Name ***Period*** ***Date***

Newton's Second Law

Driving Questions

What is the relationship between the net force applied to an object and its motion?

Background

Like Newton, we will observe a simple system to look for a relationship between net force and motion. From earlier studies, we know that a mass hung from a spring experiences a force due to gravity and a restoring force from the spring. In equilibrium, the two forces are equal and opposite. When the mass is displaced, one of the two forces is greater, thus causing a non-zero net force pointed towards the equilibrium position. We will investigate how this net force is related to the motion of the system.

Materials and Equipment

For each student or group:

- ♦ Data collection system
- ♦ Force sensor
- ♦ Motion sensor
- ♦ Right angle clamp
- ♦ Hanging mass
- ♦ Spring
- ♦ Rod stand
- ♦ Balance (1 per classroom)
- ♦ Short rod

Safety

Add these important safety precautions to your normal laboratory procedures:

- ♦ Exercise care when stretching and releasing the spring. Be sure that the mass(es) are securely attached.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

○	○	○	○
Oscillate the mass on the spring, and begin collecting data.	Plot net force measured by the force sensor versus acceleration.	Use the linear curve fit to determine the slope of the line.	Connect the Motion Sensor and the Force Sensor to your interface

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect a force and a motion sensor to the data collection system. �(2.2)

3. ☐ Display Position on the y-axis of a graph with Time on the x-axis. �(7.1.1)

4. ☐ Why is a "Measurement versus Time" graph chosen to view the data? What is another way that might be used to view the data?

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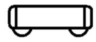
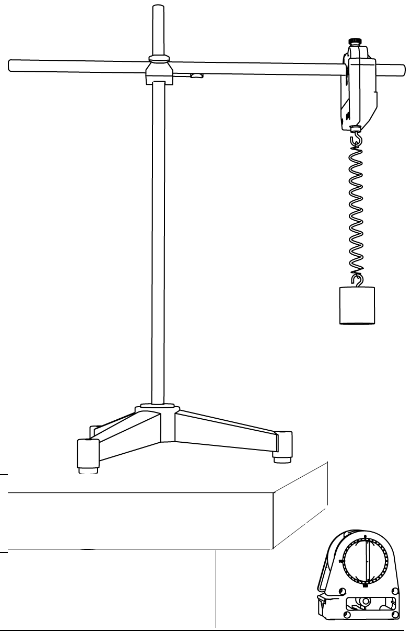
5. ☐ Make sure that your sampling rate is set to at least 20 samples per second, and if your motion sensor has a selector switch, set it to the cart or near setting. �(5.1)



6. ☐ Connect the force sensor to the short rod and the short rod to the rod stand using the right angle clamp.

7. ☐ Use a spring to hang the mass from the force sensor hook, and position it above the motion sensor. You may need to place the motion senor on the floor for the mass to have sufficient room to move.

8. ☐ Objects moving away from the motion sensor are moving in the positive direction. Based on the position of the motion sensor, would a push from the force sensor be in the positive direction or a pull?

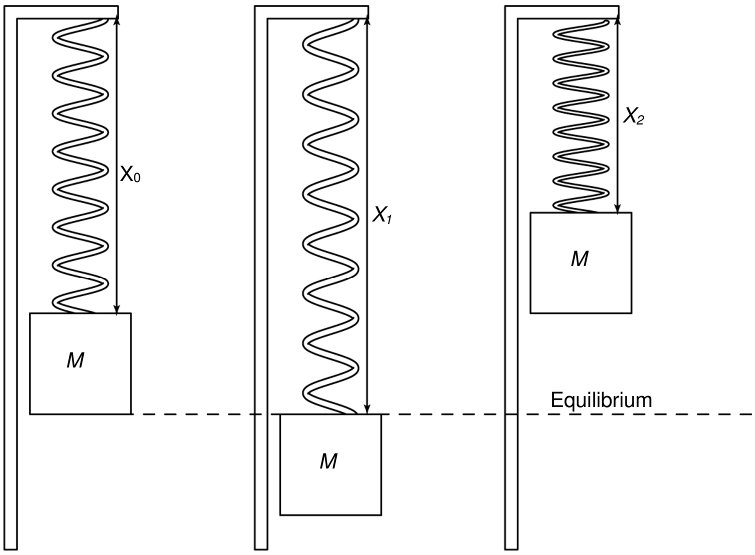


9. ☐ If necessary, change the force measurement so that the direction of the force aligns with the direction of the motion sensor.

