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Bloodstain Pattern Simulations: A Physical Analysis

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INTRODUCTION

Description

Following graphical and vector analysis, this lab exercise is an open-ended or discovery activity. Students receive bloodstain pattern evidence from a crime scene. They must then answer a series of questions through inquiry, observation, measurement, and analysis. To complete this challenge, students reconstruct the evidence through four standard models to derive qualitative characteristics and quantitative relationships that address the evidence at the crime scene. In addition, students will utilize the following impact equation and the concept of free fall in which an object falls from rest.

$$\text{impact} = \text{mass} \times \text{velocity}$$

$$\text{free fall velocity from resting position} = (\text{gravitational acceleration}) \times (\text{time})$$

Student Audience

This activity is designed for secondary students learning about the applications of physics.

Goals for the Activity

The main goals of this activity are for students to

- construct “evidence” similar to that found at a crime scene and derive specific characteristics and mathematical relationships from standard models;
- follow procedures for measurement, organization, and analysis of evidence from a hypothetical crime scene and draw conclusions using a database of standards;
- emphasize and enhance the skills of observation;
- consider and develop an appreciation for the complexity of evidence that may occur at an actual crime scene; and
- understand the interrelationships of vectors, impact, and free fall.

Recommended Placement in the Curriculum

This activity should be conducted in an introductory or applied physics course as a practical application unit utilizing vector and graphical analysis in forensic science.

STUDENT HANDOUT

Bloodstain Pattern Simulations: A Physical Analysis

Purpose

Determine the following characteristics pertaining to bloodstain patterns at a crime scene:

- the height from which a droplet fell,
- the travel direction of a drop colliding with a stationary surface,
- the angle of impact of blood on a smooth surface, and
- the origin of blood spatter in two dimensions on a smooth surface.

Materials

Part A

Per group

- eyedropper
- ring stand and clamp
- meterstick or metric tape
- white paper stock (Recycle if possible.)
- newsprint (optional, may add a factor of difficulty in measurements)
- calipers
- V-8 vegetable juice or tomato-soup concentrate (Do not dilute. One can of soup is enough for a class.)

Part B

Per group

- small container of approximately 100 mL of juice or concentrate
- white paper stock or newsprint
- toothbrush

Part C

Per group

- ring stand and clamp
- eyedropper
- meterstick or metric tape
- protractor
- 5, 10-cm-wide cardboard strips cut from cereal boxes (The length of the strip equals the height of the box.)
- calipers

Part D

- same as for Part B

Part A: Height from Which a Droplet Fell

Procedure

1. Mount an eyedropper perpendicular to the floor or countertop with a ring stand and clamp.
2. Place paper that is identical to that from the crime scene over the floor or countertop at the base of the ring stand.

3. Fill the dropper with vegetable juice or tomato-soup concentrate.
4. Adjust the dropper so that the tip is 15 cm from the surface of the paper.
5. Squeeze out a single drop to splatter on the paper below. Slide the paper over and squeeze another drop. Repeat for a total of five drops.
6. Allow the drops to dry. Record significant observations about the drops. It may help to illuminate the paper from behind to highlight the droplets. Using calipers, measure the diameter of each red stain and record.
7. Repeat steps 4 through 6, each time raising the dropper tip an additional 15 cm until a 135-cm vertical distance is reached.
8. Record your observations and measurements in Table 1.
9. Calculate the average diameter of the drops from each height. Record your calculations and observations in Table 2.

Table 1						
Height (cm)	Diameter (mm)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
15						
30						
45						
60						
75						
90						
105						
120						
135						

Table 2		
Height (cm)	Average Diameter (mm)	Characteristic Observations
15		
30		
45		
60		
75		
90		
105		
120		
135		
crime scene		

Questions

1. Describe the relationship between the distance of fall and the diameter of the droplet.
2. What characteristic observations did you make concerning your standard?
3. What was the extrapolated distance of fall at the crime scene?
4. What possible sources of error could have occurred during the procedure?
5. What adaptations did you make or would you suggest in performing this activity?
6. How do the following equations relate to your data? Design a brief mathematical example to illustrate this relationship.

$$\text{impact} = \text{mass} \times \text{velocity}$$

$$\text{free fall velocity from resting position} = (\text{gravitational acceleration}) \times (\text{time})$$

Part B: Direction of Travel of Blood

Procedure

1. Lay paper that is identical to the crime scene paper smoothly on the floor.
2. Dip a toothbrush into a small container of juice or concentrate.
3. Grip the toothbrush in your hand so that when your arm hangs freely at your side, the bristles of the brush point vertically up toward the ceiling.

