

Additional Crime Scenes for Projectile Motion Unit

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Building students' ability to transfer physics fundamentals to real-world applications establishes a deeper understanding of underlying concepts while enhancing student interest. Forensic science offers a great opportunity for students to apply physics to highly engaging, real-world contexts.¹ Integrating these opportunities into inquiry-based problem solving in a team environment provides a terrific backdrop for fostering communication, analysis, and critical thinking skills. One such activity, inspired jointly by the museum exhibit "CSI: The Experience"² and David Bonner's *TPT* article "Increasing Student Engagement and Enthusiasm: A Projectile Motion Crime Scene,"³ provides students with three different crime scenes, each requiring an analysis of projectile motion. In this lesson students socially engage in higher-order analysis of two-dimensional projectile motion problems by collecting information from 3-D scale models and collaborating with one another on its interpretation, in addition to diagramming and mathematical analysis typical to problem solving in physics.

The activity is designed for two class periods or one lab block. The three scenarios include only problems in which projectiles are launched horizontally, targeted for first-year physics courses, but can be readily adapted to more challenging scenarios better suited to more advanced levels.

Key learning goals for students are:

1. Recognize the independent aspects of horizontal and vertical motion.
2. Extract salient facts from text as well as three-dimensional models.
3. Apply and negotiate problem-solving skills to unfamiliar albeit interesting contexts.

Students are welcomed as detectives into the classroom with introductory music and a short video clip from the popular TV series "CSI." Three corners of the room contain a crime

scene (Gangster Shooting, Hotel Jumper, and Road Rage), including a poster with background information, a three-dimensional scale mock-up of the crime scene created in advance by students in search of extra credit, and an information sheet detailing the investigative team's assignment.

Students are then broken up into investigative teams, given a timeline for working at each scene, and released to begin their investigations and solve the crimes, with groups assigned to one of the starting crime scenes detailed below.

Crime Scene #1: Gangster Shooting

Context:

Horatio Leafbottom, a newly initiated member of Gangster's Union Local #219, was shot in the shoulder at a recent union meeting for refusing to apologize after making strong comments on the topic of the superiority of cats as pets. Luckily, the bullet traveled straight through Leafbottom's shoulder. He will make a full recovery. Because of the chaos at the time, however, Leafbottom cannot make a confident determination of the shooter's identity. Police investigators have narrowed the suspect field to the three candidates who were armed and in the room at the time.

Janice Jackson, a small-time software pirate, was found carrying a .38 Special. Aloisus Datarcy, a suspected weapons dealer, was found with a .45 Automatic Colt Pistol (ACP). Merv Redwood, suspected money launderer, was apprehended with a .357 Magnum. All three guns had been fired recently.

Neither the bullet nor the shell casing was found at the crime scene. However, based on Leafbottom's testimony, you can pinpoint where in the room Leafbottom was standing when he was shot. Further, the emergency doctor's report indicates definitively that, based on entry and exit wound locations, the bullet emerged from Leafbottom's shoulder with a perfectly horizontal velocity. The bullet left Leafbottom's shoulder 1.6325 m above the ground. The hole in the wall was centered 1.627 m above the ground, 5.5 mm below Leafbottom's exit wound, and 3 m behind Leafbottom (Fig. 1).

Potential scenarios:

1. Janice Jackson shot Leafbottom with a .38 Special.
2. Aloisus Datarcy shot Leafbottom with a .45 ACP.
3. Merv Redwood shot Leafbottom with a .357 Magnum.

Background information:

FBI firearm expert Lorenzo Nofingers has provided you with the following table (Table I) showing estimated muzzle velocities based on the firearms confiscated from the suspects. Further, ballistics testing indicates that passing through

Table I. FBI Muzzle Velocities.

Firearm	Muzzle Velocity (m/s)
.357 Magnum	442
.38 Special	300
.45 ACP FMJ	250



Fig. 1. Gangster Shooting diorama.

Leafbottom's shoulder would slow each bullet down to 30% of its initial muzzle velocity. You may reference this information in your final report.

Your assignment:

You must assist the police in identifying the shooter and provide a detailed justification in your report for the police, the district attorney, and for the lead editor of *Gangster Today* magazine.

Crime Scene #2: Hotel Jumper

Readers are directed to Bonner's original article³ for technical details and a diagram for this crime scene.

Context:

Alonzo Green, a 45-year-old attendee at the 23rd Annual Skydivers Convention, was found dead on the sidewalk of the Odyssey Hotel by a hotel bellhop at 4:57 Tuesday morning. Based on the damaged concrete surrounding Green's remains, coupled with the open window from his room 14 stories above, it is obvious Green fell from his room to the concrete below.

Less obvious, however, is the cause of Green's death. Inspectors first on the scene, after talking to Green's wife, assumed Alonzo, an expert skydiver, jumped from his room in an attempt to perform a daredevil dive into the swimming pool and came up 2.3 meters short. The medical examiner's report showed some discrepancies, however. Given the massive damage to Green's body, no conclusive determinations could be made. Interviews with hotel patrons and staff indicate the Greens had been arguing late into the evening of Alonzo's death.

To further cloud the story, the Greens took out a \$2 million life insurance policy just three months ago. Mrs. Green stands to walk away with a lot of money if her husband's death is ruled accidental.

Potential scenarios:

1. Alonzo Green was murdered when his wife pushed him out his bedroom window.
2. Alonzo Green died accidentally attempting a stunt jump from his 14th-story window.

Background information:

FBI crime and physiology expert Dr. Sandra W. Corning provides you with a report showing typical velocities for various activities (Table II). You can reference this information in your final report.

