

Includes  
Teacher's Notes  
and  
Typical  
Experiment Results



***Instruction Manual and  
Experiment Guide for the  
PASCO scientific  
Model SE - 9072***

# ***CONSTANT VELOCITY TUBES***



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The exclamation point within an equilateral triangle is intended to alert the user of important operating and safety instructions that will help prevent damage to the equipment or injury to the user.

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## Introduction

The Transparent Devices Constant Velocity Tubes are simple devices that students can use to generate velocity vs. time data for exercises to improve their graphing skills. Three Plexiglas tubes contain colored, oil-based liquids of two different viscosities. A bubble of air trapped in each of the liquid columns rises at a constant velocity that is determined by the viscosity of the liquid. The fourth tube contains a colorless oil and two balls, one made of steel and the other made of plastic.

## Equipment

### INCLUDED

- SE-9072 CONSTANT VELOCITY TUBES (4)

### ADDITIONAL EQUIPMENT REQUIRED

- Meter stick or metric ruler
- Clock with sweep second hand, or stopwatch

## Maintenance

- Clean with mild nonabrasive dish soap.
- Store in original box, out of direct sunlight. The ball containing tube must be stored chamber side up.



- *Do NOT store in chemical storerooms.*

- **Removing an air bubbles from ball containing tube:** The tube containing the steel and Teflon balls contains a small air chamber to allow for the expansion of the oil in the adjoining main chamber. The stopper with a small hole in it separates the two chambers. When stored correctly, daily variations in temperature will gradually "pump" any excess air from the main chamber to the air chamber. Students should be instructed to keep the air chamber side upward whenever possible to prevent air from entering the main chamber as large amounts of air can reduce the accuracy of the experiment. Small amounts of air should have a negligible effect on the results. Should such a large air bubble appear, simply hold the tube with the air chamber pointed up and tap the tube GENTLY on the floor. A slightly faster method of removing the bubble is to alternatngly hold the tube under running hot tap water for 10 seconds followed by a stream of cold tap water. The air chamber must remain up during this operation.
- If a tube breaks, absorb oil with paper towels and dispose in the trash unless otherwise directed by your school's policy.
- If the oil is ingested do not induce vomiting unless otherwise directed by a medical professional.
- See MSDS sheets included.
- The fluids may cause stains on some materials. Stains may usually be removed by simple procedures such as the use of a laundry stain remover.
- The purple and blue tubes contain highly refined #21 mineral oil. The red and colorless tubes contain highly refined #10 mineral oil. Please refer to the MSDS mineral oil included for a short-listing of exposure concerns.

## Pre-Lab Exercise: Graphing in the Lab

### Purpose

To help students develop graphing skills that will be needed to complete the activities with the Constant Velocity Tubes

### Background

Graphs are an effective way of presenting numerical data in a laboratory report, but that is not their only use. Graphs can also be used to determine the mathematical relationship between two variables. In the following graphing exercise, you will work with two types of variables: an *independent variable* and a *dependent variable*. An independent variable is the part of the experiment that you change in a measured, controlled way. The dependent variable is the part of the experiment that changes as a result of the changes in the independent variable.

This exercise will help you develop the graphing skills you will need in your experiments with the Constant Velocity Tubes. You will draw a graph of experimental data that were previously collected.

In a previously conducted experiment, a measured volume of liquid mercury (independent variable) was added to a glass beaker, and then the mass of the beaker and mercury (dependent variable) was determined with a platform balance.

### Procedure

1. In an experiment, there are generally several variables that might possibly affect the dependent variable. If we can arrange to allow only one of these to vary and hold the others constant during the experiment, it is far easier to interpret the results. Besides the volume of liquid, the kind of liquid is an example of a variable which might possibly affect the mass reading; thus the kind of liquid used should not be changed during the experiment. Can you think of any other variables that should be held constant in this experiment?

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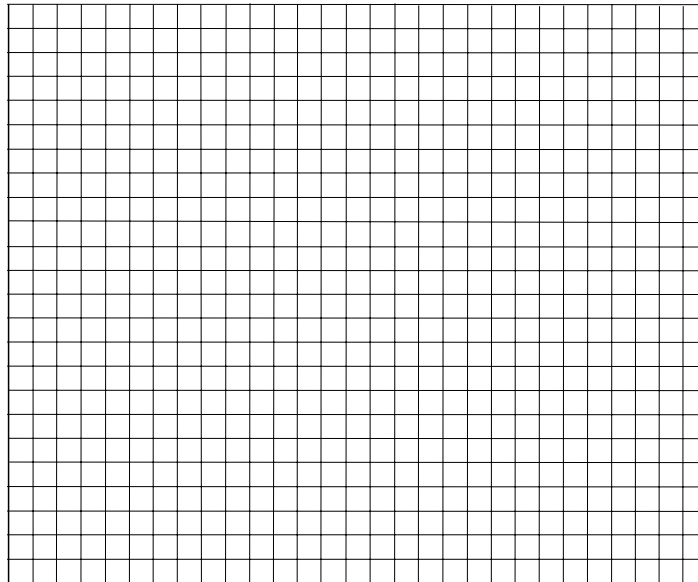
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2. For the first data point of this experiment, the beaker was filled to the 250 ml mark with liquid mercury, and the mass reading from the pan balance was 3,600 g. Next, the beaker was emptied and then filled to the 50 ml mark. The mass reading was then 1000 g. Notice that these first two sets of data represent two extreme possibilities. Why do you suppose such values were chosen?

