Forensic Use of Light

Course
Forensic Science

Unit VI
Forensic Hair & Fiber Analysis

Essential Question
How are the properties of light used in the collection and analysis of trace evidence?

TEKS
§130.295(c)
(2)(F)
(6)(E–H)
(7)(A)

Prior Student Learning
- *Lab Safety*
- *Scientific Method*

Estimated Time
9½ hours total
- *3 hours lecture*
- *1 hour engage*
- *4½ hours activities*
- *1 hour quiz and exam*

Rationale
Light, mostly white light and ultraviolet, is used to collect evidence at the crime scene. Forensic scientists use equipment/technology and various scientific theories about light to analyze, identify, and match trace evidence. Therefore, comprehending the properties of light is essential to understanding how light is used in the field of forensics.

Objectives
The student will be able to:
1. Describe the electromagnetic spectrum and light characteristics such as waves, wavelength, frequency, and speed.
2. Explain and utilize scientific technology, such as various microscopes, types of lasers, and the spectrophotometer, that apply the properties of light to investigate trace evidence.
3. Determine the identity of trace evidence by applying scientific theories of light such as light refraction, diffraction, dispersion and the atomic emission spectrum.

Engage
Do an Internet search for a video using the following: Flame Test 07. Show the students the video and then have them answer the following questions (also found on the Flame Demonstration Handout). After five minutes of reflection on their answers, lead the class in a discussion about the properties of the flames. Use the Flame Demonstration Key and the Discussion Rubric for assessment.
- How could this chemical property of compounds/elements be used in forensics?
- What causes the flames to be different colors?

Key Points
I. Forensic Use of Light – an understanding of light energy, its properties, its uses, and its technological applications is fundamental in the study of forensics
  A. Location/Collection of Evidence with Light – light, and all of its sources, is used to locate evidence
  B. Observation of Evidence with Light – once evidence has been located and collected, light is used to observe it
  C. Analysis of Evidence with Light – science has made many discoveries about light, and these are applied to analyze forensic evidence

II. Wave Theory of Light
  A. Light and Sound Similarities
    1. Light travels in the form of waves, just like sound waves; in fact, many of the properties of light are comparable to sound waves
    2. Our ears hear different sounds because of the different

frequencies of sound
3. Our eyes see color because of the different frequencies of reflected light
4. Just like there are sounds our ears cannot detect, there are colors of light we cannot see

B. Light and Sound Differences
1. Light waves are much faster than sounds waves
2. Sound waves require a medium to travel through; light waves can travel through a vacuum

C. Wave Definitions
1. Wave – when some form of energy (light, sound, water) is transferred by a disturbance in a medium (light waves do not require a medium)
    a) Longitudinal (or compressional) waves – energy is transferred in the same direction the wave is moving (waves that travel like a flexible helical spring toy that somersaults down steps)
        (1) Example – sound waves
    b) Transverse waves – energy is transferred perpendicularly in a ripple effect (like ripples in a puddle)
        (1) Example – light waves
2. Wavelength (λ) – the distance from the top of one wave to the top of the next
    a) Larger waves have a longer wavelength
    b) Smaller waves have a shorter wavelength
    c) The unit used for light wavelength is the meter (m)
        (1) Although you will see centimeters or even nanometers, these must be converted to meters to do any type of frequency formulas
3. Wave Speed (c) – different wave mediums travel at different speeds
    a) The speed of light is 3.0 x 1010 cm/s or 3.0 x 108 m/s (speed is considered as though in a vacuum)
    b) The unit of speed of a wave is meters/second, although you will see other units like centimeters/second
4. Frequency (v) – the number of waves that pass per unit of time; wavelength and frequency are inversely related
    a) Longer wavelength means shorter frequency (the waves are farther apart, so there are less waves per second)
    b) Shorter wavelength means higher frequency (the waves are closer together, so there are more waves per second)
    c) The unit for frequency showing cycles per second is the Hertz (Hz)
    d) Frequency and wave energy are synonymous
5. Wave Formula
    a) The speed of light is 3.0 x 108 m/s
    b) Symbols
        (1) c = speed of the type of wave (can be the speed of light)

(2) λ = wavelength (meters)
(3) v = frequency (Hz)

c) Wave formula in symbols – c = λv
d) A variation with the speed of light substituted for (c) – 3.0 x 108 m/s = λv
e) Wave formula in words – speed equals wavelength times frequency
f) So the speed of a wave is a product of frequency and wavelength

6. Amplitude – the height of the wave from the bottom (trough) to the top (crest)
   a) Amplitude is also thought of as the energy the wave carries
   b) Wavelength, speed, and frequency do not change just because the height (amplitude) of the wave changes

