Court TV

Forensics in the Classroom

Developed as part of a continuing educational partnership with the
American Academy of Forensic Sciences

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Unit 2 Teacher Overview: The Car That Swims

Level of Difficulty: Intermediate

UNIT DESCRIPTION:

After being introduced to the mystery and the information gathered by the police at the scene, students will perform two lab activities to elucidate the facts of the case. (If this is the first Forensics in the Classroom unit you have used, your students should go over the Forensics Terms and FAQ Sheet before performing the lab activities.) In the first lab activity, students will make a shoeprint casting to identify a shoeprint impression discovered at the scene. In the second lab, they will design a device to illustrate Archimedes' Principle to understand and explain how a car can float on water for a short period of time. Finally, students will complete a lab report to summarize their findings in the case. The story's epilogue can be revealed at the beginning of Lesson 3, or once students have completed their reports.

IN ADDITION TO THIS TEACHER OVERVIEW, UNIT 2 INCLUDES:

Lesson 1: Introduction to Forensics and the Mystery

- Forensics Terms and FAQ Sheet handout (optional)
- Mystery Synopsis handout

Lesson 2: Shoeprint Casting

- Shoeprint Casting activity sheet

Lesson 3: Archimedes' Principle

- Archimedes' Principle activity sheet
- Investigative Report
- Unit 2 Epilogue

DESIRED OUTCOMES:

After completing the unit, students should:

- Understand and perform scientific inquiry
- Understand thermochemistry — exothermic reactions, entropy
- Understand Archimedes' Principle
- Improve their estimation, problem solving, and calculation skills
- Synthesize several pieces of information to determine the course of events

NATIONAL STANDARDS ADDRESSED:

After completing the unit, the student should understand:

- Chemical reactions
- Conservation of energy and the increase in disorder
- Interactions of matter and energy
- Structure and properties of matter

IMPORTANT TERMS:

Archimedes' Principle – states that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid

Buoyancy – the upward pressure exerted by the fluid in which a body is immersed

Dental stone – a form of gypsum, composed largely of calcium sulfate, chemically identical to plaster of paris but which sets up a more highly-ordered molecular structure for a harder, more precise casting

Endothermic – a process that absorbs heat

Entropy – the amount of disorder in a system. Numerically it is related to the number of states a system of objects can assume

Exothermic – a process that releases heat

Hydrate – a molecule or solid compound that has water molecules loosely bound to it

Plaster of paris – a form of gypsum composed largely of calcium sulfate that sets up a less-ordered molecular structure than dental stone

Shoeprint casting – a mold taken of a shoe impression made in mud, soil, snow, or other surfaces; used to compare the impression to a suspect's shoe or foot

MYSTERY SYNOPSIS:

Early one morning, two fishermen spot a submerged car a good distance from the shoreline. Police are excited because it matches the description of the getaway vehicle used in an armed robbery the previous day. Police run a check on the tag and the Vehicle Identification Number (VIN) to find the owner. Police arrive at teenager Sarah Riley's home to ask some questions after the license plate number and VIN identify her parents as the owners of the car. Sarah is the principal driver of the car, but she claims that the car had been taken, as a prank by one of her friends, from a party she attended the previous night. She refuses to say who it was. Police find her story fishy, so they must rely on physical evidence examined by students to get to the truth.

Preparation and examination of casts of the shoeprints found along the shoreline should lead students to place Sarah at the scene of the accident. Based on that evidence, students should conclude that Sarah must have lied about what happened. Students then use a device illustrating Archimedes' Principle to theorize how the car made it so far from shore before sinking. Students eventually learn in the epilogue that Sarah made a bad choice by trying to drive home from a friend's party even though she had been drinking. She lost control of the vehicle, running it off the road and across a short beach into the water. She escaped unharmed through an open sunroof and concocted the prank story to cover up her accident.

MATERIALS NEEDED:

Reproducibles

1. Forensics Terms and FAQ Sheet (optional)
2. Mystery Synopsis
3. Shoeprint Casting activity sheet, including information on exothermic reactions and how shoeprint castings are made and used
4. Archimedes' Principle activity sheet, including questions that ask how a car can float on water, despite weighing thousands of pounds
5. Investigative Report handout, detailing what information needs to be provided to conclude the investigation

Lab Equipment and Chemicals

Shoeprint Casting Activity – Lesson 2:

- Plaster of paris or dental stone
- 1-gallon Ziploc® bags
- Cardboard strips for surrounding the prints (or metal trays in which to set the impressions)
- Talcum powder
- Paint stirrers
- Reinforcement materials – small sticks, toothpicks, or small pieces of metal wires
- A putty knife, screwdriver, or similar tool to pry up the cast when it is finished
- A pair of girl's casual, sneaker-style shoes

Archimedes' Principle Activity – Lesson 3:

- Troughs (to simulate the car) made of a compound denser than water (preferably metal – lasagna pans work very well)
- Heavy objects such as tools or ball bearings (several for each student or group)
- Large tubs, sinks, or fish tanks in which to float the troughs (large lasagna pan works well as trough)
- A balance capable of measuring 10 to 20 kilograms, depending on the size of the troughs used (optional)
- Balances

ORDER OF ACTIVITIES:

1. Introduction to Forensics (optional) and Mystery Introduction
2. Footprint Casting
3. Archimedes' Principle
4. Investigative Report

You can present students with the story's epilogue upon successful completion of the first two lessons, or hold a classroom discussion to share various theories and the mystery conclusion until the end of Lesson 3.

ADDITIONAL RESOURCES FOR TEACHERS:

http://www.scdps.org/cja/csr-mix.htm
This site provides pictures detailing the casting process.

http://www.und.edu/dept/chem/NDCCFC/mccarthy/index.htm
This site provides an online slide show about the chemistry of plaster and mortar.

http://www.fbi.gov/hq/lab/handbook/examshoe.htm
An official site of the FBI, it has several pictures and some good background information for shoeprint and tire tread examinations.

http://projects.edtech.sandi.net/kearny/forensic/burglary/evidence/ftprintinfo.htm#casting
This site has very detailed instructions about how to mix a shoeprint casting and how to make an impression of a shoeprint.

http://www.hondacars.com/models/accord_sedan/features.html
This site provides dimensions of a typical sedan, which you can use in the Archimedes' Principle activity.

http://www.uncwil.edu/nurc/aquarius/lessons/buoyancy2.htm
This site provides additional experiments on buoyancy.

http://www.aafs.org
The Resource/Forensics section provides additional links to forensic publications and organizations.