4. Standing on the paper, quickly flip your forearm up to form a right angle with your upper arm. At this point, a nice “blood” spatter should have formed on the paper. This step may be repeated for better results. Allow the spatter to dry, and analyze it.
5. Save the results for Part D.

Data

Describe the spatter.

Questions

1. What observation can you make concerning the droplets’ direction of travel?
2. Which direction did the droplets travel in the crime scene? Be specific.
3. Explain the droplet shape in terms of friction.

Part C: Angle of Impact

Procedure

1. Arrange an inclined plane with the brown cardboard side of a cereal box up and the printed side down facing the countertop. An additional ring stand may be used for support.
2. Mount an eyedropper perpendicular to the countertop with a ring stand and clamp.
3. As the cardboard stands on end perpendicular to the countertop, the angle of impact (or angle to the dropper) is 0° and the angle with the countertop is 90° . Using a protractor or trigonometric measurements, adjust the cardboard incline to an impact angle of 15° with respect to the dropper. (The incline will be 75° with respect to the countertop. See Figure 1.)

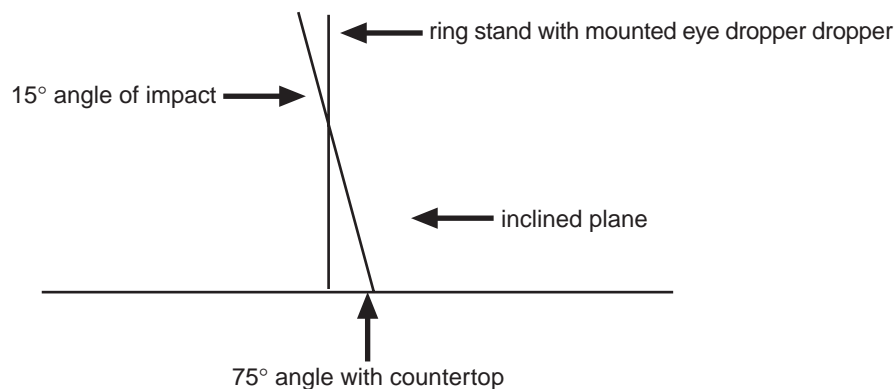


Figure 1: Setting up the angle of impact

4. Elevate the dropper to a point 20 cm above the incline and squeeze a drop onto the incline.
5. Leaving the incline stationary, slide the ring stand with the dropper above a clean area on the incline, keeping the distance the same. Squeeze another droplet. Repeat once more. Record your results in Table 3.

6. Allow the droplets to settle so that measurements can be made. Measure the length of elongation (disregard disjointed tailing) and the maximum width of the droplet.
7. Increase the angle of impact by 15° to 30° . Repeat steps 4–6.
8. Continue increasing the angle of impact by 15° intervals through an angle of 75° . Repeat steps 4–6 for each new angle.
9. Using the data from Table 3, calculate the average elongation and width for each angle. Record these averages and your observation in Table 4.

Analysis

Prepare two graphs. On one, plot elongation on the x axis and angle of impact on the y axis. On the other, plot width on the x axis and angle of impact on the y axis. Extrapolate the crime scene impact angle from each graph.

