Do You See What I See? Light and Latent Evidence Detection

by Jackie Smith, 2018 CTI Fellow
William A. Hough High School

This curriculum unit is recommended for:
Honors or Advanced Forensic Science, Honors Physics

Keywords: light, electromagnetic spectrum, latent evidence, alternative light source, ultraviolet light, infrared light

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This curriculum unit teaches students about light and its applications in the field of forensic science. The unit begins with a study of the dual theory of light and the electromagnetic spectrum. It covers the interactions and reactions of light with matter. The unit then looks at how the properties of light, including its interactions and reactions with matter, can be used to locate and analyze latent evidence at a crime scene. It covers the use of alternative light sources to detect blood, saliva, sweat, accelerants, ink alterations, hairs, fibers, fingerprints, footprints and more. This unit is an interesting way to explore light and its applications to practical science.

I plan to teach this unit during the coming year to 44 students in 12th grade Advanced Forensic Science.

Introduction

"When am I ever going to use this in real life?" Any trigonometry, physics or chemistry teacher will tell you they have heard that lament from a student at some point in their career. Forensic Science is the answer to that question. With the plethora of true and fictional crime shows on television, most students have a passing familiarity with modern forensic science. Many of them will tell you they love *Forensic Files* or *CSI*. At the same time, many of those same students will tell you they are not "science" people. However, if you put a wall of blood spatter in front of them with a dead body on the floor, they will work diligently to figure out where the killer was standing or what position the victim was in when they were attacked. They will use trigonometry and physics to answer those questions, but they will be engaged and enjoying what they are doing. Forensics is like hiding a child's peas in their mashed potatoes. They are doing real, high-level science but they enjoy doing it.

Rationale

The most important aspect of forensic science is to be able to find evidence at a crime scene. Without this, there is nothing else. Sometimes at a crime scene, evidence will be obvious. A broken window, a body on a bed, or a bullet casing on the floor are all examples of forensic evidence that is readily visible to crime scene investigators (CSIs). However, there may be a world of evidence at a crime scene not visible to the naked eye. Latent evidence detection at crime scenes is one of the most fundamental and yet challenging aspects of a crime scene investigator's job. Fingerprints, blood and gunshot residue are just a few of the types of evidence found at crime scenes that may not be visible to the naked eye and will require special handling to locate and document. This unit focuses on the use of light in different forms to locate and analyze latent evidence at crime scenes. It nurtures students' interest in forensics while introducing them to new, high-level lab skills. It also develops critical thinking and problem solving skills while encouraging communication and teamwork.

Demographics

William Amos Hough High School is a large suburban high school of over 2700 students located in the small town of Cornelius, North Carolina just north of Charlotte. We opened our doors in 2010 to serve the northern part of the Charlotte-Mecklenburg School District. Eighty-four percent of our graduates go on to either two- or four-year colleges while 16% join the military. Twenty-six percent of our students are minorities and 18% are free or reduced lunch students. Honors Forensic Science classes averaged 36 students during the 2017-2018 school year. Advanced Forensic Science classes were slightly smaller with an average of 29 students per class. During the 2018-2019 year, forensics has students whose native languages are Italian, French, German, Spanish and English.

We offer a comprehensive college preparatory program in the arts and sciences. Classes are taught at the Standard and Honors levels and we offer 26 Advanced Placement courses in conjunction with the College Board. Students may explore their interest in the sciences through electives. We offer Honors Forensic Science and Honors Advanced Forensic Science to meet that need. With the overwhelming popularity of forensics in pop culture, these courses grab students' interest while teaching them valuable lab skills and critical thinking. The first-level course covers many of the basic areas of forensics such as crime scene processing, DNA analysis, blood spatter analysis, footprint analysis and toxicology. The second-level course builds on some of the basic materials but extends them further and includes new topics such as Forensic Botany, Accident Reconstruction, Counterfeiting and Art Forgery. Honors Forensic Science is a pre-requisite for Advanced Forensic Science. This curriculum unit is geared toward the advanced class and will look at the difficulties of locating and documenting some types of evidence at crime scenes and will explore the use of light to visualize otherwise invisible evidence.

Unit Goals

Course standards for this unit require that students be able to explain the Dual Theory of Light and the Electromagnetic Spectrum. They must also be able to describe how light interacts with matter, as this is the basis for locating and analyzing latent evidence. Students will look at interactions such as absorbance, reflection and refraction. They will also study light reactions with a focus on fluorescence. Students need to understand how this information is relevant to forensic science in terms of microscopy, spectroscopy and imaging. Students should be able to identify what types of latent evidence can be visualized with different light sources. Finally, students should be able to use various light-based techniques to visualize different types of evidence and then to document the evidence sufficiently well so that it is admissible in court.

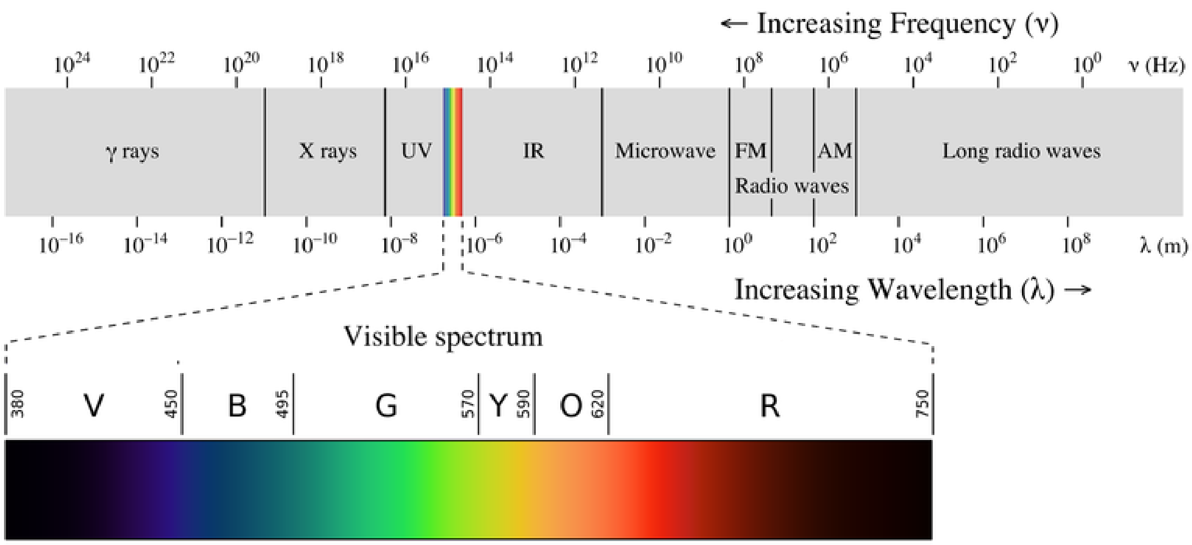
Content Research

Light plays a role in forensics in a variety of ways. First, evidence must be located. Regular visible light or specialty light sources such as black (UV) lights, infrared lights and colored filters fulfill this purpose. Once evidence has been located, it must be observed and have hypotheses formed about it. Finally, the evidence must be analyzed so that conclusions can be drawn. Light offers a range of testing options from microscopes to spectrophotometry. However, before students can understand how to visualize and analyze evidence using light, they need to understand what light is and how it interacts with matter. Once they have mastered these concepts, they can explore how light's interactions with different types of matter can be used to identify, document and analyze an evidence sample.

Electromagnetic Spectrum

Visible light is one small part of the electromagnetic spectrum (EMS). The EMS is all known forms of electromagnetic radiation arranged by wavelength.[1] For forensic purposes, the most important parts of the EMS are visible light, infrared radiation and ultraviolet radiation. These different forms of electromagnetic radiation have characteristic properties such as visibility/invisibility, wavelength, color and frequency.[2]

Figure 1. The Electromagnetic Spectrum.



