10. Newton's Third Law

Driving Questions

When you push on a wall, does it push back?

When you jump up in the air, the gravity of the earth pulls you back down, but is your gravity pulling up on the earth?

Background

It is important to recognize that forces are like shoes—they occur in pairs. It is impossible to have a single force, such as to have an action force without having a reaction force. Even inanimate objects like walls and floors can exert forces. Sir Isaac Newton recognized this phenomenon to be so important that it became part of his third law of motion. In this experiment, you will observe both a pushing force (collision) and a pulling force to better understand these pairs of forces.

Materials and Equipment

For each student or group:

- Data collection system
- Force sensor (2)
- Dynamics cart (2)
- Dynamics track
- Compact cart mass, 250-g
- Discover friction accessory
- Spring force sensor bumper
- Collision cup force sensor bumper
- Rubber band
- Balance (1 per classroom)

Safety

Follow all standard laboratory procedures.

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.

Give the carts a gentle push so that they collide, and record the results for analysis.	Compare the peak value of force from each sensor.	Zero both force sensors.	Mount a force sensors on each of the carts, and place the cart-force sensor combination on the track.

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.

Part 1 – Action and reaction forces when two bodies push against each other

Set Up

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

2. ☐ Connect the force sensors to the data collection system. �(2.2)

3. ☐ Display two graphs simultaneously, each with Force on the y-axis and Time on the x-axis, such that the Time axes are aligned and the force measurements can be compared. �(7.1.11)

4. ☐ Change the y-axis of one of the two graphs to the opposite force measurement. For example, If both sensors are measuring Force, push positive, change one to Force, pull positive. �(7.1.9)

5. ☐ Why should you change the y-axis of one of the two graphs to the opposite force measurement?

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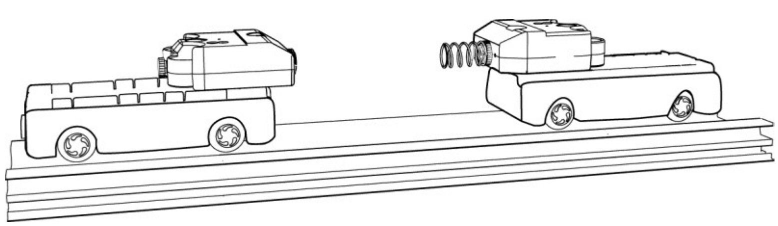
6. ☐ Set the sampling rate to 250 Hz. �(5.1)



7. ☐ Mount a force sensor on each cart, and attach the spring bumper to one force sensor and the collision cup to the other force sensor.

8. ☐ Decide which will be Cart A and which will be Cart B.

9. ☐ Place the carts on the track at either end so that when they collide, the impact will be between the two force sensors.

10. ☐ Press the zero button on each force sensor.

11. ☐ You will examine four different collisions, but before you record data you will predict what the forces associated with each collision will be. Complete the chart below to summarize your predictions. (Your predictions should simply state whether you expect the forces to be the same or different. If you expect the forces to differ in size, specify which you expect to be greater).

Table 1: Predictions – pushing

Collision	**Mass**		**Initial Motion**		**Predicted Force of Interaction**	
Number	**Cart A**	**Cart B**	**Cart A**	**Cart B**	**Force Sensor A**	**Force Sensor B**
1	Same as B	Same as A	Towards B	Towards A		
2	Same as B	Same as A	Rest	Towards B		
3	Heavy	Light	Towards B	Towards A		
4	Heavy	Light	Rest	Towards A		

Collect Data

12. ☐ Start data recording, and then gently push the carts toward each other. �(6.2)

13. ☐ Allow the carts to collide, and then stop data recording. �(6.2)

14. ☐ Place one cart at the end of the track and the other in the middle of the track.

15. ☐ Start data recording, and then push the cart at the end toward the cart in the middle. �(6.2)

16. ☐ Allow the carts to collide, and then stop data recording. �(6.2)

17. ☐ Place the carts at either end of the track, and place the compact mass in cart A.

18. ☐ Start data recording, and then push the carts toward each other. �(6.2)

19. ☐ Allow the carts to collide, and then stop data recording. �(6.2)

20. ☐ Place one cart at the end of the track and the other in the middle of the track.

