MSET Demonstration Package

Calibration

Mentis Sciences Education Toolkit Vision and Development History

Located in the historic Mill District of downtown Manchester, Mentis Sciences is an engineering firm which provides advanced material design and manufacturing capabilities to Department of Defense customers. Mentis specializes in the design, development and testing of advanced composite materials with a goal of providing unique flexibility, rapid development and prototyping for various composite applications.

Mentis Sciences, Inc. was founded in 1996 by John F. Dignam, following more than thirty years of service at the Army Materials Research Lab, where he served as the Director of Missile Materials. John F. Dignam spent most of his lifetime promoting national security and developing the most effective material systems to aid in countering global threats. He founded Mentis Sciences to continue promoting innovation, expertise, and emerging materials and manufacturing technologies, that will enhance U.S. security and promote economic growth.

His legacy continues under the strong and visionary leadership of John J. Dignam, who brings unique and innovative technical expertise to solving some of the nation's most daunting engineering challenges. The core values of ethics, integrity, community service, and commitment to excellence instilled by John F. Dignam live on with John J. Dignam and the Mentis team, and are apparent in every aspect of the company's structure, personality, and operations.

Mentis Sciences Internship Program recruits local high school students in good academic standing who reside in the HUBZone area of Manchester, NH. Successful youth with good attitudes and high motivation to work and learn have come through various avenues including non-traditional avenues like the Manchester Police Athletic League, The Salvation Army, and Manchester's Office of Youth Services.

Mentis makes a serious commitment of its resources to support the internship program by providing short courses in STEM related disciplines, student engineering activities and mentoring activities. In result of these courses, Mentis Sciences started to see a gap in STEM education. Biology and Life Science concepts were often the focus of science in the classroom, technology often included a smartphone app and engineering was nonexistent. Our interns and every student deserve to be introduced to STEM concepts with tools and resources that allow them to experience concepts hands-on and in a collaborative environment.

With this vision for our students, Mentis transferred skills used in their own manufacturing facility every day and descaled the concepts and tests into one integrated unit. Mentis has developed an integrated STEM toolkit that configures to complete 40 STEM tests. With limited lab space and budgets for lab testing equipment being tight, the Mentis Sciences Engineering Toolkit (MSET) departs from the high cost limited functionality of current educational testing systems.

The MSET offers a unique view into the world of material testing and physical science. Data indicates the MSET Program increased student participation in the classroom, interest in STEM careers and opportunities for females in STEM. Students develop a deep understanding in STEM, engineering and physical science concepts.

In many ways, the internship program and new shared vision has provided Mentis employees a new sense of purpose in their work. Mentis is now expanding their vision for the MSET program, beyond their own interns and are offering the MSETs STEM educational opportunities to other schools and educational partners in their community and around the United States.

Mentis believes that every student, no matter their upbringing or education status, should have the opportunity to learn, pursue their dreams and have the high-quality resources to so. This enrichment MSET program has proven to be beneficial, providing life-changing experiences for interns, students, as well as Mentis employees. We are excited to share it with you.

Calibration Introduction

In this unit students will explore the relationship between the load cells and the strain data output due to how the output strain will correlate to a force value. Students will develop the ability to map out a best fit linear curve that will correspond to a more accurate load cell the better the fit of the line is and/or the amount of data points taken along the range of force values of the load cell. The goal of this exercise is to prepare students and apply these concepts in an inquiry-based project where they will learn how variances in a calibrated system can throw off calibration and how the calibration curve can be altered to calibrate the system again.

The materials in this section have been created and organized to assist teachers in the design of lessons that use the MSET equipment and applied inquiry-based projects that are aligned with the Next Generation Science Standards, as well as the Massachusetts Science and Technology/Engineering Curriculum Framework.

Teachers

Teachers should review the Understanding by Design unit plan with particular attention to the Essential Questions students will be expected to answer by the conclusion of the unit. Throughout the lessons and experiences, teachers should assess students' progress toward their capacity answering the essential questions. Finally, teachers should use the rubric to assess students' comprehension and application of the foundational principles associate with the lesson, experiment and materials covered in the unit.

Students

It is assumed that students participating in this unit will have experience in the following areas:

1. The concept of a "linear" response and how that relates to a best fit curve.
2. Basic mechanical skills to configure the MSET based on written and visual instruction.
3. Basic algebra knowledge.
4. Inputting different scale factors for different load cells and realizing the affect they have on the output of load in the software.
5. Basics of how a system is calibrated and the steps that are taken to do so.

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UbD Chart – Calibration

<table>
<tr><th colspan="3">Desired Results</th></tr>
<tr><td rowspan="6">STANDARDS/ESTABLISHED GOALS

<u>Next Generation Science Standards</u>

Engineering Design:
HS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions

Forces and Interactions:
HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion.

<u>Massachusetts State Standards</u>

Technology and Engineering:
HS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions.

HS-ETS3-4(MA). Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to calibrate a load cell and optical encoder to assure that equipment is performing accurately.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…
1. Load cell and optical encoders are used to measure force, as well as, rotational or linear motion.
2. Load cells measure compressive, tensile, torsional, shear and other types of forces.</td><td>ESSENTIAL QUESTIONS

1. What are tensile and shear forces?
2. Why is calibration an important part of engineering and using equipment?
3. How is shear force measured?
4. How is tensile force measured?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…
• The importance of calibration coefficients or “sensitivities”.
• How to apply “sensitivities” across multiple experiments.
• Sensors on load cells are called strain gages.
• Strain gages measure resistance changes that are converted to voltage and amplified.
• Optical encoders measure the movement of an object.
• Photo sensors measure the interruption of light sources as an object rotates.</td><td>Students will be skilled at…
• Calibrating the MSET to assure that the load cell and optical encoders to assure the efficacy of measurements across experiments.
• Select appropriate calibration techniques and apply these calibration processes in multiple experiments utilizing the MSET.
• Analyzing data using computer software and plotting data points to examine differences.</td></tr>
</table>

Evidence

Assessment Evidence

PERFORMANCE TASK(S):
1. Calibrate a new load cell and verify accuracy of the calibrated cell. To accomplish this the students will select a load cell and perform a calibration to generate a sensitivity of the new cell. The students will select one of the MSET experiments that involve static tests and choose the appropriate calibration with differing load cells (e.g. 5kg and 10kg).

OTHER EVIDENCE:
The essential questions will be used as an entrance/exit slip to determine growth in understanding. The following computational problem will also be used as an entrance and exit slip.

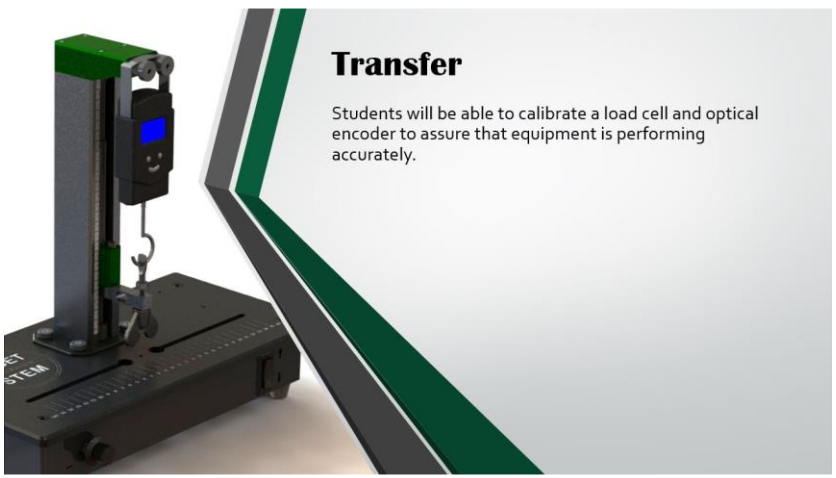
See Table 3. Sensor Scale Factors MSET experiment 01 Calibration

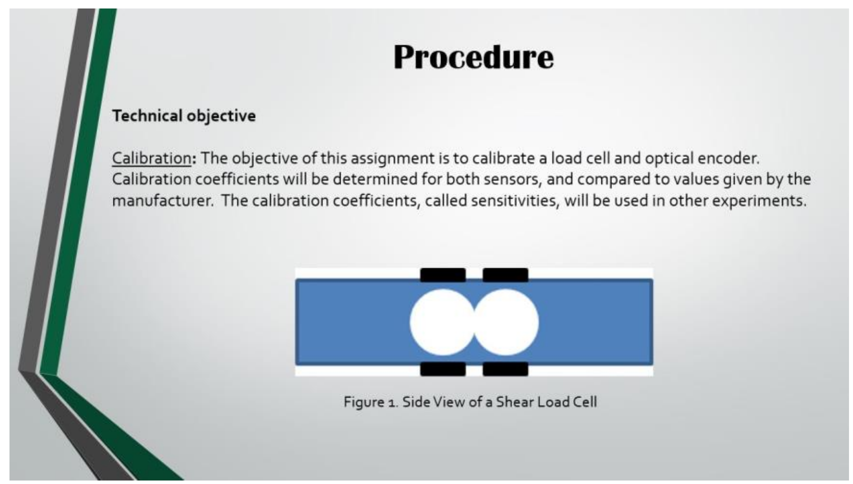
Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction

See outline of Calibration experiment summary included.

PowerPoint Template for Instruction – Calibration





Procedure

Approach

Calibration: This procedure covers the calibration of the 780g load cell, 5kg load cell, 20kg load cell, 50kg load cell and the motor encoder. Upon completion of the calibration, a scale factor will be generated for each sensor. These scale factors will be referenced each time the sensors are used in a future experiment.

Standards/Established Goals

Next Generation Science Standards

Engineering Design:

- HS-ETS1-4 Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions

Forces and Interactions:

- HS-PS2-1 Analyze data to support the claim that Newton's second law of motion.

Standards/Established Goals

Massachusetts State Standards

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- HS-ETS3-4(MA): Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties.

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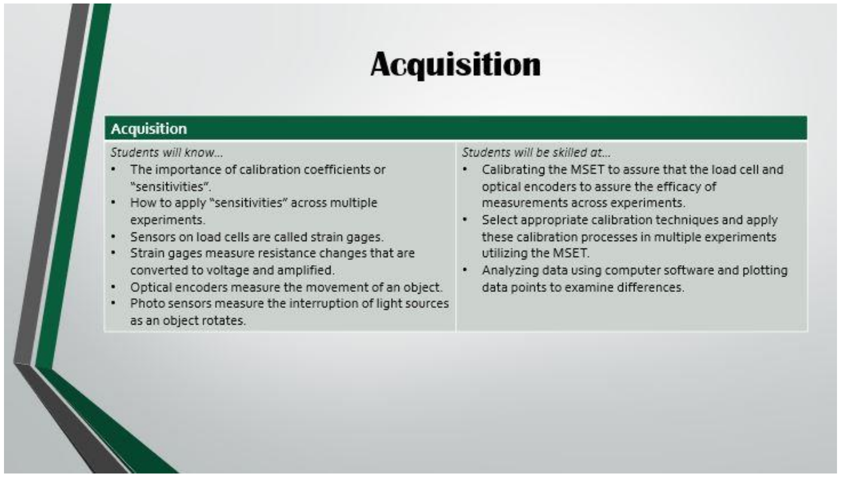
Meaning	
UNDERSTANDINGS: *Students will understand that…* 1. Load cell and optical encoders are used to measure force, as well as, rotational or linear motion. 2. Load cells measure compressive, tensile, torsional, shear and other types of forces.	ESSENTIAL QUESTIONS: 1. What are tensile and shear forces? 2. Why is calibration an important part of engineering and using equipment? 3. How is shear force measured? 4. How is tensile force measured?