LESSON 1:
INTRODUCTION TO FORENSICS AND THE MYSTERY

OBJECTIVE:
Students will review the Forensics Terms and FAQ Sheet about forensic science. (The extent of the forensics review should be based on whether students have already completed a unit associated with these materials.)

MATERIALS NEEDED:

Reproducibles
- Forensics Terms and FAQ Sheet (optional)
- Mystery Synopsis

TIME REQUIRED:
- Teacher Prep Time: 30 minutes
- Class Time: 45 minutes (much shorter if you've covered forensics basics in a previous unit)

LESSON DESCRIPTION:
In this lesson, students will be introduced to (or will review) forensic science, focusing on various investigative techniques and evidence examination activities used by investigators. Students will then read about the mystery and discuss the information available to them.

BACKGROUND INFORMATION:
Before beginning this lesson, you should become acquainted with the history of forensics and types of tests that can be performed. Be prepared for questions from students about a variety of forensics-related topics, as they will be curious about certain techniques that they have seen on TV. They may have many misconceptions that need to be corrected.

LESSON STEPS:

1. Begin by activating the students' prior knowledge of forensics. If you have already completed at least one unit of the program, your students will likely recall their experiences with the unit(s). Even if this is their first unit, many students will be familiar with current TV shows that use forensics as the central theme. If this is your first unit, ask students to write a definition of forensics in their notebooks before you start the discussion, so that everyone gets a chance to answer before an especially interested and knowledgeable person provides the definition.

2. Hand out the Forensics Terms and FAQ Sheet as an introduction or a review. Explain to students that in this unit, they will get to perform some of the tests that are described. It will spark students' interest when they realize that they get to be part of solving a mystery.

3. Distribute the Mystery Synopsis. Read it aloud or silently, then discuss the scenario to ensure all students understand the task. In the discussion, students can also hypothesize if Sarah is lying (and if so, why they think so) and how the car could have ended up so far out from shore. Because the synopsis indicates that shoeprints were recovered at the scene, it serves as natural lead-in to Lesson 2, the Shoeprint Casting activity.

ACADEMIC EXTENSIONS/MODIFICATIONS:

- To abridge this unit, you can assign students to read the Forensics Terms and FAQ Sheet handouts and the Mystery Synopsis for homework. Then, combine Lesson 1 and Lesson 2 into one class period by beginning the lesson with a brief discussion of forensics followed by the mystery introduction and the first lab.

- Another way to save time with this unit is to have students cast their prints first, then, while the casts are drying, students can go over the Mystery Synopsis and the FAQ Sheet.

STUDENT HANDOUT

FORENSICS TERMS AND FAQ SHEET

Q: What is forensic science, and how can it aid in criminal investigations?

A: Forensic science isn't limited to just criminal investigations. It is essentially the application of science to law in events subject to criminal or civil litigation. More commonly, though, it is applied to the investigation of criminal activity. The term "forensic science" includes a number of different technical fields, including (but not limited to) physics, chemistry, biology, engineering, psychology, and medicine. Forensic scientists might study the path a bullet took, DNA evidence found at a crime scene, or the mental and emotional state of a suspect. Investigators turn to forensic scientists to discover additional evidence that requires specialized training to analyze and interpret.

Q: How long have investigators been using forensic science?

A: Forensic science has been around for nearly 900 years. The first recorded application of medical knowledge to the solution of a crime was in the year 1248. The first known use of a forensic chemical analysis was in 1836 when James Marsh, a Scottish chemist, detected arsenic poisoning in connection with a criminal investigation. Techniques involving blood typing have been used since 1900, when Karl Landsteiner discovered human blood types. Developed only within the past 20 years, DNA tests are now commonplace, and are revolutionizing the field.

Q: What are some types of evidence that investigators look for?

A: A few clues that investigators look for are

- Fingerprints, palm prints, and footprints
- Shoeprints
- Fibers from clothes
- Blood spatters
- DNA samples (can be from hair, skin cells, blood, semen, saliva)
- Residue from accelerants (compounds used to speed up fires set by arson)
- Gunshot residue on hands and clothing
- Bullet casings
- Tool marks (marks left on a bullet by a gun when fired)
- Insect and mold growth in a body as well as body temperature (to determine time of death)
- Bullet residues around bullet holes
- Pattern of gunshot residue spray (can determine the distance the shooter was from the victim)
- Gunpowder burns

STUDENT HANDOUT

Q: Why are fingerprints important?

A: If you look at the palm side of your hands and feet, you will see a maze of lines in your skin curving, breaking apart, and joining back together. The places where skin ridges break apart and join together are unique for every person. This unique pattern allows forensic investigators to trace a print found at the scene of the crime back to a specific person. Even identical twins will have different fingerprints!

Though one of the older forms of investigative techniques, fingerprint identification is not without some controversy. One recent court ruling declared that fingerprint examination and identification did not qualify as a "science," in part because an examiner subjectively decides if a set of prints match. There is no uniform set of requirements used by all analysts to determine a positive match, so critics argue that fingerprint identification should not be considered scientific evidence. It is important to note, however, that other court challenges to the science of fingerprint identification have been rejected.

Q: How long after a crime can DNA evidence be collected?

A: DNA is a wonderfully stable molecule. Researchers have been able to recover usable DNA from Egyptian mummies thousands of years old. Each individual strand of DNA is made of strong, unreactive bonds. The strands of DNA twist around each other to form the well-known double helix, concealing weaker hydrogen bonds in the middle of the molecule. There are so many billions of hydrogen bonds that even though one is not strong by itself, the cumulative effect is strong enough to keep DNA intact.

Q: How is the scientific method reflected in a criminal investigation?

A: The scientific method involves many steps: researching a problem, hypothesizing an answer, testing out the answer, and — if the answer is wrong — starting the process over. Investigators of a crime follow this same process by taking a general survey of the crime scene, hypothesizing who might have committed the crime based on the evidence present, and testing the evidence that they find to see if it implicates a suspect. The process continues until a theory can be proved with evidence. One pitfall that investigators try to avoid (but don't always succeed in avoiding) is forming conclusions too early in an investigation. By concentrating too soon on a particular theory or suspect, investigators can neglect or even miss evidence that is not part of their working theory.

Q: Are some forensic tests, by their nature, NOT conclusive?

A: Yes, not all tests performed by forensic investigators are conclusive. Some tests, such as luminol and phenolphthalein (used to indicate the presence of blood) and certain gunshot residue (GSR) tests, are presumptive, meaning they do not indicate absolute proof for what the investigator is testing. When investigators use presumptive tests, which are often quick, easy, and sensitive ways to initially screen evidence from a crime scene, they must then follow up with conclusive tests that provide concrete results.