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3. It is useful to sketch a graph of the data as it is collected and examine the pattern as it forms. Make a graph on the grid below using the data above, as follows:
- a) Label the horizontal axis with the name of the independent variable (sometimes called the “control” variable). Follow the name with the type of units of measurement being used in parentheses ( ). In a similar manner, label the vertical axis, which is used for the dependent variable.
  - b) Number the axes. Start numbering with zero at the origin (lower left corner).
    - When numbering the axes, number the lines, not the spaces. Choose a regular numbering system (e.g. by fives, tens, fifties, etc). Adopt a spacing system that numbers every second, every fifth, or possibly every tenth line. These choices make it easier to locate and plot data from metric system measurements, as compared to systems involving numbering every three or four lines. The numbering system chosen will depend on the largest numbers that will need to be plotted.
  - c) Plot the data points. Make small, precise points. Then, because small points are hard to find, make them more obvious by surrounding each point with a small circle, triangle, or similar figure. These are called *point protectors*.



- If you feel uncertain about your work thus far, you should seek help before proceeding.
- Drawing a graph as an experiment proceeds can help you to decide what to do next. The two points plotted are just the beginning of a pattern. Obtaining and plotting additional data points makes the pattern become clearer.

4. On the same graph, plot this additional data:

150 ml — 2,500 g                      and                      100 ml — 1,600 g

5. Looking at your graph, what volume would you suggest be used next?

\_\_\_\_\_

6. Now plot this data pair: 200 ml — 1,300 g

► Plotting data on a graph helps reveal mistakes. If the graph is made as the experiment is being done, the mistake can be corrected. Later, it may be difficult or impossible to reconstruct the experiment and correct the error.

7. Which of the data points on your graph represents a mistake? \_\_\_\_\_

► It is not wise to immediately discard data that “looks wrong”. Many important new discoveries in science “looked wrong” at first. In this case, however, a simple mistake was made: the “1” and the “3” in the last mass reading were transposed. The data pair should have been: 200 ml — 3,100 g.

8. Correct the mistake noted.

9. By now a pattern should be clear. To make the pattern more visible, draw a *best-fit* line (the line that most closely follows the pattern revealed by the data points). Since the pattern seems to be straight, it is appropriate to use a straight edge to draw the line. (A transparent plastic straight edge is particularly useful for this purpose.) Extend the line all the way to the vertical axis.

► You may find that the points don't quite fit on the line. This is because all of our data include uncertainty. The uncertainty is due to imperfections in the measuring tools, our inability to read these tools perfectly, and perhaps the fact that other variables have varied despite our attempts to keep them constant. The odds are that some of the points are too high, and some are too low. Even though the uncertainty in the data makes the locations of the data points slightly in error, we can discover the pattern that represents the *true* relationship between mass and volume. We assume that the truth is that the pattern is a straight line, and that the points miss the line due to errors.

► Computer programs, including built-in programs in some calculators and *Data Studio*® can also draw a *best-fit* line. The process is called *curve-fitting*. If we decide in advance that a straight line is the appropriate pattern, the process is called *linear regression*.

➤ In algebra, a graph of this type is described by the equation  $y = mx + b$ , where:

$y$  is the quantity on the vertical axis,

$x$  is the quantity on the horizontal axis,

$m$  is the slope, and

$b$  is the  $y$ -intercept (also called the vertical intercept).

By replacing each of these abstract symbols with the actual items dealt within the experiment, the mathematical equation can be transformed into a physics equation.

**10.** In the space below write the equation that results when you replace the symbols  $y$  and  $x$  with the actual physical units, *mass* and *volume* in the equation for a straight line,  $y = mx + b$ :

**11.** In the space below, substitute  $y$ -intercept value (360 grams) for  $b$  in the equation (notice that the dimensional units *grams* are part of the value):

**12.** It is unlikely that your graph shows a  $y$ -intercept of *exactly* 360 g. What is the value of the  $y$ -intercept, *according to your graph*?

**13.** Calculate the slope,  $m$ , as follows:

The slope,  $m$ , is found from the formula  $slope = rise / run$ . The first step in finding slope is to mark two points directly on your best-fit line. Label these points so they won't be confused with data points. The farther apart you place them, the more accurate your result will be. Choosing points that are on one of the grid lines will also improve your accuracy.

**a)** Select two points on the best-fit line, and read their coordinates from your graph:

First Point:  $y_1$ -coordinate \_\_\_\_\_  $x_1$ -coordinate \_\_\_\_\_

Second Point:  $y_2$ -coordinate \_\_\_\_\_  $x_2$ -coordinate \_\_\_\_\_

Did you remember to record the units of measurement, as well as the number?

**b)** Calculate the rise and run from these coordinates.

rise ( $y_2 - y_1$ ) = \_\_\_\_\_ run ( $x_2 - x_1$ ) = \_\_\_\_\_

Did you remember to record the units of measurement, as well as the number?



c) Now calculate the slope (don't forget the units):

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{y_2 - y_1}{x_2 - x_1} = \underline{\hspace{4cm}}$$

► Your answer should be approximately 13.4 g/ml. You should not expect to get exactly this answer.

d) Now substitute this value for slope (*m*) in the formula:

► This equation allows us to calculate the mass reading that would result if some other volume of mercury were tried. Using algebra to solve for volume, we can also obtain an equation that tells us what volume of mercury to use to cause some particular mass reading.