Acquisition
Acquisition
Students will know…
• The importance of calibration coefficients or "sensitivities".
• How to apply "sensitivities" across multiple experiments.
• Sensors on load cells are called strain gages.
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Students will be skilled at…
• Calibrating the MSET to assure that the load cell and optical encoders to assure the efficacy of measurements across experiments.
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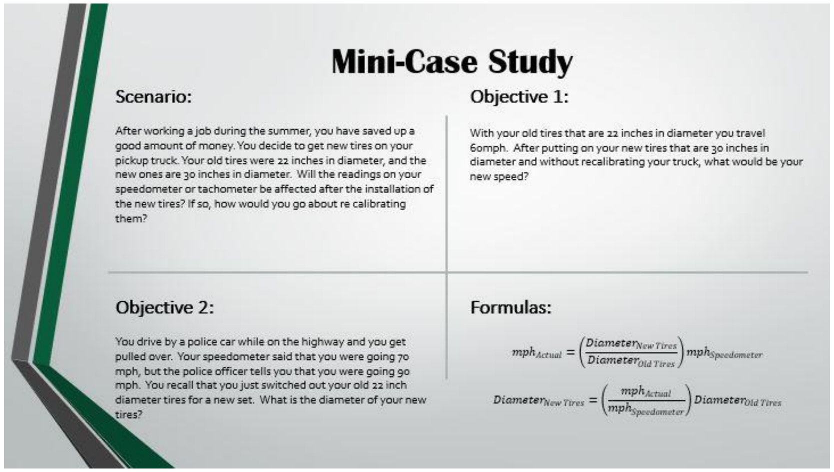
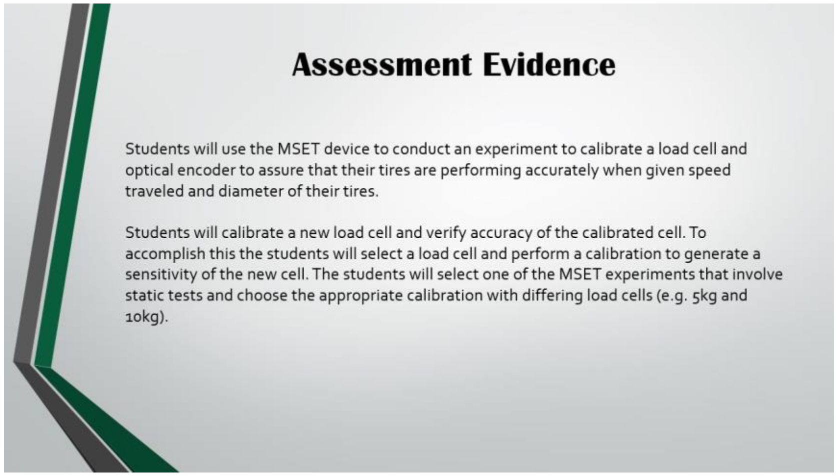


Mini-Case Study
Scenario:
After working a job during the summer, you have saved up a good amount of money. You decide to get new tires on your pickup truck. Your old tires were 22 inches in diameter, and the new ones are 30 inches in diameter. Will the readings on your speedometer or tachometer be affected after the installation of the new tires? If so, how would you go about re calibrating them?
Objective 1:
With your old tires that are 22 inches in diameter you travel 60mph. After putting on your new tires that are 30 inches in diameter and without recalibrating your truck, what would be your new speed?
Objective 2:
You drive by a police car while on the highway and you get pulled over. Your speedometer said that you were going 70 mph, but the police officer tells you that you were going 90 mph. You recall that you just switched out your old 22 inch diameter tires for a new set. What is the diameter of your new tires?
Formulas:
$mph_{Actual} = \left(\frac{Diameter_{New\ Tires}}{Diameter_{Old\ Tires}}\right) mph_{Speedometer}$
$Diameter_{New\ Tires} = \left(\frac{mph_{Actual}}{mph_{Speedometer}}\right) Diameter_{Old\ Tires}$



Assessment Evidence
Students will use the MSET device to conduct an experiment to calibrate a load cell and optical encoder to assure that their tires are performing accurately when given speed traveled and diameter of their tires.
Students will calibrate a new load cell and verify accuracy of the calibrated cell. To accomplish this the students will select a load cell and perform a calibration to generate a sensitivity of the new cell. The students will select one of the MSET experiments that involve static tests and choose the appropriate calibration with differing load cells (e.g. 5kg and 10kg).

MSET Experiment Procedure– Calibration

Technical objective

The objective of this assignment is to calibrate a load cell and optical encoder. Calibration coefficients will be determined for both sensors, and compared to values given by the manufacturer. The calibration coefficients, called sensitivities, will be used in other experiments.

Background

Load cells and optical encoders are used to measure force, and rotational, or linear motion. Load cells come in a wide variety of designs, and can be used to measure compressive, tensile, torsional, shear and other forces. The MSET uses a shear style load cell for measuring tensile and compressive forces. Shear load cells are often used in digital scales. They are used in scales because they are not subject to errors associated with the location the force is applied. Figure 1 shows the cross section of a shear load cell with four sensors attached.

Figure 1: Side View of a Shear Load Cell

The sensors most commonly used on load cells are called strain gages. Strain gages are simply a small wire that changes resistance when a load is applied. The resistance change for gages is relatively small. Because of this the signal is converted to a voltage and amplified. The conversion from resistance to voltage is done by connecting the four sensors together in a configuration shown in Figure 2, called a Wheatstone bridge.

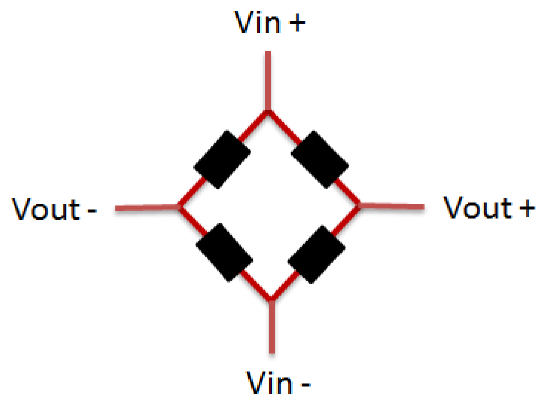


Figure 2: Wheatstone Bridge

The Wheatstone bridge requires power to work using a voltage source “Vin +” with a return current path to “V-”. The output voltage generated by the load cell is shown as Vout. If the resistance of each of the our strain sensors of the load cell are equal to each other, the output voltage will be zero. Applying a load results in an imbalance of the Wheatstone bridge. This imbalance causes a change in output voltage. This output voltage is small (millivolts), but can then be amplified making it easier to measure small changes in the load.

The relationship between load and output from the load cell is either given in units of mass per output voltage expressed in Equation #1. This scale factor “*SF*” can be converted to mass per bit expressed in Equation #2. The term “bit” in the denominator is the smallest change detectable by the computer board used to acquire data. A 10-bit board will have 2^{10}or 1024 discrete increments that can be detected.

$$SF = \frac{gms.}{volt} \qquad \text{eq. (1)}$$

$$SF = \frac{gms.}{bit\ count} \qquad \text{eq. (2)}$$

Optical encoders are a common instrument used to measure the movement of something attached to it. As an example, encoders are used to measure the rotational speed of a motor. The encoder is normally attached to the motor with a coupler that transfers rotational motion from the motor to the shaft of the encoder. Figure 3 shows the external features of an optical encoder.

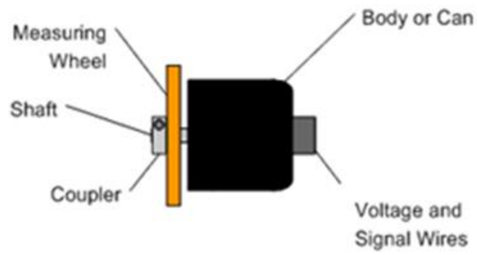


Figure 3: Components of an Optical Encoder

The shaft of the encoder is attached to an internal disc with slots cut into it. An optical light source or LED (light emitting diode) is used on one side of the disc while a photo sensor is attached to the other side. As the disc rotates the light source is interrupted resulting in pulses of light sensed by the photo sensor as seen in Figure 4.

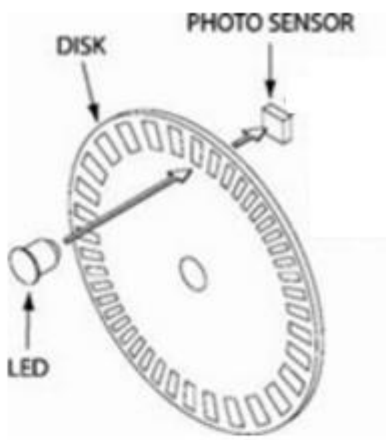


Figure 4: Disc, Diode and Photo Sensor

An electronic circuit is used to condition the pulse of light as it passes a slot on the disc. Voltage pulses are then detected by a computer board configured to count pulses, represented in Figure 5. Each pulse represents a known rotational motion of the encoder. By counting pulses, the total rotation can be calculated. The MSET uses an encoder to measure rotations of the lead screw which is directly related to the linear motion of the carriage.

