Name:

2.1 Distance and Length

Question: How do we accurately communicate length and distance?

1 Estimating

a. Look at a meter stick but do not use it to measure anything yet. Imagine holding a meter stick up to your body. Estimate your height in meters. ________________________

b. Use the meter stick to measure your height in meters. How far off was your estimate compared with the actual measurement? Express your answer as a percent of your actual height.

2 Estimate lengths and distances in meters

Use your sense of how long a meter is to estimate the following lengths.

a. The length of your classroom. ________________________

b. The diameter of your pencil's eraser. ________________________

c. The height of your desk or laboratory bench. ________________________

d. The length of a paper clip. ________________________

e. The distance from where you live to this lab or classroom. ________________________

3 Significant digits and measuring length

Measure and record each length using the proper number of significant figures.

1. The length of your classroom. ________________________
2. The diameter of your pencil's eraser. ________________________
3. The height of your desk or laboratory bench. ________________________
4. The length of a paper clip. ________________________
5. The length of your physics textbook. ________________________

4 Analyzing the results

a. Which estimate was closer to the actual measurement, the length of a paper clip or the length of your lab or classroom? Can you think of why?

b. Use a map to estimate the distance from your school or lab to your home. Next time you travel from your home to school, use the car's (or bicycle's) odometer to measure the distance. Compare the measurement with your estimate.

5 Area

a. Calculate the area of one side of a sheet of paper in square inches.

b. Convert the length and width measurements from inches to meters.

c. Calculate the area in square meters.
Hint: The answer is much less than 1 m^2.

d. Estimate the area of the floor of your lab or classroom.

e. How many sheets of paper would it take to cover the floor of your lab or classroom? Explain how you arrived at your estimate, and show any calculations you made.

6 Volume

a. How many liters fit in a cube that is 30 centimeters on a side?

b. Calculate the volume of a cylinder that has a radius of 4 centimeters and a height of 20 centimeters. The volume of a cylinder is approximately 3.14 × radius × radius × height. This relationship is often written $V = \pi r^2 h$. How many liters fit in this cylinder?

7 Volume by experiment

a. Calculate the height of a cylinder that has a radius (r) of 4 centimeters and a volume of 1,000 cm^3. (Hint: The volume of a cylinder is $\pi r^2 h$.)

b. How close did 1 liter of sand come to matching the height required to make a volume of 1,000 cm^3?

Extra space for notes and performing calculations:

Name:

2.2 Time

Question: How do we measure and describe time?

1 Using the Timer as a stopwatch

There are no questions to answer in Part 1.

2 Mixed units for time

a. Arrange the following three time intervals from shortest to longest:

1) 4 hours, 23 minutes and 15 seconds (4:23:15) 2) 250 minutes 3) 16,000 seconds

3 Using the photogates

a. Exactly what action do you take to start and stop the Timer? Be very specific in your answer. Someone who has never seen the photogate before should be able to read your answer and know what to do with the light beam to make the Timer start, and what to do to make it stop.

b. If you block the light beam several times in a row, does the Timer add each new measurement to the last one or does it start at zero every time you break the beam? Your answer should provide observations that back up what you say.

4 Using the Timer with two photogates

a. What starts and stops the Timer when *only* the "A" light is on?

b. What starts and stops the Timer when *only* the "B" light is on?

c. What starts and stops the Timer when *both* "A" and "B" lights are on?

d. Does the Timer still make measurements when there are no lights on?

e. What happens if you go though photogate A once and through photogate B multiple times? When answering this question, you might want to think about a race where all the runners start together but you want each runner's individual time for finishing the race.

5 Accuracy, resolution and precision

a. *Resolution* means the smallest interval that can be measured. Try using one photogate to determine the resolution of the Timer. Give your answer in seconds and tell how your observations support your answer.

b. The word *accuracy* refers to how close a measurement is to the true value. Which of the following statements best describes what you know about the accuracy of time measurements made with the photogates? Give a reason for your answer.