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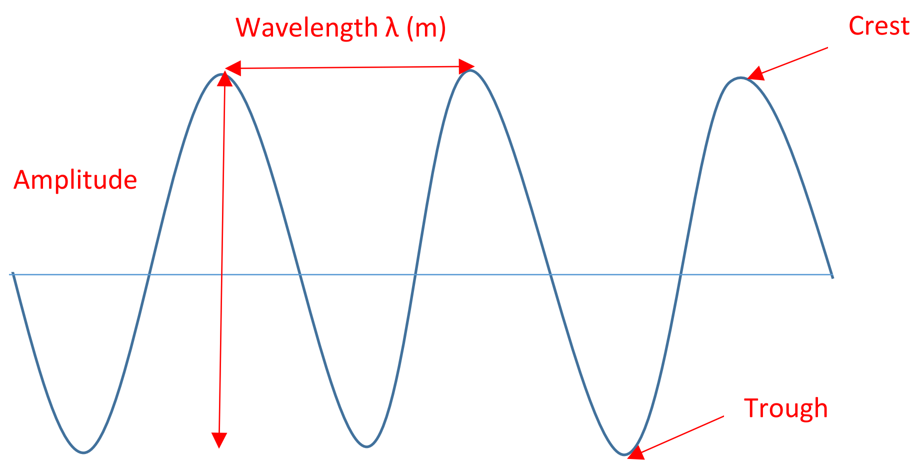
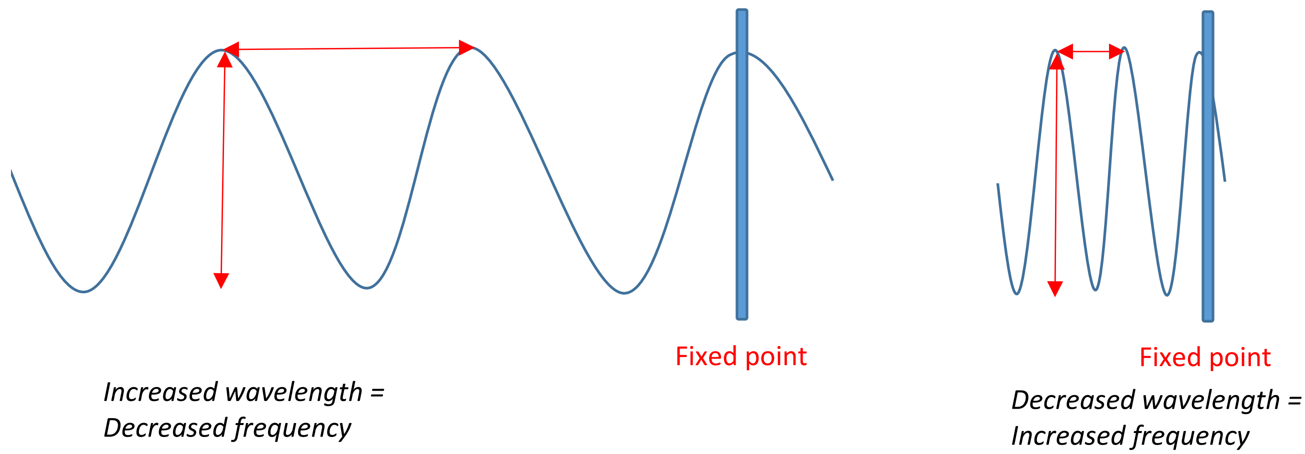
All light travels in waves. A wave is simply the movement of energy. The figure below illustrates the different parts of a wave.

Figure 2. Parts of a Wave.



The distance between the same spot on two successive waves is called the wavelength λ and is measured in meters.[3] Waves travel at different speeds in different media. The speed of a light wave, c, in a vacuum is approximately 3.0×10^8 m/s.[4] The frequency of a wave, ν, is the number of waves that pass a given point in a unit of time.[5] For example, at the beach, the ocean waves may pass a pier at the rate of 40 waves per minute. The metric unit of frequency is cycles (number of waves) per second or the hertz (Hz). Waves with longer wavelengths will have lower frequencies because it takes them longer to pass the given point.

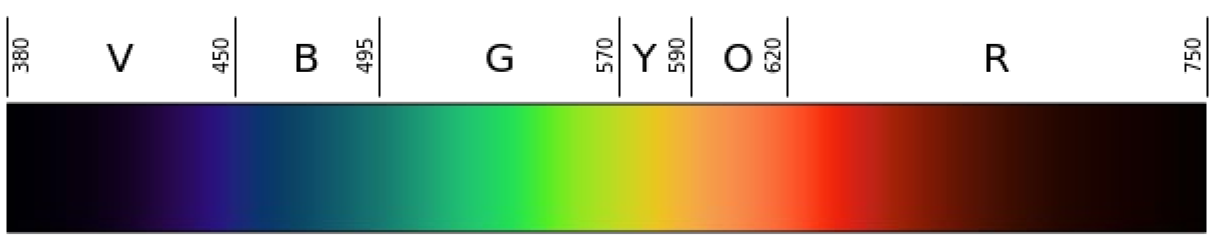
Figure 3. Frequency is inversely proportional to wavelength.



Wavelength, wave speed and frequency are related by the formula $c = \lambda \nu$, where c is the speed of the wave, λ is the wavelength and ν is the frequency.[6] The amplitude of a wave is the height of the wave from the trough to the crest. The amplitude is a measure of the energy of the wave. Notice in Figure 3 although the wavelength changes quite a bit, the amplitude, or energy, of the wave does not change at all. Amplitude is independent of changes to wavelength, speed or frequency.[7]

Ultraviolet light falls on the EMS just above x-ray radiation beginning around 10 nm and extending to the visible portion of the spectrum at approximately 380 nm. UV light is invisible to the human eye but has many uses including disinfecting food.[8] It is used extensively in forensics to detect and analyze evidence. Visible light falls between 380 nm and approximately 750 nm and can be broken down into the basic color range remembered as ROY G BIV. The figure below gives approximate wavelengths for each visible color.

Figure 4. Wavelengths of Visible Light in nanometers.



Adjacent to visible light on the EMS in the longer wavelengths is infrared light. It runs from about 700 nm to 1 mm. The part most useful for detecting and analyzing evidence in forensics is called near-IR and goes up to about 2500 nm.

While light travels like a wave, it also acts like a particle in the way it transfers energy to electrons. Every element has a defining number of electrons. Electrons gain and lose energy as photons, which are packets of light energy.[9] As these electrons gain energy, they move to a higher orbital. When they lose energy, the electron drops back down to its original orbital and the lost energy is released as a photon of light. Different elements emit this light at different energy levels causing each element to have its own unique emission spectrum.

Figure 5. Emission Spectrum of Hydrogen

Image in the Public Domain.

Light Emissions

There are two main classifications of light emissions – hot (*incandescence)* and cold (*luminescence)*.[10] Incandescence is the light produced when heat causes an object to emit energy to its surroundings as a broad continuous spectrum of visible and invisible radiation. An example would be a fire or an incandescent light bulb. Luminescence is the emission of a specific narrow range of discrete wavelengths that results when an electron in an excited state of a molecule or material relaxes to a lower energy state. An example would be fluorescent lights.

There are several types of luminescence based on how the electron is initially excited, such as chemiluminescence, thermoluminescence and photoluminescence.[11] Chemiluminescence is light produced as the result of a chemical reaction, such as a glow stick or luminol reacting with blood. Thermoluminescence is when a material begins to glow due to the application of heat. Photoluminescence can be broken up into two groups: fluorescence and phosphorescence.

Fluorescence occurs when electrons absorb shorter wavelength light, get excited, jump to a higher energy level and then emit light as they leave the higher energy level to return to their original state.[12] The emission of light happens almost immediately. The emitted light will always be of a longer wavelength than the excitation light. This is called the Stokes shift.[13] Ultraviolet light is the best way to visualize fluorescence. Since many biological fluids such as saliva, semen, and sweat fluoresce under ultraviolet light, it is possible to visualize and record these types of evidence using forensic light sources and appropriate cameras.[14]

Objects that phosphoresce also absorb lower wavelength radiation but they retain the excited electron for much longer. Electrons drop back to their original state after much more time has passed which results in the longer wavelength light being visible for much longer. Certain organisms such as dinoflagellates exhibit phosphorescence, which can make large areas of a lake or bay, appear to glow at night. Phosphors are also found in the human body, especially in fluids.

