How Do You Weigh Up?

Summary

In this activity, students will build a simple scale using springs or similar materials, such as rubber bands. Once assembled, students will develop a calibration curve, then validate the accuracy of their scale.

After completing this activity, students should be able to:

- Explain how a spring scale works.
- Describe the relationship between the deformation of an elastic material due to an applied load.
- Develop and use a mathematical model and graphical representation of data.
- Apply the engineering design process.

South Carolina Academic Standards

This activity can be adjusted as appropriate to meet the needs of teachers in different grade levels.

This activity maps to the following South Carolina standards for Science:

- Science and Engineering Practices (grades 6-8)
- Forces and Motion (grade 8)

This activity maps to the following South Carolina standards for Mathematics:

- The Number System (grades 6-8)
- Ratios and Proportional Relationships (grades 6-7)
- Expressions, Equations, and Inequalities (grades 6-8)
- Data Analysis, Statistics, and Probability (grades 6-8)
- Functions (grade 8)

This activity can also map to the following South Carolina standards for English Language Arts:

- Inquiry-Based Literacy Standards
- Writing Standards
- Communication Standards
- Disciplinary Literacy

Setting the Stage

Before the students start working, initiate discussion about the topic using some of the following open-ended questions.

1. What do we use scales for? What does a scale measure?
2. Where do you commonly see scales?
3. What are some different types of scales?
4. Why are scales important?
5. How does spring scale work?
6. Draw a picture of a spring scale.
7. Where have you seen a spring scale?
8. What is the difference between mass and weight?

Materials

- Stand (or wooden craft sticks taped together or a piece of rigid material)
- Rubber bands (or springs)
- S-hooks (or paper clips)
- Sample cup with handle (or paper cup with a string handle)
- Loose material to weigh (sand, rocks, marbles, etc.)
- Empty container
- Ruler
- Digital scale

Test Procedure

Test Set-up

1. Assemble your scale set up as shown in Figure 1.

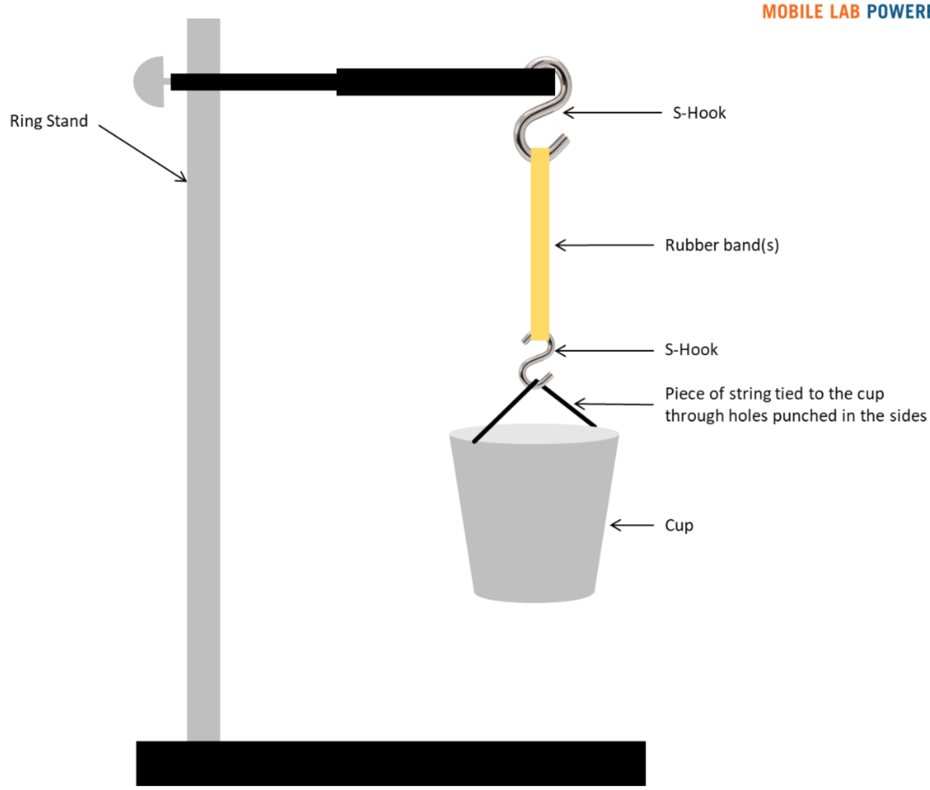

Figure 1. Scale set-up

Data Collection

1. Measure the length of the rubber band (in mm) with no load in the cup. Record this value in the first line of your data table (mass = 0 g).
2. Use the digital scale to measure out 50 g of material (sand, marbles, rocks, etc.).
    a. Place an empty paper cup on the scale and press the "Tare or Zero" button. The scale should read "0 g" with the empty cup on the scale.
    b. Add 50 g of material to the empty cup.
3. Place this 50 g of material into the cup hanging from your scale. Be careful that all of the material you measured makes it into the scale cup.
4. Measure the length of the rubber band in mm.
5. Record the total mass in your scale cup and the length of the rubber band on Data Table 1.
6. Repeat steps 2-5 (50 g increments) until you can't fit any more material in your scale cup.

