Science in Motion
Ursinus College

Name_______________________________ Section________

BALLISTICS LAB

INTRODUCTION:

OBJECTIVES:

- Compare questioned bullets and shell casings to spent bullets and shell casings from three different firearms to determine which firearm fired the bullet
- Determine the outer diameter of the bullet head portion of a dummy round in millimeters, then convert to millimeters to inches and express in caliber in English units.
- Measure the trajectory of a projectile
- Determine the origin of a projectile based on multiple bullet holes in a room.
- Determine height of suspect based on bullet trajectory and location of shooter in a room.

BACKGROUND

Forensic casework involving firearms and ballistics usually involves modern handguns, shotguns, and rifles. Handguns include revolvers and semi-automatic pistols. Modern firearms are designed to accept cartridges of a specified caliber. A cartridge contains a powder charge, a projectile, a primer cap that is struck by a firing pin and a case to hold all the components. When the primer cap is struck there is a small explosion which detonates a powder charge inside the cartridge. That detonation instantaneously releases a tremendous volume of gas which creates a “forcing cone”. The forcing cone drives the projectile out through the barrel.

Modern pistols, revolvers and rifles have a “rifled” barrel, which means the barrel is designed to impart a twist on the projectile as it travels down the barrel. This twist is analogous to the twist given to a football when it is thrown in a spiral pass. The twist allows the projectile to travel further in a straight line. Shot guns and smooth bore rifles do not impart a twist to the projectile, which means the projectile doesn’t travel as far or as straight.

Figure 1 shows a Smith and Wesson revolver having a four inch long barrel and capable of firing six cartridges before reloading. Figure 2 shows a revolver with the cylinder opened and ready to receive cartridges. For the revolver to fire, the cylinder must rotate one positon either right or left, depending on the manufacturer of the gun. The cylinder rotates by squeezing of the trigger or by manually cocking the hammer which is located at the top rear of the gun. This rotation of the cylinder places a cartridge under the firing pin. A complete squeeze of the trigger causes the firing pin to strike the primer cap which results in the projectile being fired. Empty casings are held in the chambers.

Figure 1

Figure 2

Figure 3

Figure 3 shows another type of handgun called a semi-automatic pistol. “Semi-auto” pistols are popular because they generally have a higher capacity and are easy to reload and conceal than revolvers. The pistol shown in Figure 3 is a Sig Sauer 0.45 caliber, semi-automatic pistol. It has a moving slide that will load cartridge into the firing chamber which are supplied by a removable magazine. A magazine of cartridges is inserted into the bottom of the pistol grip. The slide is manually moved backwards to feed a cartridge into the firing chamber. This movement of the slide also cocks the hammer. Part of the gases from the explosion are used to push the slide backward to open the chamber, eject the empty casing, feed the next cartridge into the firing chamber, and leave the hammer in the cocked position.

When a cartridge is fed into the firing chamber, there is the potential for causing tiny scratches and dents to the casing. Also, when the casing is ejected from the pistol, there could be marks left on the casing. These marking can be used to link casings from a crime scene with casing fired from a known firearm. The breach face of the casing, the part of the casing that holds the primer cap, and which is closest to the firing pin, contains a number of useful pieces of information (Figure 4). It includes the manufactures stamp along with the caliber of the cartridge.

Figure 4

Caliber is a general term that refers to the approximate diameter of the bullet. The term general is used because a .38 caliber bullet has the same diameter as a .357 Magnum bullet and is very close in diameter to a nine millimeter bullet; however the ammunition is not totally interchangeable between the different guns. A .40 caliber bullet has the same diameter as a 10 millimeter bullet however it can't be loaded into a 40 caliber pistol. A firearms examiner will look for scratches or gorges on the breach face of the cartridge and for the damage pattern on the primer cap. When the firing pin strikes the primer cap, the cap will be dented. Examiners will look to see if the dent is centered or closer to the edge of the cap as well as the circularity of the dent and its depth. Figure 5 contains the breach face of a spent casing. Note the manufacturer's information and the caliber as well as the damage to the primer cap. If similar damage patterns exist on other casings fired from the same gun then theses features can be used to match casings at a crime scene to a known gun.