Figure 6. Examples of (a) incandescence, (b) chemiluminescence, (c) fluorescence and (d) phosphorescence.

(a) **Incandescence** – tungsten filament light bulb

(b) **Chemiluminescence** – chemical reaction takes place inside glow sticks

(c) **Fluorescence** – Luminol fluoresces in the presence of blood and UV light

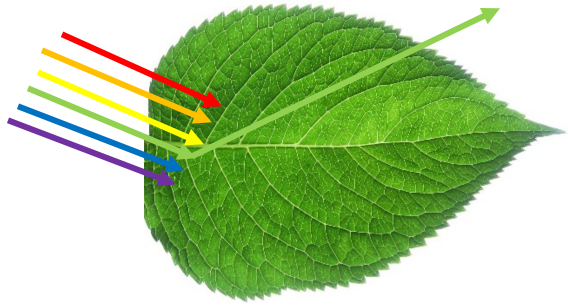
(d) **Phosphorescence** – *Panellus Stipticus* and other organisms phosphoresce naturally

Images in public domain.

Light Interactions

Light can interact with matter in many ways. It can be absorbed, reflected, transmitted, emitted, or refracted. For example, most plants absorb all colors or wavelengths of visible light except green. The wavelength of light corresponding to the color green is reflected back at the viewer and therefore the plants appear green. Similarly a red shirt contains a dye that absorbs all wavelengths of visible light except red. The red is reflected back so the shirt appears red in color. Different types of matter have distinct characteristics of absorption or reflectance that allow forensic scientists to identify the substance.[15]

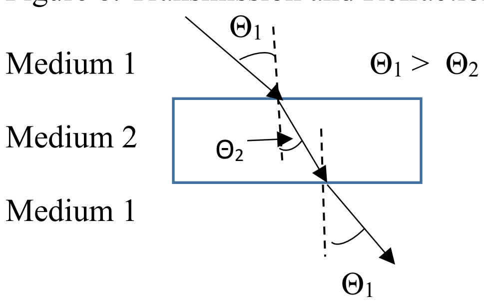
Figure 7. Absorption and Reflection of Light.



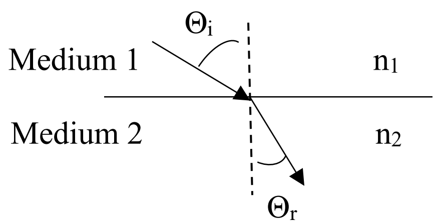
All colors of the visible spectrum hit the leaf, but only green light reflects back. This gives the leaf its green color. The leaf absorbs all other colors. *Image in public domain.*

When light is transmitted through a substance, the vibrations of the electrons are passed on to nearby electrons through the material until the light emerges in the exact same spot on the other side of the object. Materials that can fully transmit light are therefore transparent.

Figure 8. Transmission and Refraction of Light.



The light exits Medium 2 at the same angle as it entered Medium 2.



where Θ_i is the angle of incidence and Θ_r is the angle of refraction and n_1 and n_2 are the respective refractive indices of the media.

When light travels through two or more different media with different refractive indices, the light will bend. The speed of the light wave, as well as its direction, change. This is called refraction. Each transparent material has a characteristic refractive index that can be determined in a lab and then used to identify the material in question.

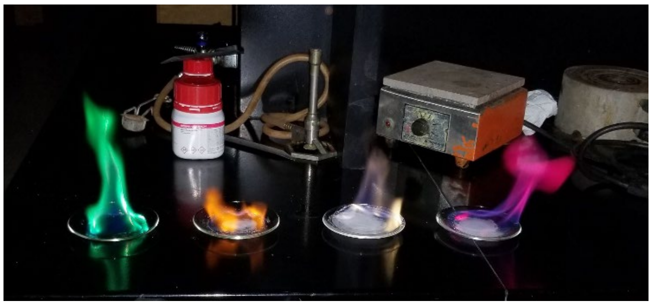
Forensic Use of Light

All of these properties of light are useful in forensics. Light's properties are used to locate, observe and analyze evidence at crime scenes. The wavelengths of light most useful to forensics are visible, ultraviolet, infrared. To obtain these wavelengths at a crime scene, investigators use alternative light sources (ALS). Use of ALS at crime scenes enhances visualization of evidence by using fluorescence, absorption and oblique lighting techniques.[16] ALS can be used to detect latent fingerprints, body fluids, hairs and fibers, bruises, bite marks and wound patterns, variations in ink on documents, gunshot and explosives residue, human bone fragments, teeth, tire tracks, shoe prints, narcotics and many more kinds of trace evidence at crime scenes.[17]

Visible light is used at all crime scenes to locate evidence. Crime scene technicians carry powerful white lights in their kits to use in locating this evidence. Obvious examples of visible evidence at a crime scene are a body, bullet casings, and broken glass. Visible light applied to a surface at an oblique angle will help visualize a footprint on a dusty floor and other less immediately obvious evidence.[18]

Visible light is also used in the analysis of many types of evidence. Simply using a dissecting light microscope to examine a fingerprint or a bullet casing is one way light aids in forensic investigations. Determining the refractive index of an unknown substance by measuring the amount that light bends in a substance or observing the color change in a flame test are ways of using visible light to analyze and identify unknown substances. For example, as discussed above, each element emits characteristic wavelengths of light. When burned, boron emits a bright green color, while strontium emits a beautiful scarlet shade. Below is an example of a flame test that can be used to tentatively identify compounds.

Figure 9. Flame Test.

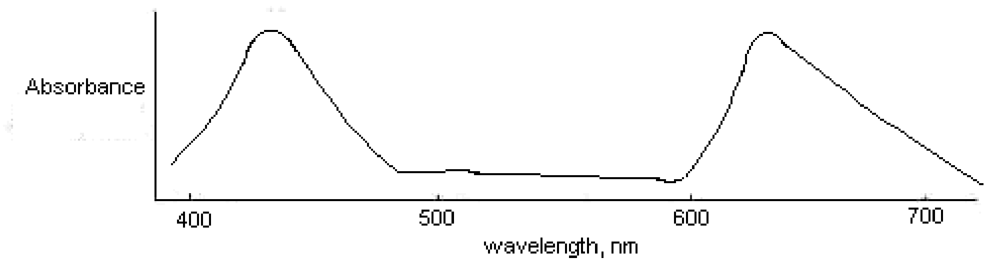


From left, boron, sodium chloride, zinc chloride and strontium.
Photo by Jackie Smith

Magnification uses visible light. Magnifying lenses help detectives find trace evidence such as hairs and fibers. Stereomicroscopes are used to view and analyze that evidence on a macro scale. On a microscopic scale, compound microscopes are used to observe and analyze evidence. There are more types of microscopes than are within the scope of this paper to discuss but a few of the ones most commonly used in forensic applications include the bright field microscope, fluorescence and IR/UV microscopes and immersion microscopes.[19]

Spectroscopy is another use of light that plays a major role in forensic science. It uses light in the visible range to characterize substances. Many high school science departments have a UV/Vis Spectrometer, which shoots individual wavelengths of light through an object to determine the percent of light transmitted or absorbed at each wavelength. The resulting graph of the wavelength and absorbance data is known as the material’s absorption spectrum. Each material has its own unique absorbance spectrum.

Figure 9. Absorbance Spectrum of Green Kool-Aid.



The Kool-Aid tested here absorbed light in the blue (400-500 nm) and red (600-700 nm) ranges while it reflected most light in the 500-600 nm range, which is green light. Thus, the Kool-Aid is green.

There are also spectrometers that use infrared light to analyze materials. Raman spectroscopy uses a laser on a substance and measures the pattern of light scattering that results. A portable version of one type of spectrometer is the Breathalyzer used by police on the side of the road to check for drunk drivers.

The visible evidence, however, is usually just the tip of the iceberg. The most common form of evidence at a crime scene is latent evidence. Examples include fingerprints, hairs and fibers, bloodstains that have been cleaned up, and gunshot residue. These types of evidence are much more difficult to see with the naked eye and require special handling to locate and collect them.

