The Mathematics of Miniature Golf

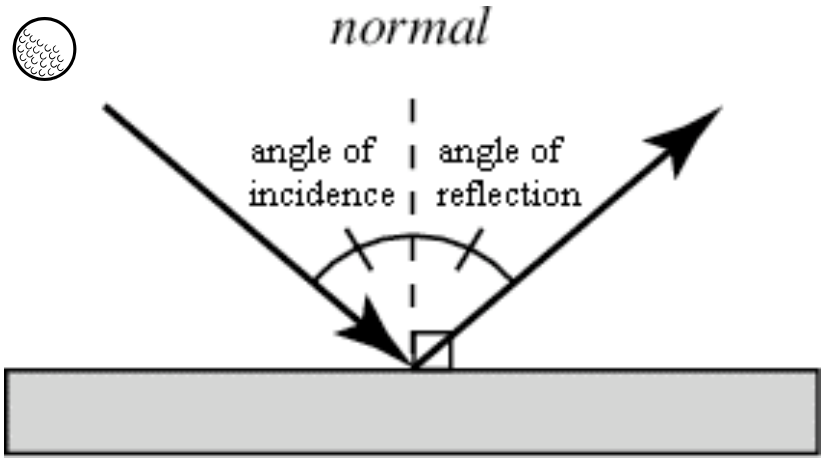
Though you might never have thought about it before, the rules of physics and mathematics can be used to predict and explain the game of miniature golf! During this project, you will use your knowledge of angle measures to explore the path of a ball on miniature golf courses.

BOUNCING OFF SURFACES

When a ball is rolled without spin against a wall, it bounces off the wall at the same angle it hit the wall. This is a fundamental law of physics called the Law of Reflection. It is stated:

> The angle of incidence is equal to the angle of reflection.

- ❏ The **angle of incidence** is the angle at which the ball approaches the wall.
- ❏ The **angle of reflection** is the angle at which the ball bounces off the wall.
- ❏ Both of these angles are measured from what is known as the normal line – an imaginary line drawn perpendicular to the wall (at a perfect 90° angle).



Notice: The gray box represents the wall. The normal line is drawn perpendicular to the wall. The angle of incidence and the angle of reflection are exactly equal. The arrow on the right shows the direction the ball will travel after it bounces off the wall.

Grade 5 Unit 3

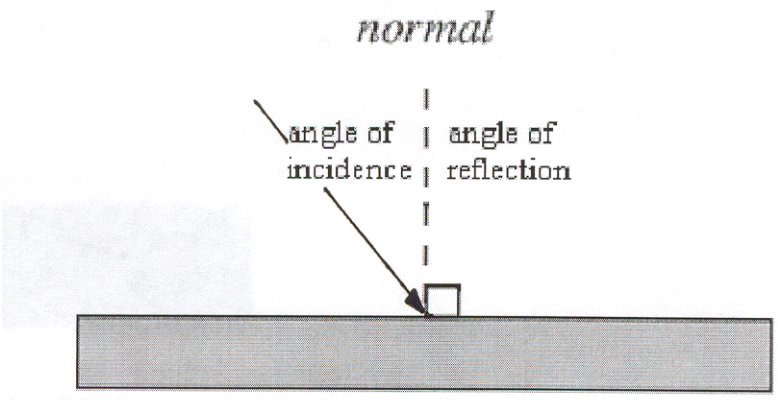
PREDICTING A BALL'S PATH

Try some of your own. On each diagram below, show the ball's path after bouncing off the wall. Show your work.

Example 1:

A. The ball approaches the wall at an angle of 38°. This angle is called the angle of incidence and is measured from the normal line.

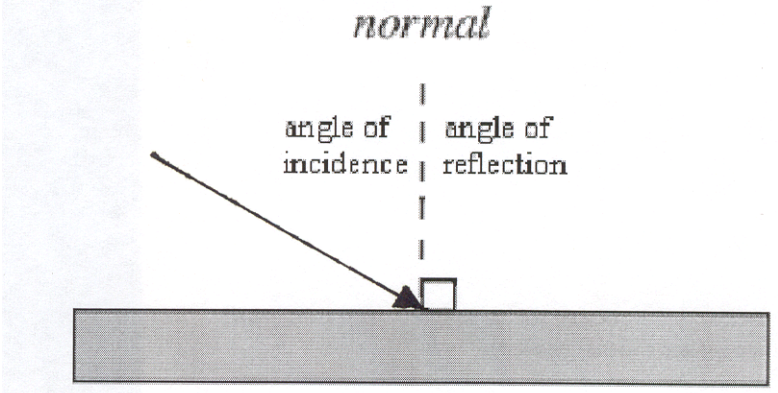
B. Draw in the ray showing how the ball will bounce away from the wall. Be sure to use your protractor to make the angle of reflection exactly equal to the angle of incidence.