Figure 5

When a bullet travels down a rifled barrel there are features carved into its exterior by the inside of the barrel. First there are the lands (raised areas on the bullet caused by indentations in the barrel) and the groves (cut out areas caused by raised areas inside the barrel) (Figure 6). Next, because of the rifling there will be evidence of either a left or right twist imprinted on the bullet (Figure 7). The amount of twist and whether it is left or right, are all manufacturer characteristics. The number and width of the lands and grooves are also indicative of the manufacturer of the firearm. These features are consistent in guns of the same make and model. As a gun is fired repeatedly, the barrel undergoes very tiny changes that leave small changes to the marking on the spent bullet. It is these added fine details that allow spent bullets at a crime scene to be matched to the spend bullet from a reference gun.

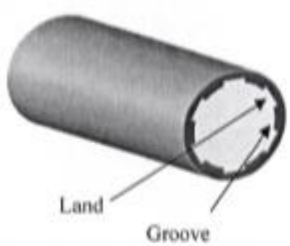


Figure 6

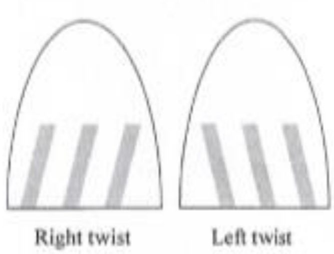


Figure 7

STATION 1: Comparison of Questioned and Known Bullets

1. Examine the embedded bullet marked *Crime Scene*.

2. In Data Table 1, record the twist imparted by the gun that fired it, and the relationship between the widths of the lands and grooves (eg. equal widths, lands wider than grooves or grooves wider than lands.

3. Examine the bullet marked Suspect 1.

4. In Data Table 1, record the twist imparted by the gun that fired it, and the relationship between the widths of the lands and grooves (as above).

5. If the twist and relationship between the lands and grooves match Crime Scene, then place Suspect 1 so that it aligns bottom to bottom with Crime Scene.

6. Slowly rotate Suspect 1 to see if you can find an orientation where one set of land and grooves exactly aligns between the two bullets. If you find such an alignment, check to see if all the pairs of lands and grooves also exactly align. Then check to see if the striations or markings that you observe form an uninterrupted path between Suspect 1 and Crime Scene for all pairs of lands and all pairs of grooves.

7. If you find an alignment where all of the lands and grooves are exactly the right corresponding width and where you see uninterrupted paths of striation lines between Suspect 1 and Crime Scene, you would declare “match”. Record any attributes that did not match in the comments column of Data Table 1.

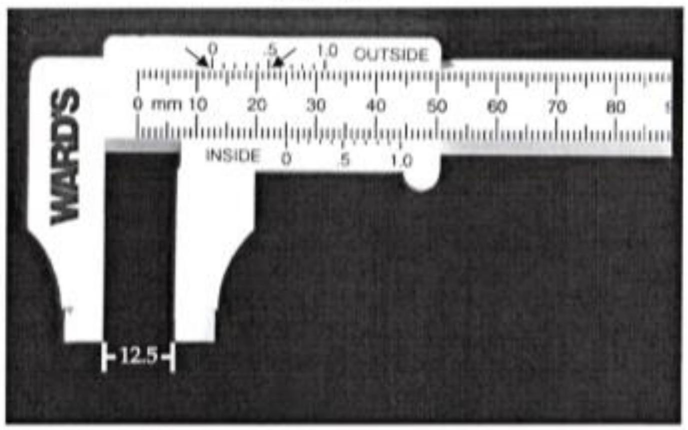
8. Repeat Steps 3-7 for Suspect 2 and Suspect 3.

STATION 2: Measuring Bullet Caliber

How to use a Vernier caliper.