The most common light reactions used in forensics are chemiluminescence and fluorescence. In chemiluminescence, a substance such as blood reacts with a reagent such as Luminol to emit light. Fingerprint detection uses chemical reactions with ninhydrin and iodine to visualize latent fingerprints at a crime scene. Fluorescence results when energy is added to a substance, which excites its electrons, which move to a higher energy level. When the electrons fall back down to their original state, they emit photons of light. This phenomenon is demonstrated with the use of ultraviolet and infrared lights to make substances such as bodily fluids fluoresce.

Instructional Implementation

Forensic science lends itself well to many types of instructional activities. Brief lectures with guided notes will be used to introduce the main concepts to students. There will be interactive warm-ups and spot assessments included in the guided notes to check for student understanding and reinforce learning. There will be several simple activities to communicate background information as well. Students will examine real-life case studies in which light was used to detect latent evidence to understand how what they are learning is used in real life. Once they have mastered the basics, students will move into more hands-on activities. This unit includes several labs that use various types of light to locate, observe and analyze evidence. Students will work with UV light to detect fingerprints and bodily fluids in two labs. In two other labs, students will work with IR radiation to detect blood evidence and altered documents. As part of their final exam in Advanced Forensic Science, students work a mock crime scene complete with locating, observing and analyzing evidence. A section of evidence will be added to the crime scene, which will require students to demonstrate their knowledge of the use of light in latent evidence detection.

Day 1

On the first day of this unit, I will give the students a brief pre-assessment on what they know about the properties of light, the electromagnetic spectrum and the use of light in forensic investigations. I will then introduce the unit with a flame test demonstration (See Appendix 2) to spark students' interest in the subject of light. Next, I will go over the objectives for this unit so students have a roadmap of what they will learn. I will then present notes and review activities on the Dual Theory of Light and the electromagnetic spectrum. Students will be asked to visually compare and contrast the wave and particle theories of light. We will wrap up day one with a brief practical exercise on the use of the compound microscope to be sure all students are proficient with its use.

Day 2

Today will begin with a warm-up reviewing yesterday's information. We will then discuss light's interactions and reactions with matter. Notes will cover absorbance, reflection, refraction and transmission as well as luminescence. Students in Advanced Forensic Science study refraction in depth, including labs, in another unit, so I will not go into refraction deeply here. If you do not cover it anywhere else in your curriculum, this would be an excellent place to cover refraction.

We will discuss various forensic techniques that capitalize on these properties of light. Today the focus will be on fluorescence. Various bodily fluids that may be found at a crime scene naturally fluoresce, as do materials such as accelerants used in arsons. Students will explore fluorescence and determine the best combination of light and goggles to observe various colors. They will be given alternative light sources at varying wavelengths from 365 nm (UV light) to 625 nm (visible red light) as well a barrier goggles in yellow, orange and red. They will then examine various objects and substances with the different wavelengths of light and color filters. Ultimately, they will be asked to identify unknown substances at a "crime scene." (See Appendix 3)

Day 3

Today we will focus on forensic uses of light, specifically to locate, identify and possibly quantify evidence at a crime scene. Students will be introduced to the use of oblique lighting techniques at a crime scene to detect latent evidence such as shoe prints. We will discuss the use of infrared light to detect potentially forged documents by noting differences in inks. Different inks will fluoresce differently under IR light. Students will conduct a lab where they compare several different types and brands of inks to detect differences (see Appendix 4).

Day 4

On Day 4, we will continue our exploration of forensic uses of light with an experiment where students are asked to evaluate different fabrics and different dilutions of blood. (See Appendix 5.) Student will learn how to prepare a serial dilution of synthetic blood. The different dilutions will be applied to various types of fabrics. Once dry, students will examine the fabric samples with IR light to determine on which fabrics and at what dilutions blood is visible. This research will help them to predict the likelihood of success at finding latent blood evidence on fabrics at a crime scene. It will also help them make predictions about which methods of blood detection might be most effective under different circumstances at a crime scene. This lab requires the fabrics to dry overnight, so if time remains, we will begin the Stations Lab from Day 5 now.

Day 5

Students will explore the use of color changes and chemical reactions to visualize latent evidence at crime scenes. Today's labs will be set up as stations. Station 1 will be a ninhydrin fingerprint developing activity. Students will use ninhydrin to develop latent fingerprints. (See Appendix 6.) At Station 2, students will develop latent fingerprints using an iodine fuming technique. At Station 3, students will practice developing fingerprints with silver nitrate. Finally, at Station 4, students will perform a simple cyanoacrylate (Superglue) fuming experiment to develop latent prints.

Students will also conduct the second part of the IR Blood lab today. This involves examining the fabrics under IR light and collecting data.

Day 6

Students will experiment with simulated blood, Luminol, bleach and UV lights. (See Appendix 7.) Many people think they can clean blood up from a crime scene using bleach. Bleach combined with blood fluoresces brightly in the presence of Luminol. Students will try to clean up a bloodstain and then document what effect the bleach actually had. They will look at the chemical reaction between blood, bleach and luminol and discover how it produces fluorescence.

The rest of today is reserved for finishing any parts of the labs remaining and writing up lab reports and results.

Day 7

Today we will wrap up this unit with an assessment of students' knowledge and skills. Ideally, I will set up a small mock crime scene and have students, working in pairs, examine the scene for latent evidence. I would include latent fingerprints, blood and possibly saliva. I would also include some type of writing such as a check or a ransom note in the scene. While there isn't time to have students actually perform all of the possible tests they have just learned, I would ask them questions about the crime scene that require them to identify potential latent evidence and describe in detail how they would test for that evidence. I would ask them to explain how the tests work and what the expected results would look like. I can also give them a more traditional test to assess their learning in this unit. See Appendix 8 for a sample assessment.

Appendix 1: Teaching Standards

AFS-FUL-1 Students should understand the properties of light.

- AFS-FUL-1a Students should be able to explain the Dual Theory of Light.
- AFS-FUL-1b Students should be able to explain the electromagnetic spectrum.

Understanding the basic properties of light is essential to then understanding how to use light in a forensic setting to visualize latent evidence. This material should be review for students at this level.

AFS-FUL-2 Students should be able to describe how light interacts with matter including absorbance, reflection, refraction and transmission.

The way light and matter interact is the basis of how light is used in forensic investigations. Absorbance and reflection are the basis of all color observations. Each material has a characteristic refractive index by which it can be identified.

AFS-FUL-3 Students should be able to describe how light reacts with matter including fluorescence.

There are chemical reactions that produce light which aid in the observation and identification of evidence.

AFS-FUL-4 Students should understand how light's interactions and reactions aid in forensic science.

- AFS-FUL-4a Students should be proficient using a compound microscope.
- AFS-FUL-4b Students should be able to conduct simple UV/Vis Spectroscopy testing.
- AFS-FUL-4c Students should be able to develop fingerprints using ninhydrin and iodine fuming techniques.
- AFS-FUL-4d Students should be able to use Luminol or Blue Star to detect blood at a crime scene.
- AFS-FUL-4e Students should be able to differentiate between different inks used on a document.

Students should be able to synthesize all of the material from this unit to become proficient in the use of light techniques in a forensic setting. Objective four compiles some of the many different ways light can be used to locate, observe and identify latent evidence at crime scenes.

Appendix 2: Flame Test Demonstration/Lab

Name: ___Teacher Version___________________________ Date: _________ Block: ______

Flame Test Lab

Purpose: The purpose of this lab is to understand how different metal and metalloid ions can be identified by determining the color of the flame produced when they are burned.

Materials:

Water-soaked popsicle sticks Obtain enough popsicle sticks for each lab group to have at least five sticks. Soak them overnight in a container of distilled water. Do not touch the sticks with your bare hands after this point as the salts on your fingers can interfere with the test. On the day of the lab, wearing gloves, empty the container and rinse the sticks with fresh distilled water.

Bunsen Burners

Lighters

Beakers with water (for putting out the sticks) Put out five beakers with water at the front of the room and label them "Unknown #1" through "Unknown #5" for students to place their used sticks in.