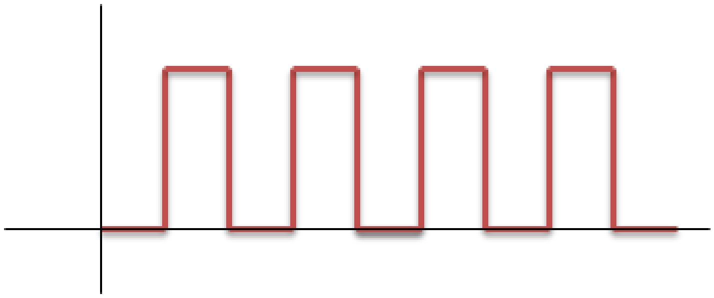


Figure 5: Encoder Pulses

The scale factor is calculated in the same way for the encoder as the load cell. Instead of *grams per bit count,* the encoder scale factor is in *mm per bit count*. See equation 3

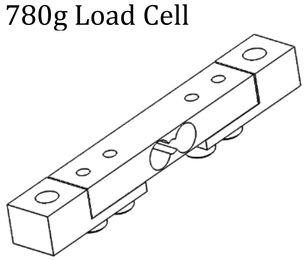
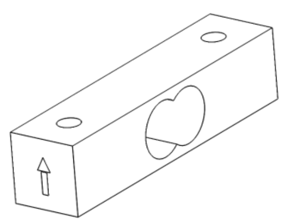
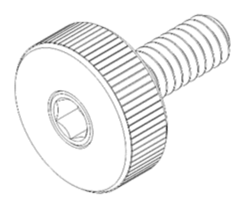
$$SF = \frac{mm}{bit\ count} \qquad \text{eq.(3)}$$

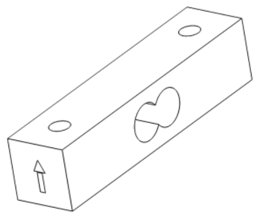
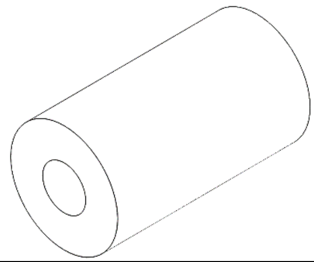
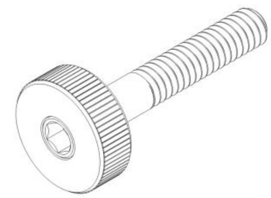
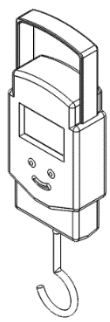
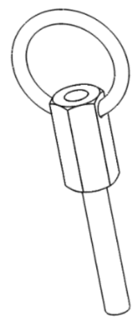
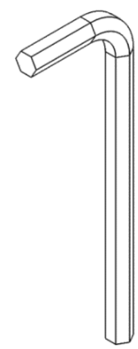
Approach

This procedure covers the calibration of the 780g load cell, 5kg load cell, 20kg load cell, 50kg load cell and the motor encoder. Upon completion of the calibration, a scale factor will be generated for each sensor. These scale factors will be referenced each time the sensors are used in a future experiment.

Experiment Setup

1. Gather the following components:

780g Load Cell 	5kg Load Cell 	¾" Thumbscrew 

50kg Load Cell 	Thumbscrew Spacer x2 	1-3/8” Thumbscrew 
Digital Scale 	Hanger Assembly 	4mm Hex Wrench 

2. In addition to the components listed above, gather a writing instrument and notebook in which to record data.
3. Attach the tower to the base plate as shown in the Quick Setup Guide. **Safety shield must be used for this experiment; it has been omitted from the following illustrations for clarity purposes.**
4. If a load cell is attached to the carriage, remove it using the provided 4mm hex wrench

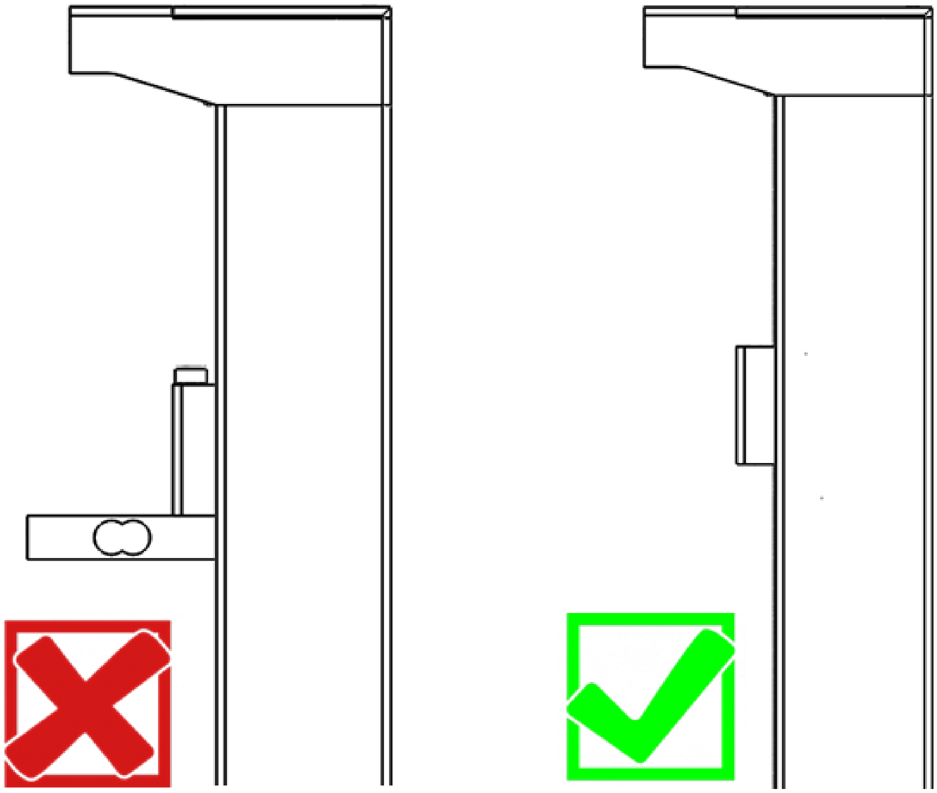


Figure 6: Load Cell vs. no Load Cell

5. Attach the two thumbscrews and spacers as shown in Figure 7.

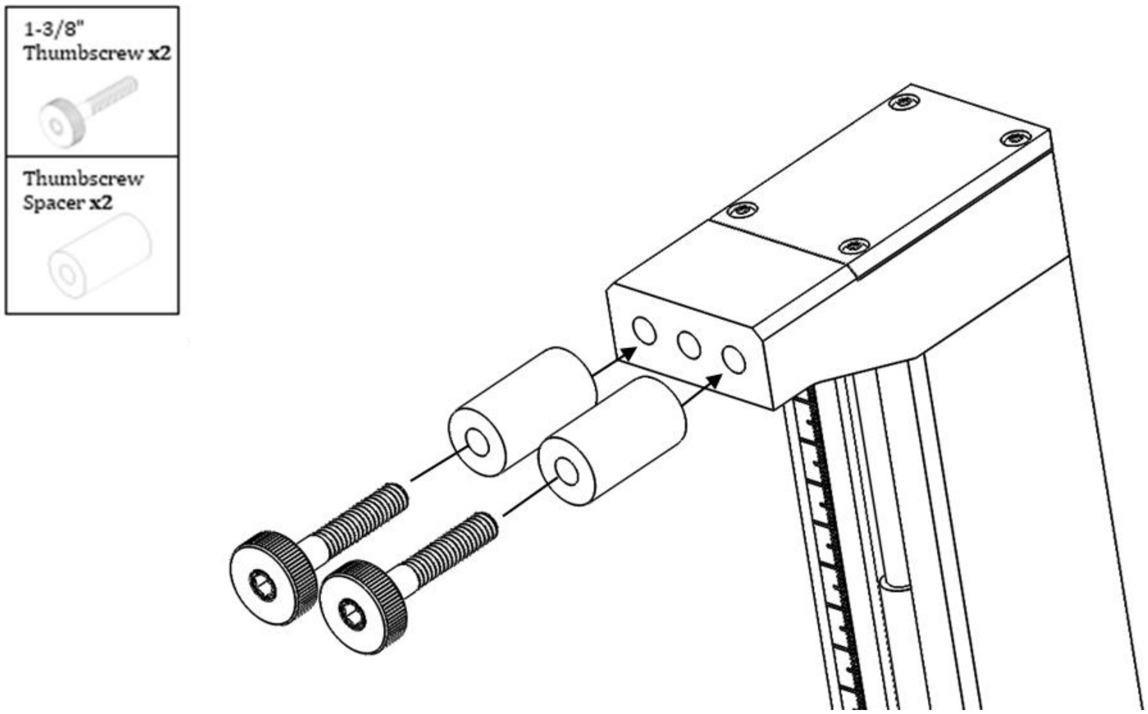


Figure 7: Placement of Thumbscrews and Spacers

Experimental Procedure

Encoder Calibration

1. Adjust the position of the carriage until the top is level with the 2cm mark on the tower scale.

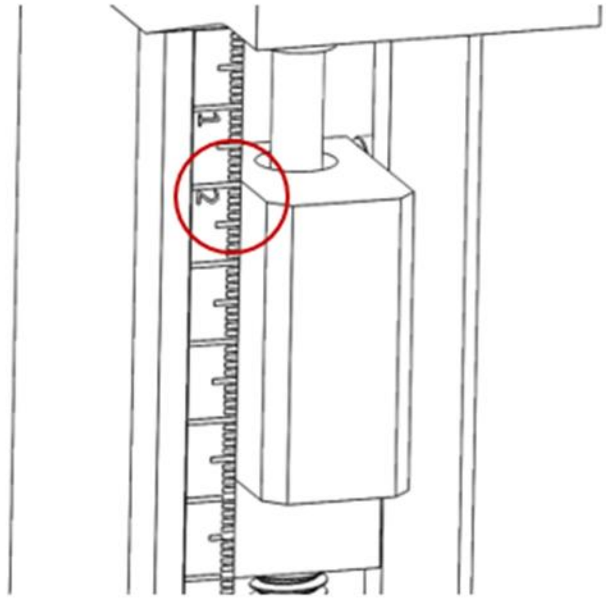
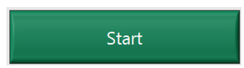


Figure 8: Alignment of Carriage

2. Click “Calibrate” followed by 

to launch the experiment

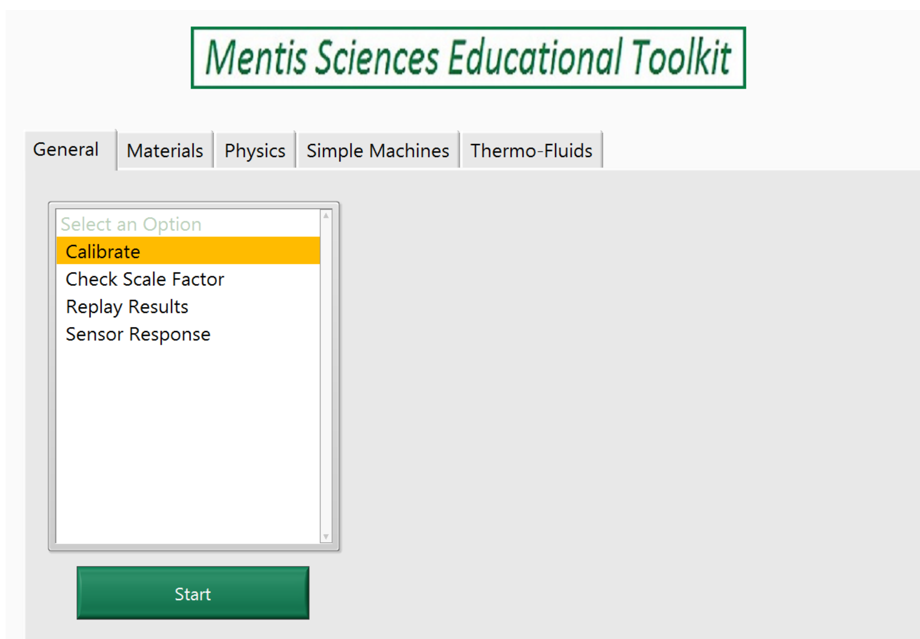
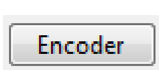


