PURE Insights

Volume 11 | Article 4

2022

How Trigonometry Can Solve a Murder

Delaney N. Bishop
Western Oregon University, dbishop17@mail.wou.edu

How Trigonometry Can Solve a Murder

Abstract

Who killed Mr. Williamson? Is Mrs. Williamson telling the truth? Or is she lying to save herself? The answer to all of those questions can be determined through the use of blood spatter that was created during the course of events that led to Mr. Williamson's death. Specially trained analysts, known as blood spatter analysts, use mathematics equations to determine the location of individuals and objects at a crime scene during the time that the violent crime takes place. The equations that blood spatter analysts use in their calculations comes from a division on math known as trigonometry. Investigators then use those calculated locations to determine if their witnesses or suspects are telling the truth through comparison.

Keywords

Trigonometry, Blood spatter, Forensic Chemistry, Forensics, Math

How Trigonometry Can Solve a Murder

Delaney N. Bishop, Western Oregon University

Faculty Sponsor: **Dr. Leanne Merrill**

Who killed Mr. Williamson? Is Mrs. Williamson telling the truth? Or is she lying to save herself? The answer to all of those questions can be determined through the use of blood spatter that was created during the course of events that led to Mr. Williamson's death. Specially trained analysts, known as blood spatter analysts, use mathematics equations to determine the location of individuals and objects at a crime scene during the time that the violent crime takes place. The equations that blood spatter analysts use in their calculations comes from a division on math known as trigonometry. Investigators then use those calculated locations to determine if their witnesses or suspects are telling the truth through comparison.

Keywords: Trigonometry, Blood spatter, Forensic Chemistry, Forensics, Math

Picture this: Mrs. Williamson is standing trial for the murder of her husband, Mr. Williamson, who was ruled to have died from blunt force trauma. Mrs. Williamson told investigators that her husband was putting lawn decorations up in their attic when he accidentally fell and hit his head on the stair's railing, killing him instantly. When investigators arrived, the scene before them did not fit the wife's story of an "accident." How could investigators corroborate Mrs. Williamson's claims?

To confirm the wife's claims, investigators must determine the victim's position during the time of bloodshed by analyzing the blood spatter left at the scene using a method that you learned in high school but may have forgotten about: trigonometry. Blood spatter analysis is the study of patterns of blood spatters that are left behind at a crime scene (Guerra 1). Despite what we have come to believe, blood spatter analysis is not accurately depicted in popular television shows such as *Dexter* or *Numb3rs.* Blood spatter analysts cannot determine the exact sequence of events that take place nor can they determine the exact position of the origin of the blood spatter (Freeman and McManus). An analyst can only determine the approximate positions of the victim and assailant, and it is up to the investigators of the case to determine what happened based on the positional information and evidence gathered (Freeman and McManus).

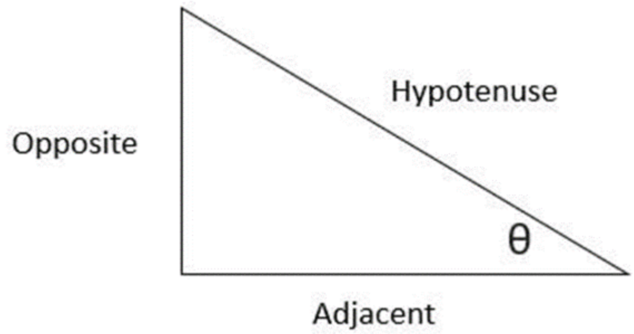
The first methodical study of blood spatters was published in 1895 by Dr. Eduard Piotrowski of the University of Krakow in Poland and was titled "Concerning the Origin, Shape, Direction and Distribution of the Bloodstains Following Head Wounds Caused by Blows" (Freeman and McManus). The research done by Dr. Piotrowski influenced many investigators in the early 20th century in France and Germany (Freeman and McManus). However, the first evidence of blood spatters used in a legal case in the United States did not show up until 1955 in the highly publicized case of the State of Ohio v. Samuel Sheppard (Freeman and McManus). In the State of Ohio v. Samuel Sheppard case, Mr. Sheppard was arrested for the suspected murder of his wife whom he claimed was killed by an intruder (Holmes). During Mr. Sheppard's first trial, the prosecution presented evidence that included an analysis of bloodstains found in the house and used Mr. Sheppard's affair with Susan Hayes, a former lab technician at Bayview Hospital, to establish a motive for the murder. The defense failed to convince the jury of Sheppard's innocence, and he was convicted (Holmes). Ten years later, in an appeal trial, Dr. Paul Kirk presented more information on the previously used bloodstain evidence used from when Mr. Sheppard was convicted (Holmes). This new information showed the position of the assailant and the victim, and his research revealed that the attacker struck the victim with their left hand (Holmes). Mr. Shepperd was right-handed; therefore, he could not have been the attacker (Holmes). After that, the field saw vast expansion and modernization by Herbert MacDonell who also developed training courses to continue to train blood spatter analysts (Freeman and McManus). Since then, blood spatter analysis has become an accepted source of evidence by the judicial system for use during court cases (Freeman and McManus).

