Name Period Date

14. Newton's Third Law

Equal and Opposite

Driving Question

What is meant by equal and opposite forces, and what does this have to do with Newton's third law of motion?

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Force sensors with hooks (2)
- ☐ Strong rubber band

Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not over-stretch the rubber band.
- Do not apply a pushing or pulling force greater than 50 newtons to the force sensors (doing so will damage the sensors).

Thinking about the Question

A force is a push or a pull. Objects can interact with one another by applying forces to each other.

If you have ever watched or participated in any sport, you have seen and experienced forces. Soccer players know that applying a large force to the ball, in the direction of the opponent's goal, is one good way to score. They hope that an opponent is not able to apply a similar large force to the ball—but in the opposite direction—before the ball enters the goal. Likewise, basketball players can apply a small, upward force to the ball just under the hoop or a large force from beyond the three-point line, in the hope of getting the ball to its target.

Occasionally, in some sports, large forces are exchanged between the players themselves, without the involvement of a ball. Football players are experts at applying pushing forces to one another. In fact, they are so good at using force to their advantage, that their progress down the field is often measured not in yards but in inches!

Discuss with your lab group members some examples of forces applied in opposite directions. Try to think of several additional examples that have to do with sports, and several that do not have to do with sports. Next, discuss with your group some examples of forces that are equal in size. Again, come up with some ideas from sports as well as some ideas that have nothing to do with sports.

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.**

◯	◯	◯	◯	◯
Collect additional data so you have multiple trials of the same experiment.	Record force data.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Use a rubber band to connect the hooks of two force sensors together.	Apply a series of pulling forces to a pair of force sensors connected together.

Investigating the Question

☐ **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 – Making predictions

1. ☐ Write your predictions for the following:

   a. How will the graph of force (pull = positive) look when you pull on the hook of the force sensor for a few seconds and then let go?

   b. How will the graph of force (push = positive) look when you pull on the hook of the force sensor and then let go?

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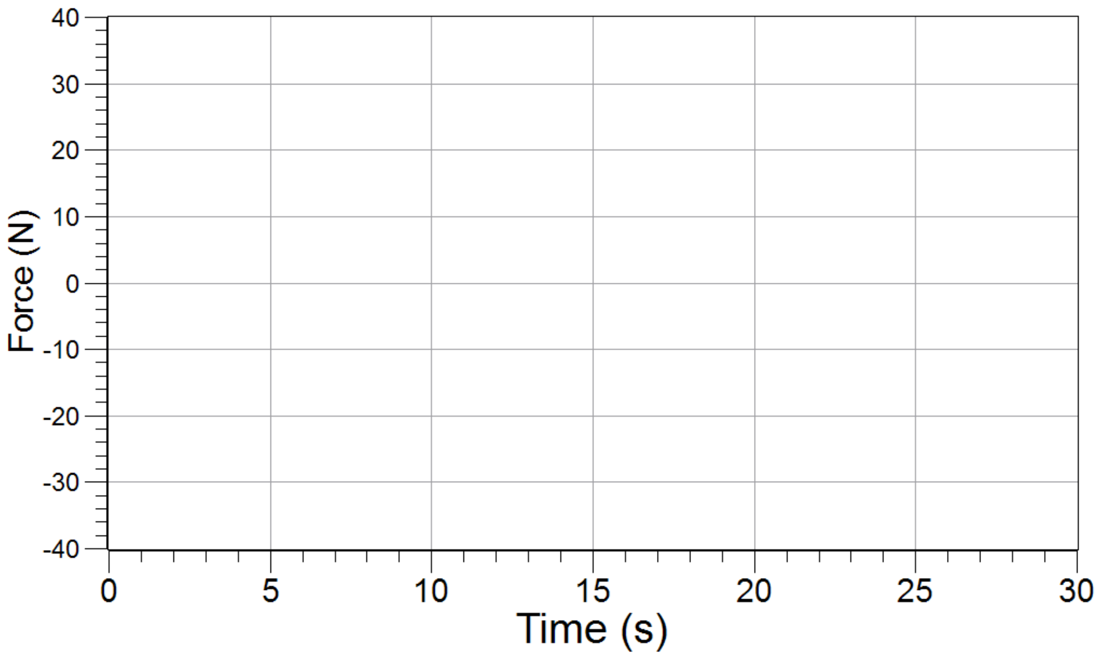
c. In the space below, sketch a force versus time graph that reflects your predictions.