Figure 9: Experiment Location

3. Click 

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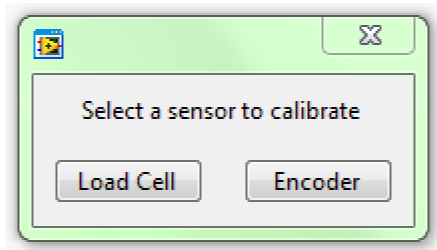
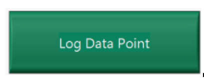


Figure 10. Calibration Options

4. In the notebook, create a table as shown in Table 1.

Table 1. Encoder Calibration Data Table

Displacement (mm)	**Bit Count**
0	
5	
10	
15	
20	
25	

5. Enter 0 into the "Travel" field and click 

.
6. Record the output count in the cell corresponding to 0mm in the table

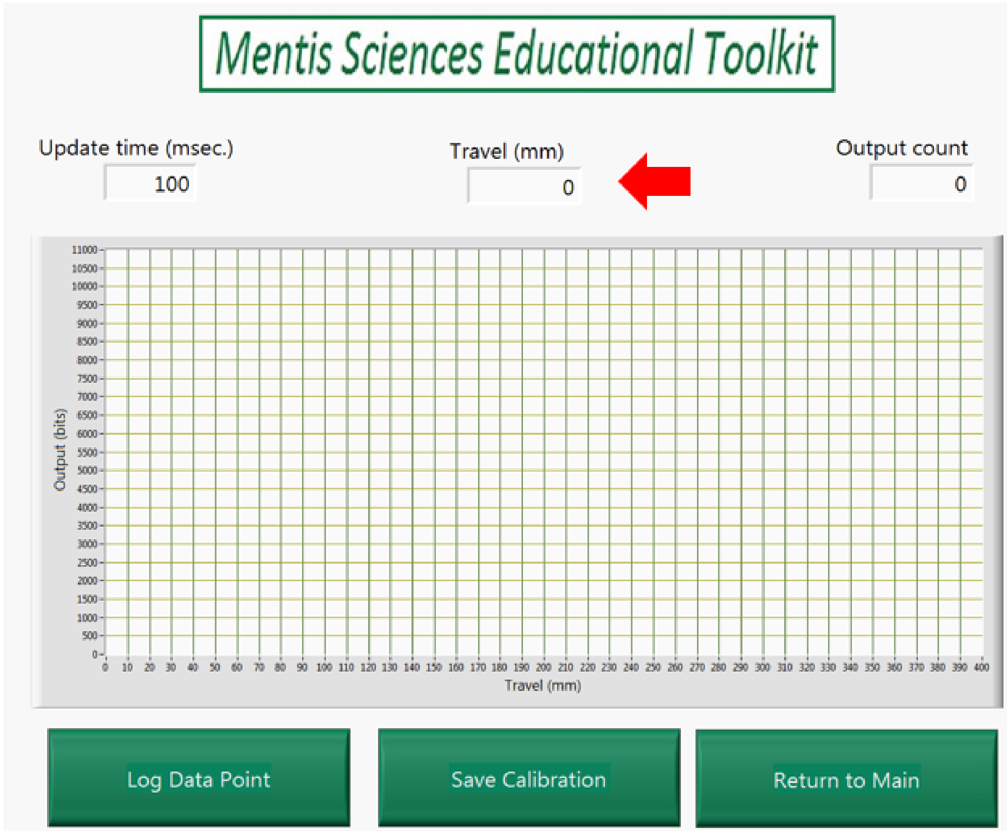
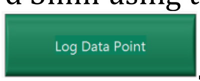


Figure 11. Displacement Calibration Screen

7. Next, with the speed control set to its slowest setting, displace the carriage downward 5mm using the tower scale for reference and enter "5" in the field and click 

. Record the output count in the table for 5mm.

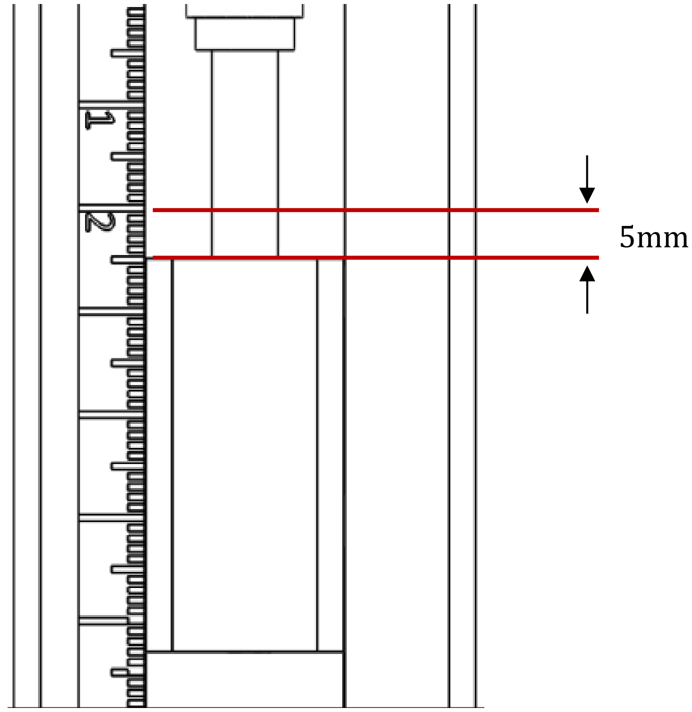
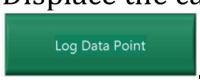
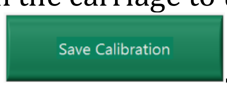


Figure 12: Carriage Displacement

8. Displace the carriage another 5mm and enter “10” in the field and click 

. Record the output count in the table for 10mm.
9. Continue in this fashion until you have displaced the carriage 25mm then return the carriage to the 2cm mark
10. press 

.
11. Click “yes” to save the encoder scale factor.
12. Next, to verify the scale factor select “Check Scale Factor” on the main menu.

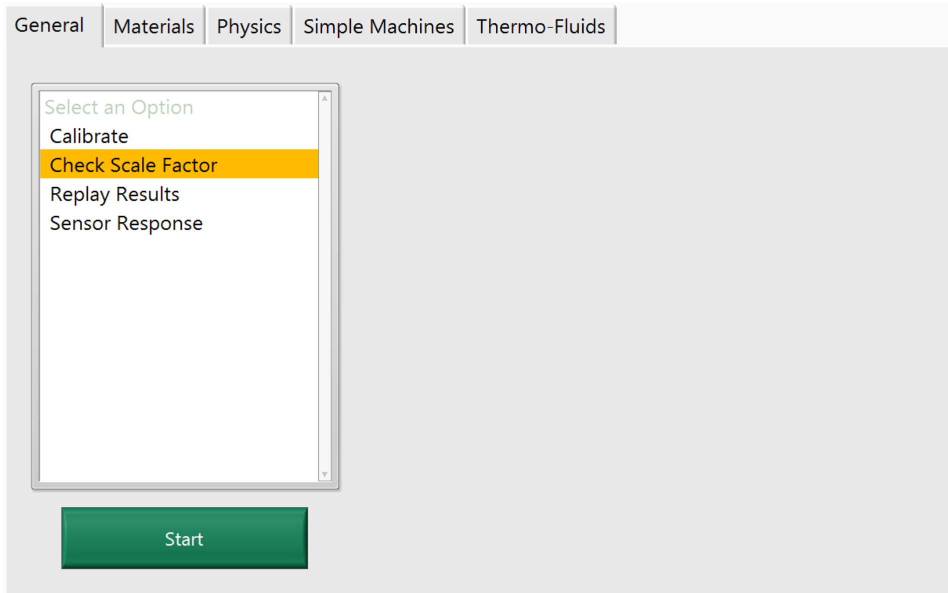


Figure 13: Check Scale Factor Location

13. Press Encoder.
14. If needed, press Remove Bias to zero out the reading.

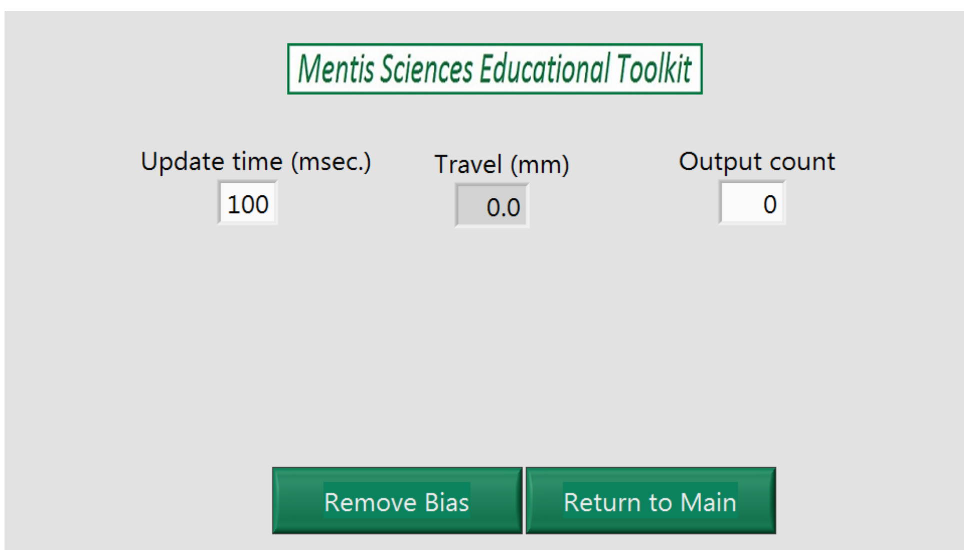


Figure 14. Encoder Scale Factor Check Screen

15. Displace the carriage a known distance using the scale on the MSET tower.

16. Read the number displayed in “Travel” read out and compare it to the distance on the tower scale.
17. Ideally you would like the scale and the readout to be within a 10% error. If you find that the error is consistently above 10% it is strongly recommended that you rerun the calibration to obtain a better calibration factor. If your readings are greater than 15% then it is vital that you rerun the calibration.

$$Error = \frac{|Readout - Tower\ Scale|}{Tower\ Scale} \times 100 \qquad \text{eq. (4)}$$