From blood spatter, trained specialists can determine the type of weapon, the velocity of blood, the number of blows, position, and movements of the victim (Freeman and McManus). Specialists can also determine the movements of the assailant during and after the attack and whether the death was instantaneous or delayed (Freeman and McManus). The different types of blood spatter are categorized into low, medium, and high-velocity depending on the spatter's varying terminal velocity (Martin). Each category of blood spatter can also be identified by analysts based on their varied appearances (Martin). In the case of Mr. Williamson's fall, the blood spatter analyst determined that blood spatter caused by a fall from a ladder would create low-velocity blood spatter. Let's look at how that can be used to determine the position of the victim at the time of the crime.

The most common method of determining the victim's position at the time of bloodshed is through the measurement of three quantities: the angle of impact, the area of convergence, and the height from which the blood fell (Rajchgot). This is done through *trigonometry,* which is the study of triangles (Lynch; Rajchgot). In trigonometry, one can use the side lengths of a right triangle to calculate the angles contained inside the triangle (Lynch). The reverse method in trigonometry can also be done when using provided angle measurements to calculate the side lengths (Lynch). The study of triangles includes the measurement of the angles of triangles (Abramson et al 577). In blood spatter analysis the analyst uses a branch of trigonometry called Right Triangle Trigonometry (Abramson et al 593). In Right Triangle Trigonometry, one angle in the theoretical triangle must equal exactly 90° (Abramson et al 593). The three trigonometric equations, which are sine, cosine, and tangent, are used to calculate the measurements of the two acute angles in a right triangle and use the legs of the triangle for the calculation (Abramson et al 593). In the trigonometric functions, the opposite leg is the leg of the triangle that is across from the angle that the individual is wanting to measure, the adjacent leg is the one that is right next to the angle that is wanting to calculate, and the hypotenuse is always the longest side of the triangle (Abramson et al 594). If there is one thing you remember from high school, it is probably SOHCAHTOA, the common mnemonic for remembering these relationships because of the letters formed from each function (Abramson et al 593).

In the case of blood spatter analysis, the tangent function is used to calculate the height from which the blood fell before it hit a surface. To help visualize this I have attached a diagram of an example of the setup of a right triangle for a calculation and the trig functions are listed below. In the example below, the angle being measured is represented by the Greek letter theta, θ. A blood-spatter analyst will use the tangent function to calculate the height that the blood fell from the area of convergence. However, before an analyst calculated that, they need to calculate the angle of impact and area of convergence.