Development of the Calibration Curve

1. Plot the mass vs. length data points on the Graph 1.
    a. Which is the independent variable and which is the dependent variable?
    b. Label your axes appropriately.
    c. Use as much of the graphing area as you can.
2. Draw a best-fit curve (or line) through the data points.
3. If the curve is linear, you can determine the equation for the line.

Validate your Scale

1. Select several objects with masses spanning the range that you used to calibrate your scale, but not exceeding the maximum mass. Be sure the objects will fit in your scale cup.
2. Place each object in the scale up and measure the length of the rubber band. Record the length in Data Table 2.
3. Using your calibration curve, determine what the mass of each object is based on the length of the rubber band. Record this as the predicted mass in Data Table 2.
4. Use the digital scale to measure the actual mass of each object and record the measured masses on Data Table 2.
5. Plot the measured mass vs. the rubber band length for each object as an "X" on Graph 1.
   a. What does this mean?
   b. Do these data points fall on the line you have drawn? Why or why not?
6. Calculate the percent error for each object and record this in Data Table 2.
7. Plot the mass vs. the percent error on Graph 2.
   a. Is the percent error consistent across your range of masses?
   b. Is your scale more accurate for lighter or heavier objects?
   c. Why do you think this is?

Calculations

Equation for a Line

$$y = mx + b$$

y = length, mm
x = weight, g
m = slope (or spring constant), g/mm
b = y-intercept (or length of the rubber band with no material in the cup), mm

To calculate the slope, select two points on the line (points 1 and 2).

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

y_1 = length of point 1, mm
y_2 = length of point 2, mm
x_1 = weight of point 1, g
x_2 = weight of point 2, g

Percent Error

$$Percent\ Error = \frac{|Predicted\ Weight - Measured\ Weight|}{Measured\ Weight} \times 100\%$$

Follow-up Questions

1. How does a spring scale work?
2. What are the sources of error in your experimentation?
3. How can you reduce the percent error of your scale?
4. What you change about your scale if you needed to measure a larger mass, say 2000 g?
5. What are some other applications where you could use the process of calibration and validation?

Vocabulary

- **Accuracy** – level of correctness.
- **Calibrate** – to determine or check the graduation of an instrument giving measurements.
- **Deformation** – change of form; distortion.
- **Elasticity** – property of a substance that enables it to change its length, volume, or shape in response to a force, but return to is original dimensions when the load is removed.
- **Error** –difference between an observed value and the true value of a quantity.
- **Mass** – the quantity of matter as determined from its weight.
- **Validate** – to confirm.
- **Weight** – the force that gravity exerts on an object, equal to the mass of the object times the acceleration of gravity.

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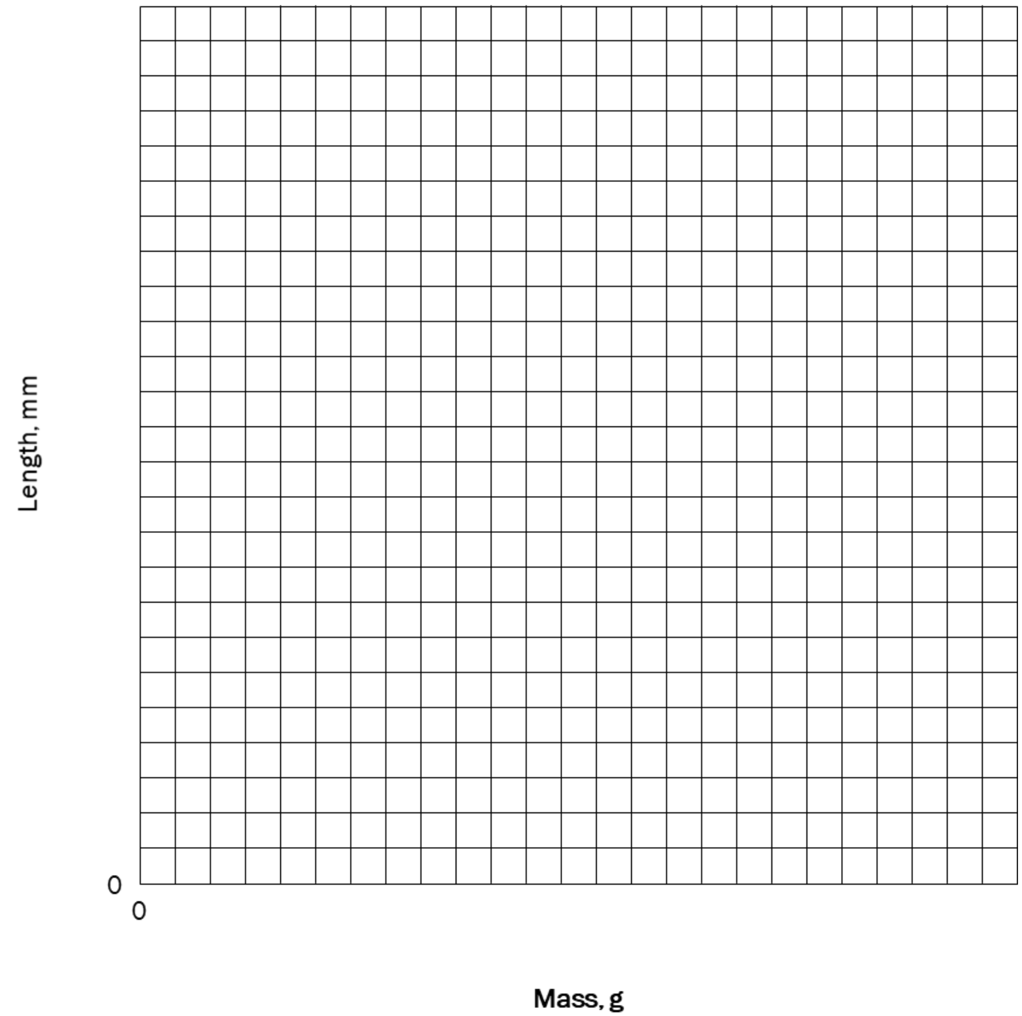
Engineer's Notebook