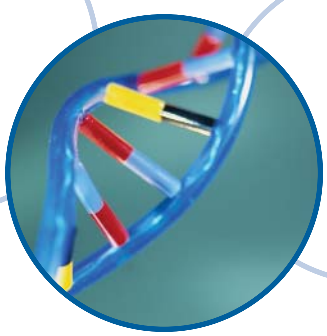
STUDENT HANDOUT

Q: What is the difference between a "suspect" and a "person of interest"?

A: Sometimes investigators designate people as "suspects," and sometimes they refer to them as "persons of interest." However, there is no published definition that distinguishes the difference between the two. Generally speaking, investigators consider someone a suspect once he/she becomes an official focus of an investigation. Initial evidence or circumstances make it clear that the person is a likely perpetrator of a crime. Further, once someone is deemed a suspect, police must follow certain rules for interrogation. For example, police must advise a suspect of his/her Miranda rights, and if a suspect requests a lawyer, the police must stop questioning until a lawyer is present. If someone is simply a person of interest, however, police can do some initial probing for information without such restrictions in place. If the investigation is to probe more deeply into someone's background and possible connection to a crime, the judicial system then insists that the police consider that person a suspect.

Q: What changes are occurring in the field of forensic science?

A: Experts believe forensic science will continue to evolve and provide new and exciting ways to help solve crimes. One current focus of the field is to scrutinize closely its many analytic techniques in order to strengthen their use in investigations, mainly by eliminating as many potential errors as possible. For example, by comparing cases from all over the world that involve similar uses of handwriting analysis or ballistics tests, investigators can establish improved practices from these many experiences. Many in the community of forensic science hope to improve on the techniques already in place by establishing standards and using careful error analysis.



STUDENT HANDOUT

FORENSICS TERMS

Autopsy: the internal and external examination of a body after death. An autopsy is performed to confirm or determine the cause of death and establish other pre-death conditions, such as the type of food last consumed and the time it was consumed.

Ballistics: the study of the motion of bullets and their examination for distinctive characteristics after being fired. Examiners can use this evidence to match bullets or bullet fragments to specific weapons.

Blood Spatter: the pattern of blood that has struck a surface. This pattern can provide vital information about the source of the blood. Blood spatter can help determine the size and type of wound, the direction and speed with which the perpetrator or victim was moving, and the type of weapon used to create the blood spill.

Bloodstain Interpretation: the interpretation of size, shape, orientation, and distribution of bloodstains on various surfaces. Information about the event can be derived from the proper interpretation of the stains.

Bullet Track: the path of a bullet or projectile as it passes through matter, such as a body or a wall.

Caliber: the diameter of the bore of a rifled firearm, usually expressed in hundredths of an inch or in millimeters. For example, a Colt 45 has a bore of .45 of an inch.

Catalyst: a substance that accelerates a chemical reaction but is not itself permanently changed by the reaction.

Composite Drawing: a sketch of a suspect produced from eyewitness descriptions of one or more persons.

Criminology: the study of criminal activity and how it is dealt with by the law.

DNA: deoxyribonucleic acid. Occurring in the form of double-helix strands, DNA contains genetic code. In each individual among the higher organisms, identical DNA occurs in the nucleus of every cell and serves to define that individual's characteristics. In addition to the portions of the DNA that encode the proteins making up all the individuals of a species, there are portions of "junk" DNA unique to each individual within the species. Often an individual's DNA appears in the blood and other body fluids. This provides a powerful technique for uniquely identifying the person or animal who left traces of such fluids at a crime scene. Indeed, this is the best method presently known for such identification.

DNA Electrophoresis: the technique by which DNA fragments are placed in a gel and charged with electricity. An applied electric field then separates the fragments by size, as part of the process of creating a genetic profile.

STUDENT HANDOUT

DNA Profiling: the process of testing to identify DNA patterns or types. In forensic science this testing is used to indicate parentage or to exclude or include individuals as possible sources of bodily fluid stains (blood, saliva, semen) and other biological evidence (bones, hair, teeth).

Evidence: anything that has been used, left, removed, altered, or contaminated during the commission of a crime or other event under investigation.

Fingerprint: the unique patterns created by skin ridges found on the palm sides of fingers and thumbs.

Forensic Science: the application of science to law.

Gas Chromatograph (GC): a forensic tool used to identify the chemical makeup of substances used in the commission of crimes. The questioned substance is burned at high temperatures. The temperature at which this material becomes gas is then charted to determine its makeup.

Gene: a unit of inheritance consisting of a sequence of DNA that determines a particular characteristic in an organism.

Hemoglobin: a red blood cell protein responsible for transporting oxygen in the bloodstream. Also provides the red coloring of blood.

Latent Fingerprint: a fingerprint made by deposits of oils and/or perspiration, not usually visible to the human eye. Various technologies, including lasers, can be used to identify latent prints.

Lie Detector: also known as a "Polygraph." A machine that charts how respiration and other bodily functions change as questions are asked of the person being tested. An attempt to knowingly provide false answers can cause changes in bodily functions. Lie detector tests are usually not admissible in court because many scientists and others consider the results to be unscientific and inconsistent.

Luminol: a chemical that is capable of detecting bloodstains diluted up to 10,000 times. Luminol is used to identify blood that has been removed from a given area. It is an invaluable tool for investigators at altered crime scenes.

Physical Evidence: any object that can help explain an event under investigation. For example, physical evidence can establish that a crime has been committed, and sometimes it can provide a link between a crime and its victim or between a crime and its perpetrator.

Point-by-Point Analysis: when comparing a known object to one that needs to be identified, analysts will break down photos of each into small portions, and compare the respective similarities within those portions.

Ridge Characteristics: ridge endings, bifurcations, enclosures, and other ridge details, which must match in two fingerprints for their common origin to be established.

STUDENT HANDOUT

Serology: a technology dealing with the properties and actions of serums in blood; also known as "blood analysis."

Super Glue Fuming: techniques used to develop latent fingerprints on non-porous surfaces.
A chemical in the glue reacts with and adheres to the finger oils, and then exposes latent prints.

Toxicology: the study of poisons and drugs and their effect on human and animal populations.

Trace Evidence: material deposited at a crime or accident scene that can only be detected through a deliberate processing procedure. An individual entering any environment will deposit traces of his or her presence, and this material can be used as evidence. Common types of trace evidence are hairs and clothing fibers.

Trajectory: the path of a projectile.

STUDENT HANDOUT

Unit 2 Mystery Synopsis: The Car That Swims

THE SET UP

"Hey Jeff, how about taking the helm, huh?" Max asked, a little irritated at his son.