Data

Table 3			
Angle of Impact		Droplet	
		Elongation (cm)	Width (cm)
trial 1	15°		
trial 2	15°		
trial 3	15°		
trial 1	30°		
trial 2	30°		
trial 3	30°		
trial 1	45°		
trial 2	45°		
trial 3	45°		
trial 1	60°		
trial 2	60°		
trial 3	60°		
trial 1	75°		
trial 2	75°		
trial 3	75°		

Table 4			
Angle of Impact	Average Droplet Sizes		
	Elongation (cm)	Width (cm)	Observations
15°			
30°			
45°			
60°			
75°			
crime scene			

Questions

1. Describe the relationship between elongation of the droplet and the impact angle.
2. Describe the relationship between width of the droplet and the impact angle.
3. What was the crime-scene impact angle extrapolated from the elongation graph? From the width graph? How closely did the results agree?
4. What characteristic observations did you make concerning your standard?
5. What possible sources of error could have occurred during this procedure? For example, why might the results from the two graphs differ?
6. What adaptations would you suggest in performing this activity?

Part D: Origin of Bloodspatter

Procedure

The procedure is the same as in Part B. If good bloodspatter was achieved in Part B, it can be used here as well. Some points to notice are the following:

- Before you flipped your forearm up and forward, round droplets fell directly below the head of the toothbrush onto the paper. This is basically the point of origin.
- Select five to seven of the best-defined teardrop-shaped droplets on the paper. The better the quality of your selection, the better your extrapolation. In addition, select droplets separated by 5–10 cm for better results.
- Draw an extended longitudinal axis through the head and tail of each droplet using a meterstick. The point of linear intersection is the point of origin. It should be at or near the circular droplets at the beginning. (See Figure 2.)

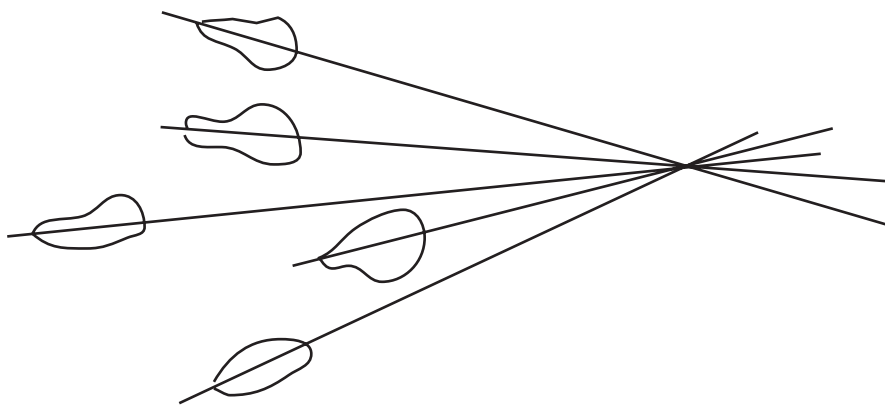


Figure 2: Finding the point of origin

- Calculate the distance, angle, and direction (vector) of the origin from the crime scene's reference point.

Data

Give the distance, angle, and direction from the reference point of the crime scene.

Questions

1. List the final characteristics of the vector leading to the origin of the bloodspatter.
2. What sources of error exist in determining the origin?

Summation Question

After performing this lab, imagine what an actual crime scene might look like. Write two or three paragraphs describing the difficulties or further considerations that must be taken into account in analyzing the scene.

Required Reading

Safestein, R. *Criminalistics: An Introduction to Forensic Science*, 6th ed.; Prentice Hall: Englewood Cliffs, NJ, 1998; pp 379–383.

Further Reading and References

Baird, J.B. "The Individuality of Blood and Bloodstains," *The Canadian Society of Forensic Science Journal*, 1978, 11, 83.

Bevel, T.; Gardner, R.M.; Bevel, V.T. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*, CRC Series in Practical Aspects of Criminal and Forensic Investigation; CRC: Boca Raton, FL, 1997.

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MacDonell, H.L. The Bloodstain Evidence Institute Website. <http://www.servtech.com/~kish/Basic/> (accessed May 8, 2000).

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INSTRUCTOR NOTES

Bloodstain Pattern Simulations: A Physical Analysis

Time Required

The actual lab procedure may be performed during a 60-minute period. A 90-minute period allows for pre-lab discussion and points of refinement.

