Name____Section______________Date__________

Experiment 1: Graphing

Introduction

The purpose of this introductory laboratory exercise is to gain experience in gathering and displaying data from a simple experiment. Refer to figure 1.1 for terminology used when discussing a graph and see appendix I for a detailed discussion about the terms.

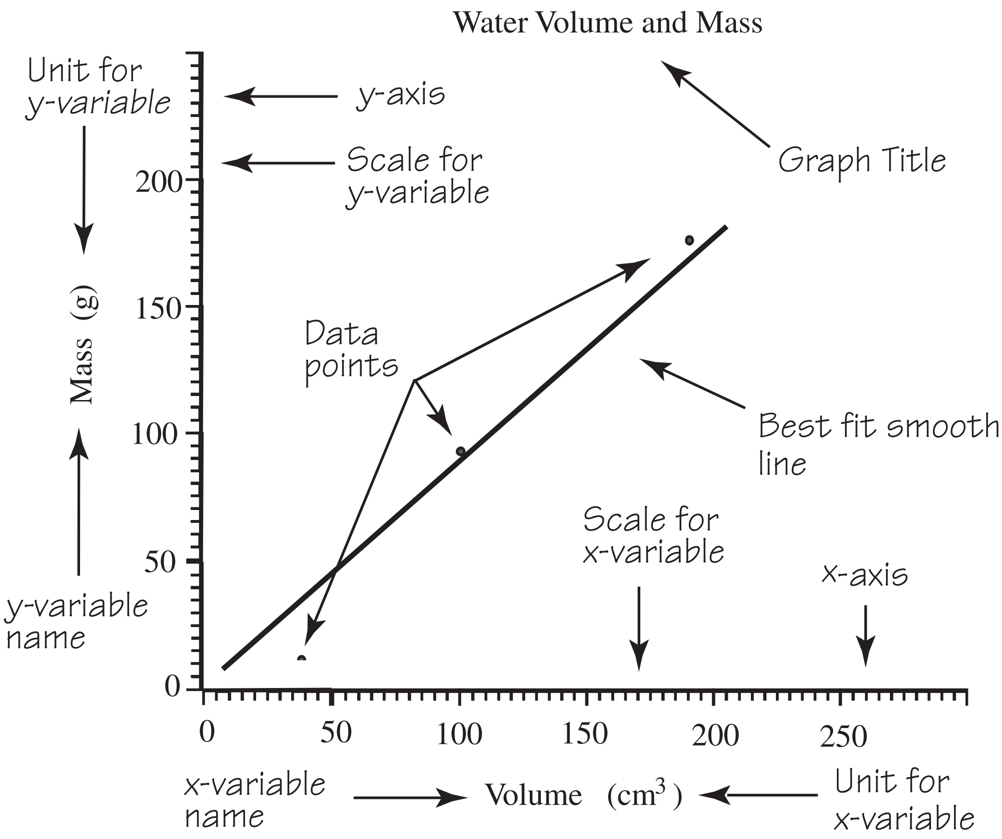

Figure 1.1

Procedure

1. Position a meterstick vertically on a flat surface, such as a wall or the side of a lab bench. Be sure the metric scale of the meterstick is on the outside and secure the meterstick to the wall or lab bench with two strips of masking tape.

2. Drop a ball as close as possible to the meterstick and measure (a) the height dropped, and (b) the resulting height bounced. Repeat this for five different heights dropped and record all data in Data Table 1.1 on page 6. In the data table, identify the *independent* (manipulated) variable and the *dependent* (responding) variable.

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3. Use the graph paper on page 9 to make a graph of the data in Data Table 1.1, being sure to follow all the rules of graphing (see appendix I on page 395 for help). Title the graph, “Single Measurement Bounce Height as a Function of Height Dropped.”

4. After constructing the graph, but before continuing with this laboratory investigation, answer the following questions:

   (a) What decisions did you have to make about how you conducted the ball-dropping investigation?