10. ☐ With the mass hanging motionless from the force sensor, press the Zero button on the force sensor.

11. ☐ Why is it important to zero the force sensor in the equilibrium position before collecting data?

12. ☐ From your previous work you learned that the force exerted by a spring is related to distance the spring is stretched $F = -kx$, and the force of gravity is equal to $F = mg$. For each diagram, draw in the forces and the net force experienced by the mass.



Collect Data

13. ☐ Pull on the mass lightly, and let go to start the mass moving up and down. Then, start data recording. �(6.2)

14. ☐ Observe and compare the motion of the object with the real time Position versus Time plot that is generated on the data collection system.

15. ☐ Stop data recording after three to four complete cycles (5 to 10 seconds depending on the spring and mass you are using). �(6.2)

16. ☐ Save your experiment as directed by your teacher. �(11.1)

Analyze Data – Position and Force

17. ☐ Display two graphs simultaneously. On one graph, display Position on the y-axis and Time on the x-axis. On the second graph, display Force on the y-axis and Time on the x-axis. �(7.1.11)

18. ☐ Ensure that your Time axes are aligned and then describe the relationship between the position of the object and the force the objects experiences.

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19. ☐ Sketch the graphs in the Data Analysis section.

Analyze Data – Velocity and Force

20. ☐ Display two graphs simultaneously. On one graph, display Velocity on the *y*-axis and Time on the *x*-axis. On the second graph, display Force on the *y*-axis and Time on the *x*-axis. �(7.1.11)

21. ☐ Ensure that your Time axes are aligned and then describe the relationship between the velocity of the object and the force the objects experiences.

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22. ☐ Sketch the graphs in the Data Analysis section.

Analyze Data – Acceleration and Force

23. ☐ Display two graphs simultaneously. On one graph, display Acceleration on the *y*-axis and Time on the *x*-axis. On the second graph, display Force on the *y*-axis and Time on the *x*-axis. �(7.1.11)

24. ☐ Ensure that your Time axes are aligned and then describe the relationship between the acceleration of the object and the force the objects experiences.

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25. ☐ Sketch the graphs in the Data Analysis section.

26. ☐ Display Time, Force, and Acceleration in a table. �(7.2.1)

27. ☐ Select three different time values, and record them in the Table 1 in the Data Analysis Section along with the corresponding force and acceleration values.

Analyze Data – Force versus Acceleration

28. ☐ Display Force on the *y*-axis of a graph with Time on the *x*-axis. �(7.1.1)

29. ☐ Change the measurement on the x-axis from Time to Acceleration. (7.1.9)

30. ☐ Sketch your graph in the Data Analysis Section.

31. ☐ How would you describe the shape of the data plot?

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32. ☐ Apply a linear curve fit to the data plot. �(9.6)

33. ☐ Add the linear fit to your sketch, and include the slope of the line.

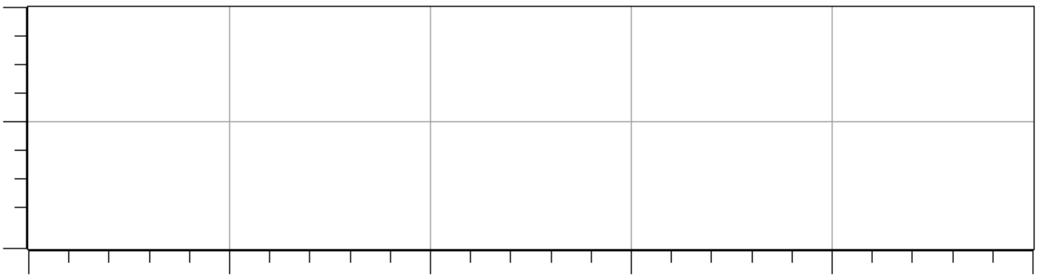
Data Analysis

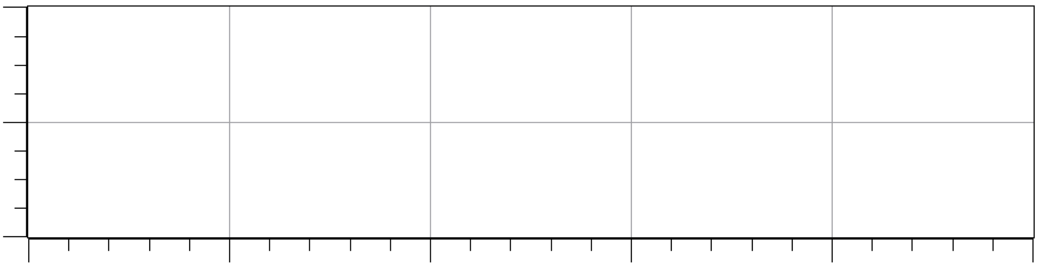
Drawing the graph: Make sure to label the overall graph, the x-axis, and y-axis, including units on the axes.

- ☐ Create a shape and/or color for each data run in the Key. Then draw graphs of your data for a single data run comparing force with position, velocity and acceleration as they change over time.

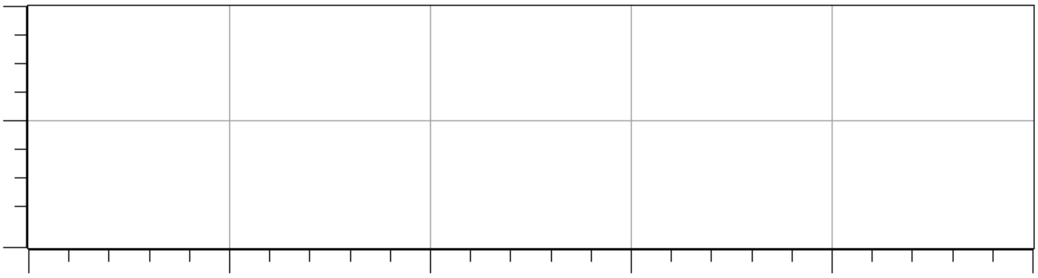
  Make sure to label the overall graph, x-axis, and y-axis. Also include units on your axes.