14. Solve the equation for volume. Ask for help if you need it.

► The original equation would be much more useful if it could apply to other substances besides mercury as well as containers other than the one that was used in this experiment. Often, reasoning allows us to adapt an equation to other purposes.

15. Look at your graph and see if you can express in words the meaning of the y-intercept. (Not the mathematical meaning, but rather some aspect of the experiment that this value represents. Hint: What is the volume at the y-intercept?)

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16. Does the value of the slope remind you of anything? How about the units? *Hint: use a reference to look up the physical properties of mercury.* Keep in mind that the numerical value we obtained by experiment will not be exact.

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17. Finally, the mass reading from the pan balance might better be called *gross mass*, which is the mass of both the container and the contents. The preceding ideas can be used to rewrite the equation into a more generally useful form:

$$\text{Gross Mass} = \text{Density of Contents} * \text{Volume of Contents} + \text{Mass of Container}$$

## Experiment, Part 1: Constant Velocity Motion and the Linear Graph

### Purpose

The purpose of this experiment is to study the motion of a bubble moving in a tube of oil and to develop a quantitative description of that motion.

### Theory

Under a given set of conditions, the motion of a rising bubble is highly repeatable. At the most basic level, describing motion involves describing position as a function of time. In this experiment, variables that might conceivably affect the bubble's motion, such as tube angle and temperature, are held constant. Position data are recorded for a variety of times.

Before position data can be meaningful, a reference frame must be defined. For convenience, the initial position of a moving object is often chosen to be zero. Since the initial position of the bubble is concealed in this experiment, it is not possible to determine the initial position of the bubble. Instead, the end of the tube will be defined as position zero, simply because this is a convenient place to measure from. Given that the position of the bubble during its motion is always above the bottom of the tube, it is most convenient to define positions above the end of the tube to be positive.

When the position-time data points from one of the tubes are graphed, a clear pattern to the data can be clearly seen. Plotting data from other tubes on the same graph produces similar patterns, but with distinctive differences that may be related to the differences in motion. The patterns that emerge are of a type familiar to algebra students, and an equation for each can readily be written.

### Procedure

***Follow your lab's safety procedures,  
Including wearing safety glasses.***

1. Obtain a PURPLE tube that has one end wrapped in paper. The paper will prevent you from obtaining data in time intervals that are too short to assure accuracy. Do not remove the paper.



Figure 1

## Constant Velocity Tubes - 4 tube set

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2. Work with a partner to practice timing the motion of the bubble as follows:
- Holding the tubing nearly horizontal, but with the wrapped end slightly higher. Allow time for the bubble to travel as far as it can under the paper wrapping (figure 1).
  - Your partner should be watching the clock (or operating a stopwatch). Choose a time interval that is long enough for the bubble to come into view, but short enough so that the bubble does not reach the end of the tube. At a convenient time your partner should say, "start."

- Quickly rotate the tube into a vertical position; the wrapped end should be downward (Figure 2).
- As a bubble comes into view, keep the index finger of one hand pointing at the bottom of the bubble as it rises. When your partner says "stop," stop moving your finger and hold it there to mark the position of the bottom of the bubble (figure 2).
- Measure the distance from the bottom of the tube to the point marked by your finger (figure 3).
- Record the time of travel and the bubble's position and plot the point on the graph.