   ✓ *Must measure the height of the ball to the bottom of the ball, not to the top or center.*

   ✓ *Larger initial heights are better - more time to react.*

   ✓ *Must be sure not to give the ball any initial velocity.*

   ✓ *Better to make the height measurements away from the device so you can look almost horizontally at the height.*

   (b) Would you obtain the exact same result if you dropped the ball from the same height several times? Explain.

No, not exactly. Not only do you have to worry about the things mentioned in (a), but the ball does not bounce the same every time. A different amount of energy will be lost each time.

   (c) Did you make a dot–to–dot line connecting the data points on your graph? Why or why not?

You should try to draw a smooth curve that best represents the data. A dot-to-dot line assumes that each value is 100 percent correct. This is not possible. A smooth curve tends to average out the errors.

   (d) Could you use your graph to obtain a predictable result for dropping the ball from different heights? Explain why you could or could not.

The graph should help you predict the bounced height relatively well. It will vary with different types of balls. In general, your predictions will be within 5-10 percent of the measured value, with the averaged data being better than the single measurement data.

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(e) What is the significance of the origin on the graph of this data? Did you use the origin as a data point? Why or why not?

The origin should be a data point in this case because the ball will not bounce if it is not dropped.

5. Make five more measurements for each of the previous five *height-dropped* levels. Find the *average height bounced* for each level and record the data and the average values in Data Table 1.2 on page 6.

6. Make a new graph of the *average height bounced* for each level that the ball was dropped. Draw a *straight best fit line* that *includes the origin* by considering the general trend of the data points. Draw the straight line as close as possible to as many data points as you can. Try to have about the same number of data points on both sides of the straight line. Title this graph, "Averaged Bounce Height."

7. Compare how well both graphs, "Single Measurement Bounce Height" and "Averaged Bounce Height," predict the heights that the ball will bounce for *heights dropped* that were not tried previously. Locate an untried height-dropped distance on the straight line, then use the corresponding value on the scale for height bounced as a prediction. Test predictions by noting several different heights, then measuring the actual heights bounced. Record your predictions and the actual experimental results in Data Table 1.3 on page 7.

8. Use a new, *different kind of ball* and investigate the bounce of this different ball. Record your single-measurement data for this different ball in Data Table 1.4. Record the averaged data for the height of the bounce for the five levels of dropping in Data Table 1.5. Repeat procedure step 7 for the different kind of ball. Record your predictions and the actual results in Data Table 1.6 on page 8.

9. Graph the results of the different kind of ball investigations onto the two previous graphs. Be sure to distinguish between sets of data points and lines by using different kinds of marks. Explain the meaning of the different marks in a *key* on the graph.

10. What does the steepness (slope) of the lines tell you about the bounce of the different balls?

The larger the slope, the bouncier the ball (less energy is lost during the collision with the floor).

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Results

1. Describe the possible sources of error in this experiment.

✓ *Difficulty in measuring the height (both height dropped and height bounced).*

✓ *Not dropping the ball from rest.*

2. Describe at least one way that data concerning two variables is modified to reduce errors in order to show general trends or patterns.

✓ *Take several readings of the same data point and take an average. This helps eliminate random errors.*

✓ *Use a graph and draw a smooth curve to get the general relationship between the two variables.*

3. How is a graph modified to show the best approximation of theoretical, error-free relationships between two variables?

Draw a smooth curve to "average out" the errors. If one data point does not seem to follow the general trend, it can be thrown out of consideration and the information should be re-determined.

4. Compare the usefulness of a graph showing (a) exact, precise data points connected dot–to–dot and (b) an approximated straight line that has about the same number of data points on both sides of the line.

The approximated straight line can be used to predict values that have not been measured. The dot-to-dot line does not give you any information about those points in between that aren't actual data points.

5. Was the purpose of this lab accomplished? Why or why not? (Your answer to this question should be reasonable and make sense, showing thoughtful analysis and careful, thorough thinking.)

(Consider whether the student has learned how to use the graph effectively. Have they determined what an impact the graph can have in the physical sciences and how to use their graph to make predictions.)