Use the movable portion of the caliper to lightly squeeze the bullet and the read the outside scale located at the top of the caliper. The whole number is read at the "0" of the **outside scale** and the decimal reading is made at the point at which the outside scale lines up exactly with a millimeter mark in the center of the caliper. For example in Figure 8 below, the measurement reads 12.5 mm. The 12 comes from the 0 on the outside scale lining up with the 12 mm mark in the center of the caliper. And the 0.5 comes from the mark in the center of the caliper matching up with the 0.5 on the **outside scale.**

Figure 12



1. Use the Vernier caliper to measure the diameter of the widest portion of the bullet head in millimeters.

2. Use a calculator to convert the millimeter measurement into inches by dividing millimeters by 25.4 mm/in. Record your answer in Data Table 2.

3. Repeat steps 1 and 2 for each of the remaining rounds.

STATION 3: Comparison of Questioned and Known Casings

1. In Data Table 3, record the manufacturer's mark and caliber of the casing marked Crime Scene.

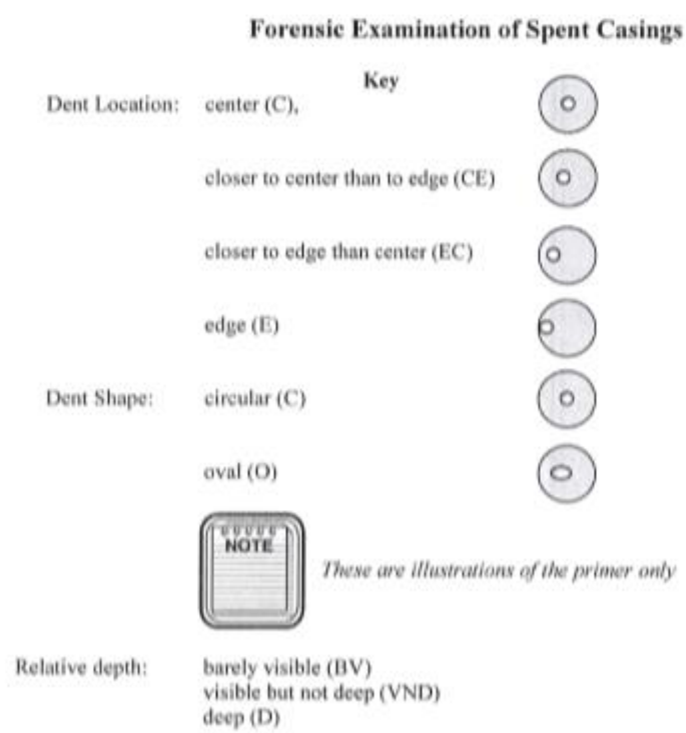
2. Examine the breach face of the casing, including the damage to the primer cap. Pay special attention to the dent produced by the firing pin striking the prier cap. Refer to the key below and note the location of the dent, the shape of the dent, and the relative depth of the dent. Note any additional dents or scratches to the breach face. Record your observations in Data Table 3.

3. Examine the sidewall of the casing. Note any dents or scratches and record them in Data Table 3.

4. Repeat steps 1-3 for the casings marked Suspect 1, Suspect 2, and Suspect 3.

5. Use the data you generated to determine if any of the casings from the suspects matches the casing from the Crime Scene. Record "match" or "no match" in Data Table 3.

Key



STATION 4: Measuring Impact Angle

1. Place a tip onto the forensic rod and insert the rod into the "bullet hole" of the acrylic ballistic block. Slide the tip in as far as it will go as shown below.

2. Place the groove on the bottom of the self-leveling protractor along the trajectory rod. Read the angle from the display on the protractor. This is called the impact angle.