Your assignment:

Based on the mock-up created by the crime lab technicians, you must determine which scenario occurred and provide a detailed justification in your report for the police, the insurance company, and the district attorney.

Table II. FBI Movement Velocities.

Age Range	Gender	Walk (m/s)	Sprint (m/s)
18-25	Female	1.3	6.9
26-33	Female	1.2	6.7
34-42	Female	1.2	6.4
43-50	Female	1.2	5.8
51-62	Female	1.1	5.3
18-25	Male	1.4	8.1
26-33	Male	1.4	7.8
34-42	Male	1.3	7.5
43-50	Male	1.3	6.9
51-62	Male	1.3	6.1

Crime Scene #3: Road Rage

Context:

Evelyn Horton, a 22-year-old university student at the School of Fabrication and Imagination, drives her car off a bridge located on Interstate 42. Evelyn escapes without serious injury thanks to her seatbelt, air bags, and crumple zones in her car. Evelyn claims she was run off the road by an enraged motorist.

Evelyn testifies that she was traveling exactly 110 km/hr across the bridge when the assailant's vehicle forced her over the edge. Upon first sighting the assailant, Evelyn claims she engaged her brakes for at least one full second before leaving solid ground. Evelyn's car plowed through the guard rail and fell off the 10-m high bridge, landing a horizontal distance of 29 m from the base of the bridge.

Police investigating the scene find no physical evidence to back up this claim, and with no sign of skid marks, they turn to you to assist them. Based on the time of day, it's also possible that Evelyn fell asleep at the wheel and is making up a story to avoid embarrassment, or perhaps dreamed up the assailant. Her insurance company is also interested, as her policy doesn't cover damages due to driving while over-tired.

Police need to know whether this was an accident or a malicious act from an enraged driver, as they will dedicate a large percentage of their investigative resources toward finding Evelyn's attacker if this is indeed a crime scene.

Potential scenarios:

1. Evelyn was forced off the bridge by an enraged motorist (Fig. 2).
2. Evelyn fell asleep at the wheel and drove through the guard rail and off the bridge.

Background information:

The guard rails along the side of the bridge have been tested and shown to reduce the velocity of any car impacting them by approximately 10 m/s, regardless of incoming velocity. The braking capacity of Evelyn's car, given the road conditions and state of Evelyn's tires, is -8.83 m/s^2 . You may reference this information in your final report.

Your assignment:

Based on the mock-up created by the crime lab technicians and the data provided, you must assist police in determining whether Evelyn was forced off the road or whether she fell asleep at the wheel. Whatever your conclusion, you must justify it in a report that will be provided to the police, the district attorney, and Horton's insurance company.



Fig. 2. Road Rage crime scene.

Results and assessment

In all three cases, the same basic projectile analysis skills are used, but in very different contexts. In the first crime scene (Gangster Shooting), students analyze the situation to calculate the muzzle velocity of the bullet and therefore identify the shooter. The twist in this scenario that appeared to give students the most trouble was working to interpret the statement “ballistics testing indicates that passing through Leafbottom’s shoulder would slow each bullet down to 30% of its initial muzzle velocity.”

In the second crime scene, Hotel Jumper, initially developed by David Bonner of Hinsdale South High School, students are not given actual measurements, but instead must use the scale on the three-dimensional model of the hotel and the hotel courtyard to determine what happened. As the metric system is a recent introduction for many of our students, this provides excellent reinforcement in unit conversions. Note that a variety of scales and actual values may be used, but for the problem given, a 14th-story height equivalent to about 40 m and a pool-to-hotel distance of roughly 19.7 m worked out well for an accidental death.

In the third and final crime scene, Road Rage, students must connect their work with one-dimensional kinematics into their analysis of projectile motion. This can provide occasional frustration, as some groups had to work through several iterations of the problem before realizing they must divide the total path of the car into several smaller segments in order to utilize their physics toolset to piece together what happened to the errant driver.

Assessing learning for this activity can take on many different forms depending on the preferences and intentions of the teacher. Our students were individually assigned to write a one-paragraph letter, or “final police report,” for each crime scene, formally stating the conclusion and its supporting evidence. Other possibilities for assessment of this lesson include having each team summarize their respective results onto whiteboards—which might align nicely with modeling-friendly instruction. Alternately, students can simply turn in their work showing their calculations as if they were word problems, which might help students to see the problem-solving strategies utilized in examining these 3-D model contexts are the same as those used in word problems.

To obtain basic feedback on the students’ perceptions of the activity, investigation teams took a few minutes to reflect on index cards about not only what they discovered at each crime scene, but also what patterns and strategies they had discovered for working with projectile motion problems. Examples of student reflections include:

- “I was able to use real-life situations with a visual to better understand projectile motion.”
- “It helped us learn to work backwards in order to get the answers.”
- “With this lab I understand that it is essential to break problems into horizontal and vertical components.”
- “Even though it made my brain hurt and was extremely challenging, I think it was helpful.”

Detailed activity sheets and poster printouts for this lesson can be downloaded from www.aplusphysics.com/educators/activities/forensics.html.

References

1. Toni Feder, “Physicists in forensics,” *Phys. Today* **62**(3), 20–22 (March 2009).
2. “CSI: The Experience,” Fort Worth Museum of Science and History, 2007; www.csitheexperience.org/.
3. David Bonner, “Increasing student engagement and enthusiasm: A projectile motion crime scene,” *Phys. Teach.* **48**, 324–325 (May 2010).

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