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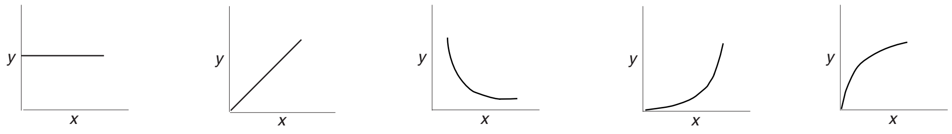
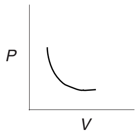
Invitation to Inquiry

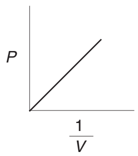
Measurements of variables involved in some physical relationship will often yield a straight line, and this relationship is said to be direct, or *linear*. There are more types of relationships between variables, and most can be identified as producing one of five basic shapes of graphs. These are identified, left to right, as no relationship, linear, inverse, square, and square root.



Data that yields a straight line has a linear relationship and can be described algebraically by the slope-intercept form of an equation, $y = mx + b$ where m is the slope and b is the y intercept. If a graph results in one of the three curves, data can be manipulated to produce a straight-line graph. For example, a graph of the pressure changes of a confined gas that occurs with changes in volume might produce a graph that looks like this:



Since this curve is an inverse relationship, the plot is redone as P vs. 1/V. The graph now looks like this:



As you can see, it now has a straight line that can be described by the slope-intercept equation to describe Boyle's law.

After giving the possibilities some thought, look for relationships that might result in something other than a direct relationship. Make measurements, graph your data, then decide which of the five shapes the graph resembles. If the data results in one of the curves, try manipulating the data to generate a straight-line graph. For example, obtain a toy dart gun and dart. Vary the weight of the dart by taping small masses to the dart, then measure the height the dart is propelled. What is the relationship between the weight of a dart and the height it is propelled? What is the shape of a graph comparing the weight and height and what does this mean about the relationship?

What other relationships can you find in the lab, outside, or between any two variables in everyday occurrences? Can you find an example of each of the five shapes of graphs?

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Data Table 1.1 Single Measurement Data: 1st Ball		
Trial	Height Dropped independent variable	Height Bounced dependent variable
1	30 cm	21 cm
2	40 cm	28 cm
3	60 cm	44 cm
4	80 cm	60 cm
5	100 cm	72 cm

Data Table 1.2 Averaged Bounce Data: 1st Ball						
	Bounce Height					
Dropped Height	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
30 cm	20 cm	21 cm	23 cm	24 cm	22 cm	22 cm
40 cm	26 cm	30 cm	28 cm	29 cm	26 cm	28 cm
60 cm	42 cm	45 cm	43 cm	44 cm	42 cm	43 cm
80 cm	58 cm	59 cm	60 cm	60 cm	58 cm	59 cm
100 cm	72 cm	73 cm	75 cm	76 cm	74 cm	73 cm

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Data Table 1.3	Predictions and Results: 1st Ball					
Trial	Single Measurement Data			Averaged Data		
	Dropped Height	Predicted Bounce	Measured Bounce	Dropped Height	Predicted Bounce	Measured Bounce
1	60 cm	29 cm	28 cm	60 cm	28 cm	28 cm
2	70 cm	51 cm	49 cm	70 cm	50 cm	49 cm
3	90 cm	66 cm	65 cm	90 cm	66 cm	65 cm

Data Table 1.4	Single Measurement Data: 2nd Ball	
Trial	Height Dropped *independent* variable	Height Bounced *dependent* variable
1	30 cm	24 cm
2	40 cm	32 cm
3	60 cm	49 cm
4	80 cm	66 cm
5	100 cm	77 cm

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Data Table 1.5	Averaged Bounce Data: 2nd Ball					
	Bounce Height					
30 cm	28 cm	24 cm	26 cm	27 cm	26 cm	26 cm
40 cm	35 cm	34 cm	30 cm	31 cm	32 cm	32 cm
60 cm	47 cm	47 cm	50 cm	49 cm	47 cm	48 cm
80 cm	65 cm	62 cm	65 cm	65 cm	63 cm	64 cm
100 cm	80 cm	78 cm	79 cm	80 cm	78 cm	79 cm

