NAMES: _____
PERIOD: _____

Ballistics: Student Investigation Sheet

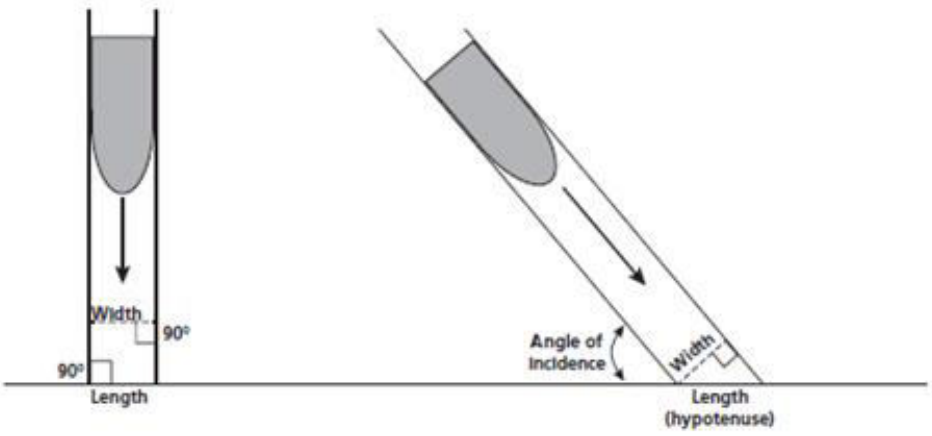
Ballistics is the study of projectile motion and a critical area of investigation in forensic study. When a projectile is fired from a rifle or handgun, it travels at a specific velocity. A projectile in motion can be described by both horizontal and vertical motions. The motion in two directions is represented mathematically as a parabola.

For projectiles that travel less than 20 meters, the effect of gravity is negligible, so forensic scientists use a straight line to represent the projectile path. The analysis then uses right triangle trigonometry instead of the entire parabola. Forensic scientists know the atmosphere (including wind and humidity) may affect the trajectory of a projectile.

How are the trajectory calculations completed?

If a projectile enters an object at a 90-degree angle to the surface, the projectile will make a circular hole. If the projectile penetrates at an angle, it will leave an elliptical hole. Based on the geometry of the ellipse, we can determine the angle of entry of the projectile. To determine angle of entry, the investigator measures the *minor axis* (horizontal) of the ellipse and the *major axis* (vertical) of the ellipse. The major axis of the ellipse becomes the hypotenuse of a right triangle, and the width becomes the opposite side of a right triangle. Using the sine function, the angle of incidence of the bullet can be calculated.

Angle of incidence is calculated as: **sin Θ = minor axis/major axis**



Essential question

1. How can holes left by projectiles aid forensic investigations?

Investigation objectives

Below, calculate the angle of incidence given a projectile hole.

Materials

Each student should have:

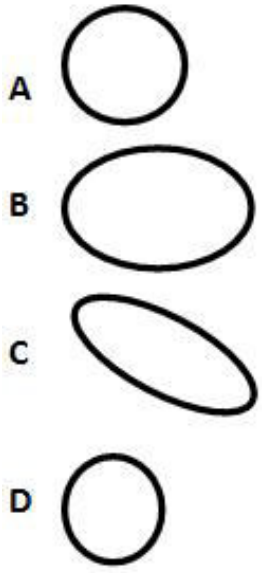
- Ballistics Student Investigation Sheet
- Metric Ruler
- Calculator with Trigonometry Functions

Activity

2. Below is a set of practice termination perforations. Measure the minor axis and major axis in millimeters and then calculate the angle of incidence. *Show your work in the space provided below.*

