $y = k z$

If that graph weren't a straight line, then we guessed wrong and we would start over with a different equation, like $y = x^2$.

6. Give this a try with the data from Lab 2.1. Guess an equation-form, manipulate the x data appropriately, plot the new \sim straight line graph (or at least *more* straight), and derive the k as the slope of that straight line graph.



7. Now write the final form of the equation in terms of distance and time. Include units (use cm and seconds).

8. Test your equation to see if it works: plug in 3 random times to see if the equation predicts the distance according to the graph (show comparisons):