3. Record the impact angle in Data Table 4 in the results section.

4. Repeat steps 1-3 for each bullet hole.

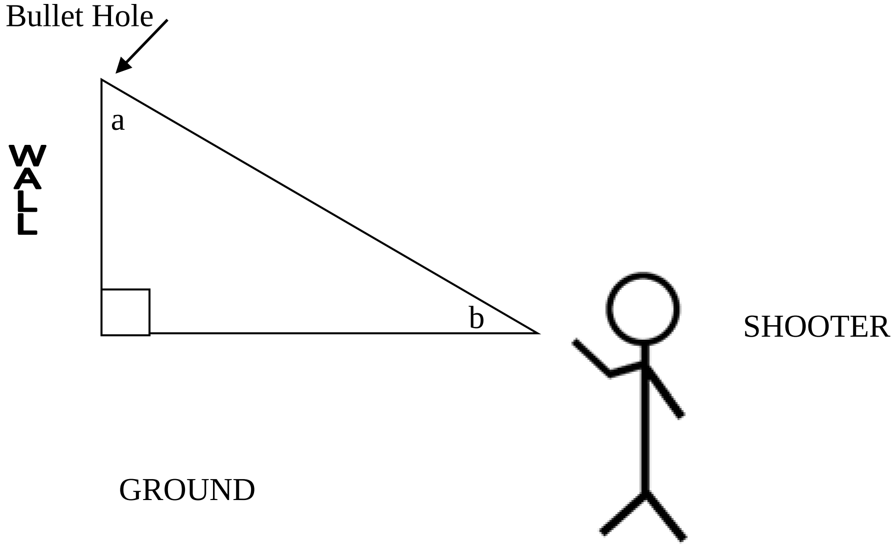
5. On the Diagram 1 in section 4 of the results, the impact angle is labeled as angle a.

6. Angle b is called the angle of elevation or depression depending on where the shot came from. If the shot was from below, angle b is an angle of elevation. If it came from above, angle b is the angle of depression. See Diagram 1.

7. The sum of the interior angles of a right triangle is 180°. Using the angle of impact you found for each bullet hole, determine what the angle of elevation/depression (angle b) is for each bullet hole. Record the measure of angle b in the Data Table 4.

   Hint: 180-90-angle a = angle b

Diagram 1



STATION 5: Determining Trajectory Using Trajectory Rods and Ballistic Blocks

1. Sketch the crime scene and the location of the "bullet holes." Indicate North on your sketch.

2. Insert a tip onto the forensic rod and insert the rod into the bullet hole.

   You have now located the flight path for the projectile. It is important to realize this only gives you the direction from which the shot was fired and not the distance from which it came.

3. Line up the provide laser so that it is parallel with the trajectory rod extending from the bullet hole. This will enable you to visualize the trajectory of the bullet.

4. Working with a partner, tie a piece of string to the rod and using the laser as a guide extend the string along the path of the laser. Tape the end of the string to the floor.

5. Repeat steps 2-4 for any additional bullet holes.

6. Do any of the trajectories intersect? If so, draw the intersection point on your crime scene.

STATION 6: Determining Approximate Height of Suspect Based on Trajectory Data

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.
Sine (sin) = Opposite/Hypotenuse
Cosine (cosin) = Adjacent/Hypotenuse
Tangent (tan) = Opposite/Adjacent

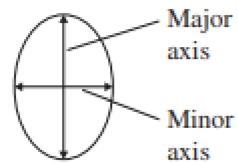


Figure 1.

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, the angle of impact (i) can be calculated as shown below.

FORMULA 1
Sin (i) = length of minor axis/length of major axis
Sin (i) = 13/19
impact angle = sin–1(13/19)
impact angle = 43.17° or 43° (to the nearest degree)

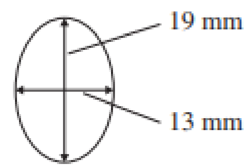


Figure 2.

Reminder: sin-1 is the inverse of sin. On a scientific calculator sin(-1) is obtained by hitting the 2nd button and then the sin button.

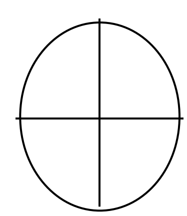
Step 1 Calculate Impact Angle

Because the bullet hole in this crime scene is high up on the wall, we have include an identical tracing here in Figure 3. Measure the major axis and minor axis for the bullet hole in Figure 3 in millimeters. Record your results in Data Table 6A.

Using **FORUMULA 1** calculate the impact angle (angle a) and record your answer in Data Table 6A.