Data Table 1.6	Predictions and Results: 2nd Ball					
Trial	Single Measurement Data			Averaged Data		
	Dropped Height	Predicted Bounce	Measured Bounce	Dropped Height	Predicted Bounce	Measured Bounce
1	50 cm	41 cm	40 cm	50 cm	40 cm	40 cm
2	70 cm	56 cm	57 cm	70 cm	56 cm	57 cm
3	90 cm	72 cm	73 cm	90 cm	72 cm	73 cm

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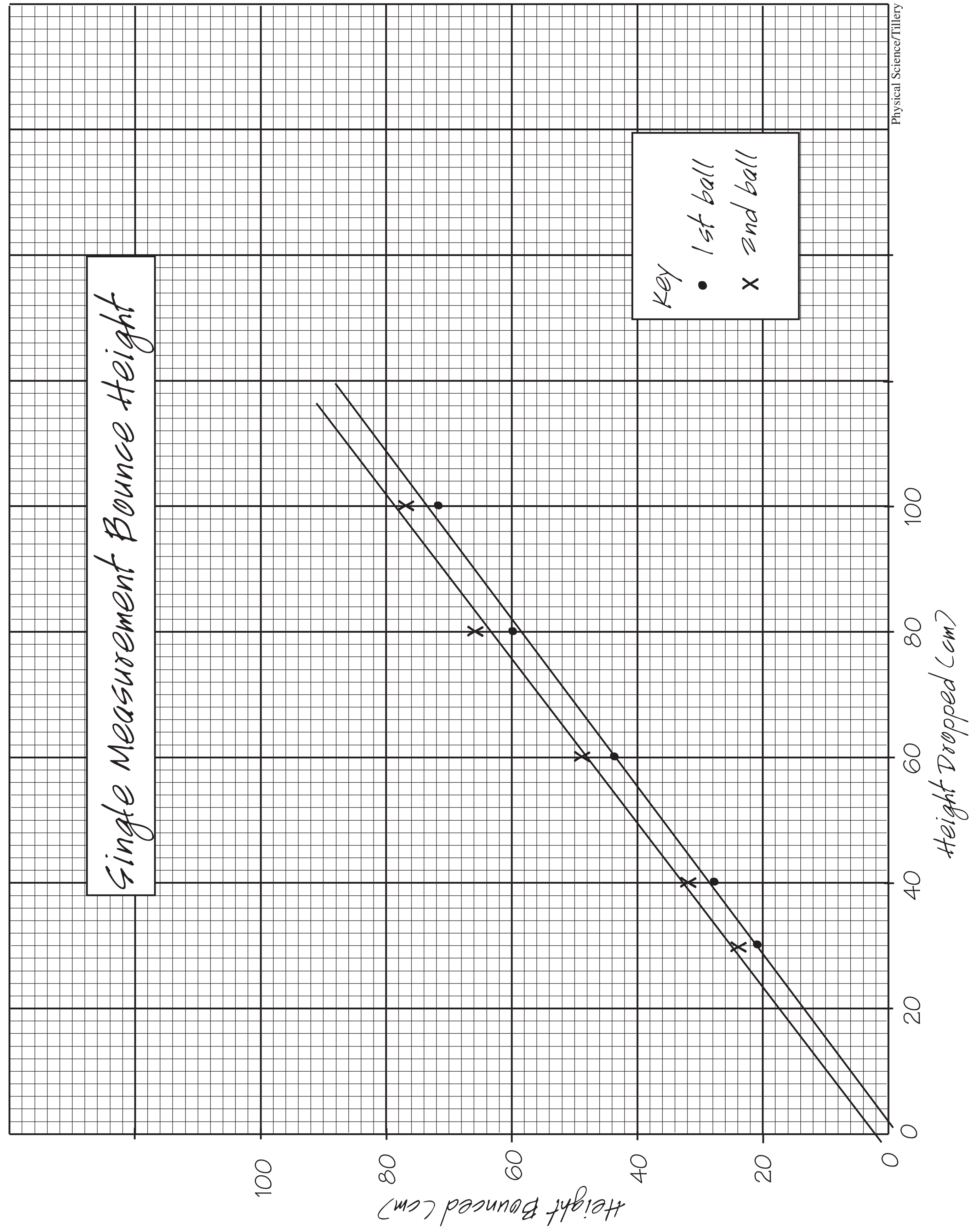