"Sorry. It looked like you needed help casting off," Jeff answered, returning his father's irritation.

"No. Let's go. We're late already."

Neither of them said anything else as the boat got underway. They'd gotten out late because Jeff just couldn't wake up, and Max was angry about it. Rather than leaving before dawn, they'd left a little after sunup. "Fish don't like getting suntans," his father had said more times than Jeff cared to remember. He waited for the old guy to remind him again.

Still, Jeff really liked piloting the boat, and he kind of liked the fishing. He didn't even mind waking up early. Sometimes he just overslept.

As they navigated out toward deeper water, Max suddenly bellowed at Jeff, "ALL STOP!" Jeff pulled back on the throttle until the engines were chugging along at an idle.

"What, dad?" What now, Jeff wondered. When he peered back to look where his dad was leaning over the gunwale, Jeff's gum dropped right out of his mouth and made a little "sploosh" in the water. It looked to him like a car was just below the surface of the water. "Is that a Honda?" Jeff said in disbelief, trying to imagine how and why a car would be underwater and so far out from shore.

"Sure does look like it," Max said. "What the devil's it doing way out here? Who'd take their car out into the bay and just drop it?"

"I dunno. It's not very banged up either." It was clear through the open sunroof that no one was inside the car.

"Should we try to tow it in?" Jeff asked.

"No, we shouldn't touch it."

"It's not that deep here. I can just dive down and hook the rope—"

"Son," Max interrupted his suggestion, "if anything, we should stay put until the authorities get here. Just radio it in." Then Max sighed and shook his head. "It's obvious we're not getting any fish today, are we?"

STUDENT HANDOUT

THE INVESTIGATION

By the time the police arrived, the sun was well up. They broke into groups, sending several divers down to investigate the car while detectives talked to Jeff and Max.

Detective Hunter took the lead in the questions. "So you didn't touch it, right?"

"No," Jeff replied, glad for once that he took his father's advice.

Both Jeff and Max told the police that they came this way each morning. The car had not been there the day before. They were sure of that. Well ... mostly sure. They just couldn't see how they would have missed something like a submerged car. Though they asked Jeff and Max several times how they knew that the car hadn't been there the day before, the police seemed pleased that the submerged car was "fresh." What Jeff and Max didn't realize was that a robbery had occurred the previous day and the vehicle underwater matched the description of the getaway car.

After getting phone numbers from Jeff and Max in case they had any further questions, the police let them go. It was too late for fishing at that point, so they headed back to the docks.

Police divers examined the car, and there didn't appear to be any exterior signs of damage except for some slight scratching and denting of the driver's side door. It was jammed shut, and all of the windows were up. The sunroof was open and several small crabs were already exploring the interior of the car, however. The police took down the license plate number and the Vehicle Identification Number (VIN) on the dashboard to try to trace the car to its owner.

When the police ran a check, both the plate number and the VIN matched and were registered to a Mrs. Kelly Riley who lived nearby. Stolen cars were used frequently in armed robberies, so police immediately suspected that robbers had stolen Kelly Riley's car before committing the crime. This particular vehicle hadn't been reported stolen, however, so Detective Hunter rode out to pay an early-morning visit to the Riley household to ask them about the apparent theft of their car.

Kelly Riley answered the door and listened in disbelief as Detective Hunter explained why he was there and where her car had been found. For the first time that morning, she realized the car was not parked in its usual spot in the driveway. "What?? In the bay?!" she exclaimed, in total shock. "My daughter Sarah drives that car, and she just got in — she spent the night at a friend's house. I just assumed she drove home . . ." Kelly didn't try to hide her concern. "Sarah! Would you come to the front door, please?! There's a detective here with some questions about the Honda that . . . seems to be missing from our driveway at the moment."

Sarah's groggy feeling disappeared immediately. The sight of a detective at the door with her mom made her visibly nervous. "Good morning," Sarah said to the detective.

"This detective says that they found *my* car — that *you* drive — in Echo Bay . . . literally underwater."

STUDENT HANDOUT

Kelly and Detective Hunter waited for Sarah to respond, her mother more impatient than the detective.

"In the bay?! I . . . I can't believe it. Those . . . jerks." Sarah seemed upset, but not shocked.

"What jerks?" Detective Hunter inquired.

"Well, I was at a party last night, and some 'friends' played a prank on me and took the car. They must have accidentally driven it into the water. That's what must have happened." Sarah started to show more signs of being upset.

"So you were nowhere near the bay last night? And what about yesterday afternoon at 3:30?" Detective Hunter's second question confused Sarah and her mother since they didn't know about the robbery.

"No! I was at the party, and then I spent the night with my friend Hannah. That's it. Yesterday afternoon I was home; Mom was here, too. The car was in the driveway."

It was apparent that the Riley's car was not the same one involved in the crime. The detective hid his disappointment. Then Sarah added, "I can't believe they'd do something so stupid!"

"Who are 'they'?" Kelly and Detective Hunter asked in unison.

"Do I have to say? I mean, they're jerks and all . . . " Sarah was searching for the right words. "It's just that they'll deny everything. And do the police need to be involved? I'm sure it was just a prank, you know?"

"You don't have to press charges, ma'am, but you will be responsible for paying to have the car taken out of the water. And I'm sorry to say that the water damage has totally ruined it, more or less."

Kelly Riley was visibly angry and didn't hesitate to answer. Her daughter had been in trouble before, and Kelly always suspected some of her daughter's friends were troublemakers. "Oh, we'll be pressing charges, all right. Our insurance won't be paying for this, so Sarah, tell the detective who did it!"

"It's not fair! It was just a prank. And . . . I don't even know who it was exactly. Just punish me for it, since they're my friends," Sarah wailed.