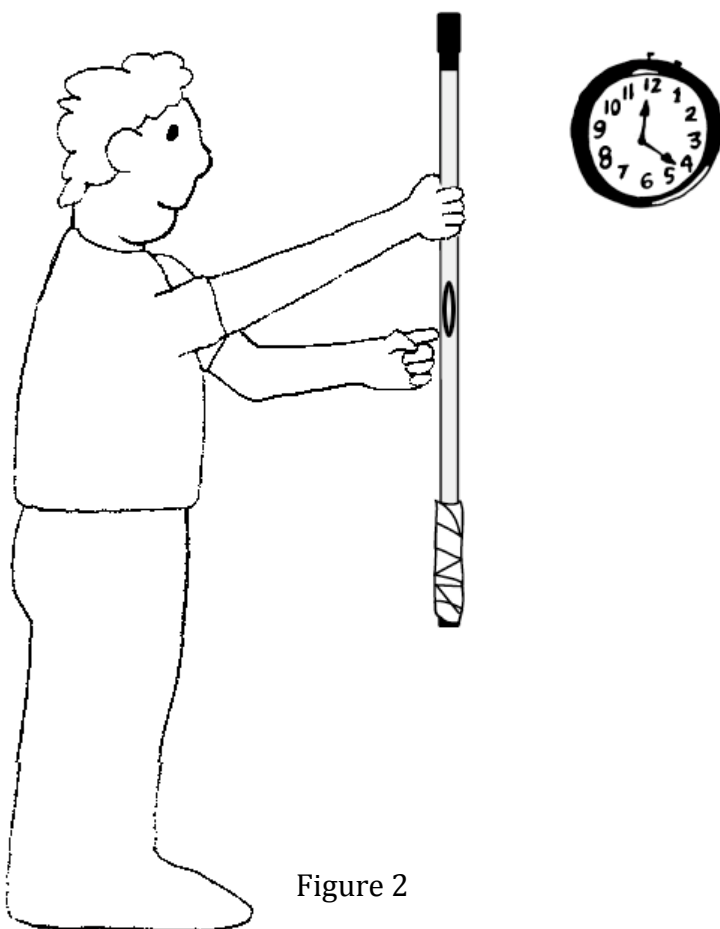


Figure 2

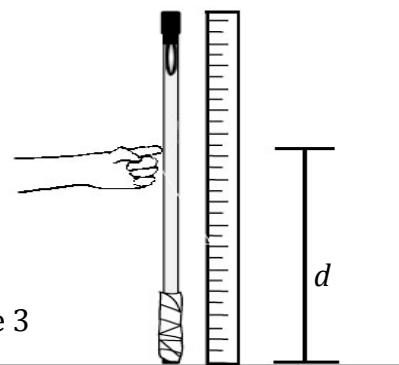


Figure 3

## Constant Velocity Tubes - 4 tube set

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3. Do the above for two different time intervals. Choose one time interval that is short enough so that the bottom of the bubble has emerged from the paper wrapping. Choose another time interval almost long enough to permit the bubble to reach the top of the tube. Enter your data into the data table on page 13.
4. Prepare the graph on page 14, and plot the two data points.
5. Choose other lengths of time between these two extremes. Enter the data into the data table. Plot the points as you go and examine the pattern as it forms. Choose additional times to try based on missing parts of the pattern. Be on the lookout for obvious mistakes as you plot the points. Do not rush to throw out any of your data, though.
6. Draw a best-fit line that represents the pattern your data has made on the graph. A straight line drawn with a ruler should do a good job of representing the pattern of the data. If it does not, ask your instructor for advice. Label your new line "purple tube" just above the line on the graph.

If time permits, improved accuracy can be obtained by repeating a time more than once and plotting the average position for that length of time.

7. If necessary, extend your line until it meets the vertical axis. What is the value of the y-intercept? (be sure to include units on your measurements)
  - Purple tube y-intercept: \_\_\_\_\_
  - Red tube y-intercept: \_\_\_\_\_
  - Blue tube y-intercept: \_\_\_\_\_
8. What is the meaning of the y-intercept? (Not the mathematical meaning, but the meaning in terms of the details of this specific experiment.)  
\_\_\_\_\_  
\_\_\_\_\_
9. Now repeat steps 1-8 using the **RED** tube. Try to obtain approximately the same amount of data for this tube. Use the same graph you used to graph the data for the purple tube to graph this data (you may want to use a different symbol to represent these new data points). Label your best fit-line for this data, "red tube."

Constant Velocity Tubes - 4 tube set

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10. Compare the best-fit lines from the two tubes for similarities and differences. Try to explain the reasons for them.

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11. Now repeat steps 1-8 with the **BLUE** tube. Again, try to obtain approximately the same amount of data for this tube. Use the same graph you used to graph the data for the purple tube to graph this data (you may want to use a different symbol to represent these new data points). Label your best fit-line for this data, "blue tube."

12. Compare this line to the other two lines. Try to explain the reasons for any similarities or differences between the lines.

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13. At this point, your instructor may ask you to stop for further discussion. If not, go on to step 14 on the next page.

Constant Velocity Tubes - 4 tube set

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14. Unwrap the paper from all three tubes to verify your explanation from question 12.
15. Did your best-fit line for the blue tube correctly show its y-intercept to be at a point higher than the y-intercepts for the other two tubes? \_\_\_\_\_
16. Measure the distances for the bottom of the blue tube (point zero) to the top of the stopper in the tube. Distance: \_\_\_\_\_ (don't forget units of measurement)
17. This distance should equate closely to the y-intercept of your best-fit line for the blue tube. Does it? \_\_\_\_\_
18. Why or why not?

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***The remainder of the analysis may be performed outside the lab.***

19. For each of the three tubes you experimented with, calculate the slope of the best-fit line. Fill in the blanks showing the results of your intermediate steps, as well. Don't forget to include units of measurement.

**PURPLE** tube

First Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

Second Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

    rise = \_\_\_\_\_                    run = \_\_\_\_\_

    slope = \_\_\_\_\_

**RED** tube

First Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

Second Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

    rise = \_\_\_\_\_                    run = \_\_\_\_\_

    slope = \_\_\_\_\_

**BLUE** tube

First Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

Second Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_

    rise = \_\_\_\_\_                    run = \_\_\_\_\_

    slope = \_\_\_\_\_

## Constant Velocity Tubes - 4 tube set

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20. What arguments can you offer, based on this experiment, that the speed of the bubble is the same as the slope of the position vs. time graph?
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In algebra, a graph of the type seen in this experiment is described by the equation:

$$y = mx + b$$

where:  $y$  is the quantity on the vertical axis,

$x$  is the quantity on the horizontal axis,

$m$  is the slope, and

$b$  is the  $y$ -intercept (also called the vertical intercept).

21. Write equations for each of the three tubes you experimented with by substituting into the basic equation above the appropriate values for slope and  $y$ -intercept, as well as the names of the variables that  $x$  and  $y$  represent.