Unknown powders #1 - #5 This part will depend on the inventory in your chemistry department. Some of more commonly available materials are lithium, calcium, copper, sodium, barium, and potassium. Try to get elements or compounds that will give students five different colors. If you have two materials that each give off a blue-green flame, they will have no way to distinguish the materials in this lab. Use the following table to help select your materials. NOTE: Some of the materials in this list are very toxic (eg. Arsenic). If you are unsure about the toxicity or safe handling of any of the substances you choose to use, please discuss safe handling and disposal procedures with a knowledgeable person in your chemistry department or consult the MSDS sheets for those materials.

Gloves

Goggles

Color Group	**Color**	**Material**
Reds	Magenta	Lithium compounds
	Scarlet or crimson	Strontium compounds
	Red	Rubidium
	Orange-Red	Calcium compounds
Yellows	Gold	Iron
	Intense yellow	Sodium compounds
Greens	Emerald	Copper (II) non-halide
	Bright green	Boron
	Faint green	Antimony and NH_4 compounds
	Yellow-green	Barium, manganese (II)
Blues	Azure	Lead, selenium, bismuth, cesium, copper (I), indium, $CuCl_2$

	Light blue	Arsenic
	Greenish-blue	$CuBr_2$, antimony
Purples	Violet	Potassium compounds (not borates, phosphates or silicates)
	Lilac to red-purple	Potassium, rubidium

Procedure:

1. Google and watch "Flame Test 07" on You Tube.
2. Put on your gloves and goggles.
3. Obtain five water-soaked popsicle sticks from the front table and place them on a clean, dry paper towel.
4. Obtain a container of one of the unknown powders from the front table.
5. Carefully open the container and dip the end of one stick into the powder. Do not dip it in more than 1 cm deep.
6. Close the container.
7. Light your Bunsen burner.
8. Slowly wave the unknown powder on the stick through the flame and observe all changes to the flame. Record your observations.
9. Place your used stick in the appropriate beaker on the front table and return the unknown powder container to the front table.
10. Repeat steps 6 through 11 for the remaining four unknowns.
11. Clean up your work area. You MUST keep your goggles on as long as anyone's Bunsen burner is on.

Analysis

1. How can the differences in flame color be used in forensics? Describe a scenario when this test could be useful to a case.
   Unknown substances found at a crime scene could be burned to check for flame color. Elements and compounds emitting certain colors can be identified in this manner. For example, a table at a crime scene contains small piles of a gray powder, along with scales, glassine envelopes, copper wire and containers of nails. Suspecting a possible bomb-making operation, you flame test the gray powder at the scene. The flame turns a faint green in the presence of the powder. You conclude that the powder could be antimony (a component of gunpowder) or an ammonium compound (used in explosives). You immediately confirm you are dealing with a bomb-making situation.
2. What causes the flames to be different colors? Hint: You may need to do some outside research to fully answer this question.
   The heat of the flame causes the electrons in the substance to become excited and jump to a higher energy level. When those electrons fall back to their original energy levels, they emit a photon, which is a packet of light energy. Each element has its own unique energy levels when excited and therefore emit a signature spectrum from which they can be identified.
3. Based on your observations and the information in the Flame Color Chart below, what are the identities of the five unknown powders? Justify your answers.
   See data table. Results will depend on what substances you used for your unknowns.

Data Table Flame Test.

Unknown #	Initial Observations	Flame Observations	Identity of Unknown
1			
2			
3			
4			
5			

Flame Test Colors

Symbol	Element	Color
As	Arsenic	Blue
B	Boron	Bright green
Ba	Barium	Pale/Yellowish Green
Ca	Calcium	Orange to red
Cs	Cesium	Blue
Cu(I	Copper(I)	Blue
Cu(II)	Copper(II) non-halide	Green
Cu(II)	Copper(II) halide	Blue-green
Fe	Iron	Gold
In	Indium	Blue
K	Potassium	Lilac to red
Li	Lithium	Magenta to carmine
Mg	Magnesium	Bright white
Mn(II)	Manganese(II)	Yellowish green
Mo	Molybdenum	Yellowish green
Na	Sodium	Intense yellow
P	Phosphorus	Pale bluish green
Pb	Lead	Blue
Rb	Rubidium	Red to purple-red
Sb	Antimony	Pale green
Se	Selenium	Azure blue
Sr	Strontium	Crimson
Te	Tellurium	Pale green
Tl	Thallium	Pure green
Zn	Zinc	Bluish green to whitish green

Name: __(Student Version)___________________________ Date: ________ Block: ______

Flame Test Lab

Purpose: The purpose of this lab is to understand how different metal and metalloid ions can be identified by determining the color of the flame produced when they are burned.

Materials:

Water-soaked popsicle sticks
Bunsen Burners
Lighters
Beakers with water (for putting out the sticks)
Unknown powders #1 - #5
Gloves
Goggles

Procedure:

12. Google and watch "Flame Test 07" on You Tube.
13. Put on your gloves and goggles.
14. Obtain five water-soaked popsicle sticks from the front table and place them on a clean, dry paper towel.
15. Obtain a container of one of the unknown powders from the front table.
16. Carefully open the container and dip the end of one stick into the powder. Do not dip it in more than 1 cm deep.
17. Close the container.
18. Light your Bunsen burner.
19. Slowly wave the unknown powder on the stick through the flame and observe all changes to the flame. Record your observations.
20. Place your used stick in the appropriate beaker on the front table and return the unknown powder container to the front table.
21. Repeat steps 6 through 11 for the remaining four unknowns.
22. Clean up your work area. You MUST keep your goggles on as long as anyone's Bunsen burner is on.

Analysis

4. How can the differences in flame color be used in forensics? Describe a scenario when this test could be useful to a case.
5. What causes the flames to be different colors? Hint: You may need to do some outside research to fully answer this question.
6. Based on your observations and the information in the Flame Color Chart below, what are the identities of the five unknown powders? Justify your answers.

Data Table Flame Test.

Unknown #	Initial Observations	Flame Observations	Identity of Unknown
1			
2			
3			
4			
5			

Flame Test Colors

Symbol	Element	Color
As	Arsenic	Blue
B	Boron	Bright green
Ba	Barium	Pale/Yellowish Green
Ca	Calcium	Orange to red
Cs	Cesium	Blue
Cu(I	Copper(I)	Blue
Cu(II)	Copper(II) non-halide	Green
Cu(II)	Copper(II) halide	Blue-green
Fe	Iron	Gold
In	Indium	Blue
K	Potassium	Lilac to red
Li	Lithium	Magenta to carmine
Mg	Magnesium	Bright white
Mn(II)	Manganese(II)	Yellowish green
Mo	Molybdenum	Yellowish green
Na	Sodium	Intense yellow
P	Phosphorus	Pale bluish green
Pb	Lead	Blue
Rb	Rubidium	Red to purple-red
Sb	Antimony	Pale green
Se	Selenium	Azure blue
Sr	Strontium	Crimson
Te	Tellurium	Pale green
Tl	Thallium	Pure green
Zn	Zinc	Bluish green to whitish green

Appendix 3: Color Lab

The Color Lab allows students to experiment with how different substances and objects will appear under different wavelengths of light with different color barrier googles. Once students have a good understanding of how different wavelengths of light will interact with various items, they will study various substances such as blood, urine, saliva, and gasoline with the lights and goggles. Finally, they will be given one or more "crime scenes" to examine with the light sources for latent evidence.

This lab uses flashlights that put out light at the following wavelengths: 365 nm, 455 nm, 530 nm, and 625 nm as well as plain white light. Sirchie has an alternative light source kit that comes with seven visible light wavelength flashlights, one UV light, a tripod, and yellow, orange and red barrier goggles. (See https://www.sirchie.com/megamaxx-trade-3-watt-alternate-light-system.html#.W9RyRZNKjIU.) Additional goggles are sold separately.

To set up this lab, I gathered sets of objects in as wide a range of colors as I could find. For example, I found red, pink, orange, yellow, green and blue paper clips, the same colors of string, and paper squares colored with a range of magic marker colors. You can use anything that comes in a range of colors. I glued these objects to a poster board ("Color Board") to minimize them disappearing during lab. I used a board with a dark blue background, but any color will work. Just have your students explain what, if any, effect the background color has on what they see!