STUDENT HANDOUT

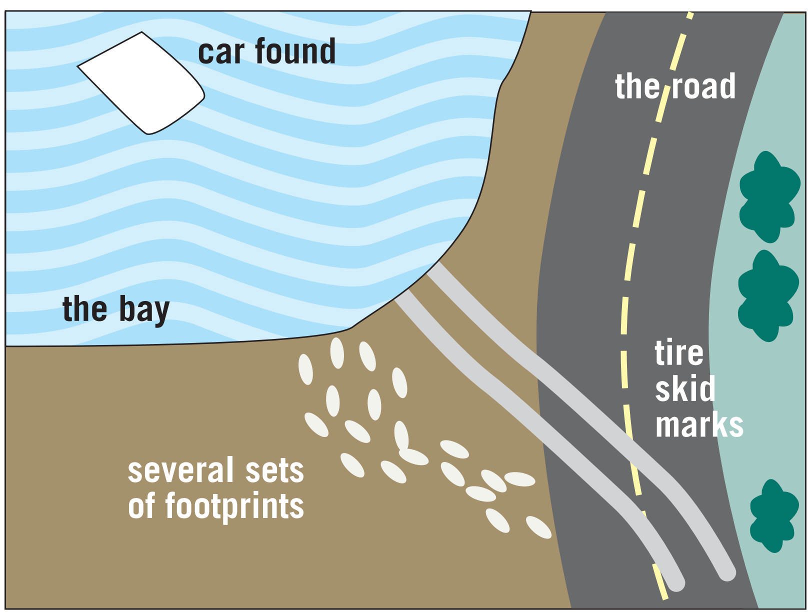
"Don't worry. You'll be punished, missy. Now . . . who did it?!" Again, Kelly waited for her daughter to answer. Detective Hunter was considering a different approach.

"No! I won't!" And Sarah ran to her room.

"It's okay, Mrs. Riley. She'll come around, I'm sure," Detective Hunter offered. "Here's my card. When Sarah's ready to talk, give me a call."

Detective Hunter left feeling that something about Sarah's story didn't add up. She seemed unsure of which friend had played the prank on her, and he got the feeling she was covering something up. She swore that she had been nowhere near the bay, yet she seemed to have an awfully quick explanation for how the car got there. How could she possibly have known that her friends had driven it into the water? Detective Hunter suspected that shoeprints and tire tracks found on shore where the car entered the bay would give him some clues about what really happened. But that still left the question of how her car had gotten so far away from shore.

To keep the scenario clear in his mind, the detective drew the following sketch depicting where the car was found relative to the shoreline, the shoeprints, and the road:



YOUR TASK

Was Sarah lying about what happened? To prove the truthfulness of her story, you need to figure out if her shoeprints match those found by the detective on the shoreline at the point where the car entered the water. You also need to explain how her car, weighing several thousand pounds, could have ended up so far out in the water.

LESSON 2: SHOEPRINT CASTING

OBJECTIVE:

Students will make a shoeprint casting by mixing plaster of paris (or dental stone) and water and pouring it into a shoeprint found at the scene. They will then compare the casting that they made with the shoe of the story's main character to determine that she was present at the scene of the accident.

MATERIALS NEEDED:

Reproducibles

1. Mystery Synopsis
2. Shoeprint Casting activity sheet, including information on exothermic reactions and a discussion of how shoeprint castings are made

Equipment and chemicals

- Plaster of paris or dental stone (Note: For this activity, students will need approximately 5 lbs each of plaster of paris or 2 – 3 lbs each of dental stone. See the Background Information.)
- 1-gallon Ziploc® bags
- Cardboard strips for surrounding the prints (or metal trays in which to set the impressions)
- Talcum powder
- Paint stirrers
- Reinforcement materials – small sticks, toothpicks, or small pieces of metal wires
- A putty knife, screwdriver, or similar tool to pry up the cast when it is finished
- A girl's pair of casual, sneaker-style shoes and one or two other shoe types and sizes

TIME REQUIRED:

- Teacher Prep Time: 2 hours
- Class Time: 45 minutes one day, 15 – 30 minutes the next

LESSON DESCRIPTION:

Because detectives were able to recover several shoeprints on the shoreline where the vehicle entered the water, students will try to determine if the car's principal driver was present at the scene of the accident. Their findings will either corroborate or disprove her explanation of what happened.

BACKGROUND INFORMATION:

This activity can be completed using either plaster of paris or dental stone. While plaster of paris is less expensive, dental stone creates a quicker, harder casting. Dental stone costs approximately $2 – 3 per pound and can be ordered from any dental supply company.

Before beginning this lesson, familiarize yourself with the chemistry of plaster of paris and dental stone as found at any of the following websites:

- http://www.und.edu/dept/chem/NDCCFC/mccarthy/index.htm
- http://www.scdps.org/cja/csr-mix.htm
- http://projects.edtech.sandi.net/kearny/forensic/burglary/evidence/ftprintinfo.htm#casting

To learn more about the role of shoeprint examinations in investigations, the following website from the FBI includes pictures and background information for shoeprint and tire tread examinations:

- http://www.fbi.gov/hq/lab/handbook/examshoe.htm

If you are completing this lesson in several classes, students should be able to reuse the shoeprint impressions you make, as the castings, if done properly, should not alter the impressions themselves.

LESSON STEPS:

Lab Preparation

1. Obtain a pair of girl's sneakers that will represent Sarah's shoes.

2. Find a slightly muddy section of ground outside or prepare a large area with a dirt spreading. Make a variety of shoeprints with a variety of shoe sizes. Make several using your own shoes, and enlist other teachers to place their own shoeprints in the soft ground. Make three or four sets of shoeprint impressions with 'Sarah's shoes.' Be sure that the area will not be disturbed before you can begin casting with the class. Create at least one print for each student or team of students. (Note: If you use metal trays, follow the same procedures by making the prints in the trays.)

3. Measure out 5 lbs. of plaster of paris powder or 2 – 3 lbs. of dental stone powder into each 1-gallon Ziploc® bag. Prepare one bag for each student or team.

4. Since plaster of paris is fairly runny, students will need to place a cardboard form around each shoeprint to keep the plaster from running before it hardens. The form can be made out of cardboard strips and should be big enough to encircle the shoeprint with a 1-inch border around the edge of the print. You will need to instruct students on how to create the form before they begin. You can find an example of a form in Figure 8 on the following website: http://www.scdps.org/cja/csr-cast.htm

   If students are casting prints in trays, cardboards forms are not necessary.

5. Provide a set of small sticks, toothpicks, or wire for each casting. Students will use these as reinforcement to set the castings. (Not necessary if you use dental stone.)

Please note: If this lab occurs on a different day from the introduction of the mystery, ask students recall the overall mystery, as well as some of its specifics, focusing on why they are creating a shoeprint casting.

Lab Execution

1. Depending on class size, you may want to divide the students into teams. Have the students perform the lab as written in the procedure. Students should add the water to the powder and pour the mixture at the beginning of the period, as the plaster casts need to set for at least 30 minutes. (Dental stone sets up in 7-10 minutes.)

2. While the casts set, discuss thermochemistry and what happened (and is happening) in the plaster/water mixture. Activate students' prior knowledge of plaster by talking about medical casts they may have had in order to protect a fractured bone.

3. Caution students to be extremely gentle with the casts when they lift and handle them, as the plaster needs 24 hours to set fully.