Purple Tube Equation: \_\_\_\_\_

Red Tube Equation: \_\_\_\_\_

Blue Tube Equation: \_\_\_\_\_

22. By replacing each of these abstract symbols with the actual items dealt with in the experiment, the mathematical equation can be transformed into a basic equation of motion. Write a basic equation for motion using the words *position*, *time*, *velocity*, and *initial position*.
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Constant Velocity Tubes - 4 tube set

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**Data Tables**

**Purple Tube**

Time (s)	Position (cm)

**Red Tube**

Time (s)	Position (cm)

**Blue Tube**

Time (s)	Position (cm)

**Steel Ball (Part 2)**

Time (s)	Position (cm)



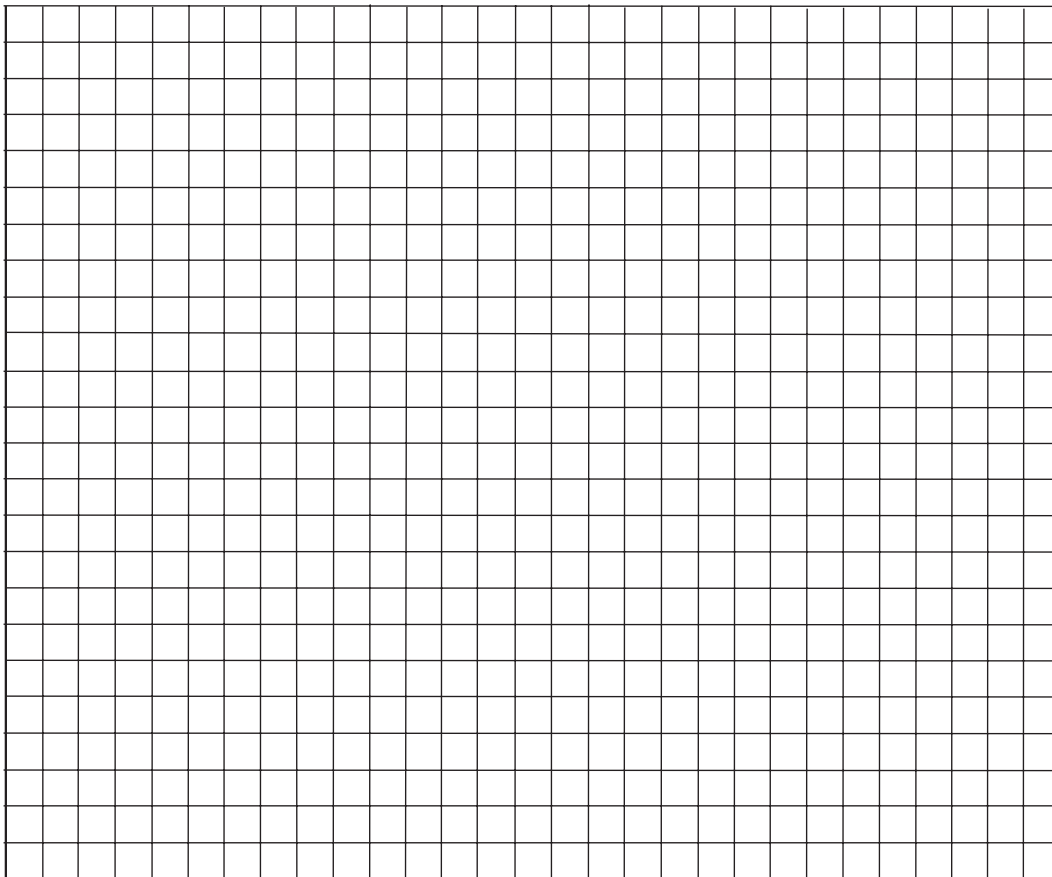
Constant Velocity Tubes - 4 tube set

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**Teflon Ball (Part 2)**

<b>Time (s)</b>	<b>Position (cm)</b>

**Graph**



## Experiment, Part 2: Constant Negative Velocity

### Purpose

The purpose of this part of the experiment is to study and graph the motion of two small balls as they descend through oil in a tube and to relate that motion to the graph of the ascending bubbles already studied.

### Procedure

1. Obtain a **colorless transparent** tube containing two small balls (one steel, the other teflon). Note that there is a small chamber at one end containing air and a small amount of oil. This is the end that the balls will fall FROM. It is normal for there to be a small bubble of air in the main part of the tube with the balls. If that bubble is larger than the size of one of the balls themselves, see your instructor.
2. Work with a partner to practice timing the motion of the steel ball as it falls as follows:
  - a. Holding the tubing nearly horizontal, but with the small chambered end held slightly LOWER than the rest of the tube, allow time for the balls to travel to the chamber's stopper and come to rest (figure 4).
  - b. Measure the distance from the opposite end of the tube (point zero) to the starting position of the steel ball. This is where the ball is when time equals zero. Record this data point in the table on page 13 and make a corresponding point on the graph on page 14.
  - c. Your partner should be watching the clock (or operating a stopwatch). Choose a time interval that is long enough for the steel ball to begin to move, but short enough so that the ball does not reach the bottom. At a convenient time your partner should say, "start."
  - d. Quickly rotate the tube into a vertical position such that the steel ball begins to fall.
  - e. As a ball falls, keep the index finger of one hand pointing at the bottom of the ball. When your partner says "stop," stop moving your finger and hold it there to mark the position of the ball in relation to point zero (the bottom of the tube).