Load cell Calibration-780g

1. Attach the 780g load cell to the carriage with the arrow pointed upwards as seen in Figure 15.

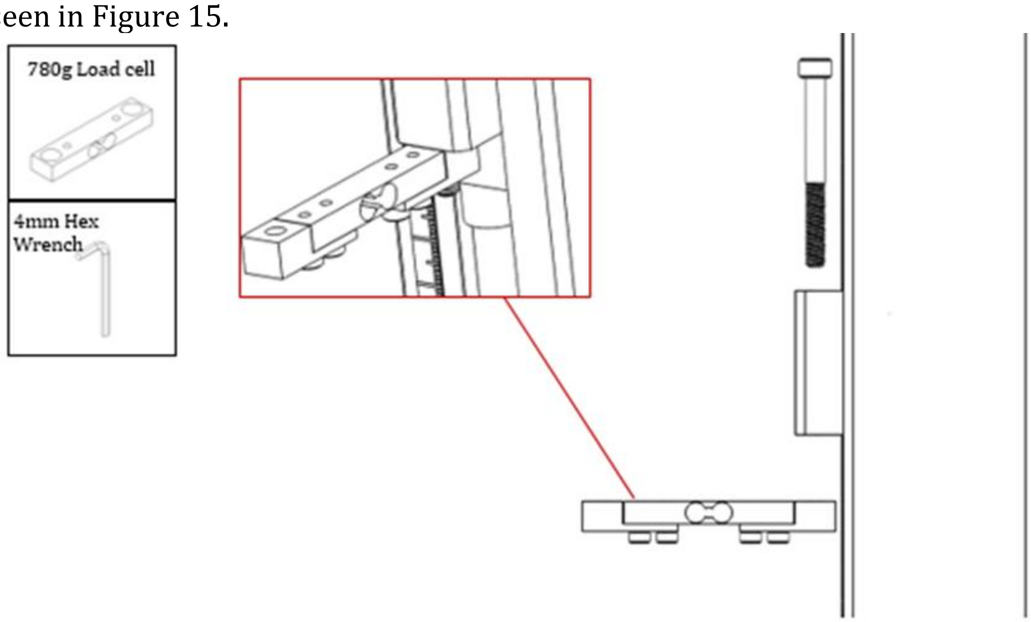


Figure 15: Placement of 780g Load Cell

2. Plug the load cell into port 1 at the back of the SIM.

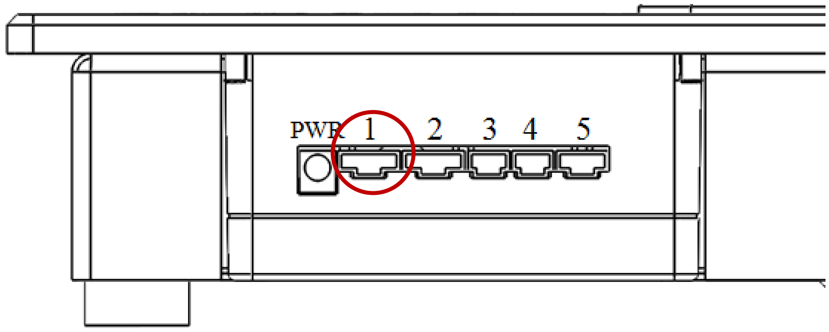


Figure 16: Port 1 on SIM

3. Attach the hanger assembly to the load cell as seen in Figure 17.

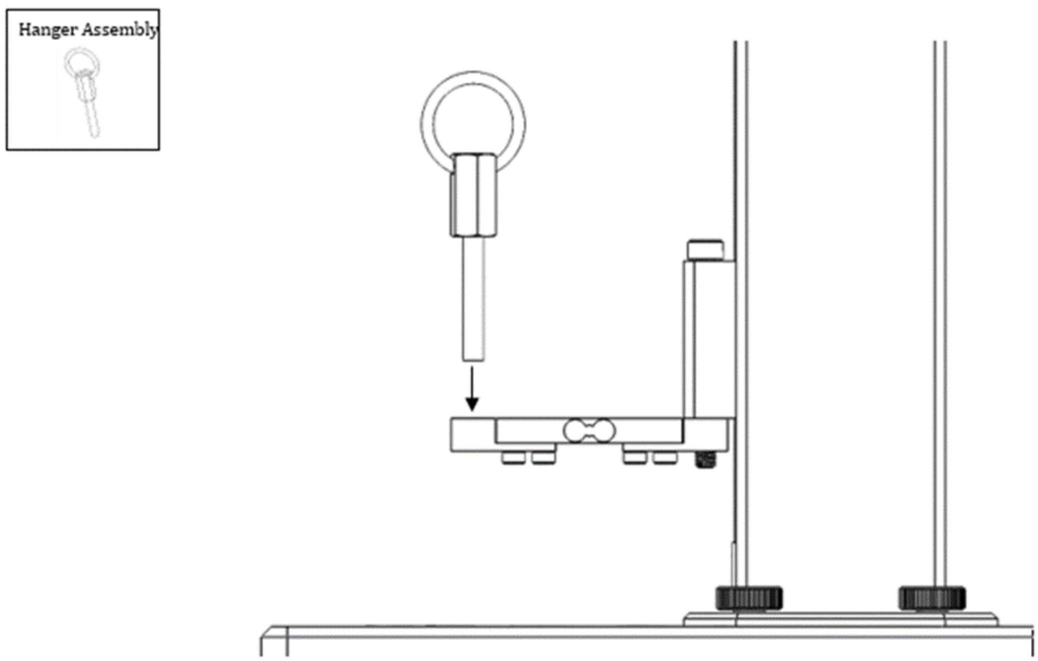
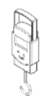


Figure 17: Attachment of the Hanger Bolt Assembly and Wing Nut

4. Adjust the height of the carriage until the top is level with the 18cm mark on the tower scale.

5. Place the digital scale on the thumbscrew spacers and place the hook through the ring of the hanger bolt as seen in Figure 18.

Digital Scale



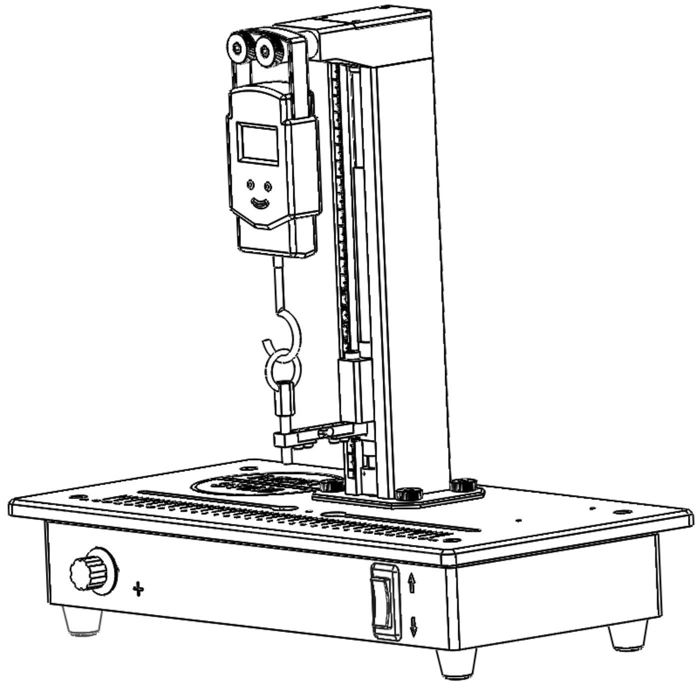


Figure 18: Setup for 780g Load Cell Calibration

6. Continue to thread the hanger bolt into the loadcell until most of the slack between the ring and scale hook is removed but there is no load on the loadcell
7. Turn on the scale.
8. If you are using the scale for the first time, it may need to be configured to work properly with the MSET. The display should read in units of “kg”. If not, press the “unit” button until “kg” is indicated. Finally, the “lock” feature must be disabled. To do this, press and hold the “Tare” button until “L-OF” appears on the screen.

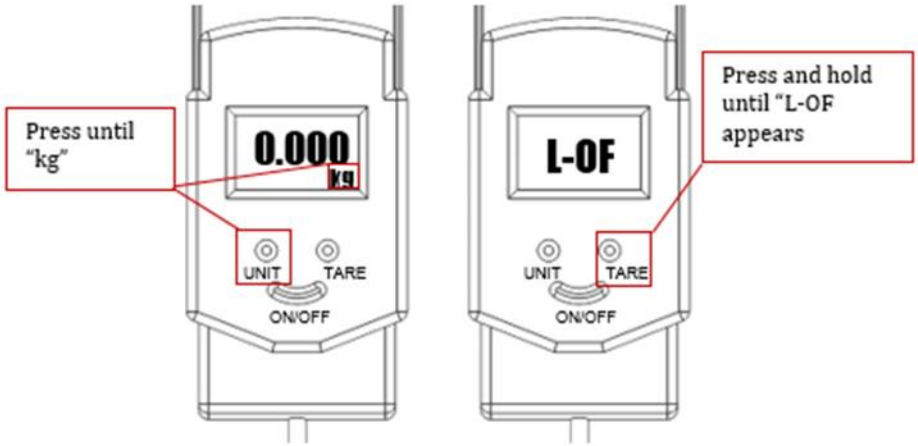


Figure 19: Digital Scale Operation

9. Click "Calibrate" to launch the calibration experiment.

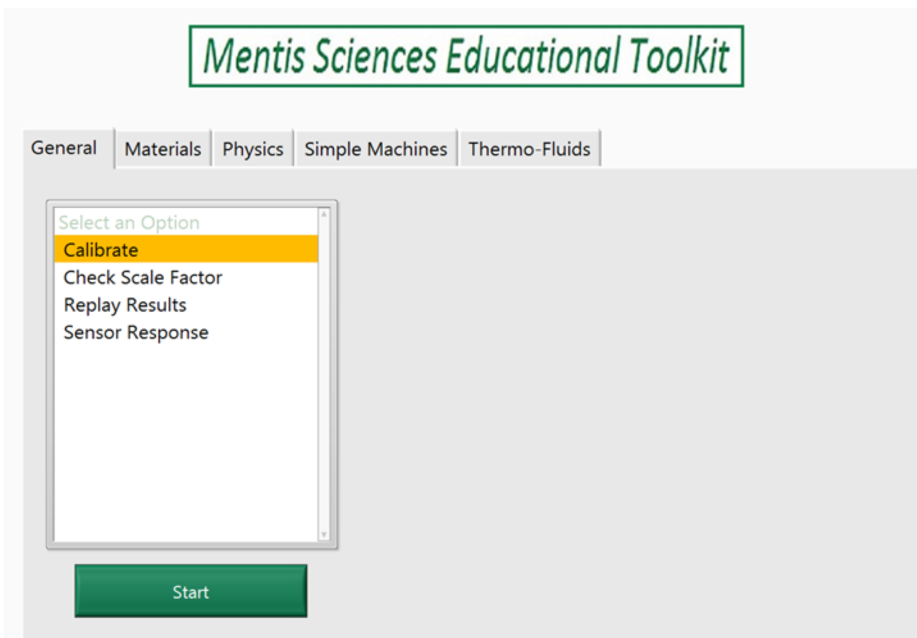


Figure 20: Calibration Experiment Location

10. On the next screen click  to begin the load cell calibration

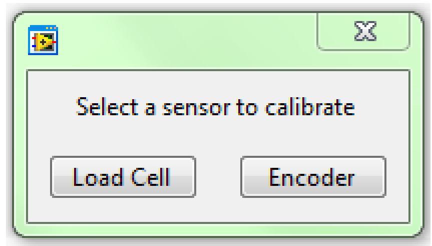
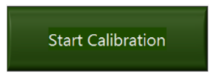


Figure 21. Calibration Options

11. Verify that the 780g load cell is connected to terminal 1 and select the 780g load cell from the menu. Press  to begin the calibration.

