Bullet Trajectory Analysis

Introduction

One bullet hole can help solve a crime! Determine the height of a suspect based upon the bullet trajectory.

Concepts

- Forensics
- Ballistics
- Bullet trajectory

Background

Bullet analysis or ballistics is an integral component of forensic science. Forensic scientists are able to use ballistics to determine many key components about a crime. For example, a bullet hole in a wall, ceiling, piece of furniture, etc. allows scientists to determine what kind of gun was used, the distance the shooter was from the bullet hole as well as the height of the shooter. Often we think of bullet holes as round, but this very rarely occurs. The only way for a bullet hole to be perfectly round is if the gun is held straight out from the shooter's shoulders to the wall and shot into the wall at a 90° angle. Most of the time the gun is shot from an angle, no matter how small, producing an ellipse-shaped hole. Elliptical bullet holes allow investigators to calculate the location of the gun when the bullet was shot.

Basic geometry is required to determine impact angles, distance of the shooter and height of the shooter. Remember the acronym SOH-CAH-TOA. See below for a review of each function.

Sin = Opposite/Hypotenuse
Cos = Adjacent/Hypotenuse
Tan = Opposite/Adjacent

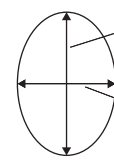

Figure 1.

In order to determine the location of the shot fired, the impact angle must be calculated. Traditionally this was done by inserting a dowel rod with the same diameter as the bullet hole into the bullet hole and measuring the angle between the dowel rod and the surface. The problem with this method is that insertion of the dowel rod can destroy other forms of evidence useful in solving the crime. Investigators now often use lasers to determine the impact angle. However, there is a simpler and more cost effective means to do so—by using trigonometry. As mentioned previously, the only way a round bullet hole will be produced is if the gun is directly against the target at a 90° angle, otherwise, the hole will be an ellipse. The ellipse in Figure 1 represents a bullet hole on the surface of the wall. The vertical line represents the major axis and the horizontal line represents the minor axis. The angle of impact can be determined using the sine function given the lengths of the major and minor axes. For example, if the minor axis is 13 mm long and the major axis is 19 mm long, what is the angle of impact?

Sin (i) = length of minor axis/length of major axis
Sin (i) = 13/19
i = $\sin^{-1}$(13/19)
i = 43.17° or 43° (to the nearest degree)

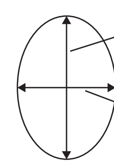

Figure 2.

The impact angle provided from the above calculations is not the most accurate means of determining the location of the shooter compared to more modern laser methods. However, it is important to realize that the greater the difference between the major and minor axis, the greater the accuracy of determining the bullet's origination location. Therefore, an ellipse with a minor axis of 19 mm and a major axis of 20 mm will not produce as accurate an angle as an ellipse with an 11 mm minor axis and a 20 mm major axis.

Now that the impact angle has been calculated, the location of the shooter can be determined by using the properties of right triangles. The three interior angles of a triangle must always add up to 180°. One of the angles will be 90°, representing the angle between the floor and the wall. Therefore, if the second angle (the impact angle) is determined from the elliptical bullet hole left in the wall, the third angle can be calculated. Using the impact angle calculation above, angle A is 43° and angle B is 90°, which is the angle between the wall and the floor. Since all three interior angles must add up to 180°, the unknown angle can be calculated: 180 – 90 – 43 = 47°. Angle C is known as the angle of elevation or angle of depression. If the bullet hole is higher than the shooter's shoulder, it would be an *angle of elevation*; if lower, it is known as an *angle of depression*.

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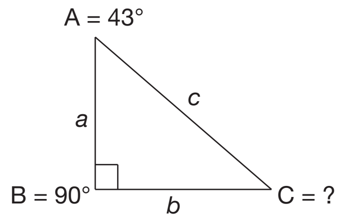
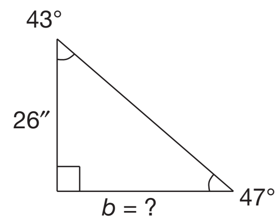


Figure 3.

In this case, the bullet hole is in the wall at 93″ above the floor, and the height of the suspect is 6′3″ (75″). Assuming the suspect's head is 8″ tall, the shoulder height of the suspect would be 5′7″ (67″). Since the bullet hole is above the shooter's shoulder, the angle from the shooter would be considered an angle of elevation. With this information, we can determine the distance the shooter was from the wall when the bullet was fired. The length of side *a* would be calculated by subtracting the height of the suspect's shoulder from the height of the bullet: 93″ – 67″ = 26″. The length of segment *a* is 26″ and the angle of elevation is 43°. The tangent function can now be used to determine the length of *b*. Tan = Opposite/Adjacent. See equation below.



$$\tan(47) = 26/b$$
$$b = 26/\tan(47)$$
$$b = 24.25''$$

Figure 4.

This information is clearly useful in that it can determine if it is possible for a given suspect to have been the shooter. For example, if the distance of *b* had been calculated to be 102″ and the room was only 8′ wide, it is not possible for someone who is 6′3″ to have been the shooter.

Materials

Crime scene simulations	Ruler, 15 cm
Calculator, scientific	Tape measure

Safety Precautions

This laboratory activity is considered nonhazardous. Please follow all laboratory safety guidelines.

Preparation

Bullet 1/Suspect 1

1. Place bullet hole 1 78″ above the ground.
2. Place footprint 1 57″ from the wall.

Procedure

1. Measure the distance from the ground to the center of bullet hole 1, in inches. Record this value as the bullet height.
2. Measure the length of the minor axis of bullet hole 1, in mm. Record this value as the minor axis.
3. Measure the length of the major axis of bullet hole 1, in mm. Record this value in the major axis.
4. Measure the distance from the wall to the tip of footprint 1, in inches. Record this value as the footprint distance.

5. Draw a triangle sketch of each crime scene and label each element as it is determined to help visualize the crime scene. *Note:* Based on tests with dowel rods and lasers done by the investigators, bullet 1 is an angle of elevation (above the shooter's shoulders).
6. Using the information provided in the background section and procedure, calculate the height of the shooter.

Disposal

All materials can be stored for future use.

Tips

- This activity is available as a student lab kit: Flinn Forensic Files—Ballistics (Catalog No. AP7750)
- You may wish to provide the major and minor axis of each bullet hole to students if step stools are not available for them to accurately measure the height of the bullet holes. The bullet holes may also be copied and placed on a lab table where the students can measure them more easily.
- Bullet Hole 1: Minor Axis = 18 mm. Major Axis = 19 mm.

Materials for *Bullet Trajectory Analysis* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7750	Flinn Forensic Files—Ballistics Student Laboratory Kit
AP8400	Tape Measure, 10'

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