Using swatches of white fabric, I then collected samples of animal blood (from the butcher), saliva, urine (placing cloth on used cat litter works for this), sweat, grease and gasoline. A few drops of each liquid is all you need. I also included a few liquids I would not expect to see fluoresce such as vegetable oil, red wine and barbeque sauce. For health reasons, I encased all biological samples in sealed Ziploc bags and attached the bags to the poster board ("Knowns Board") so the students never touch them. On three separate small boards, I attached three different samples of some these substances and mark them "Crime Scene #1" through "Crime Scene #3."

For the first board, students use the different lights and goggles as shown in the data table below to examine the different colored objects and record their findings. You can duplicate this table as many times as necessary for the number of items you have for them to examine. Students should stop after completing the first board and draw some conclusions about what they have observed. How do the different colors (wavelengths) of light interact with differently colored objects? What light/goggle combinations are the best for observing each color?

The Knowns Board should be examined next. Students should record their observations as before for each of the known substances. The more detailed their observations, the more accurate they will be when identifying the unknowns. Once they have examined all of the knowns, depending on time and class size, you can have them work to identify substance(s) at one or more "Crime Scenes." You can make each crime scene so it only has one unknown substance for students to identify or you can use multiple substances at each scene. Students should be assessed on the thoroughness of their observations, the depth of their insight on discussion questions, the accuracy of their identification of the unknown(s) and their justifications for their choices.

A light kit which includes all of the different wavelengths of light in the data table is fairly expensive. This entire lab can be adapted for use with just one UV and one IR light. Amazon has a set of 5 9-LED UV flashlights for $12.00.[20] They also have an IR illuminator kit for $25.99 that will work well.[21] Simply adjust the data table to collect information for the lights available to you. Different colored goggles are not necessary either. Get some small pieces of gels from the theater department in different colors. That works just as well. Goggles with UV protection are a must during this lab. AmazonBasics Antiscratch Safety Glasses[22] are one possibility.

Data Table 1.

(Item) EX: Red string			(Item) EX: Pink string			(Item) EX: Orange string		
λ (nm)	Goggles	Observations	Λ	Goggles	Observations	λ	Goggles	Observations
White	Red		White	Red		White	Red	
	Orange			Orange			Orange	
	Yellow			Yellow			Yellow	
365	Red		365	Red		365	Red	
	Orange			Orange			Orange	
	Yellow			Yellow			Yellow	
455	Red		455	Red		455	Red	
	Orange			Orange			Orange	
	Yellow			Yellow			Yellow	
530	Red		530	Red		530	Red	
	Orange			Orange			Orange	
	Yellow			Yellow			Yellow	
625	Red		625	Red		625	Red	
	Orange			Orange			Orange	
	Yellow			Yellow			Yellow	

Appendix 4: Using IR Light to Detect Latent Blood Evidence

Name(s): ___________________________________ Date: ______________ Block: _____

Using IR Light to Detect Latent Blood Evidence

Purpose In this lab, you will learn how to perform a serial dilution of simulated blood. You will then use the properties of infrared light to determine what fabric is best for detection of latent bloodstains.

Materials Part 1 - 20 mL animal blood in a test tube
4 additional clean test tubes
Test tube holder
5 disposable pipettes
10 mL graduated cylinder
Labeling tape and pen
50 mL distilled water
Gloves

Materials Part 2 - Cardboard sheet, labeled
White gel pen
5 samples of each of 10 types of fabric
Stapler

Materials Part 3 - Cardboard with dried blood samples from Day 1
IR light source
IR protective goggles

<u>Day One</u>
Part 1 - Serial Dilution
Procedure:

1. Collect all materials for the blood section of this lab at your workstation.
2. The test tube with the undiluted blood in it should already be labeled 100%. If not, do it now.
3. Using small pieces of labeling tape, label the other test tubes "50%", "25%", "12.5%" and "6.25%".
4. Using a clean disposable pipette and a 10 mL graduated cylinder, remove 10 mL of 100% blood and place in the 50% test tube.
5. Label the pipette 100% and set it aside. Rinse the graduated cylinder.
6. Add 10 mL of distilled water to the 50% test tube.
7. With a clean pipette, remove 10 mL of the 50% blood and place it in the 25% test tube.
8. Label the pipette 50% and set it aside. Rinse the cylinder.
9. Add 10 mL of distilled water to the 25% test tube.
10. With a clean pipette, remove 10 mL of 25% blood and place it in the 12.5% test tube.
11. Label the pipette 25% and set it aside. Rinse the cylinder.
12. Add 10 mL distilled water to the 12.5% test tube.
13. With a clean pipette, remove 10 mL of 12.5% blood and place it in the 6.25% test tube.

14. Label the pipette 12.5% and set it aside. Rinse the cylinder.
15. Add 10 mL distilled water to the 6.25% test tube.
16. Label one additional pipette 6.25% and set aside.

Part 2 - Preparing Blood Evidence (Fabric Samples)

Procedure

1. Obtain 5 pieces of each of the different types of black cloth and a cardboard sheet.
2. Using the white gel pen, as you collect each sample, label each piece with its number below:

Sample Composition	**#**	**Sample Composition**	**#**
35% rayon/65% polyester	1	50% acrylic/50%wool	6
35% cotton/65% polyester	2	5% lycra/95% cotton	7
100% cotton	3	5% spandex/95% polyester	8
35% polyester/65% cotton	4	30% polyester/70% rayon	9
100% velvet	5	30% acrylic/70% wool	10

3. Still using the white gel pen, label each of the 5 pieces of #1 with the dilutions 100%, 50%, 25%, 12.5% and 6.25%. Repeat this procedure for each of the 10 types of cloth. When you are finished, your pieces should look like this:

Cloth #	100%	50%	25%	12.5%	6.25%
1	1-100%	1-50%	1-25%	1-12.5%	1-6.25%
2	2-100%	2-50%	2-25%	2-12.5%	2-6.25%
3	3-100%	3-50%	3-25%	3-12.5%	3-6.25%
4	4-100%	4-50%	4-25%	4-12.5%	4-6.25%
5	5-100%	5-50%	5-25%	5-12.5%	5-6.25%
6	6-100%	6-50%	6-25%	6-12.5%	6-6.25%
7	7-100%	7-50%	7-25%	7-12.5%	7-6.25%
8	8-100%	8-50%	8-25%	8-12.5%	8-6.25%
9	9-100%	9-50%	9-25%	9-12.5%	9-6.25%
10	10-100%	10-50%	10-25%	10-12.5%	10-6.25%

4. Staple each of the 50 pieces of cloth to the piece of cardboard in a grid pattern as shown in the table above. Label the grid as in the example.
5. Using the 100% pipette from Part 1, place 2-3 drops of 100% blood on each of the 10 100% pieces of cloth.
6. Using the appropriate pipette from Part 1, repeat this step for each of the dilutions of blood until all 50 pieces of cloth are stained with blood.
7. Wash out all test tubes and pipettes. Return all materials to where you got them.
8. Let the fabric sit until next class so the bloodstains can dry.

Day 2

Part 3 - Detecting Blood Evidence with IR Radiation

Procedure

1. Obtain an IR light source and protective eyewear. You MUST wear the goggles while working with IR light.
2. Shine the IR light source on each of the pieces of fabric one at a time. In the table below, note the intensity of any blood made visible by the IR light. Use the scale: 0 = not visible, 1 = barely visible, 2 = visible, 3 = good visibility or 4 = excellent visibility.
3. When you are finished collecting your data, deconstruct the cardboard grids without damaging them. Throw away the pieces of cloth. Return all materials to where you got them.

Data Table 1. Intensity of IR Light on Different Dilutions of Blood on Different Types of Fabric.

Fabric #	100%	50%	25%	12.5%	6.25%
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Analysis and Conclusions

Answer all questions in narrative form (complete sentences making up coherent paragraphs!).

1. What is IR radiation? How does it work in terms of latent evidence detection?

2. Which fabric(s) best showed the presence of blood at 100% strength? To what dilution could blood still be detected on this fabric? On which fabric(s) was the weakest dilution able to be visualized? What about that fabric made this possible? On the fabrics where you were not able to visualize blood with IR radiation, what possible explanation(s) can there be?