1. The Timer is accurate to 0.001 seconds.
2. The Timer is accurate to 0.0001 seconds.
3. It is impossible to know the accuracy without more information on how the Timer determines one second.
4. A time of 0.0231 seconds is more accurate than a time of 26 seconds.

c. The word *precision* describes how closely repeated measurements of *the same quantity* can be made. When measurements are very precise, they are close to the same value. For example, an ordinary clock (with hands) can determine the time to a precision of about a second. That means many people reading the same clock at the same time will read times that are within a second of each other. It is possible to be precise but not accurate. Which is likely to be more precise: time measurements made with a stopwatch or measurements made with photogates?

Extra space for notes and performing calculations:

Name:

2.3 Mass, Matter, and the Atom

Question: How is mass described?

1 Estimating mass

a. Pick up a full (1 liter) bottle of soda to get a sense of the amount of mass in a kilogram. Next, pick up a book such as your textbook. Use the comparison to estimate the mass of the book in kilograms.

____

2 Estimate the mass of each object:

Estimate the mass of the following objects in kilograms:

a. Your pencil. ______________________

b. Your shoe. ______________________

c. A cement block. ______________________

d. Yourself. ______________________

e. An automobile. ______________________

f. A paper clip. ______________________

3 Measuring Mass

a. Use the appropriate measuring device to measure the mass in kilograms of each object below:

Your pencil. ______________________

Your shoe. ______________________

A cement block. ______________________

Yourself. ______________________

An automobile. ______________________

A paper clip. ______________________

4 Scientific notation

a. Rewrite your estimates from 2a - 2f using scientific notation.

Your pencil. ______________________

Your shoe. ______________________

A cement block. ______________________

Yourself. ______________________

An automobile. ______________________

A paper clip. ______________________

a. Look up or estimate the mass of each of these objects and write it both using scientific notation and as a decimal (ordinary) number. *It is difficult to write some of the masses as decimal (ordinary) numbers*.

a An atom of hydrogen. ______________________

b An atom of uranium. ______________________

c A grain of sand. ______________________

d The space shuttle. ______________________

e An official professional soccer ball. ______________________

f The planet Earth. ______________________

Name:

3.1 Speed

Question: What is speed and how is it measured?

1 Calculating the speed of the rolling ball

Table 1: Speed, Distance, and Time Data

Distance from A to B	Time from A to B (sec)	Speed
(feet)		(ft/sec)
(centimeters)		(cm/sec)
(inches)		(in/sec)
(meters)		(m/sec)

a. Calculate the speed of the ball in ft/sec, cm/sec, in/sec, and m/sec, and write the results in the table.

b. Which is the fastest speed of the four or are they all the same speed?

c. Is it possible that a speed of 254 and a speed of 100 could be the same speed? Explain your answer, and and state why a speed as "254" is not a very good answer.

2 Relationships between distance, speed, and time

There are no questions to answer in Part 2.

3 Setting up a controlled speed

Distance between photogates (m):

Required time from A to B (calculated, sec):

Actual time from A to B (measured, sec):

Actual speed (calculated, m/sec):

a. How did you make the time between photogates longer?

b. How did you make the time between photogates shorter?

c. Calculate the percent difference between your measured speed and 1 meter per second.

Name:

3.2 Observations of Motion

Question: Can you predict the speed of a ball rolling down a ramp?

1 Setting up an experiment

a. Look around the class and note which hole each group is using for its track. With your group, make a prediction as to which track will have the fastest ball.

b. Roll the ball down the track and record the time it takes to go from photogate A to photogate B.

c. Compare your results with other groups'. Did the times that everyone measured agree with your hypothesis about how the angle of the track would affect the ball's speed? Why or why not?

d. Is there a better way to test whether increasing the ramp angle makes the ball go faster? Explain how you would redo this experiment so the results make sense.

2 Variables in an experiment

a. What variables may affect the time it takes the ball to get from photogate A to photogate B? Use Table 1 to list all the variables discussed by your group, or by the class.

