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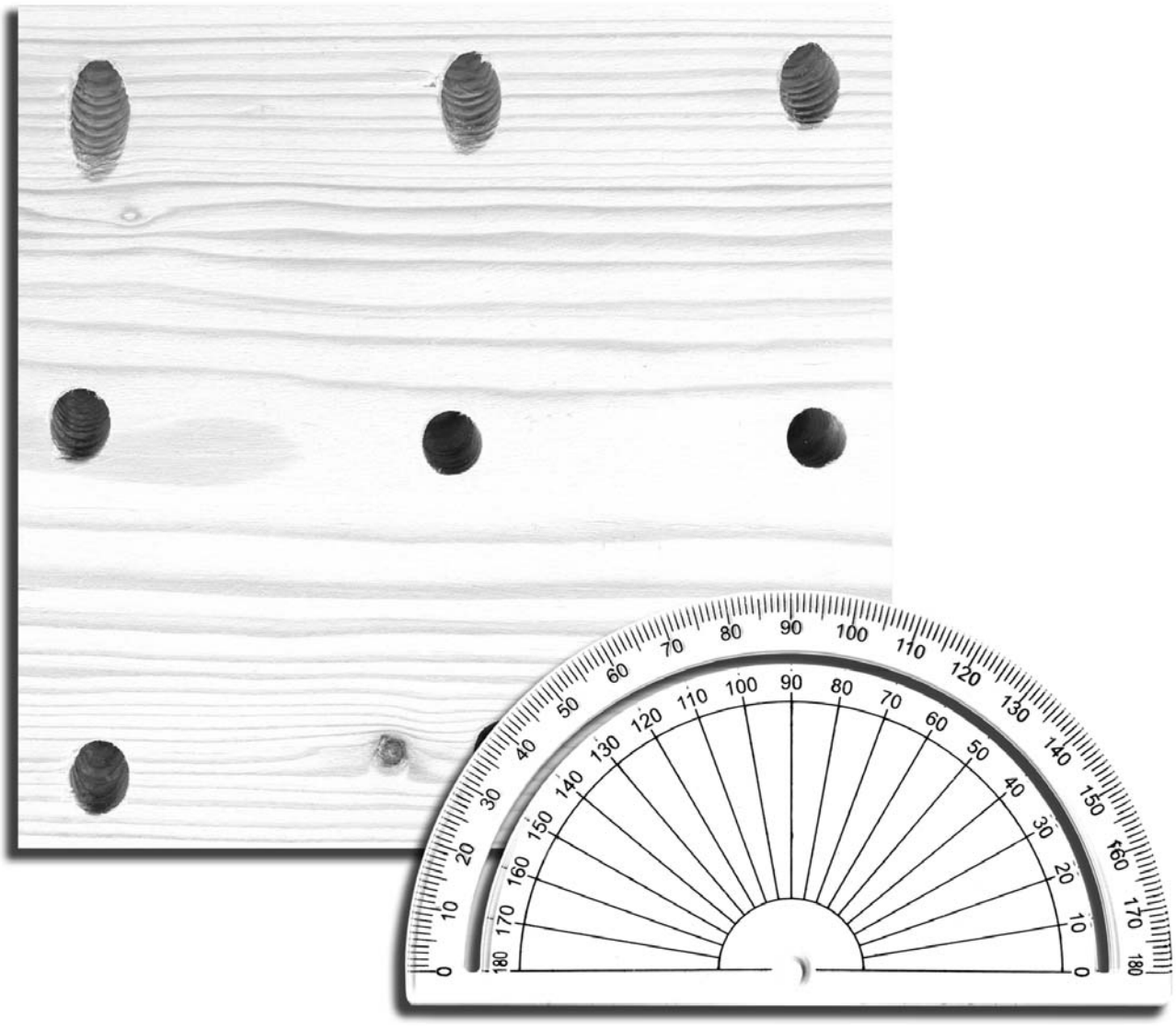
# Where's the Shooter?

## Carolina™ Bullet Trajectory Kit

**TEACHER'S MANUAL**



CAROLINA

*World-Class Support for Science & Math*

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### Teacher's Manual

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## Carolina™ Bullet Trajectory Kit

### Overview

In this simulated forensics investigation, you will hang a pre-drilled impact board with nine "bullet" holes. Nine shots have impacted the board at different angles, leaving behind telltale elliptical holes. You and your students will use basic trigonometric concepts to determine either

1) how far a shooter was from the impact board when shooting, given the shoulder height of that shooter

or

2) the shoulder height of a shooter, given his or her distance from the impact board when shooting.

This exercise is a great way to motivate students with a real-world application of trigonometry. The lab activity can be completed in one class period.

### Materials

*Included in the kit*

pre-drilled bullet impact board
protractors
trajectory string
tape
4 wooden dowels

*Needed, but not supplied*

calculator with trigonometric functions
tape measure or meterstick
step stool
caliper (optional)

**Safety Note:** As in any laboratory activity, model and instill good safety practice. Read through the entire manual before conducting the activity. You may want to conduct the procedure yourself before having your students begin. This will help you decide how best to group your class so that everyone has a role and not too many people are trying to use the impact board at the same time.