Appendix 5: Using IR Light to Detect Altered Ink Evidence

Name(s): ___________________________________ Date: ______________ Block: _____

Using IR Light to Detect Altered Ink Evidence

Purpose In this lab, you will test the fluorescence of various types of ink under IR light to determine whether a document was altered.

Materials
Cardboard sheet, labeled
White gel pen
12 samples each of 3 types of fabric (35% polyester/65% cotton, 100% cotton and 100% polyester)
Stapler
4 different permanent markers labeled P-1 through P-4
4 different fountain pens labeled F-1 through F-4
4 different ballpoint pens labeled B-1 through B-4
IR light source
IR protective goggles

Preparing Ink Samples

Procedure

1. Obtain 12 samples of 35% polyester/65% cotton and with the white gel pen, label them "A".
2. Obtain 12 samples of 100% cotton and with the white gel pen, label them "B".
3. Obtain 12 samples of 100% polyester and with the white gel pen, label them "C".
4. Staple the pieces of cloth to a piece of cardboard in a grid pattern as follows:

Table 1. Layout of Ink Sample Cloths.

Pen Type	**Cloth A**	**Cloth B**	**Cloth C**
P-1			
P-2			
P-3			
P-4			
F-1			
F-2			
F-3			

F-4			
B-1			
B-2			
B-3			
B-4			

5. Obtain 4 different permanent markers. They are labeled P-1 through P-4.
6. Obtain 4 different fountain pens. They are labeled F-1 through F-4.
7. Obtain 4 different ballpoint pens. They are labeled B-1 through B-4.
8. With each different pen, write a word or short phrase of your choosing on the appropriate piece of cloth following the grid above.
9. Obtain an IR light source and eye protection. You must wear eye protection when working with the IR light.
10. Shine the light on each of the pieces of fabric individually and using the following scale, label the intensity of the ink made visible by the IR light **in the table above**: 0 = not visible, 1 = barely visible, 2 = visible, 3 = good visibility or 4 = excellent visibility.
11. Add up the number of pieces of each type of fabric that had each level of intensity for each of the pen types and record below. For example, if on Fabric A, the permanent markers had intensities of 0, 0, 1, and 2, you would enter under column "Fabric A" a 2 on the Permanent Marker 0 line, a 1 on the 1 line, a 1 on the 2 line and a 0 on the 3 and 4 lines.

Data Table 2. Summary of Ink Intensity Data.

		Fabric A	Fabric B	Fabric C
Intensity of Permanent Markers	0			
	1			
	2			
	3			
	4			
Intensity of Fountain Pen Ink	0			
	1			

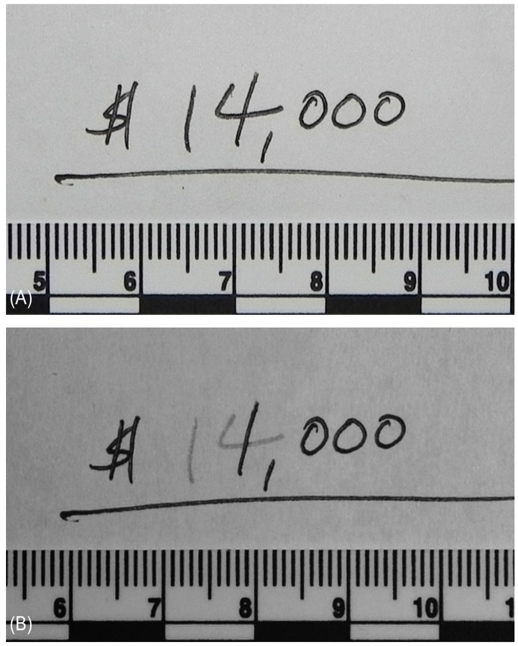
	2			
	3			
	4			
Intensity of Ball-Point Pen Ink	0			
	1			
	2			
	3			
	4			

12. Deconstruct the cardboard grid without damaging it. Throw away the pieces of cloth. Return all materials to where you got them.

Analysis and Conclusions
Answer all questions in narrative form (complete sentences making up coherent paragraphs!).

1. Which of the three types of pens (permanent, fountain or ballpoint) showed the strongest results? The weakest? How can you explain the difference?

2. You are working in a forensics lab as a latent evidence detection specialist. The police bring you a check that their suspect attempted to cash. The face amount of the check appears to be $14000, but the police are convinced that the suspect altered the check. You conduct an IR analysis of the ink on the check. Below (A) is the check photographed with white light and (B) is the check photographed with IR radiation.



What is your conclusion about the original value of the check? Explain to the police what is happening in these photos in terms of IR radiation that supports your conclusion.

Appendix 6: Fingerprint Development Lab

NOTE: Most materials in this lab are skin and eye irritants. In addition, some will stain the skin. Glove and goggles must be worn at all times while preparing for and conducting this lab.

Teacher directions to prepare the necessary solutions for this lab:

A. Ninhydrin. You can purchase from a scientific supply company such as Carolina Biologicals already in solution in a spray bottle or can or you can purchase ninhydrin powder and make your own solution. Dissolve 5 g of ninhydrin powder in 95 ml of acetone or alcohol and mix well. Dispense in a spray bottle.
B. Silver Chloride. Dissolve 1 g $AgNO_3$ in 100 ml of water. Store in the dark.
C. Fixer Solution. Add 20 g sodium thiosulfate (hypo) plus 14 g sodium bisulfite to 100 g of water and mix well.
D. Zinc Chloride. Add 3 g of $ZnCl_2$, 25 ml ethyl alcohol and 5 ml acetic acid to 70 ml of water.
E. Starch Solution. Add 2 g of cornstarch to 100 ml cold water. Bring to a boil while stirring. Cool before using.

<u>Part 1: Ninhydrin</u>

Purpose: The purpose of this lab is to use chemical reactions to visually enhance a fingerprint so that it can be analyzed and identified.

Materials:
4"x4" white paper slips
Ninhydrin solution in a spray bottle
Zinc Chloride solution
Gloves
Goggles
Heat gun
Dark box
UV light source

Precautions: Ninhydrin will stain skin and clothing. Zinc Chloride is a skin irritant. Goggles, gloves and aprons should be worn while performing this lab. Ninhydrin should be used in a fume hood or outdoors.

Procedure:

1. Place several fingerprints on a 4"x4" piece of paper.
2. Tape up your print paper on the paper on the wall.
3. Spray your paper with the ninhydrin solution until the paper is covered.
4. Wait 24 hours for the print to develop or warm the paper gently with a heat gun.
5. Identify and mark at least 5 ridge characteristics on the print.
6. Dip your ninhydrin prints in the zinc chloride solution. This should turn the print orange making it easier to visualize.

7. Place print in dark box and place UV light over the hole in the box.
8. Allow the print to dry.
9. Label the print and describe what you saw under the UV light.
10. Identify and mark at least 5 different ridge characteristics on the print.

Part 2: Silver Nitrate

Purpose: The purpose of this lab is to use a chemical technique to develop fingerprints.

Materials: 4'x 4" slips of paper
Tweezers
Tray with silver nitrate solution
Paper towels
UV light source
UV goggles
Chemical goggles
Tray with fixer solution
Popsicle sticks

Precautions: When working with UV light, UV goggles must be worn. Chemicals used in this lab are very caustic to the skin. Use gloves, goggles and aprons during this lab.

Procedure:

1. Place fingerprints on paper.
2. Using tweezers, immerse print in $AgNO_3$ for 5-10 minutes.
3. Remove paper with tweezers and drain excess liquid. YOU MUST WEAR GLOVES DURING THIS LAB!
4. Place the paper between 2 paper towels and dry it. Once dry, expose the fingerprint to bright sunlight or longwave UV light.
5. To develop the print, immerse the print in fixer solution for 15-20 min.
6. Using tweezers, remove the print from the fixer solution and blot dry.
7. Affix print to an index card.
8. Identify 5 ridge characteristics on the print.

Part 3: Iodine Fuming

Purpose: The purpose of this lab is to explore a chemical development technique for fingerprints.