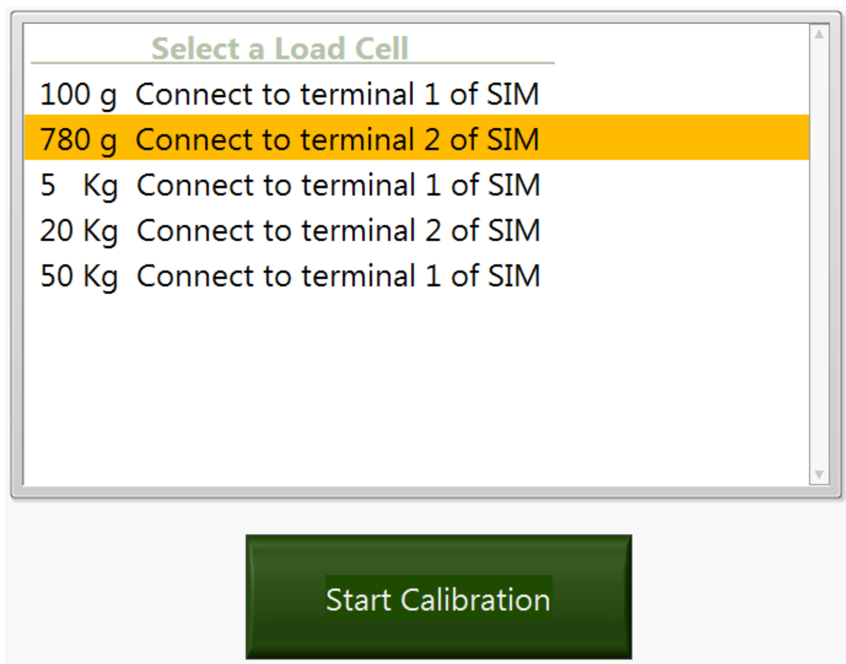
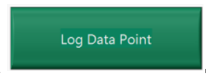


Figure 22: Sensor Selection

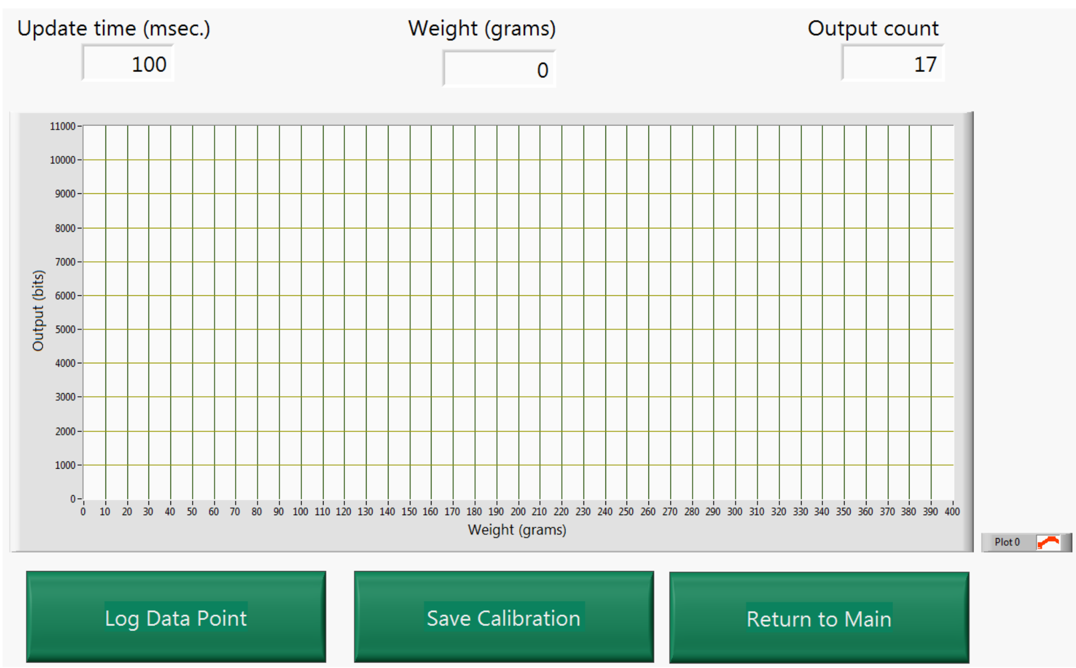
12. Generate a table, as shown in Table 2 in the notebook.

Table 2. Load Cell Calibration Data Table

Weight (g)	Bit Count
0	

13. Enter a load of 0g in the field labeled “Weight” and click 

. Record the Output Count in the cell corresponding to 0g in the table.



14. Begin applying load to the load cell by inserting the 4mm allen wrench into the hole in the hanger assembly and slowly turning the assembly until the hook on the hanging scale begins to become tight as seen in Figure 23. Collect 10 data points between 0g and 700g, pick points with a relativey even spread over the range. For each data point, wait for the scale to stabilize and enter the value displayed on the scale into the MSET program and press

. Record both the measured load in grams and the output count in the table in the notebook for each point.

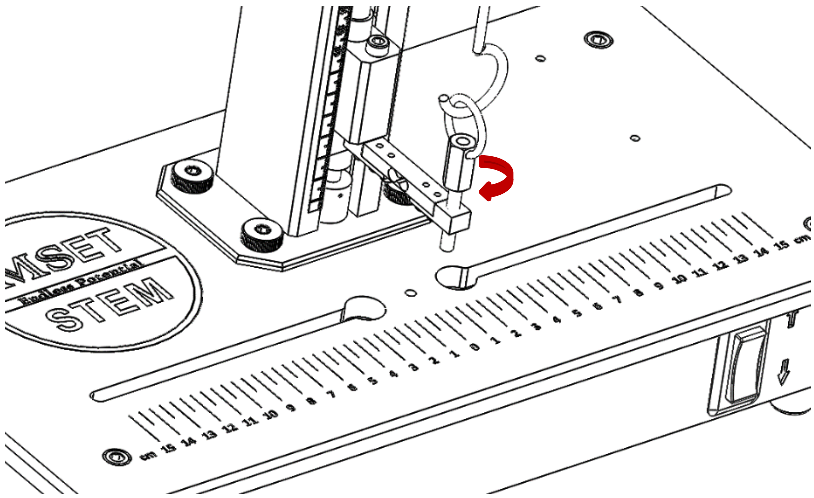
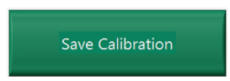


Figure 23: Applying a Load to the Load Cell

15. Once ten points have been collected, click 

and save the scale factor.
16. Next, to verify the scale factor select “Check Scale Factor” on the main menu.

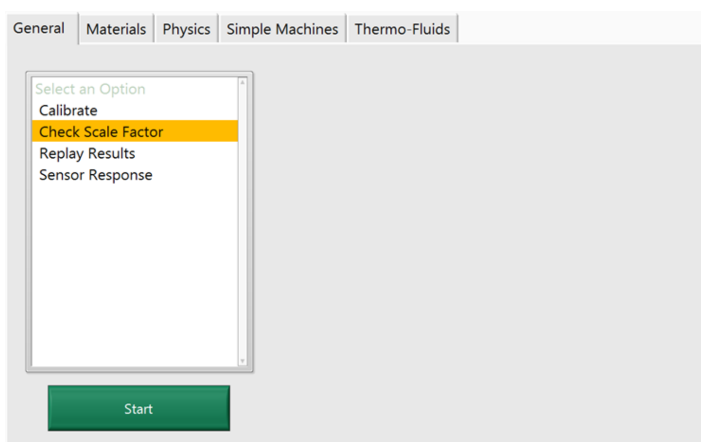
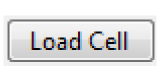
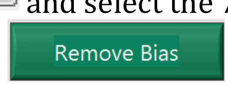


Figure 24. Check Scale Factor Location

17. Press 

and select the 780g load cell from the menu options.
18. If needed, press 

to zero out the reading.

19. Apply load to the load cell as before. Choose three points over the 700g range. For each load, record the digital scale reading and the readout on the MSET program.
20. Ideally you would like the digital scale and the readout to be within a 10% error. If you find that the error is consistently above 10% it is strongly recommended that you rerun the calibration to obtain a better calibration factor. If your readings are greater than 15% then it is vital that you rerun the calibration.

$$Error = \frac{|Readout - Digital\ Scale|}{Digital\ Scale} \times 100 \qquad \text{eq. (5)}$$

5kg Load Cell Calibration

1. Follow the same steps used for calibrating the 780g load cell for the 5kg load cell.
2. This time calibrate over a range of 0-4500g.

20kg Load Cell Calibration

1. If your MSET is supplied with a 20kg load cell, follow the same steps used for calibrating the 780g and 5kg load cells.
2. Use a range of 0-19500g.

50kg Load Cell Calibration

1. If your MSET is supplied with a50kg load cell, follow the same steps used for calibrating the preceding load cells.
2. Use a range of 0-49500g

Data Analysis

1. Retrieve the data sets that were written down for each sensor.
2. Plot calibration data points for the load cells and encoder on the provided space below. Draw a best fit line through the data.
3. Determine the scale factor for each instrument by calculating the slope of the best fit line. Do this by selecting two points on the line and using equation 5. Enter the calculated scale factor into table 1 below.