Figure 4

## Constant Velocity Tubes - 4 tube set

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- f. Measure the distance from the bottom of the tube to the point marked by your finger.
  - g. Record the time of travel and the ball's position on the table on page 13 and plot the point on the graph on page 14.
3. Do the above for several different time intervals. Choose at least one time interval that is long enough such that the ball is nearly to the bottom. Choose one short time interval (about 4 seconds). Shorter time intervals will be difficult to measure accurately. Choose other lengths of time between these extremes. Enter the data into the data table. Plot the points as you go and examine the pattern as it forms. Choose additional times to try based on missing parts of the pattern. Be on the lookout for obvious mistakes as you plot the points. Do not rush to throw out any of your data, though.
  4. Draw a best-fit line that represents the pattern your data has made on the graph. A straight line drawn with a ruler should do a good job of representing the pattern of the data. If it does not, ask your instructor for advice. Label your new line "steel ball tube" just above the line on the graph.

If time permits, improved accuracy can be obtained by repeating a time more than once and plotting the average position for that length of time.

5. Note that the y-intercept in this case is the starting position of the steel ball.
6. Now repeat steps 1-5 using the **same** tube, but this time obtain data for the Teflon ball as it falls. Note that it starts at nearly the same point as the steel ball. **Given that the teflon ball falls fairly slowly, you will want to choose only those times that are short enough to fit on your graph.** Record your data in the table on page 14. Graph the data on the graph on page 14. Draw a best-fit line that represents the pattern your data has made on the graph. Label your new line "teflon ball tube" just above the line on the graph.
7. Compare the best-fit lines from the steel and Teflon ball data for similarities and differences. Try to explain the reasons for them. For each of the three tubes you experimented with, calculate the slope of the best-fit line. Fill in the blanks showing the results of your intermediate steps, as well. Don't forget to include units of measurement.

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Constant Velocity Tubes - 4 tube set

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*The remainder of the analysis may be performed outside the lab.*

8. Now calculate the slope of the best-fit lines for each of the balls. Fill in the blanks showing the results of your intermediate steps as well. Don't forget to include units of measurement.

**Steel ball**

First Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_  
Second Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_  
    rise = \_\_\_\_\_                    run = \_\_\_\_\_  
    slope = \_\_\_\_\_

**Teflon Ball**

First Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_  
Second Point:                    y-coordinate \_\_\_\_\_                    x-coordinate \_\_\_\_\_  
    rise = \_\_\_\_\_                    run = \_\_\_\_\_  
    slope = \_\_\_\_\_

9. If you calculated correctly the slopes for these two lines should be **negative** numbers. What does this tell you about the motion of the balls?

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Again, in algebra, a graph of the type seen in this experiment is described by the equation:

$$Y = mx + b$$

where:  $y$  is the quantity on the vertical axis,

$x$  is the quantity on the horizontal axis,

$m$  is the slope, and

$b$  is the  $y$ -intercept (also called the vertical intercept).

10. Write equations for each of the two balls you experimented with by substituting into the basic equation above the appropriate values for slope and  $y$ -intercept, as well as the names of the variables that  $x$  and  $y$  represent.

Steel ball Equation: \_\_\_\_\_

Teflon ball Equation: \_\_\_\_\_

Constant Velocity Tubes - 4 tube set

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11. If you were to place the purple tube containing its bubble right next to the transparent tube containing the steel ball and turn them over such that the bubble in the purple tube launched upward at the same time the steel ball started to fall downward, when and where along their paths would they pass one another?

Hint: You should be able to answer this question by looking at the graph you produced\*.

Where: \_\_\_\_\_ (don't forget units on your numbers)

When: \_\_\_\_\_ (don't forget units on your numbers)

\*Depending on your knowledge of algebra, you could also answer the question by using algebra to find the intersection of the two equations you produced for these tubes.

12. How did you determine the values you gave as answers to question 11?

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13. Test your answers experimentally. How close were your experimental values to those you obtained from your graph?

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# Teacher's Notes

## Pre-lab Exercise

### Answers to questions

- Other potential variables that should be held constant include the container (could be a different mass), the pan balance used (might not be properly calibrated, or calibration methods could be crude), two different methods of measuring the liquid (e.g., beaker vs. graduated cylinder), or ambient temperature.
- Plotting the extremes allows one to begin the graphing process with the assurance that all data will fit on the graph and to more accurately guess the slope of the true line that represents the relationship between the variables (assuming it is a linear relationship).

5. Answers will vary.

7. the 200 ml, 1300 g point

10.  $\text{mass} = m \cdot \text{volume} + b$

11.  $\text{mass} = m \cdot \text{volume} + 360 \text{ g}$

12. Answers will vary around 360 g.

13. a)  $y_1 = 1640 \text{ g}$      $x_1 = 100 \text{ ml}$   
 $y_2 = 3675 \text{ g}$      $x_2 = 250 \text{ ml}$   
 (Answers will vary somewhat.)

b)  $y_2 - y_1 = 2035 \text{ g}$      $x_2 - x_1 = 150 \text{ ml}$   
 (Answers will vary somewhat.)