4. Remind students to write their names gently on the "upside" of the casts, so they can identify them the next day.

5. Place the casts in a location that is dry but well ventilated. Store them overnight.

6. The next day, ask students to compare the casts with Sarah's shoes. Remind them to be very specific in their points of comparison. Students should record their findings on their handouts.

7. Discuss whether anyone had a cast from the scene that matched Sarah's shoes. Using their combined results, ask students to consider the truthfulness of Sarah's story. What do their findings imply?

ACADEMIC EXTENSIONS/MODIFICATIONS:

- If dental stone is a viable option, use it. It will provide a more precise and more durable cast than plaster of paris. It can be found in dental supply stores or ordered online from http://www.redwop.com. An average shoe cast requires 2 – 3 pounds of dental stone. Add approximately 6-9 oz. of water per pound. With dental stone, you will not need any wires or sticks to reinforce the casting. For additional detailed instructions visit: http://projects.edtech.sandi.net/kearny/forensic/burglary/evidence/ftprintinfo.htm#casting

- Have students research the chemistry of mortar and concrete as a precursor or follow-up to the lab activity.

STUDENT HANDOUT

LESSON 2: SHOEPRINT CASTING

INTRODUCTION:

Shoeprint identification can help establish that a specific person was in a particular location. Though not as individualized as fingerprints, a shoeprint can indicate that a person wearing a certain type of shoe and with a similar weight was present at the scene of a crime at some point. When examining a shoeprint, investigators look for unique details of the print such as exact size of the shoe and places where the outsole may be worn down. One problem with shoeprints, however, is that they can be short lived. Weather or other traffic at the scene of a crime can destroy a shoeprint fairly quickly.

When shoeprints are found at a crime scene, investigators photograph the prints using both close-up and long-range shots. To recover an actual print for detailed examination, investigators then create a casting of the three-dimensional impression. The process for casting a shoeprint is fairly simple but must be performed with care. Casting mixture poured directly onto a print can destroy or erode the detail of the print. A casting mixture is gently poured onto a stick or spoon along the side of the shoeprint, allowed to set, and then lifted out of the print itself. Dirt and debris are then removed from the casting to reveal minute details of the shoeprint.

In this activity, you will use plaster of paris to make your shoeprint castings. Plaster of paris is a hemihydrate of calcium sulfate, written $CaSO_4 \bullet 1/2\ H_2O$. The powder is mixed with water to produce gypsum, the dihydrate of calcium sulfate, written $CaSO_4 \bullet 2\ H_2O$. The reaction that occurs between the water and the plaster of paris is as follows:

$$2\ CaSO_4 \bullet 1/2\ H_2O + 3\ H_2O \rightarrow 2\ CaSO_4 \bullet 2\ H_2O$$

This reaction produces a fair amount of heat. See if you can feel the heat generated as you mix them together. (In the dihydrate of calcium sulfate, the Ca^{2+} and SO_4^{2-} ions are held together with hydrogen-bonded water molecules in a moderately strong matrix. As the bond between the two ions is set up, energy in the form of heat is given off.)

When creating shoeprint castings, forensic scientists prefer to use dental stone rather than plaster of paris because dental stone creates a harder cast and can be cleaned when dry without damaging the cast itself. Chemically, there is little difference between the two, except that dental stone sets up with a more regular crystal structure.

In this part of the investigation, you will make a cast of a shoeprint found along the shoreline where the car entered the water. You will then compare your cast to a shoe the detective acquired from Sarah's mother. You and your classmates will then have to compare all of the shoeprint casts found at the scene with Sarah's shoes to see if there is a match.

STUDENT HANDOUT

PROCEDURE:

1. Your teacher has already measured out 5 lbs of plaster of paris powder into 1-gallon Ziploc® bags. Add 450 ml of water to one of the bags, close it, and mix the water thoroughly with the plaster. Feel the side of the bag as you mix. Is the mixture getting hot or cold?

2. Place a cardboard form around the shoeprint you are casting, leaving a few inches between the shoeprint and the form. The form will keep the plaster from running and will keep the cast thick. (Do not pour the solution yet!)

3. Sprinkle just enough talcum powder over the shoeprint to cover the impression. This serves as a fixative for the plaster. Be sure not to over-sprinkle, in order to avoid causing irregularities in the resulting cast.

4. Cut off or unzip a small portion of one of the corners of the plastic bag and slowly pour the mixture onto the stirrer while holding the stirrer to the side of the impression. After pouring half of the mixture onto the impression, lay the reinforcement materials flat on top to provide internal reinforcement to the casting. Be sure not to poke these materials through to the footprint side of the mixture. Then pour the rest of the plaster mixture as before.

5. Let the cast set for 30 minutes without disturbing it.

6. Lift the cast carefully from the impression by gently placing a putty knife or ruler under the edge of the cast. Pry the cast upwards. Some dirt may stick to the surface of the cast, but you should NOT attempt to clean it as it may damage the cast.

7. Write your name or make an identifying mark on the flat side of the cast. Allow the cast to air dry for 24 hours.

8. After 24 hours you may clean the cast very gently by blowing and brushing loose dirt and particles off. Remember that plaster is a fairly crumbly material so you must be very careful not to destroy any details of the cast.

9. Compare your shoeprint impression to the shoes taken from Sarah. Record all areas of similarity and all areas of difference. Be sure to include comparisons of length, width, shape, tread, any text that is determinable, and brand (if visible).

10. Store your shoeprint casting according to your teacher's directions.

STUDENT HANDOUT

ANALYSIS:

1. When water was added to the plaster powder, were bonds formed or broken? (Hint: Look at the chemical reaction in the introduction.)

2. Is the breaking of the chemical bonds exothermic or endothermic? What about the formation of the new chemical bonds?

3. Based on your answers to questions #1 and #2, do you conclude that the mixing of water and plaster of paris creates an exothermic reaction? An endothermic reaction?

4. Did the entropy of the system inside the bag increase or decrease?

5. Does the casting that you made appear to be from an impression made by Sarah's shoe? What features of your casting lead you to your conclusion?

6. Based on all of the shoeprint castings made by your class, can one reasonably conclude that Sarah was present at the scene of the accident? Can you reasonably conclude that she was there at the time of the accident? Examine a cast that is thought to be of her shoeprint and compare it to her shoe. What points of similarity and difference do you notice? Are there any aspects of the cast that imply it may not be from her shoe?

CONCLUSION:

Write a two to three sentence conclusion stating if you believe Sarah was present on the shoreline. Bolster your argument with specific examples of similarities or differences between her shoe and the casts that you analyzed. You will refer to this information when creating your Investigative Report.