Group Size

This lab works well for groups of 2–3 students and for all class sizes. It is inexpensive but can be messy, especially if the instructor creates a more open-ended environment for exploration.

Materials

Part A

Per group

- eyedropper
- ring stand and clamp
- meterstick or metric tape
- white paper stock (Recycle if possible.)
- newsprint (optional, may add a factor of difficulty in measurements)
- calipers
- V-8 vegetable juice or tomato-soup concentrate (Do not dilute. One can of soup is enough for a class.)

Part B

Per group

- small container of approximately 100 mL of juice or concentrate
- white paper stock or newsprint
- toothbrush

Part C

Per group

- ring stand and clamp
- eyedropper
- meterstick or metric tape
- protractor
- 5, 10-cm-wide cardboard strips cut from cereal boxes (The length of the strip equals the height of the box.)
- calipers

Part D

- same as for Part B

Safety, Handling, and Disposal

As the instructor, you are expected to provide students with access to SOPs, MSDSs, and other resources they need to safely work in the laboratory while meeting all regulatory requirements. Before doing this activity or activities from other sources, you should regularly review special handling issues with students, allow time for questions, and then assess student understanding of these issues.

Emphasize safety as if the sample in the lab were authentic blood. Students may be tempted to sample the juice. Emphasize that eating or drinking in the laboratory will not be tolerated.

Procedural Tips and Suggestions

Before preparing the lab, the instructor should become familiar with the procedure. It is imperative to create good fake samples of a crime scene for students to compare with their standard models. Highlight areas where students need to take special care or pay particular attention, or where students may experience confusion or difficulty.

Part A: Height from Which a Droplet Fell

Additional Notes

- In many schools, students and teachers recycle waste paper. This activity provides an excellent opportunity to emphasize recycling by reusing white stock paper or newsprint. The latter adds both to the difficulty in measurement and to the realism. Whichever is selected, students should be given the same paper as that used by the instructor to create a crime scene. (step 2)
- The number of trials on all parts of this lab may vary with time available. For those interested in statistical analysis, the repetition lends itself to an interdisciplinary unit in math and science. (step 5)
- The red coloring in the spatter tends not to spread with absorption as quickly as the water. One may want the students to discover this on their own rather than mentioning it in the instructions. (step 6)
- You may want to have the students design their own data tables for recording measurements and observations from which a graphical relationship may be derived. (step 8)
- Students typically observe a larger diameter of absorption of fluids than expected. Absorption characteristics vary with the type of paper. The droplet develops more spikes from its circumference with increased distance of fall. (data)

Plausible Answers to Questions for Part A

The diameter does increase with height. Through extrapolation with the students' restructured standard, the approximate height may be estimated. Each drop from similar droppers is approximately the same volume; thus, each has approximately the same mass. However, the velocity increases linearly with increasing height and thus increases the force of impact.

Part B: Direction of Travel of Blood

Additional Notes

- Small paint brushes or wooden dowel rods may be used. I had the best performance with an old toothbrush. (step 2)
- Be generous with spreading out paper because this portion of the lab can create a mess. This is a good part to conduct outdoors. (step 4)

Plausible Answers to Questions for Part B

An elongated droplet forms with a tail pointing in the direction of travel. The bulb or head of the droplet points in the direction of origin. As the most massive portion of the droplet hits the surface, the friction between the surface and the fluid is greater than the friction between the layers of fluid molecules tapering into a tail.

Part C: Angle of Impact

Additional Note

- The number of trials may vary along with the selection of angles. The droplets are less likely to dry quickly on cardboard, but they will settle soon enough for effective measurements to be taken. (step 6)

Plausible Answers to Questions for Part C

As the angle of impact increases, the elongation of the droplet decreases and its width increases. Thus, the elongation of the droplet changes inversely with its width. Thus the smaller the angle of impact, the longer the spike shooting from the main body of the droplet.