D. Electromagnetic Spectrum – there is an array of different light waves with characteristic colors, invisibilities, wavelengths, and frequencies. The entire range of known light waves is called the electromagnetic spectrum. Light waves can also be called electromagnetic radiation or “radiation”
   1. Radio waves and microwaves are not visible to the human eye; they have a longer wavelength and smaller frequency. Radios, microwaves, and cell phones use these waves (frequency is how we tune our radios)
   2. Infrared light is invisible to the human eye, but is used in technology/forensics for evidence detection/analysis (i.e. remote controls, lasers, etc.)
   3. Visible Spectrum – the middle of the spectrum is the only part of the spectrum that is detectable by the human eye
   4. Ultraviolet light (black light), also invisible to the human eye, is used to disinfect foods, but it is also used in forensics extensively to detect/analyze evidence
   5. X-rays and gamma rays are invisible to the human eye, and their radiation can penetrate the human cell and cause DNA damage. Some types of X-rays are used in analysis

E. Visible Spectrum
   1. Light (sunlight/electric light bulb) makes it possible for us to “see” anything—the light that we use to “see” is called white light
   2. White light is actually a combination of all known colors
   3. Visible light can be any color we see, from red (longer wavelength, smaller frequency) to purple (shorter wavelength, larger frequency)
   4. An object absorbs most of the visible wavelengths and reflects some of the wavelengths – this is what we see as color
   5. Examples
      a) Green color – plants absorb all wavelengths (colors) to use as energy, but reflect the light wavelength we see as the color green

b) Blue jeans – jeans absorb all wavelengths, but reflect the light wavelength we see as the color blue
c) White object – the object absorbs no wavelengths, and reflects all of them, so we see the color white (this is why the color white seems cooler to wear in the summer)
d) Black object – the object absorbs all wavelengths, and reflects none of them, so we do not see any color (this is why the color black is so hot to wear in the summer)

6. Any object will absorb and reflect different light wavelengths depending on its composition (more in this in the particle unit)
    a) The chemical compounds the object is made of
    b) Or the chemical compounds of the paint on the object

F. Forensic Use of the Electromagnetic Spectrum

1. Investigators should use all forms of light possible when gathering evidence
    a) Regular white light to detect as many items as possible (but it may not reveal all of the evidence that is present)
    b) Ultraviolet (UV) light to detect those items which will reflect invisible, shorter wavelength light (such objects will fluoresce with UV light)
    c) Infrared (IR) light to detect those items which will reflect invisible, longer wavelength light
2. A good forensic light source is made up of a powerful lamp containing all of the light wavelengths including the ultraviolet, visible, and infrared components of light

III. Particle Theory of Light – light (electromagnetic spectrum) behaves like a wave in the way it travels; however, light also acts like a particle in the way it transfers energy to electrons (this is called the Dual-Theory of Light)

A. Photon – an energized packet of light energy

1. In the late 1800's/early 1900's, scientists started to notice that not only did light behave like a wave, sometimes it seemed like there were particles of light
2. This idea of particles was combined with the Atomic Theory to create new light theories (Quantum Physics)
3. Photons of light are absorbed (energy gained) and emitted (light is given off)

B. Atomic structure review

1. Every atom has a nucleus in the middle surrounded by electrons at different orbitals, or "energy levels"; you can think of it like the sun (nucleus) with the planets (electrons)
2. These electrons are circling, or "orbiting," the nucleus
3. These orbits are in paths farther and farther away from the nucleus
4. The farther an orbital is from the nucleus, the more energy the electrons in that orbital have (or the "higher" the energy level)
5. Every element's atoms are different in their available orbitals or energy levels

6. Electrons also vibrate at specific frequencies; the frequencies of the vibrations are related to the energy level of the electrons

C. Quantum physics
1. Photons move at different frequencies depending on the frequency of the electromagnetic wave
2. Light intensity means there are more photons moving, but the photon frequency (energy level) stays the same
3. Light intensity fades over distances because the photons scatter farther and farther apart
4. If a photon is moving at the same frequency as the electron then the electron "absorbs" the photon's energy; the photon's energy has now become heat energy
5. If the photon is moving at a different frequency than the electron, all the electrons' vibrations are disrupted; this disruption causes one of the electrons to become "excited" enough that it will move up an energy level, so it is farther from the nucleus (the exact energy level reached is different for each specific element)
6. An energized electron stays at this new energy level briefly before it drops down to its original level; the time period between jump and drop differs between elements (phosphorescent elements' electrons stay at the new energy level for a longer period and then drop later)
7. This drop from a higher orbital to a lower orbital causes the electron to transfer its energy to a photon at a specific frequency
8. We see the photon's energy emitted as light. Different elements have their own specific orbitals (energy levels), so they release an assortment of frequencies of light
9. Humans can see this light energy released in the form of distinctive colors with particular wavelengths and/or frequencies, depending on each individual element
10. Atomic Emission Spectra – this is a spectrum of emissions from individual elements and it is used to identify unknown elements

IV. Categories of Light Reactions in Forensics

A. Two Sources of Light – in general, "light" refers to the portion of the electromagnetic spectrum that we see; energy (except that from heat) that causes an object to release light is a form of electromagnetic radiation that we cannot see
1. Incandescence
   a) The term for light that is produced by something that gets very hot (heat energy excites the photons)
   b) Example – a fire or the filament in a light bulb
2. Luminescence
   a) A general term for "cold" light that is not produced by heat, but another form of energy (or electromagnetic radiation) that excites the photons
   b) Example – fluorescent lights