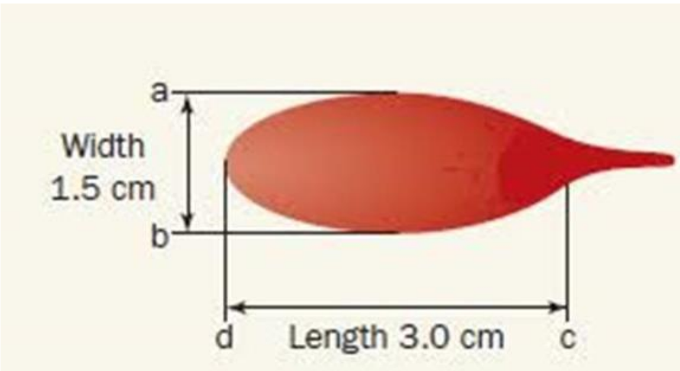
Sine θ = Opposite/hypotenuse
Cosine θ = adjacent/hypotenuse
Tangent θ = opposite/adjacent



When blood is flying through the air, it has similar physical properties to that of water (Rajchgot). Because of these properties, if a drop falls to a surface at a 90° angle, then it will leave a circular spatter pattern (Rajchgot). However, if a drop falls at any angle other than 90°, then it will leave a differently shaped spatter pattern that looks more like an oval with a tail than a circle (Rajchgot). The shape of a blood droplet changes depending on the angle at which it hits a surface because when the droplet hits a surface at an angle, different parts of the droplet hit the surface at different times causing the shape to elongate (Rajchgot). The angle at which the blood droplet hits the surface is called the angle of impact (Guerr 2). The angle of impact is determined by measuring the length and width of the blood spatter—making sure not to include the long skinny part called the tail—and plugging it into an inverse sine function which provides the angle (Gomez). It is also important to remember that the greater the difference between the width and length, the sharper the angle of impact which will create a thinner, more elongated shape (Freeman and McManus).

To measure the angle of impact of the blood spatter, another trigonometric function called Arcsine is used. Arcsine is the inverse function of sin θ that substitutes the ratio of sin with the ratio of Arcsine and returns with the angle that is between those two legs of a right triangle (Abramson et al. 594; Stewart A19). To calculate the angle, the analyst divides the width (shorter side) by the length (longer side) of the blood droplet measured in millimeters and multiplies the quotient by Arcsine ($\sin^{-1}$) (Gomez). In the case of Mr. Williamson's death, an analyst inspecting a blood droplet at the scene and determined that the width was 1.5 centimeters (15 millimeters) and the length was 3.0 centimeters (30 millimeters); this would mean that the angle of impact is 30°.

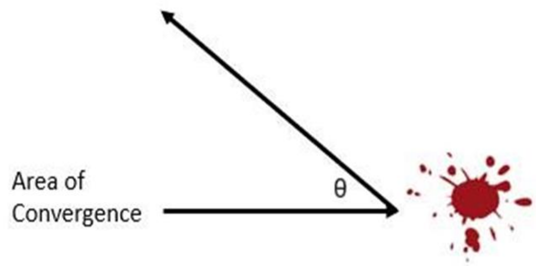
$\sin^{-1}$ (9mm/18mm) = 30˚
The angle of impact was 30°



After the analyst determines the angle of impact of multiple blood spatters, they can determine the area of convergence. The area of convergence is the area of intersection of multiple bloodstain paths in a given spatter pattern (Rajchgot). Typically, to find the area of convergence at a crime scene, analysts use the old fashioned method where strings are attached to each bloodstain down its axis to signify where they converge (Guerra). A modern-day version of this is the use of lasers (Freeman and McManus). The point at which the strings or lasers intersect is the area of convergence and a possible spot in the room from which the blood originated (Freeman and McManus). In the case of the investigation of Mr. Williamson's death, the analyst would have expected the position to be around the area of the railing of the stairs. The area of convergence is just one part of determining the position that the blood originated from during an investigation. Analysts also have to determine the height at which the blood fell in order to determine more information about the position of the victim's body during the time of bloodshed. This is especially important in the case of Mr. Williamson's death because his wife is claiming that he fell from a ladder and hit his head on the stair railing. In order to make Mrs. Williamson's claims possible the height from which the blood would need to be calculated to only a couple of feet from the surface the blood spatter hit.