LESSON 3: ARCHIMEDES' PRINCIPLE

OBJECTIVE:
Using an understanding of Archimedes' Principle, students will explain how Sarah's car managed to float a good distance away from shore before sinking.

MATERIALS NEEDED:
Reproducibles
- Archimedes' Principle handout

Equipment and chemicals
- Troughs (to simulate the car) made of a material denser than water (preferably metal – lasagna pans work very well)
- Heavy objects such as tools or ball bearings (enough for each student or group)
- Large tubs, sinks, or fish tanks in which to float the troughs
- A balance capable of measuring 10 to 20 kilograms, depending on the size of the troughs used (optional)
- Balances

TIME REQUIRED:
- Teacher Prep Time: up to 90 minutes
- Class Time: 45 minutes

LESSON DESCRIPTION:
After student investigators determined in Lesson 2 that Sarah was present at the scene of the accident, she broke down to the police and confessed. (You may provide students with the epilogue at this point, or wait until the end of the unit.) The police are unsure, however, how Sarah's car managed to get so far out from the point of entry at the shoreline. According to Sarah's story, it should be located right by the shore. By creating a device to demonstrate Archimedes' Principle, students will effectively model the behavior of the car. They will then use estimation skills and calculations to explain how the car could float out to the location where it was found before totally sinking.

BACKGROUND INFORMATION:
Students will need to understand the basics of Archimedes' Principle for this activity. In this lesson, you will also need to know the approximate dimensions for a standard family sedan. The dimensions for most cars can be found in the specifications on car manufacturers' websites. To find the dimensions and specifications for a Honda (the car used in the mystery), you can go to:
http://www.hondacars.com/models/accord_sedan/features.html

Some approximate specifications (rounded for simplicity) of note for the Accord Sedan are:

Weight = 3,000 lbs.
Length = 200 inches; Height = 55 inches; Width = 70 inches
Passenger volume = 100 cubic feet; Cargo volume = 14 cubic feet

LESSON STEPS:

Lab Preparation

1. Set out enough troughs, weights, and tubs/sinks for each group or student to have one set. At most, lab groups should be pairs, but ideally students will do this lab individually.

2. If you do not have a balance in class capable of measuring 10 to 20 kilograms (or large enough to accommodate the weight of the trough and heavy objects) you may need to weigh each object separately outside of the lab and provide students with those values.

Lab Execution

1. Students will use lots of water in this lab. Make sure that as they fill their tubs they leave the water several inches below the lip of the tubs so that as the troughs are immersed, water does not spill over. Be ready with plenty of towels.

2. In this experiment, students will use the trough to represent the car. As they add weight to the trough (simulating the car as it fills up with water), they will observe what happens to the trough in the water. Instruct students to perform the lab using the procedures provided on the handout. As students perform the lab, keep encouraging them to observe what happens as they increase the weight of the trough. When the weight inside the loaded trough increases, which in turn increases the density of the system, it will eventually cause the trough to sink, as the weight of the trough becomes heavier than the weight of the water it displaces.

3. As students estimate the dimensions of a car, check them repeatedly to make sure that their estimations are staying within the bounds of reality. (If you would prefer to skip the estimations, the Background Information field provides the dimensions for a Honda Accord for you to give to students.) Give students time in class to complete the lab questions, or assign them as homework, if needed.

4. When students have completed the lab and are finished answering the questions, distribute the Investigative Report for students to complete. Remind them that their reports need not only describe how they know that Sarah was the one who sank the car, but must also explain how the car made it so far from shore. If you have not already shared the epilogue, do so when the students have completed their reports.

ACADEMIC EXTENSIONS/MODIFICATIONS:

- If time permits, you can discuss more extensively the functioning of the trough in terms of buoyant force, to tie the lab activity into physics. As the trough displaces more and more water, the water in the tub rises reflecting the increase in the volume of water displaced and hence the buoyant force applied to the trough. (Question—If the buoyant force is increasing, why does the trough ride lower in the water?)

- In the last couple of analysis questions, students must relate the trough to the car in the story. This concept that the car starts out full of air and gradually fills with water may be difficult for some students to understand. You may want to work through this portion of the analysis in small groups. Alternatively, some students may understand the analogy better if they write it out as a creative story or a scene in a movie.

- To make the activity a bit harder, don't give students the procedure. Explain the goal, provide materials, and then let the students figure it out. Instruct students to write the procedure afterwards, so they think through what they did rather than just acting on instinct. Be sure that students explain how the activity relates to the car in the story.

- If you only have one set of equipment, divide students into larger teams and allow them to perform the experiment in rotating groups.

STUDENT HANDOUT

LESSON 3: ARCHIMEDES' PRINCIPLE

INTRODUCTION:

Archimedes' Principle states that the buoyant force on an object immersed in fluid is equal to the weight of the fluid displaced by the object. If the weight of the volume displaced is equal to the weight of the object itself, the object floats. However, if the maximum volume of fluid that can be displaced by the object weighs less than the object, then the object will not float; it sinks. For example, a cork displaces its own weight in water when only slightly immersed in water; thus it floats quite high in water. However, a solid lead object of any volume has a weight that is considerably greater than an equal volume of water, and so the lead object always sinks in water.

In this lab, you will use a demonstration of Archimedes' Principle to explain how a car could float in water even though it weighs thousands of pounds.

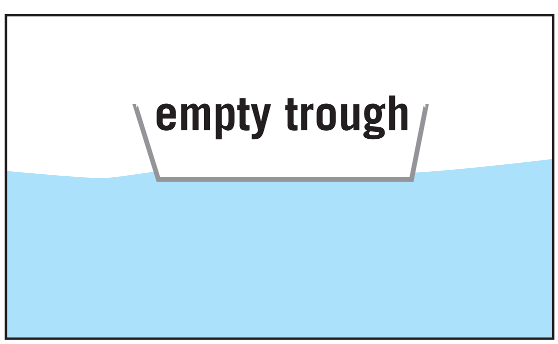
PROCEDURE:

1. Obtain a metal trough from your teacher. Measure and record its weight and volume.

2. Using equipment provided by your teacher, determine and record the weight of each of the heavy objects provided to you.