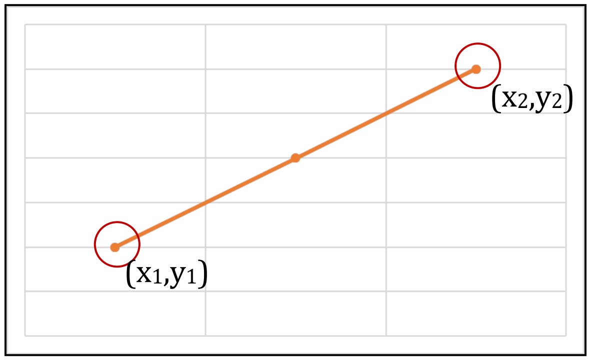


Figure 25: Example of Slope Between Two Points

$$Slope = \frac{y_2 - y_1}{x_2 - x_1} \qquad \text{eq. (5)}$$

4. Scale factors are automatically calculated by the MSET program. View the scale factors calculated by the program by navigating the "C:" drive of the PC then MSET > General > Calibrate > ScaleFactors.txt

```
100g Load Cell SF_100g=0.086     grams/count Connect to terminal 1 of SIM
780g Load Cell SF_750g=0.672     grams/count Connect to terminal 2 of SIM
 5kg  Load Cell SF_5kg=0.210     grams/count Connect to terminal 1 of SIM
20kg Load Cell SF_20kg=17.83     grams/count Connect to terminal 2 of SIM
50kg Load Cell SF_50kg=43.05     grams/count Connect to terminal 1 of SIM
Shaft  Encoder SF_Disp=263.0712    millimeters/count
Pendulum:
Degree span negative=-90 positive=+90
Count span count=102 @ -90 count=666 @ +90
Cam:
count=200 @  minumum centimeters=0.0
count=800 @  maximum centimeters=6.0
Encoder Counts per Revolution:
Encoder1=212 counts/rev
Encoder2=180 counts/rev
ComPort=02
```

Figure 26: Encoder and Load Cell Scale Factors

Enter the scale factors into Table 3. Compare the scale factors calculated in question 3 with the scale factors generated by the MSET program using equation 6.

$$\%Difference = \frac{Absolute|Calculated\ SF - Program\ SF|}{\left(\frac{Calculated\ SF + Program\ SF}{2}\right)} \times 100 \qquad \text{eq. (6)}$$

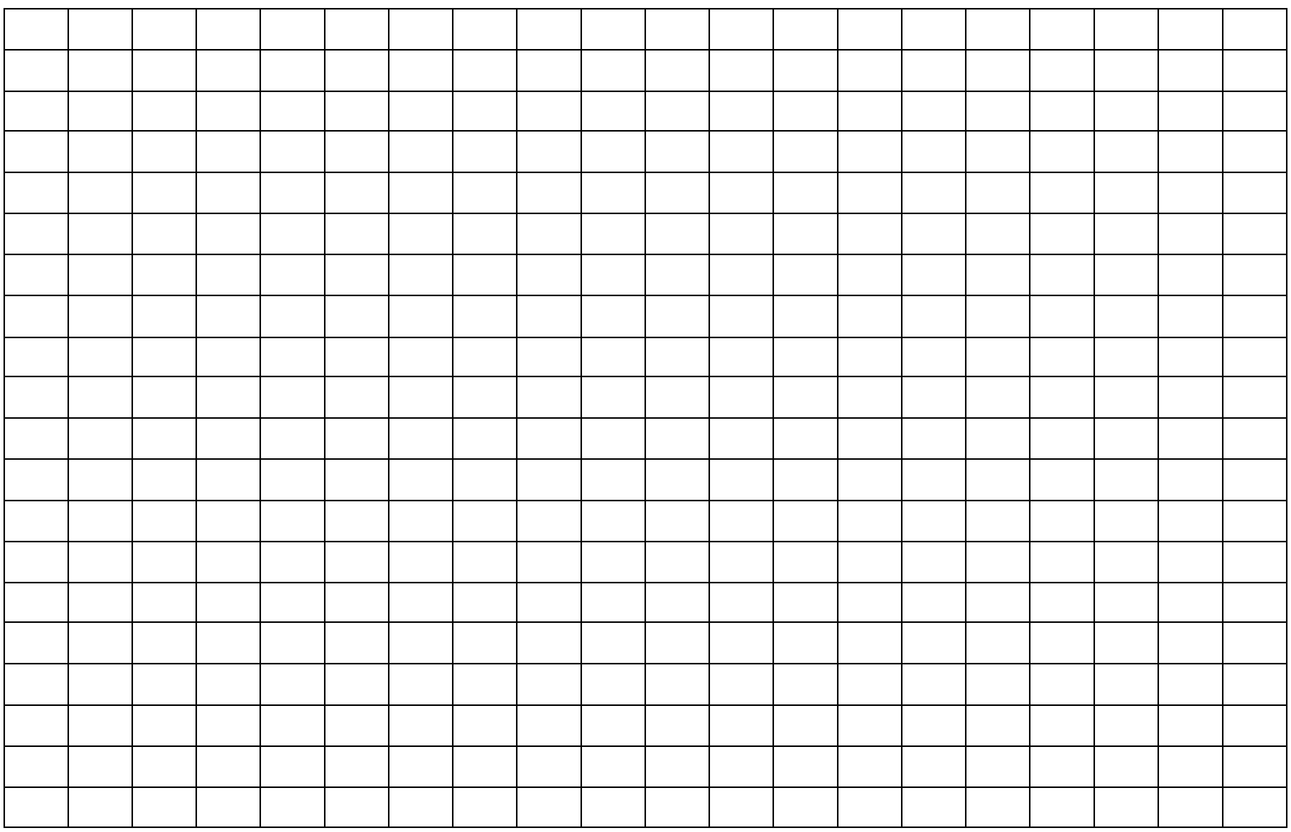
5. After zeroing a force reading the load cell displays 850 bits. Calculate the applied load using the experimental scale factor obtained from the 5 Kg load cell.

6. Solve for the carriage travel with a starting count of 110 at 0 mm, and a final count 800.

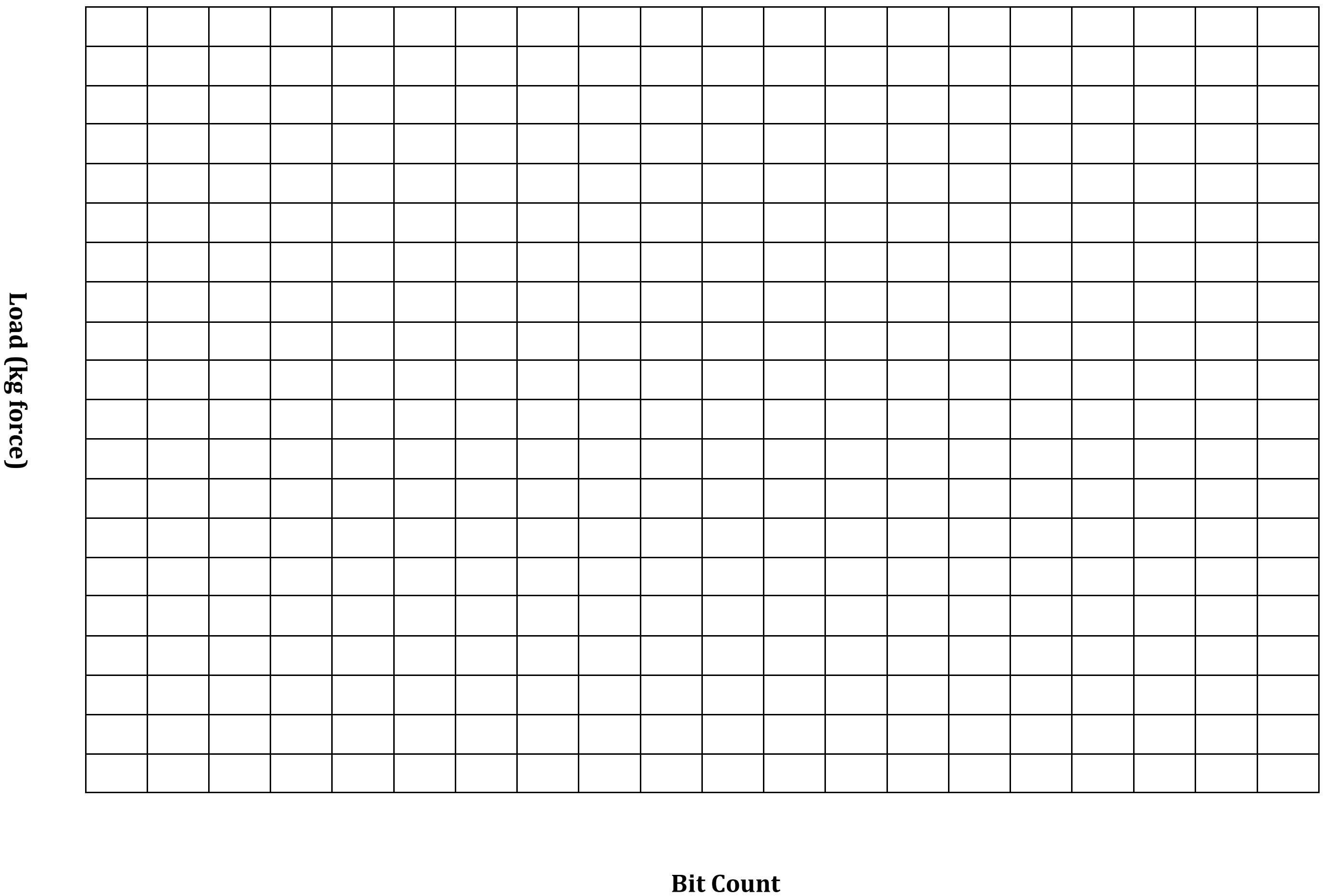
Table 3: Sensor Scale Factors

Sensor	Calculated Scale Factor	Program Scale Factor	% Diff
Encoder (mm/count)			
780g Load Cell (g/count)			
5 kg Load Cell (g/count)			
20 kg Load Cell (if applicable) (g/count)			