Table 1: Variables that affect the time between photogates

Variable	Variable

3 Doing a controlled experiment

Table 2: Variables and values for a controlled experiment

Variable	Value	Variable	Value

Once you have your new results, compare them with the results of the other groups.

a. Did your times agree with your hypothesis of how they would change with the angle of the track?

b. In one or two sentences describe why this experiment was better or worse than your first experiment. Your answer should discuss the cause-and-effect relationships and variables.

c. It is often easy to confuse cause and effect. When we see something happen, we think up a reason for it happening but we do not always get the right reason. If you drop a piece of paper and a steel weight at the same time, which one hits the ground first? If the paper is flat, the steel weight always hits first. Why does the steel weight hit first? Is it because heavier objects fall faster, or is there another reason? In your answer, give at least one other reason a steel weight might fall faster than a flat sheet of paper.

4 Finding the speed of the ball at different points along the track

Table 3: Speed, position, and time data

Position of photogate A (cm) from top of track	Time from photogate A (sec)	Distance traveled by the ball (1.9 cm)	Speed of the ball (cm/sec)

5 Graphing and analyzing the results

a. Do you notice a trend in your measurements? Does the speed of the ball change as it moves down?

b. Graph the speed of the ball versus its position. Place speed of the ball on the *y*-axis and position of photogate A on the *x*-axis. Add labels to each axis and title the graph.

Title: ____________________

y label: ____________________

x label: ____________________

c. What does the graph show about the speed of the ball?

6 Using your graph to predict the speed of the ball

a. Choose a spot on the track where you *did not* measure the speed of the ball.

b. Use your graph to find the predicted speed of the ball at that position. Record your predicted speed.

c. Use the speed formula to calculate the time it should take the ball to pass through the light beam at the predicted speed. For example, if the ball were going 100 centimeters per second, it would take.0190 seconds to pass through the beam (1.9 cm ÷ 100 cm/sec = .0190 sec).

d. Place the photogate at the spot on the track you chose in step (a) and record the time it takes for the ball to pass through the photogate.

e. How does the predicted time compare with the actual measured time? What does this tell you about your experiment and measurements?

7 Calculating percent error

a. Find the difference between the predicted time and the actual measured time.

Predicted time – Actual time = Difference

b. Take this difference and divide it by the predicted speed and then multiply by 100.

(Difference ÷ Predicted time) × 100 = Percent error

c. Use the percent error to calculate percent correct.

100 – Percent error = Percent correct

Name:

3.3 Analyzing Motion with Graphs

Question: How do you model motion?

1 Setting up the experiment

a. Suppose the ball takes a longer time to pass through photogate B compared with photogate A. Should you raise or lower the catcher end to bring the times closer together?

b. After you get the track as level as you can, calculate the speed of the ball as it passes through each photogate. Remember, speed is the diameter (1.9 centimeters) divided by the time through the photogate. How close are the two speeds? Express your answer as a percentage of the speed through photogate A. For example, the speed at B might be 1 percent slower than the speed at A.

2 Measuring the motion of the ball

Record the data in Table 1.

3 Recording your data in Table 1

Table 1: Position, Speed, and Time Data

x (cm)	t_{AB} (sec)	t_A (sec)	t_B (sec)	v_A (cm/sec)	v_B (cm/sec)

4 Graphing and analyzing your data

a. Make a position versus time graph using your data. Plot the time from A to B on the *x*-axis and the position from A to B (position of photogate B) on the *y*-axis. At this point, do not connect the data points on the graph. Be sure to label the axes and title the graph.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Is the graph a straight line or a curve?

____

c. Does the graph get steeper as the ball rolls farther, or does the graph keep the same slope the whole way? What does your answer tell you about the speed of the ball at different times as it rolls along the track?

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____

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d. Draw a triangle on your graph and determine the rise and run from the triangle (see diagram). Calculate the speed from the slope of the graph. Is the value you get consistent with other speed measurements you have made with the ball and track?

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5 The speed versus time graph

a. Make a graph of speed versus time. Speed should be the speed at photogate B (v_B) since photogate B was the one that moved. Time should be the time from A to B (t_{AB}). Put speed on the *y*-axis since it is the dependent variable. Time goes on the *x*-axis because it is the independent variable.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Describe the graph; does it slope up or down? Is it level or nearly level? Is it a line or a curve?

____

c. Remember, the distance traveled is the product of speed and time. Think about a rectangle drawn on the speed versus time graph. The width of the rectangle is the time. The height of the rectangle is the speed. Since *area* is width × height, the area on the speed versus time graph is the distance traveled.

Pick two times that correspond to measurements that are not right next to each other. Draw the rectangle that lies between the *x*-axis, the line showing speed, and the two times you chose. Calculate the area of the rectangle. It should be the same as the distance between the two positions of photogate B.

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____

Extra space for notes and performing calculations:

Name:

4.1 Acceleration

Question: How is the speed of the ball changing?

1 Setting up

Table 1: Acceleration Data

	Trial 1	Trial 2	Trial 3
t_A: time through A (sec)			
t_B: time through B (sec)			
t_{AB}: time A to B (sec)			
v_A: speed at A (sec)			
v_B: speed at B (sec)			
a: acceleration (sec)			

2 Looking at the data

a. If you moved the photogates to different places, the speeds for each of the three trials should be different from each other. Are the accelerations different? If so, by how much are they different between the three trials?

b. What would the acceleration be if you pushed the ball at the start? Would you expect it to be greater, less, or about the same compared with the acceleration you measured without pushing? Answer the question and then try it. You can give the ball a small push by rolling lightly with your finger at the start.
NOTE: Measure the acceleration a distance away from the start, so your finger does not get in the way.

c. Propose at least one way to *increase* the acceleration of the ball on the track.

3 The speed versus time graph

Record the data in Table 1.

4 Recording position, speed, and time data in Table 2

Table 2: Position, speed, and time data

x (cm)	t_{AB} (sec)	t_A (sec)	t_B (sec)	v_A (cm/sec)	v_B (cm/sec)

5 Graphing speed versus time

a. Make a speed versus time graph. Plot the speed at photogate B on the y-axis. Plot the time from A to B on the x-axis.

Title: ______________________________

y label: ______________________

x label: ______________________________

b. Is your graph a straight line or a curve?

c. The place on the speed versus time graph where the line crosses the *y*-axis is called the *y*-intercept. The *y*-intercept represents something about the ball. What does the *y*-intercept of your speed versus time graph represent? (Hint: The *y*-axis is speed.)

d. Does the ball accelerate as it rolls down the track? Justify your answer. Remember that acceleration is defined as a change in speed over time.

6 Calculating acceleration from the slope of the line

a. Using your speed versus time graph, calculate the acceleration of the ball from the slope of the line.

b. How does the acceleration from the slope compare with the acceleration you calculated from the times in Part 1 of the Investigation?

c. Is the acceleration of the ball changing as it moves down the track? Explain your answer using what you know about the slope of a straight line.

Extra space for notes and performing calculations:

Name:

4.2 A Model for Accelerated Motion

Question: How do we describe and predict accelerated motion?

1 The equations for accelerated motion in a line

There are no questions to answer in Part 1.

2 Planning the experiment

a. Write down the equations for uniform accelerated motion in one dimension using the following variables. Let:

- t be the time since the ball passed through photogate A (t_{AB}).
- x_0 be the position of the ball at time $t = 0$ *(at photogate A)*.
- v_0 be the speed of the ball at time $t = 0$ *(speed at photogate A)*.
- v be the speed at time t *(speed at photogate B)*.
- x be the position of the ball at time t *(position of photogate B)*.
- a be the acceleration of the rolling ball.

b. Derive an equation for the acceleration of the ball in terms of the three times (t_A, t_B, t_{AB}) and the diameter of the ball (d_B). These are all quantities you can measure directly.