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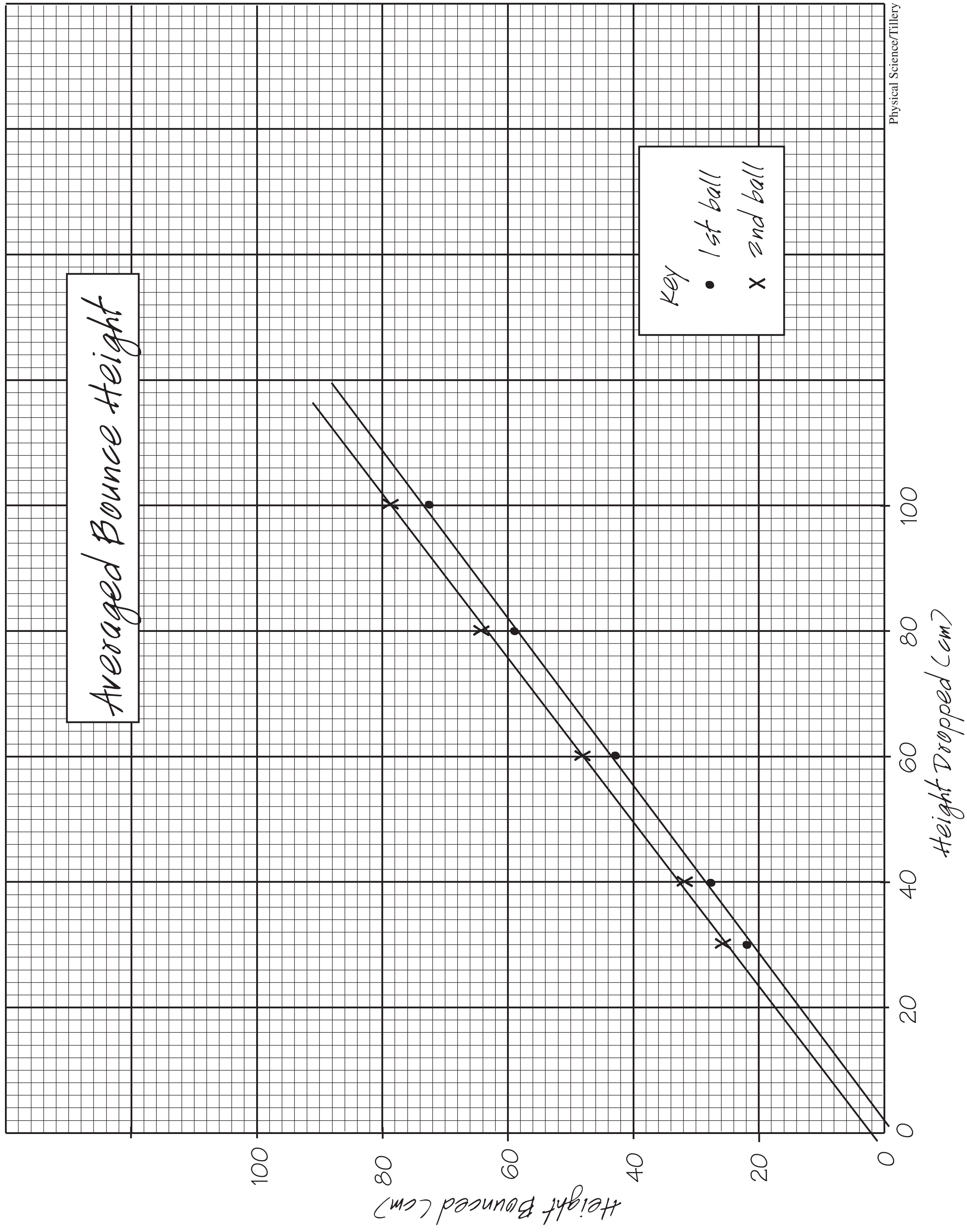

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An extra sheet of graph paper

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