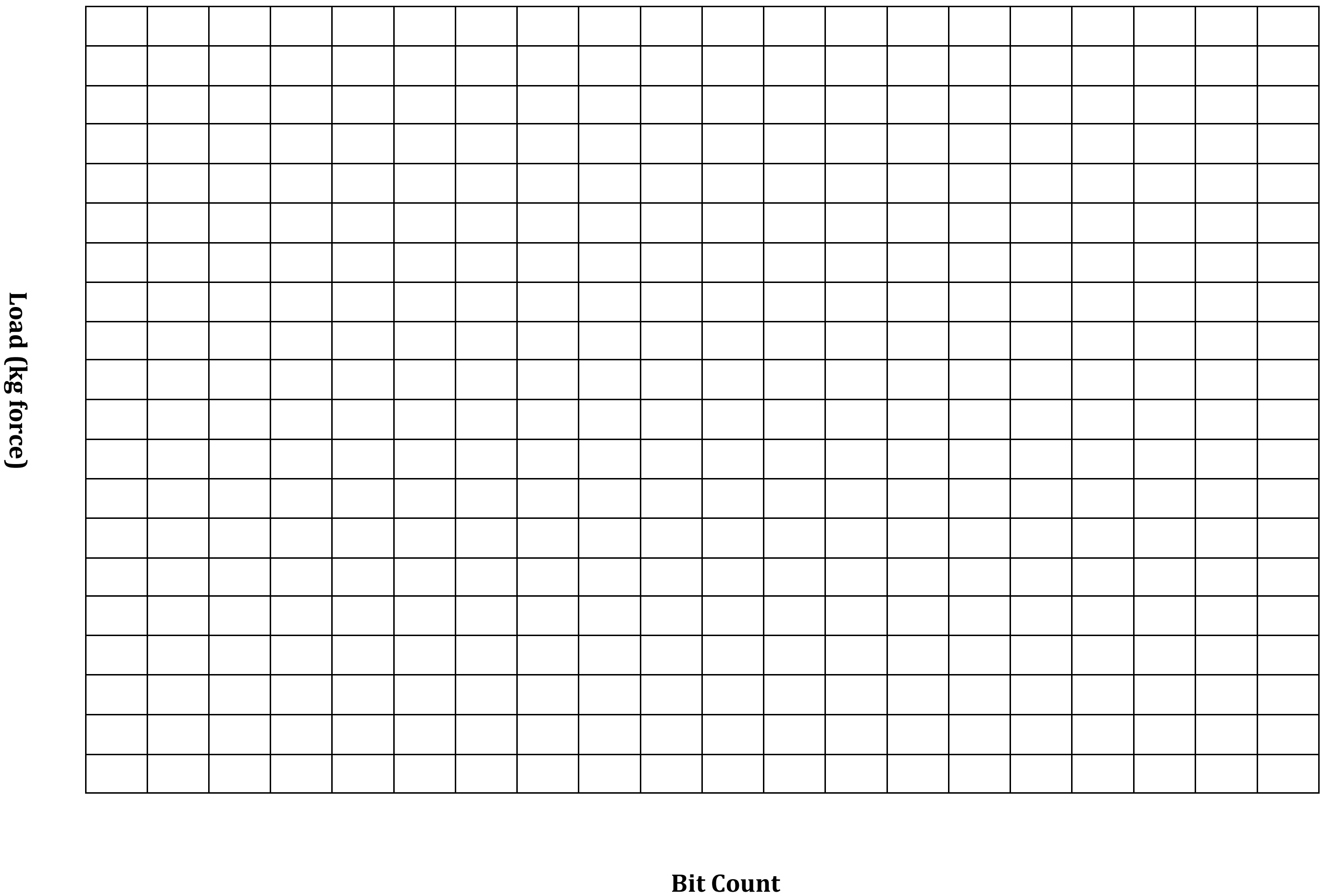
Encoder Calibration Plot



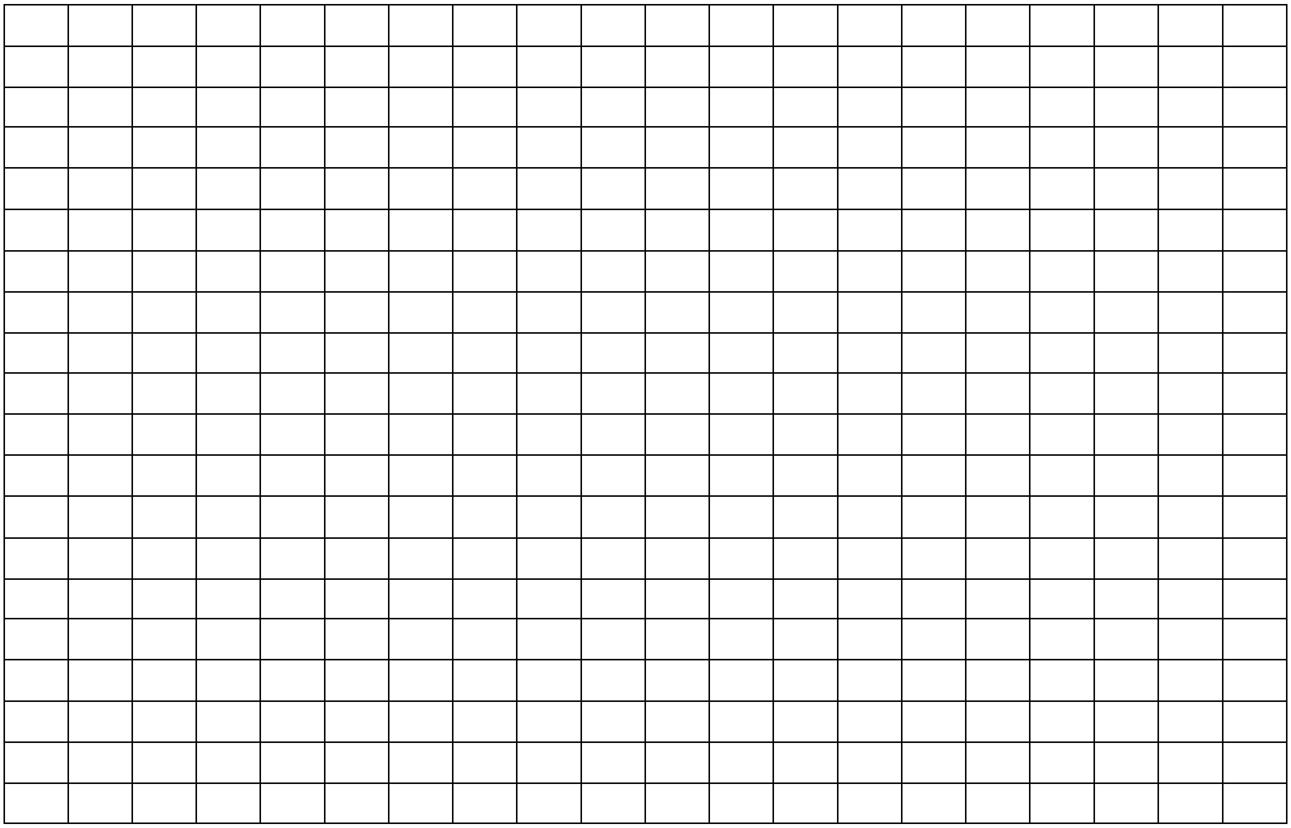
Load Cell Calibration Plot 1



Load Cell Calibration Plot 2



Load Cell Calibration Plot 3



Load (kg force)

Bit Count

MSET - CALIBRATION

Purpose

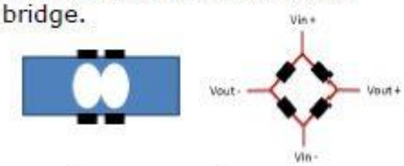
Introduce sensors and transducers to quantify physical inputs such as force, and rotational speeds. Develop a basic skill set used to determine conversion coefficients.

Sensors

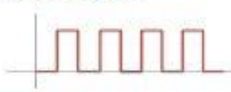
Sensors are electro-mechanical devices commonly attached to materials and placed in an environment to be measured. The sensor produces an electrical output of voltage, current, and or resistance as the input changes

Theory

Load cells convert force to a signal with strain gages and a wheat stone bridge. Resistance of the gages changes and is converted to a voltage by the bridge.



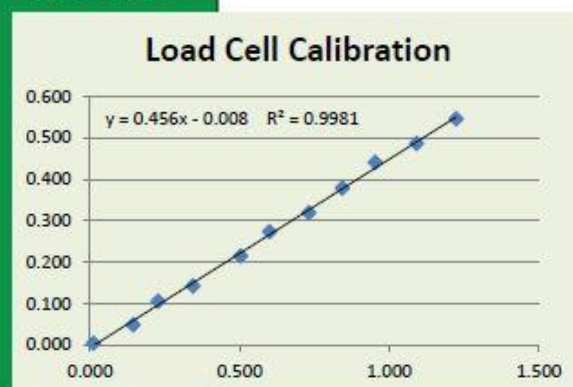
Encoders are used to measure rotational and linear movement using a light source (LED) and optical sensor. The sensor generates electric pulses that are counted when the light source passes a slots in a disk that is attached to a shaft

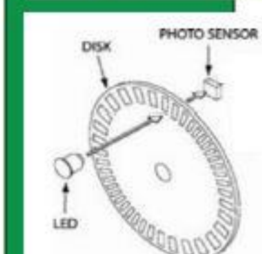


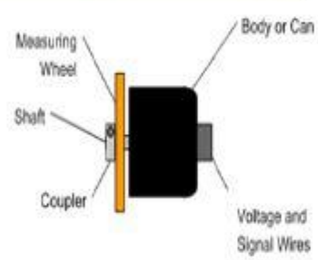
Setup

$$SF = \frac{gms.}{volt}$$

Results







www.mset.info

Inquiry-Based Mini Projects – Calibration

After working a job during the summer, you have saved up a good amount of money. You decide to get new tires on your pickup truck. Your old tires were 22 inches in diameter, and the new ones are 30 inches in diameter. Will the readings on your speedometer or tachometer be affected after the installation of the new tires? If so, how would you go about re calibrating them?

Question 1:

With your old tires that are 22 inches in diameter you travel 60mph. After putting on your new tires that are 30 inches in diameter and without recalibrating your truck, what would be your new speed?

Formula(s):

$$mph_{Actual} = \left(\frac{Diameter_{New\ Tires}}{Diameter_{Old\ Tires}}\right) mph_{Speedometer}$$

$$Diameter_{New\ Tires} = \left(\frac{mph_{Actual}}{mph_{Speedometer}}\right) Diameter_{Old\ Tires}$$

Question 2:

You drive by a police car while on the highway and you get pulled over. Your speedometer said that you were going 70 mph, but the police officer tells you that you were going 90 mph. You recall that you just switched out your old 22 inch diameter tires for a new set. What is the diameter of your new tires?

Teacher Solution Key - Calibration

Question 1:

Given:

$Diameter_{Old\ Tires} = 22in$
$Diameter_{New\ Tires} = 30in$
$mph_{Speedometer} = 60.mph$

Using the given information, solve for mph_{Actual}

Answer:

$$mph_{Actual} = \left(\frac{30in}{22in}\right)60mph = 81.8mph$$

Question 2:

Given:

$Diameter_{Old\ Tires} = 22in$
$mph_{Actual} = 90.mph$
$mph_{Speedometer} = 70.mph$

Solve for $Diameter_{New\ Tires}$

Answer:

$$Diameter_{New\ Tires} = \left(\frac{90.mph}{70.mph}\right)22in = 28.3in$$

Inquiry-Based Mini Project Rubric – Calibration

	3	2	1	0	Score
Proper Use of Equipment	Used the MSET to calibrate a load cell and optical encoder to assure that equipment is performing accurately.	Struggled with using the MSET and getting accurate data. Was able to use it and calibrate the load cells with some assistance.	Even at the end of the experiment, struggled with the used of the MSET and could not accurately calibrate the load cells.	Didn’t use the MSET	
Accuracy of Use of Terminology	Used all terms accurately including, calibration coefficient, sensitivities, load cells, strain gauges, optical encoders, and slope.	May have used all of the terms but one or two were not used accurately.	Used some of the terms but not all of them, or the terms were used but not used accurately.	Didn’t use any of the terms in the explanation of the solution	
Rationale for Solution	Provided a detailed rationale for the choices made in their solution. Explanation included how to properly calibrate a load cell and/or optical encoder and how that related to calibrating the truck’s speedometer/tachom	Provided a rationale for their solution, but could only briefly explain the calibration process and/or make connections between the calculations they completed and a rationale for their solution to the mini-project.	Provided a rationale, but their explanation was lacking the proper connections between the calibration process and the various calculations completed.	Didn’t provide a rationale for their solution	

	eter. A detailed explanation of why a particular method and experiment was chosen is included along with calculations for speed and diameter.				
Use of Mathematical Computations	Accurately completed calculations and best fit line plotting for slope then determined percent difference between MSET calculations and manual calculations to aid in calibration. Calculated stiffness of a material using the 5kg and 10kg load cells accurately and determined the sensitivity of the 10kg load cell. Calculations were used to explain the method chosen for calibration.	May have accurately calculated, slope, percent difference, stiffness, and sensitivity, however could not use it to explain why a specific method was chosen for calibration.	Attempted to calculate slope, percent difference, stiffness, and sensitivity, but included some miscalculations.	Did not complete or include proper calculations for experiment.	