Part 2 – Investigating the force sensor

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

3. ☐ Connect a force sensor to the data collection system. �(2.1)

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

5. ☐ Zero the force sensor (do this by pressing the small "zero" button near the top front of the sensor).

6. ☐ Begin data recording. �(6.2)

7. ☐ While holding the sensor steady, pull steadily on the hook. (Watch the graph – do not exceed 50 N of force).

8. ☐ How can you tell from the graph whether the hook is being pushed or pulled? What part of the graph display indicates whether the pull or push is positive? According to your data, what is another name for "negative" force? Explain why you think this.

9. ☐ Stop data recording �(6.2)

Part 3 – Equal and opposite forces

10. ☐ Connect the hooks of the two force sensors together with the rubber band.

11. ☐ Connect the second force sensor to the data collection system. �(2.2)

12. ☐ Display Force from each sensor on the y-axes of a graph with Time on the x-axis. �(7.1.10)
Set one of the force sensors to measure a *push as the positive force*, and the other force sensor to measure a *pull as the positive force*. What about this set-up is described by the term "opposite?" What about this set-up makes it "equal?" Do you think the forces you are about to apply will be balanced? Explain why you think this.

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13. ☐ Zero each force sensor.

14. ☐ Begin data recording. �(6.2).

15. ☐ Rest the two force sensors flat on your table and gently pull them apart from each other, stretching the rubber band as you do. Remember not to pull hard enough to break the rubber band.

16. ☐ Record pulling data for 20 to 30 seconds. See how much variety you can produce in your graph.

17. ☐ If there is time, have each lab group member take a turn pulling on the force sensors.

18. ☐ Stop data recording. �(6.2)

19. ☐ What did you notice about the two forces, based upon your observations of the graphs? Write your observations.

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Answering the Question

Analysis

1. How did your predictions from Part 1 compare to the results in Part 2?

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2. Sir Isaac Newton's third law of motion states that if one object applies a force on another object, then the second object applies a force of equal strength and opposite direction back on the first object. How does your data from Part 3 support Newton's third law of motion? Explain your reasoning.

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3. How could you re-state or paraphrase Newton's third law of motion in your own words?

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True or False

☐ **Enter a "T" if the statement is true or an "F" if it is false.**

__________ 1. In physical science, force is measured in units called Kelvins.

__________ 2. It is common to find forces acting alone.

__________ 3. Newton's first law of motion is related to forces that act in pairs.

__________ 4. An example of an action-reaction force pair is a balloon's air pushing out of the opening toward the left and the balloon flying off toward the right..

__________ 5. If you hit a volleyball during a game, the volleyball will push back against your hand.

_____________ 6. Stretching a rubber band between two force sensors can result in forces that are in opposite directions, but are equal in strength.

Key Term Challenge

☐ **Fill in the blanks from the randomly ordered words below. You may not use all the terms, or you may use some terms more than once,**

newtons	force	twelve	five
reaction	third	opposite	action

1. Newton's _________ law of motion tells us that if one object applies a force on another object, then the second object applies a force of equal strength, but in the opposite direction, on the first object.

2. Forces always come in_______________ – ______________ pairs.

3. When the space shuttle is launched, the ____________________ force pushes the rocket's hot exhaust gases downward, and the ______________ force of the hot gases lifts the rocket against the downward _____________ of gravity.

4. An action force of twelve ____________ pushing on an object from the right would have a reaction force of _______________ ______________pushing back against that force from the left.