Part D: Origin of Bloodspatter

Additional Note

- Because your crime scene spatter will have the circular droplets at the origin as well, you can cut off the paper where the origin exists and simply mark a reference point on the remaining paper with the spatter from which students can make their measurements. Figure 3 shows hypothetical lines of possible intersection. Students would trace their own lines. (step 4)

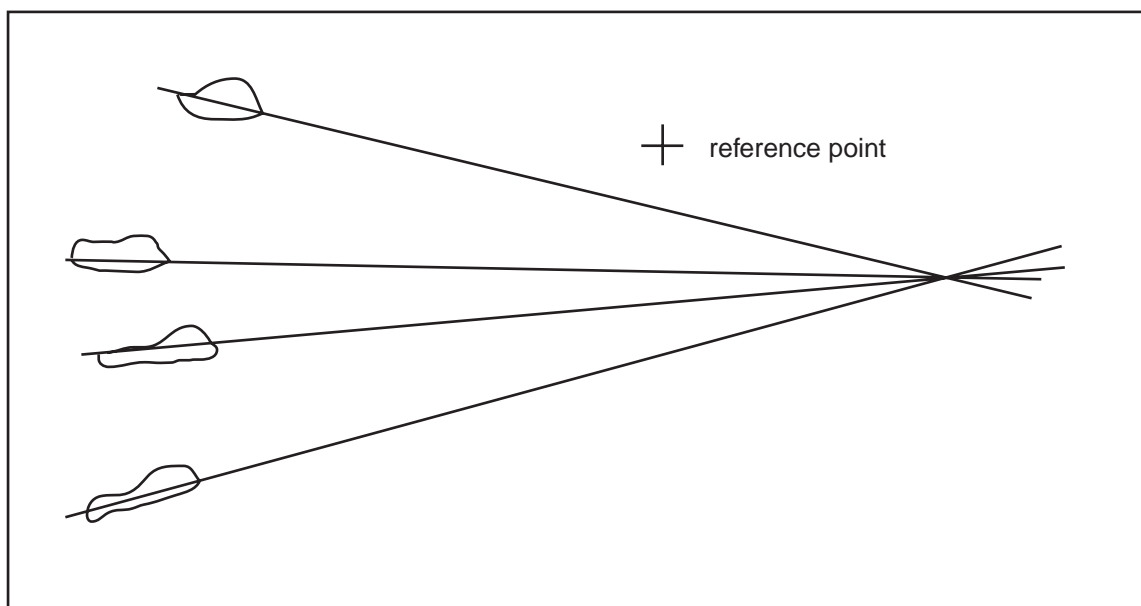


Figure 3: Finding the point of origin

Extensions and Variations

This lab lends itself to open exploration. For instance, from the information available, students may develop their own investigation or procedure to identify the physical characteristics of the blood at the crime scene. In addition, they may develop data tables to organize their information. This approach is by far more challenging and more time consuming, but it also allows students to investigate in a more realistic manner. You may also have them investigate more physical properties such as absorption on different surfaces, force, and direction in two dimensions of the spatter. The latter would take into account vertical walls and the effects of gravity. Such investigations obviously include more complex calculations. Other materials may be more effective than those mentioned earlier. Students may develop new adaptations that prove to be very effective.

The lab does not have to be performed in any particular order, and other parts may be performed while the droplets are drying. You may have one class develop the crime scene for another class, or you may create multiple scenes for each group. Remember, more thought-provoking challenges often require significant amounts of time.

For students familiar with graphical analysis, the standard model may include mathematical relationships that relate variables to one another. This is another example of interdisciplinary work between math and science.

References

- Baird, J.B. "The Individuality of Blood and Bloodstains," *The Canadian Society of Forensic Science Journal*, 1978, 11, 83.
- Carter, A. (Instructor at Adirondack Community College, Queensbury, NY). Class presentations June 28–July 2, 1999.
- MacDonell, H.L. *Bloodstain Patterns*. Laboratory of Forensic Science: Corning, NY, 1993.
- Safestein, R. *Criminalistics: An Introduction to Forensic Science*; 6th ed.; Prentice Hall: Englewood Cliffs, NJ, 1998, pp 379–383.