(Hint: when using a graphing calculator choose mode and make sure your answers are being calculated in degrees not radians). To calculate sin-1: Push 2nd button, then sin button followed by the ratio of the minor to major axis measurements.

Figure 3
Bullet Hole



Step 2 Make Measurements

Measure the vertical distance the bullet traveled by measuring the distance from the floor to the bullet hole (A) and enter into Data Table 6B.

Measure the distance from the wall to the toe of the footprint (B) and enter into Data Table 6B.

Step 3 Determine the angle of elevation

SEE DIAGRAM 2 in Results Section
Since the impact angle was calculated in Step 1, 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 to be 43° (for example), the third angle can be calculated. Since all three interior angles must add up to 180°, the unknown angle can be calculated: 180 – 90 – 43 = 47°. This angle (47°) 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.

Calculate the angle of elevation (angle b) using the formula 180-90-impact angle = angle of elevation. Record this number in Data Table 6B.

Step 4 Calculate the Height of the Suspect

There are 3 Suspects. Suspect 1 is 6'3" (75") tall. Suspect 2 is 4'11" (59") tall. Suspect 3 is 5'5" (65") tall.

For this calculation, we will assume the suspect held the gun at shoulder height and that shoulder height is 8 inches lower than the suspect's total height. For example, a 6' (72 inches) tall suspect would shoot from a height of 64 inches (72"-8").

Since we know the angle of elevation (angle b) calculated in step 3, we can again use trigonometry to find the height from which the bullet was shot. This will be the shoulder height of the suspect and is represented by line "x" on the Diagram 2.

Use Formula 2 in the results section to solve for x. Formula 2: Tan (angle of elevation)= x/distance from wall. Replacing words with symbols and rearranging the above equation you get **x= tan (angle b) * C.** Solve for x**.** Enter the value for x in Data Table 6B.

Refer to Diagram 2 in the results section 6. The approximate shoulder height of the suspect (B) can then be found by taking the height of the bullet hole from the floor (A) and subtracting the value you just found for x. A-x = B

Finally, to find the approximate height of the suspect, take the value of B (shoulder height) and add 8 inches. Or just compare B to the shoulder heights of each suspect.

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BALLISTICS – RESULTS PAGE

STATION 1

Data Table 1

Sample	Twist Direction	Land/Groove Assessment	Add'l Observations	Match/No Match
Crime Scene				
Suspect 1				
Suspect 2				
Suspect 3				

STATION 2

Data Table 2

Measurement (mm)	English Caliber (inches)	Cartridge Name	Markings on Breach Face

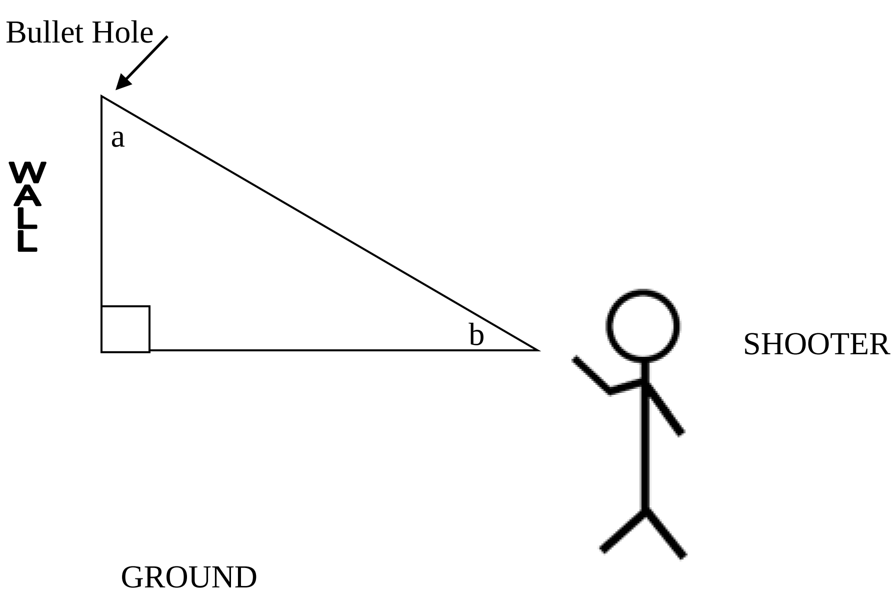
STATION 3
Data Table 3

Casing	Manufacturer's Mark	Caliber	Primer Dent Location	Primer Dent Shape	Relative Depth of Dent	Other Observations	Match/No Match
Crime Scene							
Suspect 1							
Suspect 2							
Suspect 3							