Materials: Fume hood or very well ventilated area
Iodine crystals
Weigh boats
Gloves
Goggles

Procedure: 1. Place fingerprints on two pieces of paper or index cards.

2. Put the prints in a beaker containing several crystals of iodine and cover the beaker. Iodine sublimes.
3. When prints become visible, remove them with tweezers. Watch carefully as prints develop to make sure they do not over-develop.
4. Dip one print in a starch solution. Record your observations. Why do you think this is happening? Allow your papers to air dry.
5. Cover both prints with clear tape to preserve them.
6. Wash hands thoroughly with soap and warm water.
7. Identify 5 ridge characteristics on each print.

Part 4: Cyanoacrylate (Superglue) Fuming

Purpose: The purpose of this lab is to develop latent fingerprints using a superglue fuming technique.

Materials:
clean microscope slides
Fuming chamber
Hot plate
250 ml beaker
Superglue
Aluminum foil
Water

CAUTION: This lab should only be performed in a well-ventilated area.

Procedure:
1. Assemble the development chamber.
2. Use the hot plate to heat water until it is almost boiling.
3. Place the beaker of steaming water in the fuming chamber.
4. Take an approximately 4” square of aluminum foil and shape it into a bowl that will sit on the edges of the beaker over the water.
5. Place a dime-sized drop of superglue in the foil bowl and place the bowl over the water.
6. Place a fingerprint on the microscope slide and hang the slide by a clip in the chamber. Close the chamber.
7. Wait for approximately 30 minutes.
8. Remove the slide from the chamber. Immediately wipe down the inside of the chamber with damp paper towels to remove superglue residue.
9. Examine the print. Identify 5 ridge characteristics.
10. Dust the print with magnetic powder. Describe what happens to the visibility of the print.

Appendix 7: Luminol Demonstration

The purpose of this demonstration is to show students how Luminol reacts with hemoglobin in the blood to fluoresce, making it much easier to find at a crime scene, as well as how blood can be found even after a criminal has cleaned up a crime scene with bleach.

Luminol powder can be purchased from most scientific supply companies. It needs to be mixed fresh each day you will use it, as the prepared solution does not have a long shelf life. You will need either simulated blood from a scientific supply company or animal blood from the butcher shop, prepared Luminol in a spray bottle, bleach and plenty of paper towels. You will also need to find an area that can be made absolutely dark. My science prep room works well for this and I bring the students in a few at a time.

To prepare this demonstration, I like to first take some blood on a paper towel and write a word such as “murder” on the floor. I then blot up the visible blood. Bring students to the area and ask them to see if they can find any blood. Then turn out the lights and spray the area with the blood with the Luminol solution. You should see your word glow a light blue color. Turn on the lights and ask the students if they think they can clean up the blood and not get caught for this murder. Give them a chance to wipe the floor with bleach. Then turn the lights back off and watch the area with the bleach light up! It is a neat effect to take a paper towel with bleach on it and wipe it back and forth on the floor with the lights out.

Appendix 8: Sample Assessment

Name: ____________________________________ Date: __________________ Block: ______

_____ 1. Refractive index is a tool used to study how light bends as it passes through

a) Three or more substances
b) One substance and into another
c) Four or more substances
d) None of the above

_____ 2. When light travels through any medium other than a vacuum, the particles in that medium slow the light down. As the density of the medium increases, the

a) Speed of light passing through that material increases
b) Speed of light passing through that material decreases
c) Amount of light passing through that material decreases
d) None of the above

_____ 3. The Electromagnetic Spectrum is all known types of radiation arranged by

a) Wavelength
b) Frequency
c) Amplitude
d) None of the above

_____ 4. The dual theory of light states that light behaves like

a) An electron and a proton
b) An electron and a photon
c) UV and IR
d) A particle and a wave

_____ 5. What causes the emission of light?

a) A photon moving down an energy level
b) A wave of light
c) An energized electron moving down an energy level
d) None of the above

_____ 6. Which of the following are properties of light and describe light behavior?

a) Emission
b) Absorption
c) Intensity
d) All of the above

_____ 7. What property of light does a spectrophotometer use?

a) Refractive Index
b) Dispersion
c) Intensity
d) All of the above

_____ 8. Dispersion is when white light passes through a prism and is

a) Broken up into its individual wavelengths and frequencies
b) Broken up according to the wavelength's speed
c) Broken up according to the wavelength's amplitude
d) None of the above

_____ 9. One method of determining whether a piece of evidence glass matches the glass from the crime scene is to compare the

a) Index of the evidence glass to the index of the glass from the crime scene
b) Refractive index of the evidence glass to the refractive index of the glass from the crime scene
c) Reflective index of the evidence glass to the reflective index of the glass from the crime scene
d) None of the above

_____ 10. Refraction

a) Describes the behavior of light as it travels through time
b) Describes the behavior of light as it travels from one part of one medium to another part of the same medium
c) Describes the behavior of light as it travels from one medium into a different medium
d) Describes the behavior of light as it brightens

_____ 11. Hair viewed for forensic investigations is studied both macroscopically and microscopically. Macroscopic observation might be done with a _______, while microscopic observation would be done with a ______.

a) Microscope, electron microscope
b) Spectrophotometer, stereomicroscope
c) Stereomicroscope, compound microscope
d) All of the above

_____ 12. When a material absorbs light of one wavelength and immediately emits light of a another wavelength, it is called

a) Fluorescence
b) Incandescence
c) Phosphorescence
d) None of the above

_____ 13. While photographing and recording hair and fiber evidence on a car seat, an expert searches the car seat using

a) An electron microscope
b) Oblique lighting
c) A UV or IR light source
d) None of the above

_____ 14. A leaf appears green to the naked eye because it ________ green light.

a) Reflects
b) Absorbs
c) Emits
d) Fluoresces

_____ 15. Which of the following body fluids fluoresce naturally under UV light?

I. Blood
II. Saliva
III. Semen
IV. Sweat

a) I only
b) II and III only
c) II, III and IV only
d) I, II, III and IV

Teacher Answer Key

1. B	6. D	11. C
2. B	7. B	12. A
3. A	8. A	13. B
4. D	9. B	14. A
5. C	10. C	15. C

Student Resources

"Forensic Light Source Applications." Diffraction Gratings - HORIBA. Accessed September 29, 2018. http://www.horiba.com/scientific/products/forensics/light-sources/forensic-light-source-applications/.
Easy-to-read article on what forensic light sources are and how they help detect various types of evidence at crime scenes. The different types of evidence are nicely illustrated.

Forensics, SPEX. "CrimeScope CS-16 Forensic Light Source - Product - SPEX Forensics." CrimeScope CS-16 Forensic Light Source - Product - SPEX Forensics. Accessed June 23, 2018. http://www.crimescope.com/.
Brief pamphlet that illustrates the different wavelengths of light and filters to use to visualize hairs, fibers, bruises, bite marks, gunshot residue, drugs and more.

Marin, Norman, Jeffrey Buszka, and Larry Miller. *Alternate Light Source Imaging: Forensic Photography Techniques*. Place of Publication Not Identified: Routledge, 2014.
Excellent book for reviewing basic rpinciples of light and the electromagnetic spectrum. The applications of ALS photography with ultraviolet light and infrared light are explained as well.

Teacher Resources

Sterzik, V., S. Panzer, M. Apfelbacher, and M. Bohnert. "Searching for Biological Traces on Different Materials Using a Forensic Light Source and Infrared Photography." *International Journal of Legal Medicine* 130, no. 3 (2015): 599-605. Accessed June 5, 2018. Doi:10.1007/s00414-015-1283-2.
This article is the basis for the ink and blood detection labs using an infrared light source. There is a great discussion of the authors' results for the teacher to compare with class results.

"TX CTE Resource Center." TX CTE Resource Center Home. Accessed September 8, 2018. https://www.txcte.org/resource/lesson-plan-forensic-use-of-light.
Excellent outline of dual-theory of light, light reactions and interactions and the forensic applications of those properties and reactions. The article includes several activities, labs, written assessments and practical exercises.

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For Further Research on Specific Topics

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Endnotes

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