Angle of incidence is calculated as: **sin Θ = minor axis/major axis**

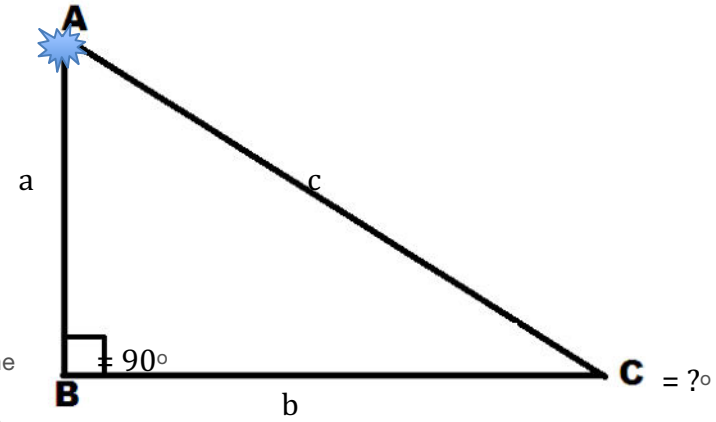
Perforation	Minor Axis	Major Axis	Angle of Incidence
A			
B			
C			
D			



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.

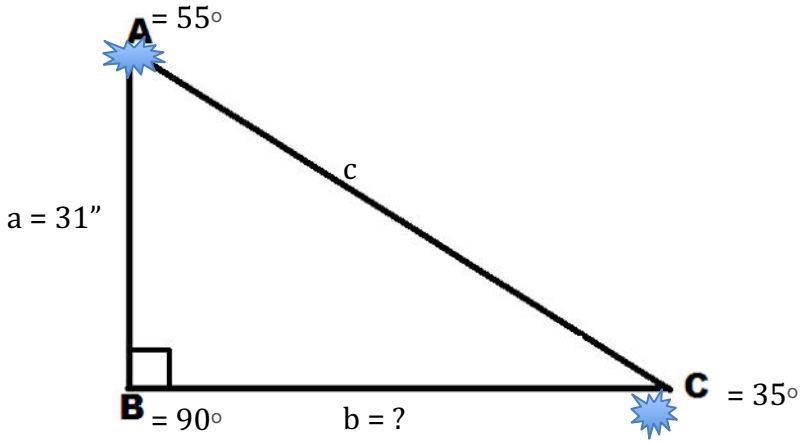
The process of reconstructing a crime scene using a single bullet hole is based on the properties of right triangles. We know that inside of a right triangle the three angles must total 180◦, and we know that one of the angles is a right angle, or 90◦ (the angle between the floor and the wall). Therefore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

$= 55^{\circ}$



Here we know that the 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 arm. We will be able to tell whether the bullet entered a surface from above or below (indicting 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:



We have a suspect who is 6'5" (77") tall, with a shoulder height of 5'9" (69"). If our bullet hole is located 8"7" (100") from the floor, with an elliptical shape pointing downwards (consistent with an elevated trajectory), we can determine where this suspect was standing in the room if he is indeed the shooter. We know that the length of the segment ***a*** is 100" – 69" = 31". Using our geometric rules, we can now determine the length of ***b***. In this exercise, we will use the tangent function, as we have the opposite length (31") and are trying to find the adjacent length (***b***). The solution goes like this:

TAN (35) = 31/***b***
b = 31/TAN (35)
b = 44.27", or about 3'8"

If this suspect is our shooter, he would have to have been standing 3'8" away from the wall when he fired. If the dimensions of the room make this impossible, we can begin to rule out this suspect.

Likewise, if we know that the shooter was about 44" away from the point of impact when he fired (perhaps we found footprints or have an eyewitness), we can determine his height:

TAN (35) = ***a***/44
A = 44 X TAN (35)
A = 30.8, or about 31"

We would then simply subtract 31" from the height of the bullet hole (100", in this example) to arrive at our suspect's shoulder height: 100" – 31" = 69"

3. Now that you know how to calculate the angle of incidence, you can extend your calculations to find the location of the shooter. There are 9 bullet holes on the board. You will be assigned one of the 9 holes to investigate. In the space provided below, calculate the minor axis, major axis, angle of incident, and the location of the shooter. *Show all your work!*

Bullet # _____

A good way to remember the sine, cosine, and tangent rules is th
SOH-CAH-TOA, meaning:
SINE = Opposite/Hypotenuse
Cosine = Adjacent/Hypotenuse
Tangent = Opposite/Adjacent