## National Science Education Standards

This kit is appropriate for introductory science classes and addresses the following National Science Content Standards:

### Unifying Concepts and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement

### Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

### Physical Science

- Structure and properties of matter
- Motions and forces
- Interactions of energy and matter

### Science and Technology

- Abilities of technological design
- Understandings about science and technology

### Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges

### History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

## Desired Outcomes

During this exercise, students will

- Follow some techniques used by forensic scientists.
- Apply some basic trigonometric concepts, including the sine, cosine, and tangent functions.

## Background

Forensic science can be defined as the use of science or technology in a court of law. This broad definition encompasses numerous scientific disciplines, including entomology, meteorology, zoology, toxicology, odontology, and engineering. The next generation of forensic scientists will need to be well versed in the general language of science and expert in at least one specialty field.

In this activity, we focus on the use of mathematics, particularly trigonometry, in forensics. We see how forensic scientists can analyze a crime scene and determine where suspects and/or victims were located when the crime occurred. One way they do this is to search the crime scene for bullet holes (in walls, ceilings, floors, furniture, etc.) and then analyze the shapes of the holes. Forensic investigators can use these shapes and basic trigonometry to reconstruct the crime scene.

If a bullet is fired straight into a wall (at an impact angle of 90°) and penetrates, it leaves behind a perfectly circular hole corresponding roughly to the size of the bullet. A hole such as this helps crime scene investigators determine the caliber and type of gun used but not the distance of the shooter when firing. If the angle is off by even the slightest degree, though, the hole is an ellipse. The smaller the angle of impact, the more elongated the ellipse. With a hole of this type, investigators can not only determine the size of the bullet, but, by using basic trigonometry, they can tell where the bullet came from.

To determine the impact angle, the angle at which the bullet struck the surface in question, an investigator might insert a dowel of corresponding size into the bullet hole and measure the angle formed between the dowel and the surface. Many types of trajectory dowels, including some with laser attachments, are available commercially. Inserting a dowel into a bullet hole before it has been properly examined, though, may destroy crucial evidence such as gunshot residue, fibers, or even biological evidence, which may have been carried into the hole along with the bullet. How, then, can an investigator find a non-invasive means of determining the location of the shooter by examining a bullet hole?

## Calculating Impact Angles

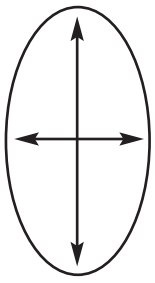
An investigator can measure the elliptical shape of the surface of the bullet hole and use trigonometry to determine the angle of impact. If the ellipse illustrated below is the surface of our bullet hole, the vertical line would be considered the **major axis** and the horizontal line the **minor axis**. We can use the sine function to determine the angle of impact if we know the lengths of both axes. *The sine of the angle of impact is equal to the minor axis divided by the major axis.* For example, if the major axis is 20 mm long and the minor axis is 15 mm long, the angle of impact (i) is calculated as follows:

$\sin(i) = \text{minor/major}$

$\sin(i) = 15/20$

$i = \sin^{-1}(15/20)$

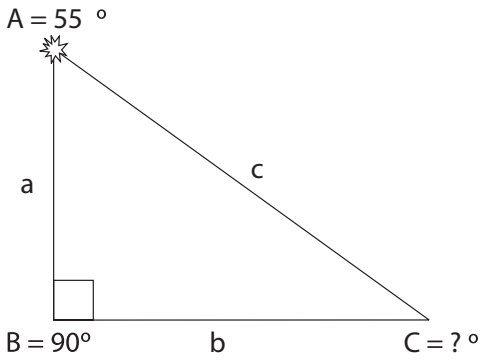
$i = 48.59°$



Typically, determining angles by measurement of the ellipse gives only a rough approximation; however, the greater the difference between the major and minor axes (i.e., the more elliptical the bullet hole), the greater the degree of accuracy of this method of pinpointing the trajectory. After the bullet hole has been thoroughly examined, you can use a dowel and a protractor to ensure that the calculated angle is accurate. Once the impact angle is firmly established, use trajectory string to reconstruct the flight path of the bullet. To do this, tape the string to the point of impact, and then extend it along one

side of the dowel and beyond to make a straight line to the floor. Tape that end to the floor. Somewhere along that line is where the shooter's shoulder was positioned.

The process of reconstructing a crime scene using a single bullet hole is based on the properties of right triangles. We know that inside a right triangle the three angles must total 180°, and we know that one of the angles is a right angle, or 90° (the angle between the floor and the wall). Therefore, if we know just one of the other two angles, we can solve for the third. Take the following example:




Here we know that angle *B* is equal to 90°. We can use the bullet hole to determine the measure of angle *A*. Let's assume, for this example, that this angle is 55°. We then know the measure of angle *C*: 180 – (*A* + *B*) = *C*, or 180 – (145) = 35°. We will call this angle the angle of elevation or angle of depression, since it is the angle to which the shooter raised or lowered the shooting arm when firing. We will be able to tell whether the bullet entered a surface from above or below (indicating elevation or depression) by observing the shape of the bullet hole. So how does all this help us reconstruct a crime scene?

If we know the length of *a* in the triangle above, we can find the length of *b*, and vice versa. That means that if we know the shoulder height of our suspect and the length of *a* (distance from impact point to a position on the wall at 90° from the shooter's shoulder), we can determine how far the shooter was from the point of impact when firing the gun (*b*). We need to use shoulder height rather than total height because this is the height from which a gun is fired. Likewise, if we know how far away our shooter was from the point of impact when firing, we can determine their shoulder height. This may help us eliminate or confirm individuals on our suspect list. It works like this: