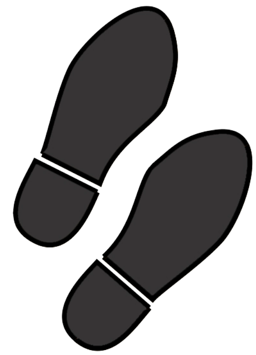
Footwear Forensics

Introduction

Tracks left by footwear are valuable pieces of evidence at crime scenes that are often overlooked. Learn the different ways that tracks from shoes can be used to develop possible suspects in a criminal case.



Concepts

- Footwear impressions/casting
- Forensics

Materials

Bio-Foam® Impression Foam System

Calcium sulfate, $CaSO_4 \cdot ½\ H_2O$, 425 g

Talc, $3MgO \cdot 4SiO_2 \cdot H_2O$, < 1 g

Water, distilled or deionized

Balance

Brush, beaker or flask type

Graduated cylinder

Plastic bag, re-sealable, 1-gallon

Ruler, cm

Safety Precautions

The BioFoam contains ≤ 1% formaldehyde. Formaldehyde causes skin and serious eye irritation and may cause an allergic skin reaction and cancer. Wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Safety Data Sheets for additional safety, handling and disposal information.

Procedure

Making the Impression

1. Obtain a box of footwear foam and open it carefully. *Note*: Touching the foam with your fingers, even lightly, will leave an impression.
2. Select a group member to make a footwear impression.
3. Step gently onto the foam, depressing your shoe about half-way through the foam. Do not place too much weight on the impression foam.
4. Carefully remove your shoe from the foam. Another group member may need to hold the box down so the impression is not damaged by wiggling your foot to remove it.
5. Very lightly sprinkle talc powder over the impression to serve as a fixative. Tap the sides of the box over a garbage can so that that talc is evenly distributed over the impression.

Preparing the Casting

6. Measure 425 g of calcium sulfate in a 1-gallon resealable bag.
7. Measure 215 mL of distilled water and add it to the plastic bag containing the calcium sulfate.
8. Seal the bag and make sure it is completely closed.
9. Shake the bag vigorously for 30 seconds.
10. Gently knead the contents of the bag for 1–2 minutes. Verify that the contents of the bag are not lumpy and are roughly the consistency of pancake batter. If not, add 10 mL more water at a time until desired consistency is achieved.

Publication No. 11312
030117

11. Open the top corner of the bag and gently pour it at an angle into the foam casting. Do not pour directly on the casting where the flow of the material will change the cast.
12. Allow the casting to harden for 30 minutes or until hard to the touch.
13. Remove the casting and foam from the box.
14. Gently peel away the layers of foam from the casting. *Note*: As the foam is removed, check that the casting has properly solidified before vigorously removing excess foam.
15. Once the impression has completely hardened, clean off the excess foam by brushing the impression with a beaker brush to remove foam from the smaller grooves of the impression.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. All materials may be disposed of according to Flinn Suggested Disposal Method #26a in the regular trash or saved for future use.

Tips

- This activity was adapted from Flinn Forensic Files—Footwear Evidence (Catalog No. AP7752), one of the kits that make up the Flinn Forensic Files.
- This activity was tested mixing calcium sulfate hemihydrate with tap water. However, depending on your water quality, it may be necessary to use distilled or deionized water.
- If desired, Shake-N-Cast™ (AP7754) can be used in place of calcium sulfate and water.

Discussion

Footwear impressions are often used to place a suspect at a crime scene. It makes sense that a criminal must enter and exit the crime scene on foot at least for a short distance, making the footprint a common denominator in most crime scenes. Criminals have realized it is important to conceal their fingerprints with gloves or their faces with masks. In fact, in the wintertime you might not think anything of a person wearing either of those accessories. However, most people don't wear shoe covers in their daily lives and doing so would cause a person to stand out.

Footwear evidence is obtained by prints or impressions. Just like fingerprints, footwear prints can be visible or latent. *Visible prints* are found when the footwear is contaminated by a foreign object such as blood or wet paint. The person then steps on a clean surface leaving a visible print. *Latent footprints* are commonly overlooked as they are not visible unless they are dusted with powder just like fingerprints. Footwear evidence can also be obtained by taking impressions. Impressions are taken when the footprint is evident on a softer surface such as wet sand, mud or snow. First, the medium is treated with a hardening spray followed by casting similar to that used to take dental impressions. Once the casting material has hardened, the 3-D model can be compared to suspects' footwear as well as saved with other evidence for future reference.

References

Hilderbrand, D. S. *Footwear*; *The Missed Evidence*. http://www.crime-scene-investigator.net/footwear.html. (Accessed September 2015).

Materials for *Forensic Footwear* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7749	Flinn Forensic Files—Footwear Evidence Individual Kit
AP7752	Flinn Forensic Files—Footwear Evidence Classroom Set, 8
AP6024	Brush, Flask, 250-mL
C0032	Calcium Sulfate, 500 g (Plaster of Paris)
C0033	Calcium Suflate, 2 Kg (Plaster of Paris)
AP7755	BioFoam® Footwear Impression
AP7754	Shake-N-Cast™ Impression Kit
AP7756	Aerosol Dust and Dirt Hardener

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

Fiber Findings

Introduction

Crime scene investigators obtain many different types of evidence at a crime scene, including samples of fibers. With this kit you will identify the type of fiber left at a crime scene by performing a series of three tests on the obtained evidence.

Concepts

- Physical and chemical properties
- Chemical bonding
- Forensics

Materials

Congo red dye bath, shared
Water, tap
Boiling stone
Forceps, metal
Hot plate
Multifiber test fabric, 3-cm
Paper towels
Pencil
Weighing dish or aluminum foil

Background

Fibers are the smallest component of a textile material. They are used to form fabric, rope, carpet, etc. Fibers gathered as evidence at a crime scene may arise from numerous scenarios. They may be transferred via personal contact between suspect and victim or they could be transferred to other items at the crime scene, such as furniture, weapons or flooring, due to a physical struggle.

Fibers may be analyzed by visual inspection based on their appearance and comparison with known samples. Identifying fibers based on appearance requires the use of a microscope to view miniscule details. Natural fibers are easier to distinguish under a microscope. Synthetic (man-made) fibers are traditionally less descriptive under a microscope because they can consist of practically any strand diameter or color. Synthetic or man-made fibers typically have a more uniform diameter and appearance than natural fibers. Therefore, while helpful as an ancillary test, microscopic analysis is not the main determining test used to identify fibers.

Fabrics are also identified based on how chemical dyes bond to them. How well a dye is attracted to a piece of cloth (its *affinity*) depends on both the fabric and the dye molecules. Chemistry thus plays an important role in how and why dyes work. Dyes are charged water-soluble compounds. Animal fibers, such as wool, are composed of protein molecules and are usually easier to dye than plant fibers such as cotton, which are composed of cellulose. Wool fibers have many *dye sites*—groups of molecules that have positive or negative charges and thus attract the charged dye molecules. Dye sites may be ionic, that is, fully charged, or polar, that is, partially charged. In general, dyes have a greater affinity for natural fibers like wool and cotton than for most synthetic fabrics. Many synthetic fabrics such as acrylic and polyester are non-polar and have fewer dye sites, making them more difficult to dye. One exception is nylon, the first completely synthetic fiber developed in the 1930s from petrochemicals. Nylon dyes more easily than many other synthetic fabrics because it has polar dye sites. Acetate, another synthetic fiber, is chemically similar to cotton, but has fewer dye sites.

Safety Precautions

Congo red will stain skin and clothing. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines. Please review current Safety Data Sheets for additional safety, handling and disposal procedures.

Publication No. 11318
030117

Pre-Lab Preparation

Congo Red Solution

1. Dilute 150 mL of 0.1% congo red solution with 300 mL of distilled or deionized water in a 1-L beaker.
2. Add 4.5 g of sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$) and 3.3 g of anhydrous sodium carbonate (Na_2CO_3) and stir to dissolve.
3. Place a boiling stone in the dye solution and heat to near boiling on a hot plate.
4. Carefully pour the resulting solution into three 250-mL beakers to ease congestion for student use. Wear heat-resistant gloves or use a hot vessel gripping device. The dye must be hot when students test their fabric.

Procedure

Note: The multifiber test fabric consists of six different fibers in the following order starting at the cream colored end: wool, acrylic, polyester, nylon, cotton and acetate.

1. Obtain a test fabric strip and mark one end of the strip with pencil so that the wool side is differentiated from the acetate side.
2. Using forceps or tongs, immerse the test strip into the congo red dye bath. *Caution:* The dye bath is very hot. Exercise caution to avoid burns.
3. After 5–10 minutes, remove the dyed test strip from the bath using forceps. Hold the fabric above the dye bath for approximately one minute to allow excess dye to drain back into the dye bath.
4. Pat the test strip with paper towels and rinse the dyed test strip under running water from the faucet or use a wash bottle. Continue rinsing the test strip until all of the excess dye has been removed and the rinse water is colorless.
5. Place the test fabric on a small piece of aluminum foil or weighing dish and allow it to dry overnight.
6. Record observations concerning the differences in color.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The congo red solution may be rinsed down the drain with an excess of water according to Flinn Suggested Disposal Method #26b.

Lab Hints

- This activity was adapted from Forensics of Fibers Student Laboratory Kit (Flinn Catalog No. FB2022).
- Other multifiber test fabrics containing 8 or 13 different fabrics are available from Testfabrics, Inc. See their website at www.testfabrics.com.
- A stereoscope (MS1161) or magnifier (AB1135) may be used to make detailed observations of the fabric sample before and after dying.

References

Collins, David. *Investigating Chemistry in the Laboratory;* W. H. Freeman & Company: New York, NY; 2006; p. 131.

Kubic, T., Petraco, N. *Forensic Science—Laboratory Experiment Manual and Workbook;* CRC Press: Boca Raton, FL; 2003; p. 93.

The materials for *Fiber Findings* are available from Flinn Scientific, Inc.

Catalog No.	Description
FB2022	Forensics of Fibers—Student Laboratory Kit
C0128	Congo Red Indicator Solution, 0.1%, 500 mL
AP6135	Multi-Fiber Test Fabric, 1 Yard

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

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

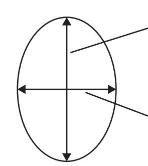


Figure 1.

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)

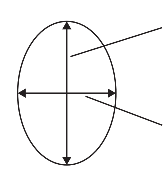


Figure 2.

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*.

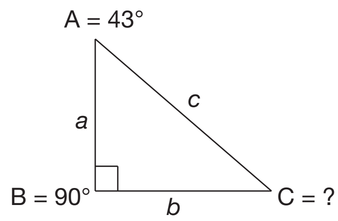
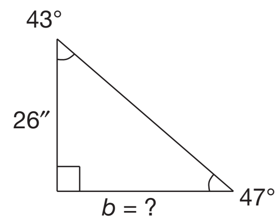


Figure 3.

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
- Calculator, scientific
- Ruler, 15 cm
- 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.

Ink Investigation

Introduction

Did you know that pens can be identified by separating their pigments by a process known as chromatography? Identify a writing instrument using paper chromatography.

Concepts

- Chromatography
- Separation of mixtures
- Physical properties

Materials

Water, tap
Cup, clear plastic, 9-oz
Chromatography sample evidence
Filter paper, 12.5-cm diameter
Filter paper "wick," wedge-shaped
Markers, water-soluble, various types, numbered
Pencil tip (or sharp object such as a pushpin)
Scissors

Safety Precautions

While this activity is considered nonhazardous, follow all appropriate laboratory safety guidelines.

Procedure

Part A. Chromatography

1. Obtain a piece of filter paper. Use a sharp pencil tip or pushpin to puncture a small hole into the center of the filter paper.
2. Select a pen and make a dot on the filter paper about 1 cm from the center hole.
3. Using a pencil, write the corresponding number that is on the pen on the filter paper near the edge so it can be identified later. See Figure 1.

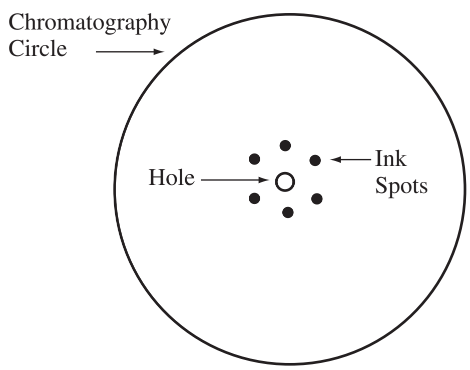


Figure 1.

4. Repeat steps 2 and 3 with the remaining pens.
5. Fill a plastic cup roughly ¾ full with tap water. Use a paper towel to dry off any water drops that are on the rim.

6. Roll up a wedge-shaped filter paper “wick” into a tight cone and insert it into the center hole. See Figure 2.

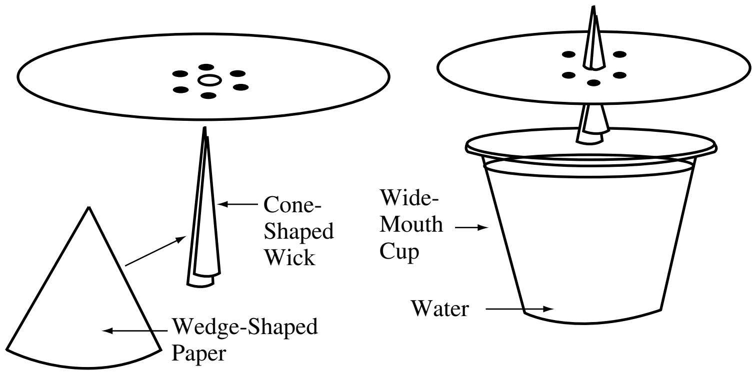


Figure 2.

7. Set the prepared filter paper circle on top of the water-filled cup and observe as the water is soaked up through the wick and then outward radially across the paper. Observe how the advancing water front acts on the spots of black ink.
8. When the water has advanced to within 1–2 cm of the outer edge of the circle (should take 10–12 minutes), carefully lift the chromatogram up and set it on a paper towel to dry.

Disposal

Dispose of the water down the drain. The filter paper disks may be saved or discarded in the trash. Save all other materials for future use.

Tips

- Experiment with a variety of different water-soluble markers of felt-tip pens to determine the composition of each. Many different brands are available at local stores.
- Try this activity with colors other than black.
- Pens such as Vis-a-vis®, Expresso, Le Pen, Papermate Flair™, Prang and Vis-Aid work well.
- Avoid excessive handling of the filter paper circles. Oils from the skin can interfere with the capillary action that draws the water through the paper.
- This activity is available as a student lab kit: Forensic Files—Ink Inspection (Catalog No. AP7745).

Discussion

Chromatography is probably the most useful method of separating organic compounds for identification or purification. There are many different types of chromatography, but most work on the principle of *adsorbtion*. The two important components of chromatography are the adsorbent and the eluent. A good adsorbent is usually a solid material that will attract and bind the components in a mixture. Paper, silica gel or alumina are all very good adsorbents. The *eluent* is the solvent that carries the materials to be separated through the adsorbent via capillary action.

Chromatography works on the principle that the compounds to be separated are slightly soluble in the eluent and will spend some of the time in the eluent (or solvent) and some of the time on the adsorbent. When the components of a mixture have varying solubilities in the eluent, they can then be separated from one another. The polarity of the molecules to be separated and the polarity of the eluent are very important. This affinity for the eluent versus the adsorbent is what separates the molecules.

Paper chromatography is commonly used as a simple analytical separation technique. In paper chromatography, the adsorbent is the paper itself. The eluent can be any number of solvents; in this lab, the eluent is water. Water is a very polar molecule. The polarity of the eluent is very important in paper chromatography since a small change in polarity can dramatically increase or decrease the solubility of some organic molecules. The organic pigments in the inks, which will be "spotted" on the filter paper, separate out as they are carried with the water at different rates. Those molecules that have a polarity closest to the polarity of the water will be the most soluble and will move outward on the radial chromatogram the fastest.

References

Cesa, I., *Elements, Compounds, and Mixtures—Flinn ChemTopic™ Labs.* Batavia, IL: Flinn Scientific, Inc., 2005; Volume 2, pp. 37–44.

Materials for *Ink Investigation* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7745	Flinn Forensic Files—Ink Inspection
AP3104	Filter paper, Qualitative, 12.5 cm

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