5. Systematic Testing: Wheel Size

Build Knowledge

INTRODUCTION

What Students Do in This Activity

Teams use their gravity cruisers to conduct formal investigations into the effects of wheel size on vehicle performance. To investigate the effects of wheel diameter, students track their cruisers' travel distance as they attach different-sized wheels. Students log their experimental data and find that larger wheels allow the gravity cruiser to travel a greater distance.

Rationale

Students continue collecting data through formal testing of the gravity cruiser. This activity shows students that the relationship between wheel size and travel distance can be tested using controlled experiments.

The Systematic Testing activities (Activities 5, 6, and 7) in the unit differ from the preceding activities in that they are structured as guided inquiry sessions. These activities are designed to help students learn how to design experiments, as well as introduce students to some of the content standards related to force and motion.

Time

1 class period

Materials

for each student:

- A copy of Homework: Predicting Travel Distance, Reproducible Master 10

Note that once Lessons 5, 6 , and 7 are completed, an interactive Gravity Cruiser game is available at http://awim.org/curriculum/gravitycar/game/gravityCruiserProject.swf. This is a wonderful activity to solidify concepts already learned.

A-Ha

The Effect of Wheel Size

The larger the wheel diameter, the farther the gravity cruiser can travel with every turn of its axle. However, increasing the wheel size also slows down the vehicle and may require increasing the axle diameter to produce enough torque to get the vehicle moving, which will reduce the gains in travel distance.

for each design team:

- a working gravity cruiser
- three sizes of wheels
- extra pennies
- design log
- a copy of Gravity Cruiser Wheel Test Data, Reproducible Master 8
- a copy of Gravity Cruiser Wheel Test Data Graph, Reproducible Master 9

for the teacher:

- overhead or LCD projector (optional)
- chart paper
- colored markers

Preparation for the Activity

If the tests undertaken in this activity are to have any validity, students' gravity cruisers must perform consistently. It is important to check all the groups' models to see if they are in good working order and give consistent results.

CLASSROOM ACTIVITY

Presenting the Activity

1. **Review briefly the discussion you had at the end of the previous session.**

   It is important to take the time to persuade students that further work in the form of systematic testing will be useful to them. They may be resistant to making any changes at all to their current design.

2. **Explain to the students that they will begin conducting controlled experiments that will help them to make their cruiser perform better.**
3. **Explain that they will compare the performance of their cruisers with and without a particular modification.**
4. **Based on the previous testing of their models what parts of the model do they think might make a difference in how far it travels?**

   Students may recognize some or all of following factors:

   - the weight (number of pennies in the vial) on the lever arm
   - the position of the weight on the lever arm
   - the size of the gravity cruiser's drive wheels
   - the position of the fulcrum relative to the lever

5. **Ask students, "How do you think changing the wheel diameter of the cruiser will change how far it travels?"**

   Students may recognize that a larger drive wheel will cause the cruiser to roll farther on each revolution of the axle.

6. **Because this is students' first time conducting controlled tests, discuss the importance of holding all but one variable constant in the testing. Introduce the concept of fair testing using the following hypothetical test to begin the conversation:**

   In a test of the optimal amount of water with which to grow plants, researchers set up four pots.

   Make a table on the board as follows:

	Pot 1	Pot 2	Pot 3	Pot 4
Planting medium	1.9 liters (2 qt) potting soil	2.8 liters (3 qt) potting soil	1.9 liters (2 qt) sand	1.9 liters (2 qt) potting soil and .95 liter (1 qt) sand
Plant	Daisy	Orchid	English ivy	Venus flytrap
Location	Windowsill	Closet	Under sunlamp	Windowsill
Amount of water	½ cup/day (120 ml/day)	1 cup/day (240 ml/day)	2 cups/day (480 ml/day)	3 cups/day (720 ml/day)
Result	Grew 10 cm (4 in.)	Died	Grew 4 cm (1.6 in.)	Grew 2 cm (.79 in.)