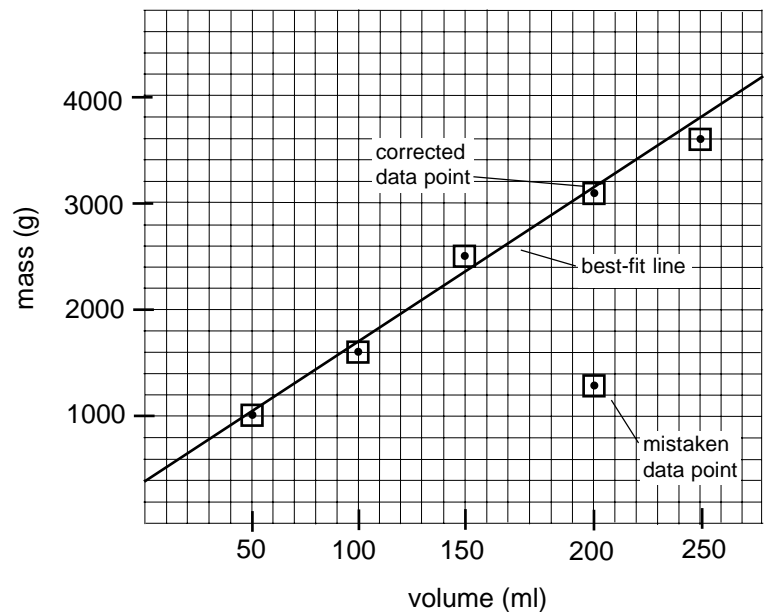
c) 13.6 g/ml  
 (Answers will vary somewhat.)

d)  $\text{mass (g)} = 13.6 \text{ g/ml} \cdot \text{volume (ml)} + 360 \text{ g}$

14.  $\text{volume (ml)} = \frac{\text{mass (g)} - 360 \text{ g}}{13.6 \text{ g/ml}}$

15. The y-intercept equals the mass of the beaker.

16. The slope represents the density of the liquid mercury. The accepted value for the density of mercury is 13.5 g/ml (room temperature) or 13.6 g/ml at 0 °C.

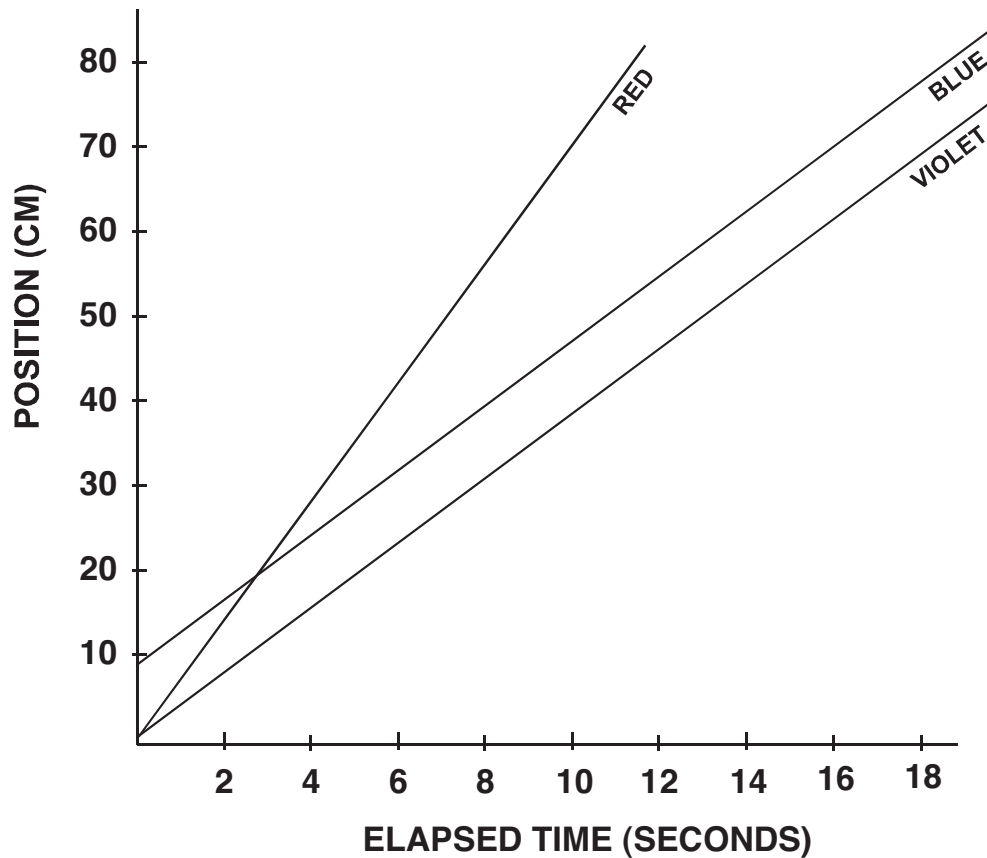


**Graph of Plotted Data**

## Experiment, Part 1

*To preserve the “discovery” aspect of the lab, you will need to cover the ends of the tubes with paper before the lab starts. A sheet of notebook paper secured with rubber bands and masking tape works well. Scotch (or cellophane) tape is very difficult to remove from the tubes.*

Completed Graph:



7. Purple tube 1 cm  
Red tube: 1 cm  
Blue tube: 9 cm

8. The y-intercept is the position of the bubble at time = 0; more simply, it is the initial position of the bubble.

10. The best-fit line for the red tube bubble should be steeper than that of purple tube due to the greater viscosity of the purple-colored oil.