Engineer's Name: ______________________________ Date: ______________

Data Table 1

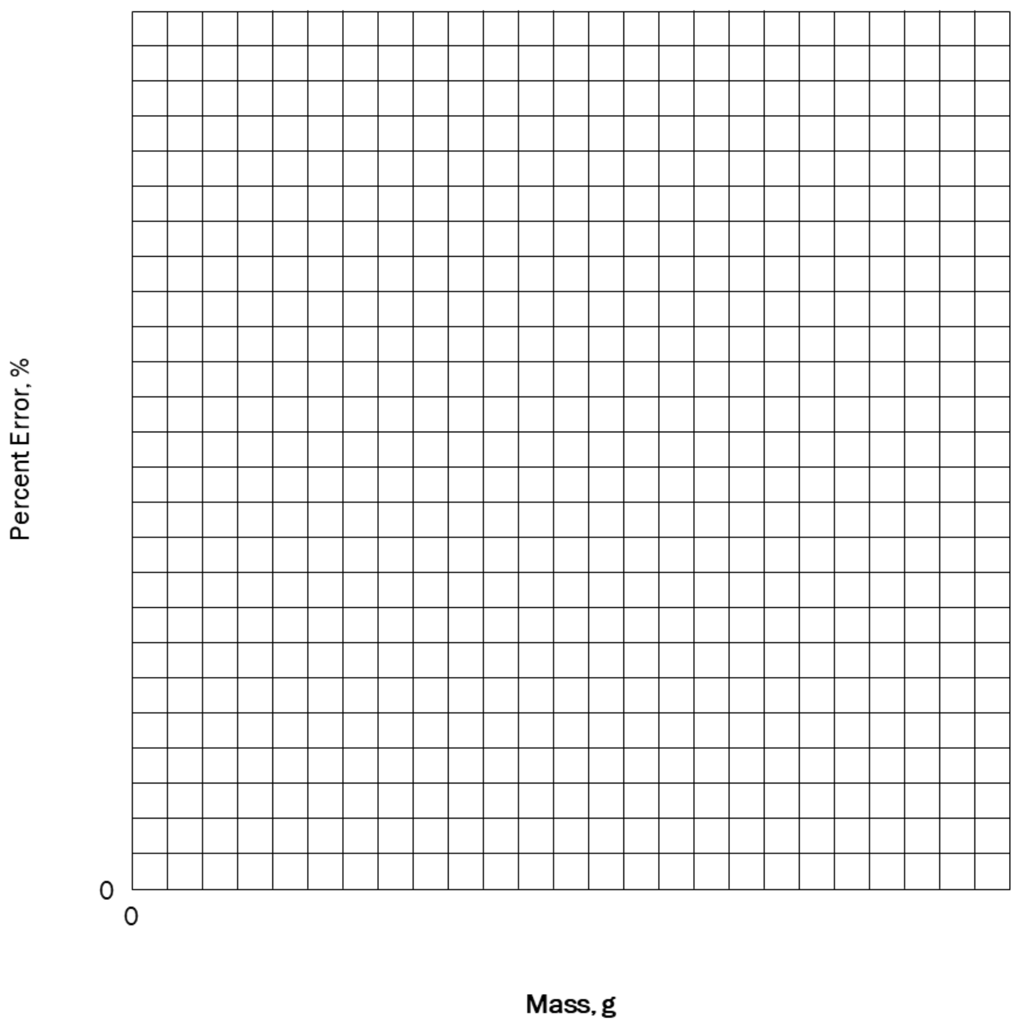
Mass [g]	Length of Rubber Band [mm]
0	



Graph 1: Scale calibration curve

Data Table 2

Object Description	Length of Rubber Band [mm]	Predicted Mass [g]	Measured Mass [g]	Percent Error [%]



Graph 2: Scale accuracy (mass vs. percent error)