CSI Physics: The Science of Bloodstain Pattern Analysis (BPA)

Lesson Overview

In this lesson, students step into the role of a forensic physicist. By applying principles of fluid dynamics, geometry, and trigonometry, learners will discover how "blood" (simulated) behaves when subjected to various forces and how these patterns can be used to reconstruct events at a crime scene.

Materials Needed

- **Simulated Blood:** (Mix 2 parts corn syrup, 1 part water, red food coloring, and a drop of blue/green for realism)
- Large sheets of white butcher paper or poster board
- Medicine droppers or pipettes
- Metric rulers and protractors
- Scientific calculator (with sine/inverse sine functions)
- Cardboard or clipboards (to create angled surfaces)
- String and masking tape
- Safety goggles and old clothing/apron

Learning Objectives

By the end of this lesson, the learner will be able to:

- Identify the three main types of bloodstain patterns (Passive, Projected, and Transfer).
- Explain how surface tension and velocity affect drop shape.
- Calculate the **Angle of Impact** using the trigonometric formula: *arcsin(Width / Length)*.
- Determine the **Point of Origin** for a series of drops using the "stringing" method.

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1. Introduction (The Hook)

Scenario: Investigators walk into a room. There is no one there, but the walls are covered in patterns of red droplets. One investigator says, "The attacker was standing exactly four feet away and used a blunt object." How do they know that? Is it magic? No—it's physics.

The Concept: Blood follows the laws of physics. Because of surface tension, blood travels through the air as a sphere, not a teardrop. When it hits a surface, that sphere deforms based on the angle and speed of impact. Today, you are the forensic analyst who will decode those shapes.

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2. Body: "I Do" (Direct Instruction)

The Physics of the Drop:

- **Passive Drops:** Created by gravity alone. As height increases, the diameter of the drop increases—until it reaches terminal velocity.
- **Satellites and Spines:** If a drop hits a rough surface, small droplets break off (satellites) or form jagged edges (spines).
- **The Geometry:** When a drop hits a surface at 90°, it is a perfect circle. As the angle becomes more acute (shorter), the drop elongates into an oval.

The Math: To find the angle of impact (θ), we measure the width (W) and length (L) of the stain. We use the formula:
$\theta = \sin^{-1}(W\ /\ L)$

3. Body: "We Do" (Guided Practice)

Activity 1: The Height Factor

1. Lay a sheet of paper flat on the floor.
2. Drop a single drop of "blood" from 10cm, 50cm, and 100cm.
3. Label each. Observe the diameter and the presence of "spines."
4. **Discussion:** Why does the 100cm drop look different than the 10cm drop? (Answer: Kinetic energy and surface tension breakdown).

Activity 2: The Angle Factor

1. Prop a piece of cardboard at a 45° angle (use a protractor to verify).
2. Drop "blood" onto the cardboard from a distance of 30cm.
3. Notice the "tail." The tail always points in the direction of travel.
4. Measure the width (the narrowest part) and the length (the longest part *not* including the tail).
5. Calculate: $\sin^{-1}(\text{Width}\ /\ \text{Length})$. Does your calculated angle match 45°?

4. Body: "You Do" (Independent Application)

The "Crime Scene" Challenge:

1. **Create:** Set up a vertical target (paper on a wall). Flick a toothbrush or a paint brush dipped in the simulated blood at the paper from an unknown angle and distance.
2. **Analyze:** Select 3 distinct, elongated drops.
3. **Calculate:** For each drop, measure W and L, and calculate the Angle of Impact.
4. **Stringing:**
   - Tape a piece of string to each drop.
   - Use a protractor to pull the string away from the wall at the exact angle you calculated.
   - Where the strings intersect in 3D space is the **Point of Origin**.
5. **Verify:** Measure the distance from the wall to where your strings meet. Was that where you were standing when you flicked the brush?

5. Conclusion (Closure & Recap)

- **Recap:** We learned that blood droplets are physical evidence that obey math and physics. By measuring an oval, we can calculate an angle; by combining angles, we can find a location.
- **Real-World Application:** This science is used in courtrooms every day. However, it's not perfect—surface texture and "air drag" can change results. This is why forensic scientists must be precise!
- **Final Thought:** How might a detective distinguish between a high-velocity wound (like a gunshot) and a low-velocity wound (like a fall) based on drop size? (Answer: High velocity creates a "mist" of tiny droplets).

Assessment

Formative: Check the student's measurements during the "We Do" phase. Ensure they are not including the "tail" in their length measurements.

Summative: The student will submit a "Forensic Lab Report" containing:

- A table showing the Width, Length, and calculated Angle for 3 drops.
- A photo or sketch of their "stringing" setup.
- A 2-sentence conclusion explaining any margin of error (e.g., "My calculation was off by 5° because the paper was slightly wrinkled").

Differentiation & Adaptations

- **For Advanced Learners:** Research "Terminal Velocity" of a blood drop. At what height does a drop stop getting bigger? Graph the height vs. diameter to find out.
- **For Support:** Provide a pre-made "cheat sheet" for the sine calculations (e.g., a table where 0.5 = 30°, 0.707 = 45°).
- **Digital Adaptation:** Use a slow-motion camera on a smartphone to record the drop hitting the surface to see the "crown" formation in real-time.

Success Criteria

- Accurately identifies the direction of travel using the drop's "tail."
- Calculates the impact angle within a 5-degree margin of error.
- Successfully demonstrates the Point of Origin using the stringing method.