12. The best-fit line for the blue tube bubble should have the same slope as that of the purple tube.

## Constant Velocity Tubes - 4 tube set

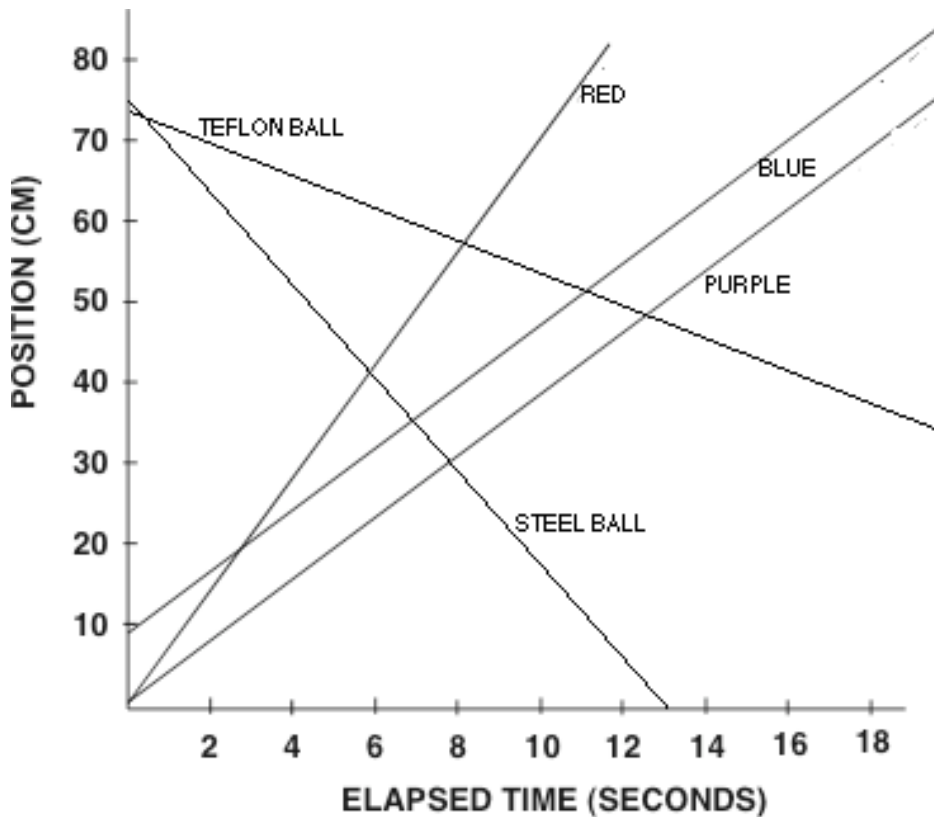
- 13.** This is a good time to take a look at your student(s) graphs and note whether they have properly extrapolated the y-intercept for the blue tube bubble. Many students will “force” their data through the origin, especially since they cannot see beneath the paper that hides it. This gives the instructor an excellent opportunity to discuss the value of extrapolation from graphed data (and the danger of unsubstantiated assumptions!).
- 15.** Answers will vary.
- 16.** 9 cm
- 17.** Answers will vary.
- 18.** Answers will vary.
- 19.** The slopes will vary depending on room temperatures. Typical values might be:
- Purple Tube slope: 3.8 cm/s
- Red Tube Slope: 5.4 cm/s
- Blue Tube Slope: 3.8 cm/s
- 20 a)** Greater slope corresponds to greater speed.
- b)** The dimensional units of the slope are appropriate for speed (velocity).
- c)** The *rise* is the change in position during a time interval, and the *run* is the elapsed time during that time interval. *Rise* divided by *run* equals the *average speed* (velocity).
- 21.** Purple position = 3.8 cm/s • time + 1 cm
- Red position = 5.4 cm/s • time + 1 cm
- blue position = 3.8 cm/s • time + 6 cm
- 22.** position = velocity • time + initial position



## Experiment, Part 2

*Do not cover any part of the colorless transparent tube (containing steel and Teflon balls) with paper.*

Sample Graph:



7. Both best-fit lines have a negative slope, and the line for the steel ball should be steeper. In both cases the origin should be within a centimeter of each other.
8. The slopes (speeds) will vary depending on room temperature. Typical values might be:
  - a) Steel ball:  $-5.54 \text{ cm/s}$
  - b) Teflon ball:  $-1.38 \text{ cm/s}$
9. The negative slopes tell us that the balls are moving downward, because in the reference system we chose, upward was positive.
10. a) Steel ball position =  $-5.54 \text{ cm/s} + 74 \text{ cm}$   
b) Teflon ball position =  $-1.38 \text{ cm/s} + 74 \text{ cm}$

## Constant Velocity Tubes - 4 tube set

11. Again answers will vary depending on room temperature, but typical values might be:

Where: 31 cm.

When: 8 sec.

12. Answers will vary.

13. Answers will vary.