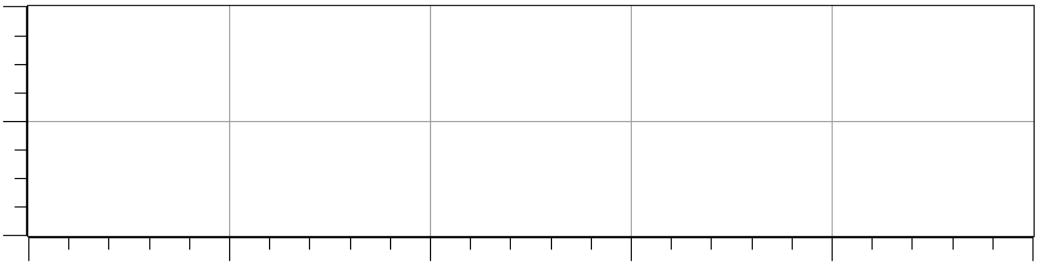
Force and Position



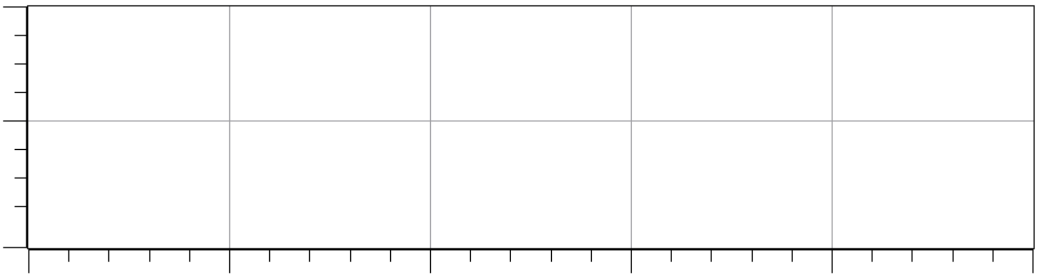


Force and Velocity





Force and Acceleration



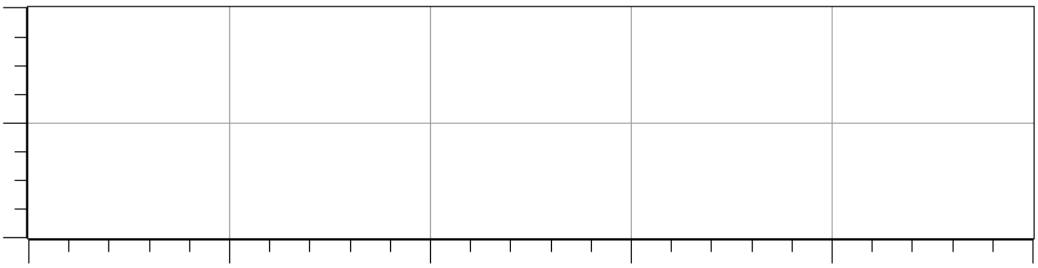
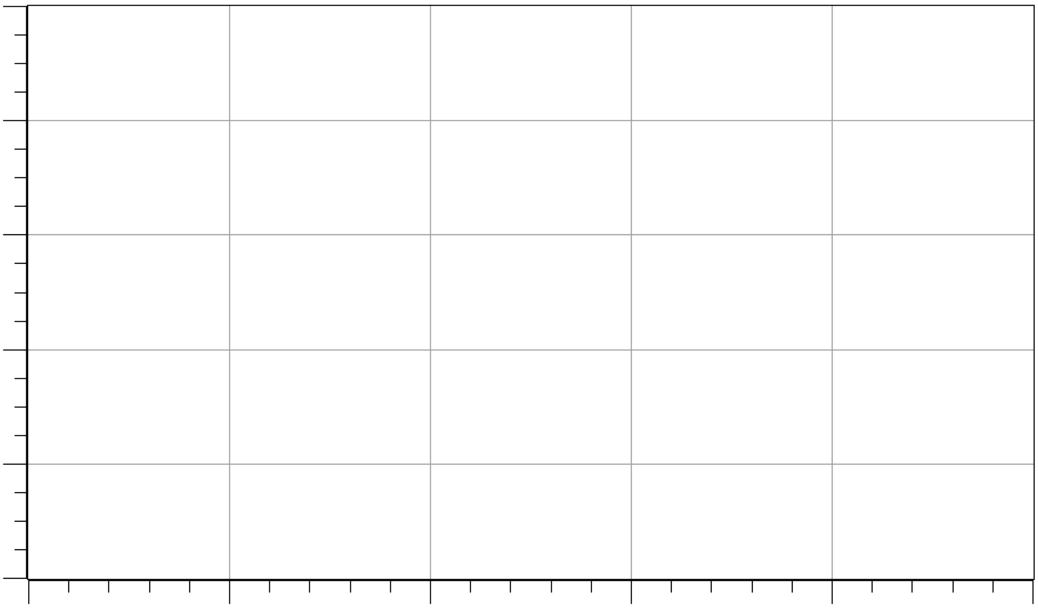


Table 1: Three points of Force and Acceleration

Time (s)	Force (N)	Acceleration (ms^2)	Force/Acceleration (kg)
		Average:	

Force versus Acceleration



Analysis Questions

1. For each Time value in Table 1, take the corresponding Force value and divide it by the corresponding Acceleration value. Then, find the average of the results to complete the table. How do the values for each Force divided by an Acceleration compare and what does this signify?