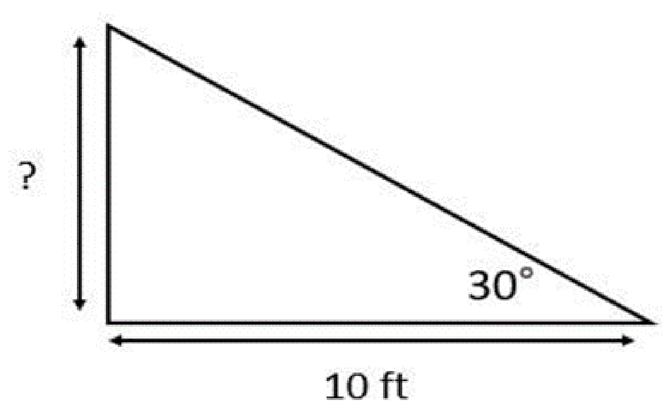
The estimated height at which the blood spatter fell from during the time of bloodshed is calculated by multiplying the distance that the spatter is from the area of convergence by the tangent of the impact angle (Gomez). A general diagram and equation can be viewed below this paragraph. The distance from the area of convergence can be determined simply by measuring the horizontal distance between the blood spatter and the area of convergence. This formula works because the distance from the area of convergence is adjacent to the impact angle and the height is opposite to the impact angle. This is based on trigonometric functions from above we know is the exact ratio that is wanted for the tangent function.

Horizontal Distance * tan θ



In the case of the investigation of Mr. Williamson's death, the angle of impact was calculated to be 30° and the distance between the blood spatter and area of convergence is 10 feet. Based on the formula, the analyst determined that the height at which the blood fell was roughly 5.77 feet or 5' 9.28" 10(tan 10˚) = 5.77ft.

The height at which the blood fell was 5.77 ft or 5' 9.28".



After their analysis, the blood spatter analyst determined that the height at which the blood spatter fell did not corroborate Mrs. Williamson's original claims that her husband fell off a ladder to the attic and hit his head on a railing. Mr. Williamson was roughly 5'10" which means that he was standing at the total height at the time of bloodshed and that he could not have hit his head on a railing, thus killing him. Due to the blood spatter evidence against Mrs. Williamson and her false claims, she was charged with homicide and interfering with an investigation which sent her to prison for many years without the possibility of parole.

REFERENCES

Abramson, Jay P., et al. *Algebra and Trigonometry*. OpenStax, 2017.

Freeman, Shanna and Melanie Radzicki McManus. "How Bloodstain Pattern Analysis Works." *HowStuffWorks Science*, 20 Jan. 2022, https://science.howstuffworks.com/bloodstain-pattern-analysis.htm

Gomez, Marcia. "Solving Crimes with Maths: Bloodstain Pattern Analysis." *Plus.maths.org*, 21 Dec. 2021, https://plus.maths.org/content/solving-crimes-maths

Guerra, Isela. "The Use of Trigonometry in Blood Spatter." *A With Honors Project*, SPARK, 2014, https://spark.parkland.edu/ah/106/

Lynch, Peter. "A Forensic Formula for Solving Crimes." *The Irish Times*, 19 Nov. 2015, https://www.irishtimes.com/news/science/a-forensic-formula-for-solving-crimes-1.2425640

Makovický, Peter, et al. "The Use of Trigonometry in Bloodstain Analysis." *PubMed.gov*, U.S. National Library of Medicine, 2013, https://pubmed.ncbi.nlm.nih.gov/23641723/

Martin, Tom. "Interpreting Bloodstain Patterns." *Crime Scene Forensics*, n.d., http://www.crimescene-forensics.com/Spatter_VS_Transfer.html

Rajchgot, Jenna. "Numb3rs 506: Magic Show." Department of Mathematics, Cornell, n.d., http://pi.math.cornell.edu/~numb3rs/jrajchgot/506f.html

Stewart, James. "Trigonometry." *Calculus Concepts and Contexts*, 4th ed., Richard Stratton, 2010, pp. A17–A24.