7. **As a class discuss, whether 120 milliliters (½ cup) of water per day is the optimal amount of water or if the experiment may not have been set up properly.**

   Students should recognize that the test as performed was extremely flawed and that there were far too many variables. Ask students to identify variables that may have affected the test results. Students should identify the following:

   - *the variety of plant*
   - *the planting medium*
   - *the plant's location*

8. **Discuss how students think that this test could have been conducted fairly.**

   Students should recognize that the variety of plant, planting medium, and location should have been the same for all four pots to make the experiment fair.

9. **Discuss how their understanding of variables should affect how they conduct tests on wheel size.**

   Students should recognize that they should be careful to change ONLY the wheel size of the cruiser when they are doing these tests.

Teacher Tip:

It is possible to conduct the Systematic Testing activities as a jigsaw activity. If you choose to do so, introduce all of the testing activities using the *Presenting the Activity* section of this activity. When all teams have completed their testing, it is very important to allow plenty of time for teams to share their results with each other.

It is also possible to forgo some or all of the Systematic Testing activities and go directly to the final design phase, although students will not automatically assimilate concepts such as potential and kinetic energy and torque just by going through the design process.

Teacher Tip:

Some cruisers may not run with larger wheels. Make sure that students know that they can add extra weight (pennies) to the penny vial to get their cruiser to move.

10. **Ask students to predict how wheel size will affect travel distance.**

    Discuss their predictions and their reasoning.

11. **Distribute a copy of Gravity Cruiser Wheel Test Data, Reproducible Master 8, a copy of Gravity Cruiser Wheel Test Data Graph, Reproducible Master 9, extra pennies, and two wheels of each size to each team.**

    Go over the column headings to be sure that students know what data to put in each box. In the Comments column, students can note, for example, whether the vehicle went fast or slow, or turned to the left or right, or needed a small push before it started.

During the Activity

12. **Ask the whole class how they think they could test effects of wheel size on cruiser performance.**

    Student answers may vary, with some students having an understanding that larger wheels will make the cruiser travel farther and others without such an understanding. Discuss why students think the way they do, asking them to back up their assertions with reasoning.

13. **Students conduct wheel size experiments in teams. Ask teams to keep their data tables in their design logs.**

14. **When they have finished conducting their trials, have teams graph their results using grouped bar graphs on Gravity Cruiser Wheel Test Data Graph, Reproducible Master 9.**

    Teams should graph the data from each trial on the reproducible master and add it to their design logs.

Teacher Tip:

It is interesting to note that increasing the wheel size slows down the vehicle and may cause it to have trouble getting started or continuing to move because it does not have enough torque. In future activities, students will explore how torque can be increased by changing the axle size and how changing axle size affects cruiser performance.

What to Look For

Be on the lookout for teams that accept bad data too easily. (For example, a team may have wildly different travel distances using the same-size wheels because the string got caught during a test run.) If this is a class-wide problem, you may wish to have a discussion about data collection. Have students consider the difference between being thoughtful about results (realizing that the string got caught, making a note on the data table, and conducting one or more extra test runs to make sure that the string was the problem) and being dishonest about results (throwing out data because you don't like the results).

Sharing and Interpreting

15. **After teams have finished their trials, have them present their findings and post their graphs where they can be seen by everyone in the class. After each team describes its controlled tests and the data they collected, have teams leave their gravity cruisers near the posted graphs.**

    This way, as the class discusses trends in the data, students can support their arguments by pointing to similarities and differences among the cruisers.

16. **Ask students, "What trends in the data do you notice?"**

    The data should show that cruisers travel farther when they have large drive wheels. Students may have also found that the cruisers have more difficulty getting started when they have larger drive wheels.

17. **Follow up with the following question. "Do these trends prove or disprove your predictions about the effects of wheel size?"**

18. **Given these findings, what size wheels should teams use if they want their gravity cruisers to go as far as possible?**

    Students should recognize that larger drive wheels will help their cruisers to travel farther.