Example 2:

A. In this example, you must use your protractor to measure the angle of incidence. Be sure to measure from the normal line.

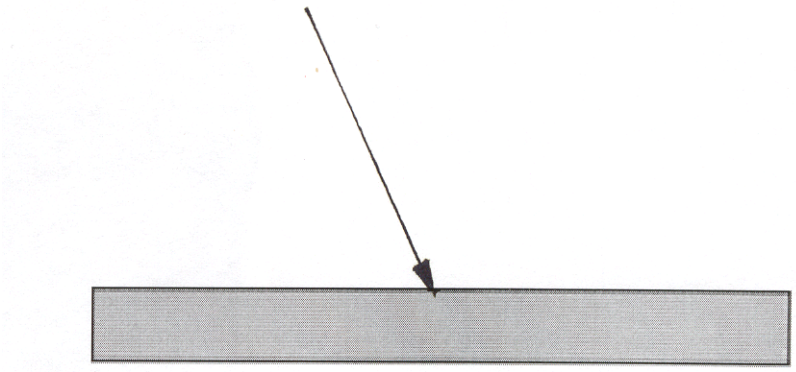
B. Now, show the path the ball will travel after it bounces off the way by drawing in an angle of reflection that is exactly equal to the angle of incidence. Again, be sure to measure the angle of reflection from the normal line.



Example 3:

A. Now, you must draw in the normal line. Remember that the normal line is always perpendicular to the wall (at a perfect 90° angle).

B. Use your protractor to measure the angle of incidence and to draw the angle of reflection.



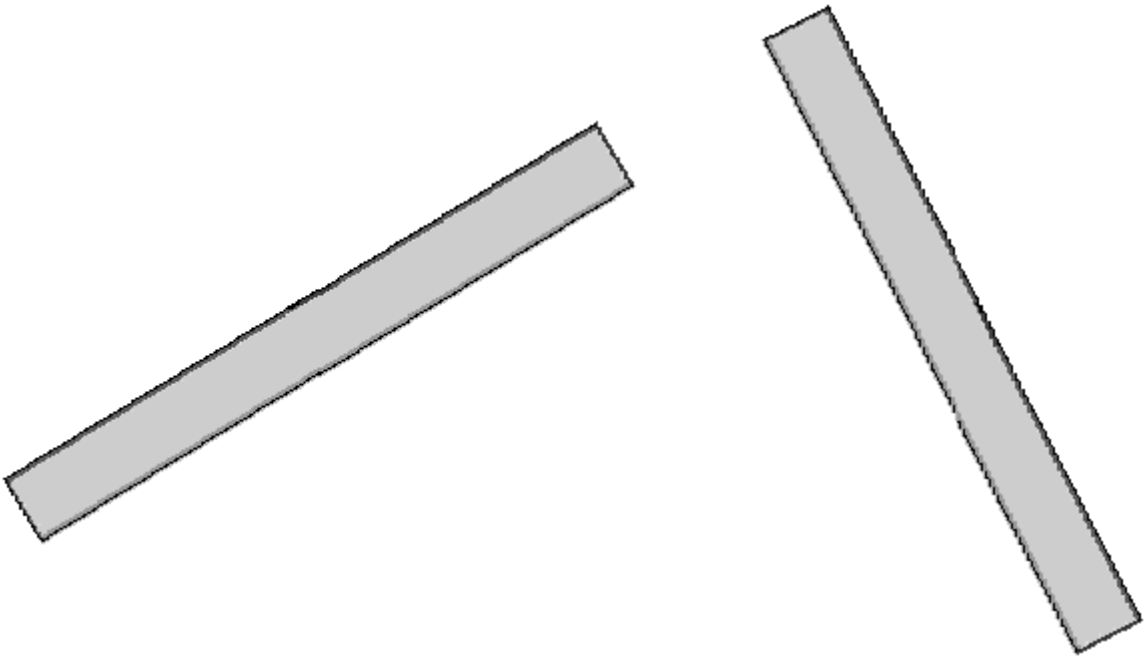
Create two diagrams of your own to show how a ball might roll into and bounce off of a wall.

Follow these steps for each diagram:

- ❏ Use a straight edge to draw the path of a ball coming toward the wall and hitting it.
- ❏ Draw the normal line perpendicular to the wall, at the point where the ball hits the wall.
- ❏ Measure the angle of incidence (from the normal line).
- ❏ Draw the angle of reflection.

Now let's make it even trickier! When a wall is slanted, all of the same rules apply. Try showing how a ball might bounce off of these walls. Follow the same steps shown above. Remember these three important ideas:

- ❏ The normal line must be perfectly perpendicular to the wall.
- ❏ Measure the angles of incidence and reflection from the normal line.
- ❏ The angle of incidence is equal to the angle of reflection.

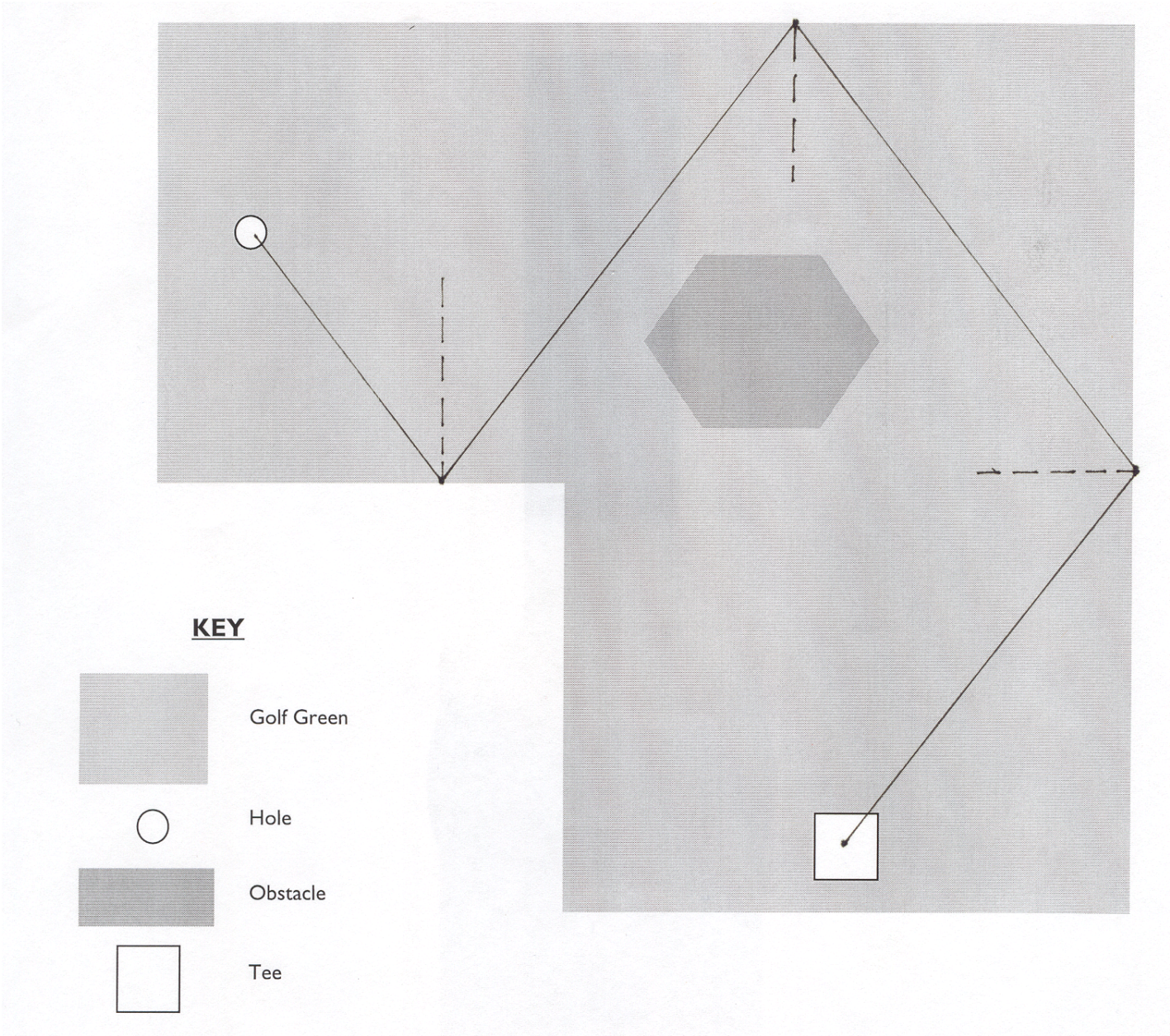


APPLYING THE CONCEPT

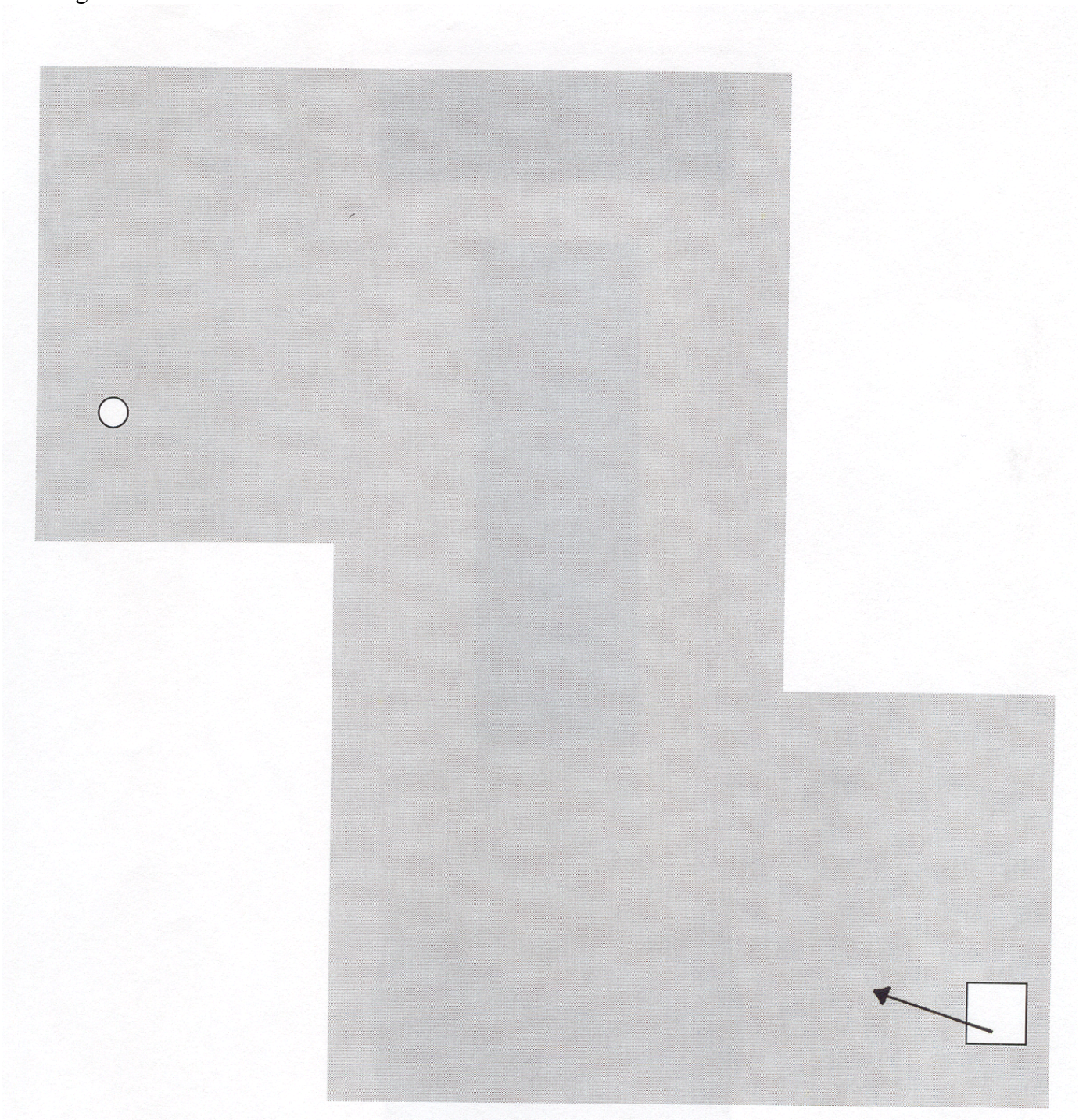
Now imagine a golf ball bouncing all over a miniature golf green. For our examples, we will pretend that friction will not slow the ball down. The ball will continue rolling in a straight line – and bouncing off walls – until it reaches the hole.

On the following pages, three miniature golf holes have been drawn. Use the key below to interpret each of the symbols. On each hole, you will show the path the ball will take to reach the hole. Remember that each time the ball bounces, the angle of incidence is equal to the angle of reflection. The first one has been done for you.

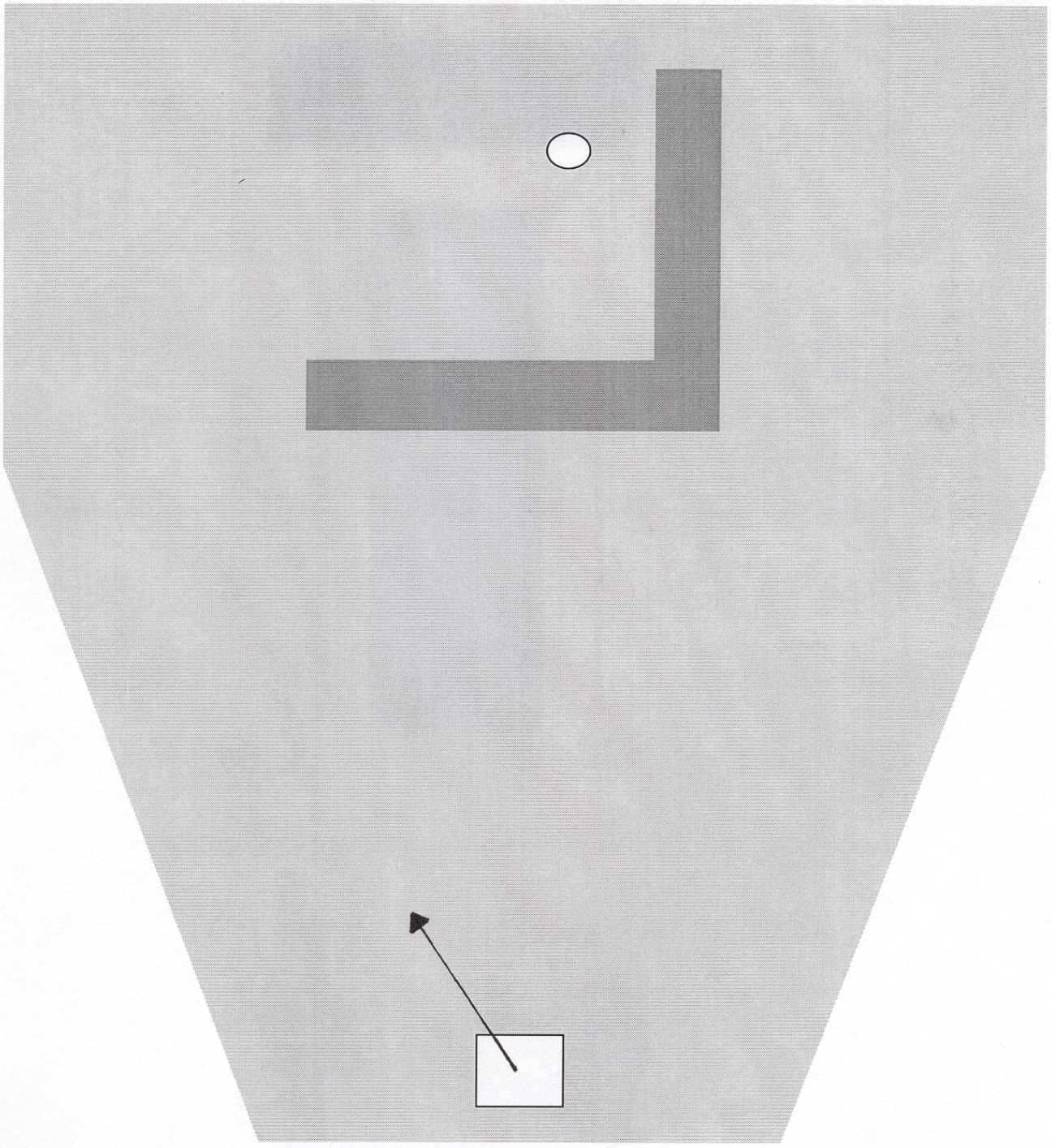
HOLE #1: Study this example.