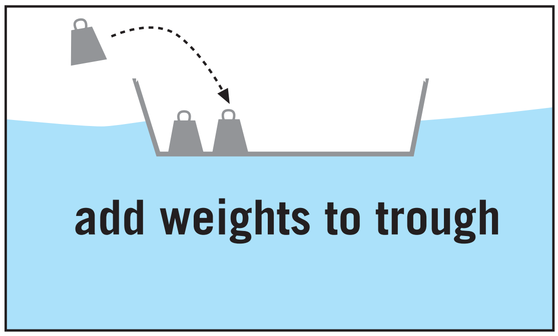
3. Fill a large tub, sink, or container with water. Be sure to leave the level of the water several inches below the rim of the container so it doesn't overflow.

4. Gently lower the empty trough, with its open side up, onto the surface of the water and let it go. Observe what happens, including noting the point on the outside of the trough that the water reaches.

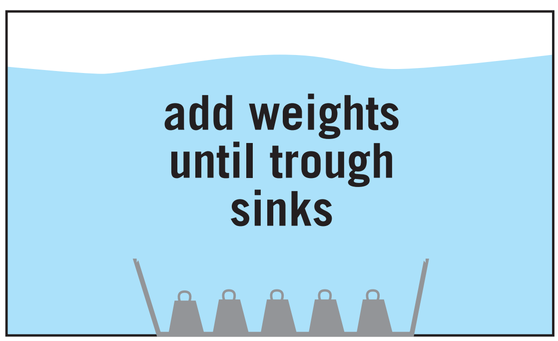


STUDENT HANDOUT

5. Place one or two heavy objects in the trough. What happens?



6. Place just enough heavy objects in the trough to make it sink. Record the weight of the loaded trough at the point it sinks.



7. Finally, remove the trough and objects from the water and then deliberately sink the empty trough and measure the volume of water displaced. Do the same with each of the objects that was in the trough when it sank.

STUDENT HANDOUT

ANALYSIS:

1. Determine the weight of water that was displaced by the floating trough with no objects added to it, based on your measurements in Step 1 and Step 4 above. Compare this with the weight of the empty trough.

2. Determine the maximum weight of water that can be displaced by the floating trough, that is, the weight of the water displaced by the trough when it's on the verge of sinking.

3. Determine the weight of the trough loaded with the maximum number of objects it contained while still floating.

4. Compare the two weights just obtained. Which is greater?

5. Why does the trough float?

6. Compare the maximum weight of water that can be displaced by the floating trough with the weight you determined for the loaded trough at the point that it sank. Which is greater? How close were they?

7. Why did the loaded trough sink? In terms of Archimedes' Principle, what caused the loaded trough to sink very fast once the water started coming in?

8. To understand how a car can display Archimedes' Principle, you will estimate the volume and weight of a car that has its windows and doors shut and is empty. With your teacher's help:

   a. Estimate the length of a car:

   b. Estimate the width of a car:

   c. Estimate the height of a car:

   d. Estimate the weight in pounds:

STUDENT HANDOUT

e. Calculate the volume of the car by multiplying the length, width, and height:

f. A car is not just a large box, so the volume that you calculated in step e is far too large, but it provides a good starting point. In addition to the irregular shape of the car, what else will affect the volume of the car?

g. A reasonable factor (for estimation purposes) is to halve the volume of the car.

h. How would you more accurately determine the volume of a car?

i. Calculate the weight of water that the car would displace.

9. How is the car in this example like the car in the mystery? What can you conclude about the car based on this experiment?

CONCLUSION:

Write a short summary of how Archimedes' Principle can be used to explain the behavior of the car in the mystery. You will use this summary when you write your report concluding the investigation.

STUDENT HANDOUT

INVESTIGATIVE REPORT

You have now uncovered many facts of the case. It is time to summarize your findings and provide an explanation for what happened. Using the evidence that you gathered during the shoeprint casting and your explanation for how the car floated out from shore, make your case. Be sure to explain how each piece of evidence fits or doesn't fit the story that Sarah provided.

DATE: ______________________________

INVESTIGATOR NAME: ______________________________

LOG OF EVIDENCE RECEIVED: ______________________________

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CONCLUSIONS: ______________________________

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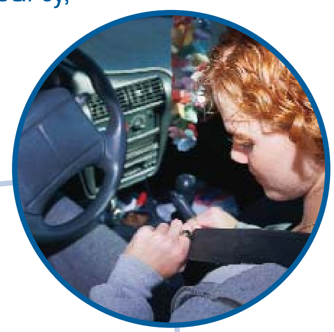
STUDENT HANDOUT

EPILOGUE: UNIT CONCLUSION

After matching a footprint casting to Sarah Riley's shoe, thus placing her at the scene, Detective Hunter returned to the Riley's home to confront Sarah and her parents with the new information.

"Sarah, at my request, your mother gave me the shoes that you wore the night the Honda went into the bay. We had some footprints, and she wanted to confirm that you weren't there." Mrs. Riley nodded to her daughter. Detective Hunter continued, "I think you know what we found out."

After a few moments of pained silence, they watched Sarah's face crack as she admitted what happened. "You're right. It was me. I'm so sorry, Mom and Dad. I went to the party, and I didn't mean to, but I guess I . . . I had too much to drink."



"You promised there wouldn't be any alcohol at that party!" Kelly Riley interrupted. "You said you'd call us if you found yourself —"

"I know. I know." Sarah's guilt was overwhelming, yet she felt great relief in 'fessing up.' "So on the way home, I was going too fast and just lost it going around that nasty curve. Suddenly the car was skidding, and it ended up in the water. I was dazed. I just sat there stunned for a minute or two — I don't really know how long it was. Then I opened up the sunroof and climbed out before it totally sank. I swam to shore. I didn't even want to see what happened to the car. I just wanted to get to shore. I'm sorry. I'm so sorry!"

Detective Hunter was solemn as he explained to Sarah the legal implications of her actions. "Sarah, I'm sorry to say you could lose your license for at least a year for driving while intoxicated. Depending on how the judge feels about it, it could be longer. You're also looking at a fine of up to $1000."

"You've got a couple of other judges at home that you need to worry about, too," her mother added. She was seething, but she spoke calmly despite being so upset. "Your father and I will talk about how long we're going to suspend your license. And how long you'll be grounded. And how you're going to pay for the damages to the car, not to mention the huge insurance premium we're going to have. And that's assuming I ever let you drive a car of mine again!"

Detective Hunter could only imagine what was running through Sarah's mind as the news sank in. He had more to share, too. "I'm afraid you'll have to attend a mandatory alcohol education program, Sarah, and once you complete it, you'll probably have to counsel other teens on drinking and driving. And your mother's right, your insurance rates will skyrocket — and stay that way for a long, long time."

After excusing himself, Detective Hunter had to turn his thoughts to another abandoned Honda that had just been located. Fortunately, this one wasn't underwater.