3 Doing the experiment

Table 1: Experimental data

Initial position (x_0, m)	Position (x, m)	Time through gate A (t_A, sec)	Time through gate B (t_B, sec)	Time from A to B (t_{AB}, sec)	Speed at gate B (v_B, m/sec)

4 Preliminary analysis

a. Use the data from Table 1 to make the speed versus time graph for the ball. Scale the graph so it starts from zero speed and zero time. The time axis (x) should be the time from photogate A to photogate B. The speed axis (y) should be the speed at photogate B.

Title: ______________________________

y label: ____________________

x label: ____________________

b. Use the data from Table 1 to make the position versus time graph for the ball. Scale the graph so it starts from zero position and zero time. The time axis (x) should be the time from photogate A to photogate B. The position axis (y) should be the position of photogate B.

Title: ______________________________

y label: ______________________________

x label: ______________________________

c. The equation of a straight line is often given in the form $y = mx + b$. The variable m is the slope and the variable b is the y-intercept. The speed versus time graph should be a straight line; therefore, the equation should apply. Rewrite the equation for a straight line for the speed versus time graph using appropriate variables from the experiment (v, v_0, x, x_0, t_{AB}, and so on). Make a table that shows how y, m, x, and b correspond to the real experimental variables.

d. From your graph of speed versus time, estimate the initial speed and acceleration.

e. Use your formula derived in Part 2b to calculate the acceleration of the ball for a few different measurements. Compare your calculation with the value you estimated from the graph.

5 Testing the equations

a. Calculate the position of the ball from the equations for uniformly accelerated motion. Use Table 2 for the results of your calculations. You need to use the initial speed, initial position, and acceleration you estimated from the speed versus time graph. Do the calculations for the same times (from A to B) as your measured data.

b. Plot the calculation on the same graph as your measured data for position versus time. You can draw the calculation as a solid line on the graph since the equation predicts the entire curve. The experimental data should be left as unconnected dots.

c. How do your measured positions compare with the positions predicted by the equation?

Table 2: Predicted and measured positions

Time (sec)	Predicted position (x, m)	Measured position (x, m)

d. Use the equation for uniform accelerated motion to calculate how long the track would have to be for the ball to reach a speed of 60 miles per hour.

Extra space for notes and performing calculations:

Name:

4.3 Free Fall and the Acceleration due to Gravity

Question: How do you measure the acceleration of a falling object?

1 Setting up the experiment

There are no questions to answer in Part 1.

2 A technique for dropping the ball from the right place

There are no questions to answer in Part 2.

3 Determining g from experiment

There are no questions to answer in Part 3.

4 Measuring data to determine g

Table 1: Time and distance data

h (m)	Time, t_A (sec)	Time, t_B (sec)	Time, t_{AB} (sec)

5 Analyzing the data

Table 2: Calculation of g

Iteration	g (m/sec^2)	v_0 (m/sec)	Formula to use
1			equation 2
2			equation 3
			equation 1
3			equation 3
			equation 1

a. Use the formula for distance traveled in free fall to derive equations 1, 2, and 3.

____

____

b. Describe how the values for g change in successive iterations of the calculation.

____

____

____

____

c. Make a graph showing each intermediate value of g on the y-axis and the iteration number on the x-axis.

Title: ____

y label: ______________

x label: ______________________________

What does the graph show you about the calculation?

____

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____

d. If you kept going with more iterations of the calculation would the value of g keep getting more and more accurate? Explain why or why not.

e. Repeat the calculation for at least two more sets of data (trials). Calculate the average value for *g* for all three trials. Calculate the percent difference between your average value and the published value of 9.82 m/sec^2. How does your result compare to the accepted value?

f. Which variable do you think has the largest uncertainty among the quantities you measured in the experiment? Why do you think so?

6 Free fall and mass

a. How does the value of g compare for the steel and plastic balls

b. Explain any differences you find in part (a) if any.