

Forces & Motion

Name: _____

Student worksheet

Date: _____

Word Bank

(when appropriate, use these words in your short answers)

- | | | |
|----------------|--------------------------|------------|
| • Acceleration | • Motion | • Velocity |
| • Force | • Newton's Law of Motion | • Weight |
| • Mass | | |

1. Questions and Hypotheses

a. What are the two questions you are investigating?

1.

2.

b. For each question, write down your hypothesis about how mass, force, and acceleration are related:

1.

2.

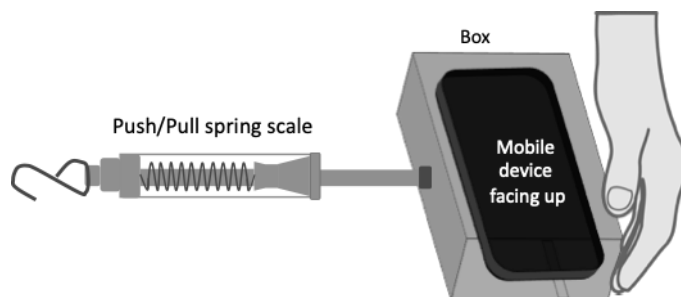
2. Experiment and Data Collection

Follow these steps to carry out your investigations:

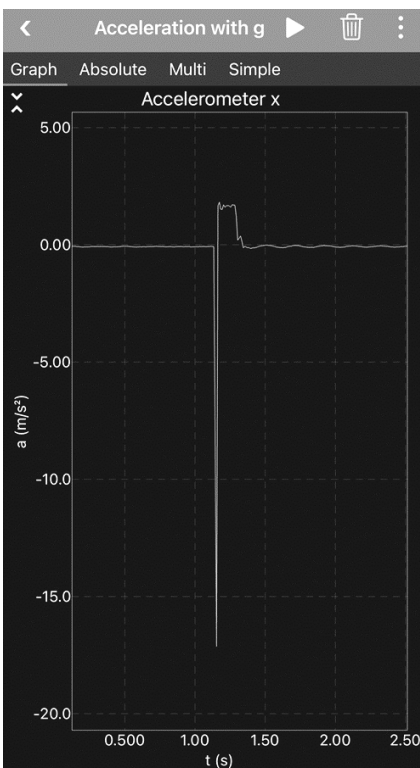
Part 1: Keep the mass constant and vary the applied force

- Open the acceleration with g sensor in the phyphox app and select the X accelerometer graph to enlarge it.
- Place the mobile device in the box with its display facing upwards and oriented in a way that it is pushed into the X direction. Tape the phone into the box, so it does not move around.

- c. Press the play button on the accelerometer within phyphox to start the recording.
- d. Push the bottom end of the spring scale into the spring to a predetermined force value while holding the end of the spring against one side of the box. Make sure that the wall of the box does not deform while applying a force on it. Keep the box in place with your hand at the opposite end as shown in the Figure below.



- e. Release the spring while at the same time removing your hand from the other side of the box.
- f. Once the box stops moving, stop the accelerometer recording, save your data, and review the graph. The graph should look similar to the graph below. There will be two peaks, one positive and one negative. Which one of the peaks will be positive or negative depends on which way you have pushed the phone. If you push the phone in the opposite direction, then the signs will be reversed, and the graph will be flipped upside-down.



- g. Repeat your measurement 5 times to make sure your data is reproducible. You can either do 5 individual recordings or one recording that includes all 5 trials. If you do individual recordings make sure to save each one before you continue with the next one.
- h. View your recording(s). You should notice 5 peaks (one for each trial) similar to the one in the figure above.
- i. The first acceleration peak is the acceleration peak of your box. Find the maximum acceleration from your graph and write the value in your data table below. You can pick any data point in your recording within the app to view its acceleration value. If your first peak is negative, then record the *absolute value* of that peak minimum as the maximum acceleration.

	Acceleration [m/s ²]					
Force [N]	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average

- k. Repeat steps c.-i. but change the amount of force that you apply to the box. Again, repeat your measurements 5 times and record your data in your worksheet. In total, test at least three different force values.

Part 2: Keep the applied force constant and vary the mass of the box

- Follow the same steps as in Part 1, but instead of varying the applied force, vary the mass of your box by adding additional weight to your box for each experiment. Keep the applied force constant by picking a single force value for all your Part 2 experiments.
- Secure your weights inside the box with tape, so they do not move around.
- Weigh the whole box, including your mobile device and the weights, on a scale before each experiment and record the mass in the data table below.
- Again, repeat your measurements for each mass 5 times and record the measured maximum peak acceleration of the five trials in the data table below.

	Acceleration [m/s^2]					
Mass [g]	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average

3. Results and Conclusion

- Calculate the average peak acceleration from your five trials for each of your experiments and enter the results in your data tables.
- Graph your data below. Make one graph showing average peak acceleration versus the applied force and a second graph showing average peak acceleration versus the mass of the box.

- c. Based on your data and graphs, discuss the following questions as a group. To get a better idea of the relationship between your variables, it might help to draw a best-fit line on your graphs. Consider inverse relationships as well.
- ? Compare your results for different applied forces. As you double or triple the force on the box, how does its acceleration change?
 - ? What is the relationship between the applied force (F) and the acceleration (a)? Justify your answer with data from your data table or graph.
 - ? Compare your results for different applied masses. As you double or triple the mass of the box, how does its acceleration change?
 - ? What is the relationship between the mass of the box (m) and its acceleration (a)? Justify your answer with data from your data table or graph.
 - ? Based on your findings, can you come up with an equation that links force, acceleration, and mass?
- d. Describe the relationship between mass, force, and acceleration in your own words below. Write down the equation your group came up with that relates all three (mass, force, acceleration).
- e. Compare the values for F and ma for each of your experiments and enter them in the table below. What do you notice about this data? Does your data prove or disprove Newton's Second Law of Motion?

Experiment	F [N]	ma [N]

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- f. Draw a free body diagram of your box during your experiment. Which forces act on the box as you are pushing it with the spring scale across the table?