2. **From the table of selected points in the Data Analysis section, does the average value you calculated for ratios of Force to Acceleration appear similar to any other parameter of your experiment?**

3. **How does the slope of the best-fit line applied to the Force versus Acceleration graph compare to the average Force/Acceleration you calculated in Table 1?**

4. **Using your knowledge of graphing, how would you express the equation of the best fit line from the Force versus Acceleration graph in terms of the variables of this experiment and in mathematical terms?**

5. **Do the units of the equation balance?**

6. **For this experimental set up, the calculated values of mass will appear higher than the actual mass of the object. What do you think the apparent systemic error is?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **We know from experience that the harder we throw a ball (apply more force), the faster it will be moving (greater initial velocity resulting from acceleration). If you throw a 1 kg softball as hard as you can, and it is traveling at 20 m/s when it leaves your hand, how fast do you think a 5 kg shot put would be traveling with the same throw?**

2. **We say that force is proportional to acceleration, Given our answer to Question 1, how would you describe the relationship between acceleration and mass?**

3. **If we launch a rocket that has been designed to produce a constant force, will the acceleration at initial launch be the same as the acceleration just before the fuel is completely expended? Explain your answer.**

4. **A similar experiment is set up such that a force sensor is used to drag a 1.5 kg brick across a table while a motion sensor is used to measure the acceleration. Several trials are conducted, but the slope of the Force versus Acceleration graph is consistently about 2. What might explain the difference? What might you do to improve the results?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which statement is true if two potatoes of different mass are launched from a potato launcher that applies the same force to each one?

- **A.** The heavier potato will be traveling faster than the lighter one.
- **B**. The lighter potato will be traveling faster than the heavier one.
- **C.** Regardless of their mass, they will be traveling at the same velocity.
- **D.** There is not enough information to draw a conclusion.

2. A rollercoaster is designed to deliver a 3 g acceleration at the bottom of a dip. The mass of the cart is 500 kg. and the rider is 100 kg. The track at this point is designed to withstand 15,000 N of force without buckling. Will the cart and rider make it through the dip?

- **A.** No, this ride will likely end in disaster.
- **B**. Yes, the cart and rider will easily make it past the dip.
- **C.** Yes, but a second rider of equal size would not make it through.
- **D.** There is not enough information to draw a conclusion.

3. If a 1,000 kg rocket is launching straight up with its engine producing a force of 39,240 N, what is its acceleration?

- **A.** 9.81 m/s^2
- **B**. 39.24 m/s^2
- **C.** 1000 m/s^2
- **D.** 29.43 m/s^2

4. The acceleration of an object is

- **A.** Proportional to the mass of the object and the force being applied.
- **B**. Proportional to the mass of the object and inversely proportional to the force being applied.
- **C.** Proportional to the net force being applied and inversely proportional to the mass of the object.
- **D.** Always perpendicular to the force of gravity.

5. The net force on an object is

- **A.** Proportional to the force of gravity.
- **B**. The vector sum of the individual forces acting on the object.
- **C.** Always balanced by the normal force.
- **D.** Both A and C.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. Newton's ____________ law predicts the following relationship between ____________, force, and mass: The acceleration of an object is directly ____________ to the net force and will always be in the same direction as the net ____________. Acceleration will be inversely proportional to the ____________ of the object, meaning that more massive objects will have less acceleration if subjected to the same net force.

Key Term Challenge Word Bank

Paragraph 1

Acceleration

First

Force

Mass

Second

Proportional

Weight