STATION 4
Data Table 4

	Bullet Hole 1	Bullet Hole 2	Bullet Hole 3	Bullet Hole 4
Angle a: Impact Angle (degrees)				
Angle b: Angle of Depression or Elevation (degrees)				

Diagram 1



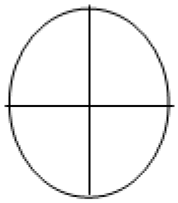
STATION 5
Crime Scene Sketch

Conclusion: ____

STATION 6

STEP 1:

Figure 3. Bullet Hole

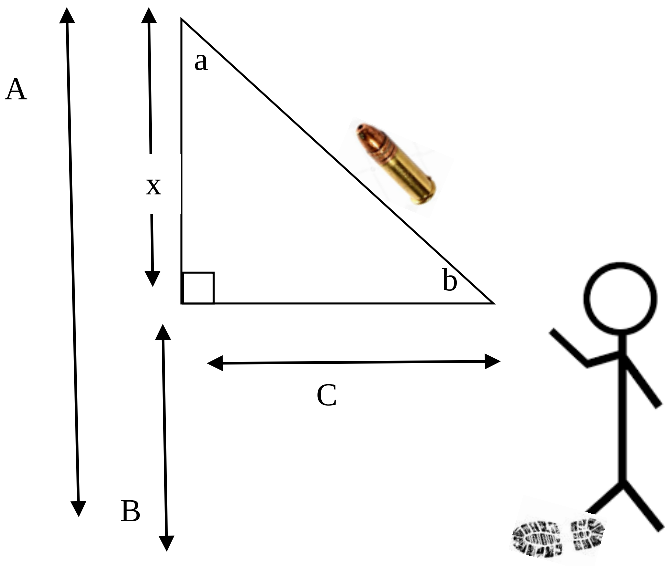


FORMULA 1
Sin (i) = minor axis/major axis
Impact angle = sin–1(minor/major)

Data Table 6A

Major Axis (mm)	
Minor Axis (mm)	
Impact Angle (degrees)	

DIAGRAM 2



FORUMLA 2

Tan (angle of elevation)= x/distance from wall

x=tan(angle b) * C

Data Table 6B

Diagram Label	Definition	Formula	Answer
A	Distance from ground to bullet hole (inches)	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	
B	Distance from ground to shoulder height of suspect (inches)	Height of Suspect – 8 inches Suspect 1 is 75 inches tall Suspect 2 is 59 inches tall Suspect 3 is 65 inches tall	Suspect 1 ____ Suspect 2 ____ Suspect 3 ____
C	Distance from wall to toe of footprint (inches)	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	
angle a	Impact Angle (from step 1)	FORMULA 1 Sin-1(minor axis/major axis)	
angle b	Angle of Elevation	(180°-90-Impact Angle)	
x	distance from shoulder of suspect to bullet hole	FORUMULA 2 Tan (angle b) * C	
B	Height shot was taken from (B)	A-X= **B**	

Compare your calculation for B to the "shoulder height" of each suspect. Can you rule any suspects out? ____

Which suspect is most likely the shooter? ____

Questions

1. Which suspect's bullet and shell casing matched the crime scene bullet and shell casing?

2. What would the conclusion be if only part of the lands and grooves aligned yet you had the entire crime scene and suspect specimens?

3. What does it mean if the crime scene bullet and the test bullet from Suspect 1's gun match in terms of lands, grooves, twist, and fine details of the striations?

4. What might it mean if a crime scene investigator finds five bullet holes, uses the trajectory rods and finds two different sets of intersections?