21. ☐ Start data recording, and then push the cart at the end toward the cart in the middle. �(6.2)

22. ☐ Allow the carts to collide, and then stop data recording. �(6.2)

Analyze Data

23. ☐ Adjust the scale of your graphs to focus on the first collision, and ensure the Time axes on both graphs are aligned. �(7.1.2)

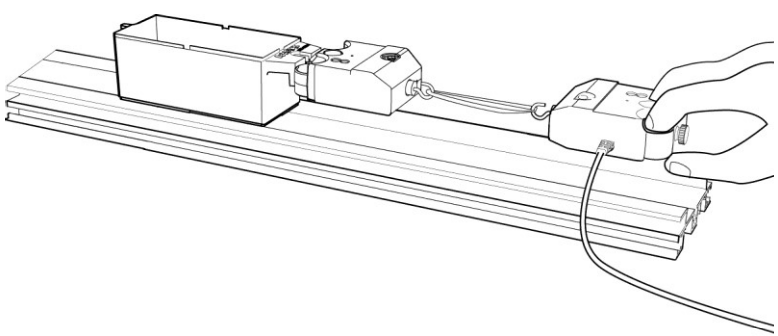
24. ☐ Sketch your graphs of Force versus Time in the Force versus Time – Pushing, blank graph axes in the Data Analysis section.

25. ☐ Find the peak force for each force sensor, and record the peak value in Table 3 in the Data Analysis section. �(9.2)

26. ☐ Show and hide data runs to find the peak force values for each run, and add these values to Table 3 in the Data Analysis section. �(7.1.7)

Part 2 – Action and reaction forces when one body pulls on another

Set Up



27. ☐ Remove the force sensors from the carts and the carts from the track.

28. ☐ Replace the spring bumper and collision cup with the force sensor hooks.

29. ☐ Place a tray from the discover friction accessory on the track, and place the compact cart mass inside the tray.

30. ☐ Attach the first force sensor to the tray from the discover friction accessory, and then connect the hook on the second force sensor to the hook on the first sensor using a rubber band.

31. □ As the person holding the second force sensor slowly moves it to the right, the rubber band will be stretched until the force exerted is great enough to cause the tray to start sliding on the track. Complete the table below to show your predictions for the size of the force recorded by the hand held force sensor with the size of the force recorded by the force sensor attached to the tray.

Table 2: Predictions – pulling

Stage of Motion	Prediction of How the Two Forces Will Compare
Force is exerted but tray is still at rest	
Tray begins to move	
Tray moves with a constant velocity	

Collect Data

32. □ Hold the second force sensor parallel to the track.

33. □ Start data recording, and then pull the tray with the second force sensor. �(6.2)

34. □ Continue to stretch the rubber band until the tray begins to move.

35. □ Drag the tray for a few centimeters, and then stop recording data. �(6.2)

Analyze Data

36. □ Adjust the scale of your graphs to show all three parts of the Force versus Time graph, and ensure the Time axes are aligned. �(7.1.2)

37. □ Sketch your graphs of Force versus Time in the Force versus Time - Pull, blank graph axes in the Data Analysis section.

38. □ Compare the force in each part of the Force versus Time graphs for each force sensor at three points in time, and record these values in each of the three parts of the graph in Table 4 in the Data Analysis section. �(9.2)

39. □ How accurate where your predictions? How does the force recorded by the hand held sensor compare to the force recorded by the force sensor attached to the tray when the tray has not yet started to move, when the tray begins to move, and when the tray moves at constant velocity?

40. ☐ How does the direction of the force recorded by the hand held force sensor compare with the direction of the force recorded by the force sensor attached to the tray?

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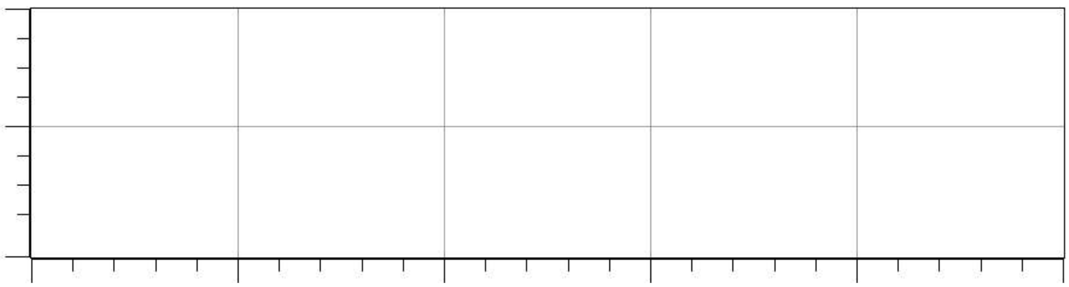
41. ☐ Save your experiment as instructed by your teacher. �(11.1)

Data Analysis

Force versus time – pushing



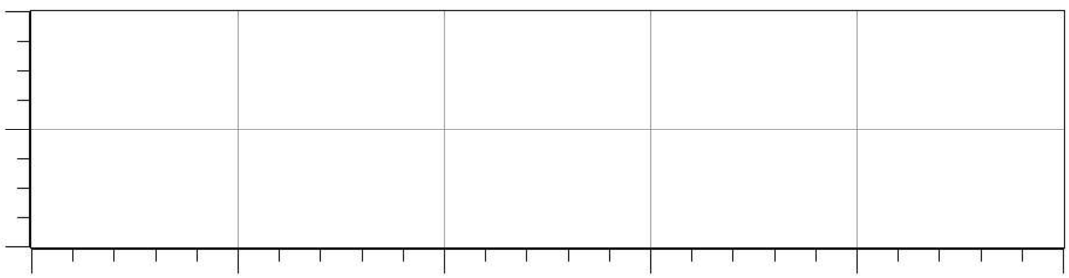
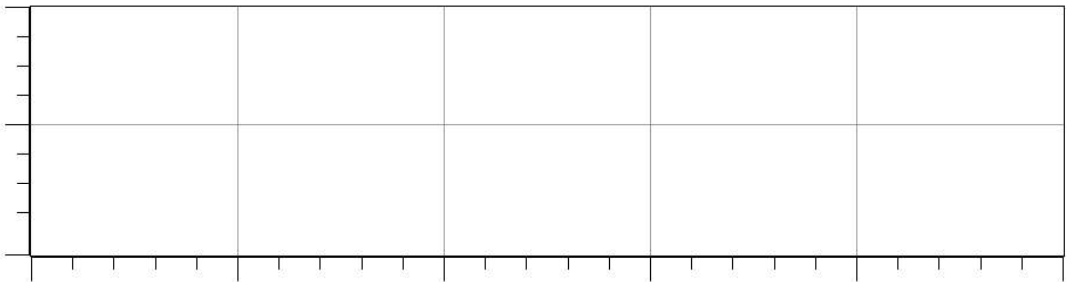


Table 3: Pushing – peak forces

Mass		Initial Motion		Peak Force	
Cart A	**Cart B**	**Cart A**	**Cart B**	**Force Sensor A**	**Force Sensor B**

Force versus time – pull



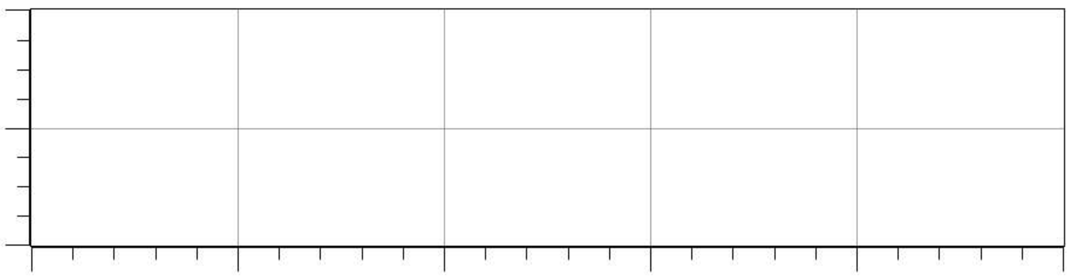


Table 4: Pulling

Stage of Motion	Force Sensor Attached (N)	Force Sensor Pulling (N)
Force is exerted but tray is still at rest		
Tray begins to move		
Tray moves with a constant velocity		

Analysis Questions

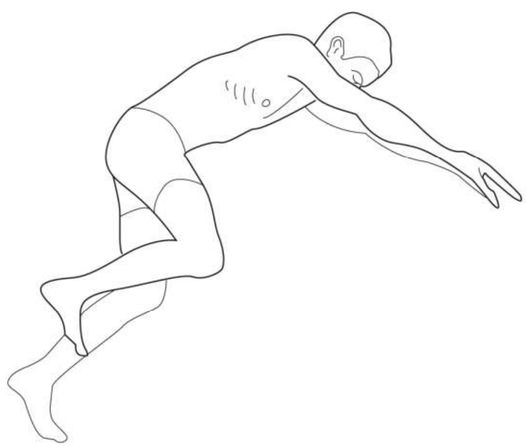
1. If you look at all of the interactions studied in this activity, how would you summarize the results in a single sentence?

2. **In Part 1 of this activity you placed a spring bumpers on the force sensors. What was the advantage in using this modification rather than using the small rubber stopper on the end of each force sensor?**

Synthesis Questions

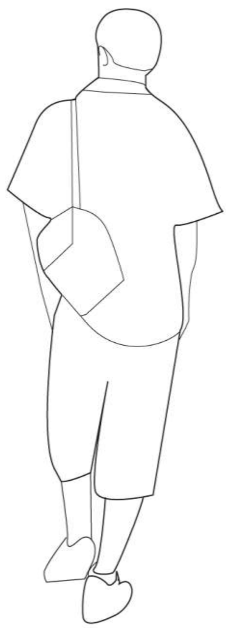
Use available resources to help you answer the following questions.

1. **A 65.0 kg Olympic diver dives from a 10 m tower. Consider the instant that the diver is in the air 1 m above the platform. Draw a free-body diagram showing the forces acting on this diver at this instant. In the table below, describe these forces in the "Action" column. Give the size and direction of the force as well as stating what exerts the force. In the "Reaction" column, give a similar detailed description of the reaction force. Assume that the gravitational field strength is 9.80 N/kg.**



Action	Reaction

2. A 65.0 kg tourist is standing in line waiting to get into a theatre. Draw a free-body diagram to show the forces acting on the tourist. In the table below, describe these forces in the "Action" column. In each case, give the size of the force, show its direction, and specify what exerts the force. In the "Reaction" column, describe the reaction for each of the action forces again giving size, direction, and the object that exerts the force.



Action	Reaction

3. **A parent pulls a sled with children at a constant velocity of 0.8 m/s across a level snow covered lawn by exerting a force of 225 N to the west. The mass of the sled and children is 85.0 kg. Draw a free-body diagram to show the forces acting on the loaded sled. In the table below, describe these forces in the "Action" column. In the "Reaction" column, give the size of the force, show its direction, and specify what exerts the force. Assume that the gravitational field strength is 9.80 N/kg.**

Action	Reaction

4. **A horse that is hitched to a stationary cart begins to pull on the cart. If the force exerted by the cart on the horse is always equal in size and opposite in direction to the force exerted by the horse on the cart, how can the horse move the cart?**

5. **A student holds a force sensor from which a 500 g mass hangs. Suddenly, the force sensor slips out of the student's hand and falls to the floor. What reading does the force sensor show as it falls to the floor?**

6. **An astronaut is about 20 m from her space station when the small rocket thrusters she uses to move around run out of fuel. If she is carrying a few tools and can also remove the rocket thruster, what should she do to get back to the space station? Explain your reasoning.**

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7. **A small economy car experiences a "head-on" collision with a large truck. If the economy car and the truck exert equal and opposite forces on each other, why is the driver of the economy car more likely to suffer serious injuries than the driver of the truck?**

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8. **Two "tug of war" teams are very equally matched. When they pull as hard as they can, the rope they are using is close to the breaking point. If your objective was to break the rope, how could you utilize the two teams to achieve this goal?**

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Multiple Choice Questions

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

1. **A student attaches a force sensor to a large block on a level surface. The student gradually increases the horizontal force exerted by the force sensor on the block until the block begins to move. If the force sensor records a value of 23.5 N the instant the block begins to move, what is the value of the size of the force exerted by the block back on the force sensor?**

A. Less than 23.5 N

B. 23.5 N

C. More than 23.5 N

D. Either more than 23.5 N or less than 23.5 N depending on the amount of friction present

2. The earth exerts a downward gravitational force on an automobile. The reaction to this force is:

- **A.** The upward force of the ground on the automobile
- **B.** The downward force of the automobile on the ground
- **C.** The upward gravitational force of the automobile on the earth
- **D.** None of the above

3. A soccer player exerts a force of 86 N on a 300 g soccer ball by kicking it. The force exerted by the soccer ball on the player's foot is:

- **A.** 0 N
- **B.** 29.4 N
- **C.** 43 N
- **D.** 86 N
- **E.** 170 N

Key Term Challenge

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

1. If a quarterback exerts a ________________ of 150 N [south] on a football, then the ________________ force is a force of 150 N [north] exerted by the football on the quarterback. If the quarterback is in the air when he makes the throw, the ball will move toward the south and the quarterback will move to the north. The ________________ of the ball will be much more significant because the ________________ of the ball is much less than that of the quarterback.

2. Newton's ________________ law is commonly stated as: To every ________________ there is an equal and opposite reaction. These forces always occur in ________________ that are equal in ________________ but opposite in ________________.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
Acceleration	Action
Force	Direction
Mass	Magnitude
Motion	Pairs
Reaction	Reaction
Weight	Second
	Third