HOLE #2: Continue the ball's path. If your work is correct, the ball should bounce twice before reaching the hole.



HOLE #3: This ball must bounce around the obstacle! Continue its path. If your work is correct, the ball will bounce three times before reaching the hole.



Your Challenge

Begin to design your own miniature golf course!

PLAN THE NAME AND THEME

First, you will need to come up with a creative theme for your miniature golf course. Think about how the obstacles, the decorations, and the surroundings might display your theme.

Use a sheet of colored construction paper to:

- ❏ Draw the sign that will show the name of your miniature golf course.
- ❏ Under the sign, write several sentences explaining the theme of your golf course and how the theme will be reflected in the features that will appear on your golf course.

CREATE THREE HOLES FOR YOUR GOLF COURSE

Use three pieces of graph paper to show a plan for three holes of your miniature golf course. Show the layout of each hole using the same format you saw in this packet. The only limitations are that your walls must be straight (no curves) and the surface of your green must be flat (no slopes).

- ❏ Draw the green, the hole, the tee, and the basic shape of any obstacles. You may use color.
- ❏ Beside the map of each hole, draw a detailed sketch of the obstacle.
- ❏ Using the Law of Reflection, show a path the ball could take from the tee to get a hole-in-one. Be sure to mark your normal lines for each bounce of the ball.

> **HELPFUL HINT:** First, draw the layout of your green. Then decide where the tee will be. Next, start drawing the ball's path. After you see the ball's path, decide where the hole should be. It's much harder to put the hole in place first

ORGANIZE YOUR WORK

Put the pages of your project together as a book or a poster.

REFLECTION

- ❏ Could you really use what you've learned here to improve your score at mini-golf? Explain in detail why or why not.

- ❏ What new ideas did this project help you learn? Did anything surprise you?

- ❏ Measure a few angles of incidence and angles of reflection from the wall, instead of the normal line. What do you notice? Can you explain why this works?

- ❏ Did you develop any "shortcuts" you used your protractor to measure/draw angles. Explain your "shortcuts"!

- ❏ What was most challenging about this project? Would you change this project in any way?

- ❏ What questions or new ideas has this project made you wonder about?

GOING BEYOND

The Physics Classroom

http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l1c.html

The Law of Reflection also explains how light bounces off surfaces. Check out this website to learn more about how light bounces. Be sure to click on the animated graphic that teaches the Law of Reflection. There are even some very challenging online questions to go with this site.

Student and Teacher Evaluation

	4	3	2	1
My final project is accurate, and shows that I have applied mathematical ideas or learned new mathematical ideas.	I did a great job! This is a good example of my best work.	I did a good job, with just a few areas to improve.	If I could do this again, there are several things I would change.	There are many ways that I could have done better on this.
COMMENT:				
I followed each step in the directions carefully.	I did a great job! This is a good example of my best work.	I did a good job, with just a few areas to improve.	If I could do this again, there are several things I would change.	There are many ways that I could have done better on this.
COMMENT:				
I used my creativity and imagination to create a final project that is unique and represents my own thoughts and ideas.	I did a great job! This is a good example of my best work.	I did a good job, with just a few areas to improve.	If I could do this again, there are several things I would change.	There are many ways that I could have done better on this.
COMMENT:				
I made effective use of class time. I was able to get myself started quickly, answer questions for myself, and stay on task.	I did a great job! This is a good example of my best work.	I did a good job, with just a few areas to improve.	If I could do this again, there are several things I would change.	There are many ways that I could have done better on this.
COMMENT:				
My presentation was clear and detailed. The students in the class learned new information about my topic.	My presentation was well done. Students learned about the topic.	My presentation was good, but there are one or two things I would improve.	Students learned a few new facts, but I could have been louder or more organized.	I needed to be more prepared for my presentation.
COMMENT:				