19. **Challenge design teams to come up with a way of figuring out how far their cruiser will travel based on wheel size.**

20. **When teams have finished figuring out how far their cruiser will travel based on wheel size, have them share their results with the class.**

    Students should be aware that the larger the wheel, the farther it travels with each rotation.

Teacher Tip:

Each team is carrying out tests on their own particular design. The designs will mostly likely vary, and it is therefore impossible to make a valid comparison across all designs. However, if each design was performing consistently, then the larger diameter wheels should give a better performance compared to the smaller ones. If one or more teams finish quickly (and their data appear consistent), challenge them to increase the axle diameter in some way (using masking tape) and repeat the tests. Give them another copy of Gravity Cruiser Wheel Test Data, Reproducible Master 8, on which to record travel distance.

What to Look For

Even though the general trend is "larger wheels = longer travel distance," it is likely that some vehicles with medium-sized wheels will achieve the same or greater distances during tests than some vehicles with large wheels. However, the rule should hold true that any individual vehicle will travel farther with larger wheels than with smaller wheels. If students note that some vehicles with large wheels did not travel as far as other vehicles with medium-sized wheels, ask them how this might happen. Elicit the idea that wheel size is only one design factor out of many, and that other gravity cruiser characteristics affect its distance capability.

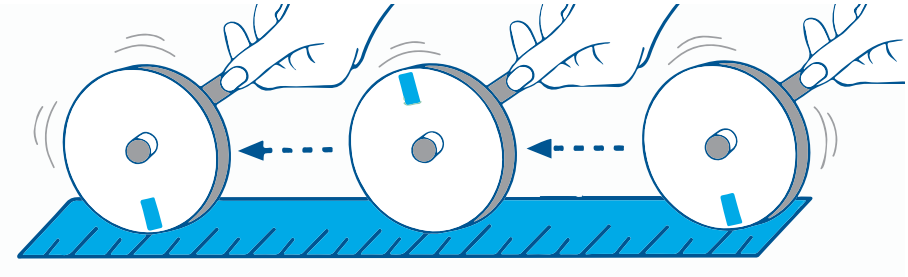
HOMEWORK

Hand out copies of Homework: Predicting Travel Distance, Reproducible Master 10. Students consider how wheel size can be used to predict travel distance and illustrate their method of prediction with a drawing or graph. Students answer this question: "When might a gravity cruiser be able to travel farther than its wheel size predicts?"

(Answer: *When the vehicle has enough momentum so that it continues to roll after the string has completely unwound from the axle.*)

EXTENSION IDEAS

1. Have students explore the relationship between wheel size and cargo-carrying capacity and report on their findings to the class. Before conducting the experiment, they should decide what data to collect and how the data tables should be arranged.
2. The circumference of a circle is π times the diameter. Have students use this relationship to express their travel distance predictions as an algebraic equation.



Teacher Tip:

If students struggle with this task, suggest that they make a mark on each size wheel and a corresponding mark on a piece of paper. Then students roll each wheel so that the mark travels back to the same position in which it started. Ask them to measure how far the wheel went in a single rotation. Students should find that the largest wheel traveled the farthest.

Name _____ Date _____

GRAVITY CRUISER WHEEL TEST DATA

Wheel Size #1: _____

Trial	Travel Distance	Comments

Wheel Size #2:_____

Trial	Travel Distance	Comments

Wheel Size #3:_____

Trial	Travel Distance	Comments

Procedure

1. Measure and record travel distance in three trials for each of three wheel sizes.
2. Conduct these tests with no cargo attached to the chassis platform.
3. Make a bar chart of your results on Gravity Cruiser Wheel Test Graph, Reproducible Master 9.

Team Members_____ Date _____

GRAVITY CRUISER WHEEL TEST GRAPH

Distance Traveled (m)

	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3
Wheel Size											

Name _____ Date _____

HOMEWORK: PREDICTING TRAVEL DISTANCE

How does the size of your Gravity Cruiser's wheels determine how far it will travel? Draw a picture or make a graph to show how you made your prediction.

Now, answer this question, "When might a gravity cruiser be able to travel farther than its wheel size predicts?"

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