3. Types of Luminescence – classified by the energy that creates the luminescence (not all examples are shown below)
    a) Chemiluminescence
        (1) Luminescence that results from energy released during a chemical reaction
        (2) Example – glow sticks, luminol spray reacting with blood
    b) Thermoluminescence – luminescence in minerals or crystals stimulated by the application of heat energy to temperatures below those needed for incandescence
    c) Photoluminescence
        (1) Light is absorbed and then re-emitted at a less energetic wavelength
        (2) Phosphors are any substance that exhibits this
    d) Two Types of Photoluminescence that Absorb Ultraviolet Energy
        (1) Fluorescence
            (a) Involves absorbing short wave energy and remits long wave energy almost immediately
            (b) Any object seen under ultraviolet light (black light); objects appear to glow
        (2) Phosphorescence
            (a) Absorbs both low heat energy and other electromagnetic energy, but has a delayed light release
            (b) Electrons do not immediately drop to their original energy level, but drop later so long wave energy (colored light) continues even after the radiation ceases—in the dark

B. Phosphors – any substance that causes an object to show photoluminescence
1. So when an object glows in the dark, or lights up under UV radiation, it is because it contains phosphors
2. Many different types of phosphors are found in many locations
    a) Rare earth minerals on the Periodic Table (especially the Lanthanides)
    b) Many transition metals on the Periodic Table
    c) Nucleic acids found in DNA
    d) Biomolecules – found in the human body, especially in bodily fluids
3. Phosphors have many uses including radar detection and plasma screen TV's
4. In forensics, investigators and scientists take advantage of the fact that there are many different types of phosphors found in the human body and other types of forensic evidence; this makes the use of UV lights irreplaceable in evidence collection

V. Review of Particle Data for the Properties of Light

A. Every element will pick up its specific frequency or frequencies from a photon, thus every element's electrons jump to its individual energy levels

B. When the electron drops back to the original level, it emits a characteristic frequency or frequencies of photons; this is seen as a particular color for each element
   1. An energy source will cause a compound or object to release a distinctive emission of light depending on its components (this is why the flame test in Chemistry is used to ID elements)
   2. This characteristic can be used in forensics to identify unknown compounds or the elements in a compound
   3. Since different substances will absorb and reflect only specific wave frequencies, a variety of wave frequencies (light sources) should be used to collect and analyze evidence

VI. Light Properties – light has many different behaviors; again, some are like waves and others are similar to particles

A. Main Types of Light Properties
   1. Emission – the production of light from a compound due to the particle nature of light causing an increase in the electron's jumping energy levels (emission of light color is specific to the composition); remember the Atomic Emission Spectrum
   2. Absorption – light energy (photon energy) is taken in because the frequency of the light wave (photon) matches the frequency at which the electrons in the atom vibrate (absorption of light is specific to composition)
      a) Energy from electromagnetic radiation becomes heat energy
      b) The object is considered opaque – no light travels through it (light is either absorbed or reflected)
      c) There is also an atomic absorption spectrum individual to each element
   3. Transmission – the vibrations of the electrons are passed on to neighboring atoms through the bulk of the material and will be reemitted as photons on the opposite side of the object
      a) Electron and photon vibrations are not exactly the same frequency, but electrons are not energized enough to move to the next energy level
      b) The object is considered transparent – all light travels through it (light is neither absorbed nor reflected)
      c) Light travels through at the same speed, there is no refraction (bending)
   4. Reflection – light energy causes a disruption because the frequency of the light wave does not match the electron's vibration frequency; another photon is released
      a) If light waves are reflected off of the surface, we see the object and its color (mirrors and chrome reflect almost all of the light waves)
      b) The object is considered opaque – light does not travel through it

c) The angle of the light wave changes, but wavelength, wave speed, and wave frequency all stay the same
d) Reflection Rule – the angle of incidence equals the angle of reflection
    (1) Angle of Incidence – the angle of the light that strikes a surface
    (2) Angle of Reflection – the angle that the light is reflected, or bounces off of the surface
e) We are changing the angles when we adjust our rearview mirrors
f) In forensics, the properties of the reflection are being utilized whenever any kind of light is used for finding, observing, or analyzing evidence

5. Refraction – the vibrating photon has the same frequency as the vibrating electron, but there is a time delay between the jump and the drop of the electron
    a) This time delay causes both the speed of the wave and the wavelength to change, but the frequency remains the same
    b) Light (or the object) seems to bend – the wave speed changes because the light is traveling through two media with different densities; since light travels through the medium, the medium is considered transparent
    c) Example – when you look through the side of a clear glass of water with a spoon in it, it appears that the spoon bends as it enters the water (two media of different densities: air and water)
    d) The light wave bends because the direction of the light wave changes
    e) The light wave direction changes because the wave speed and the wavelength both change
    f) Frequency
        (1) Does not change in refraction, so the color does not change
        (2) The wave formula explains this:
            speed = wavelength x frequency (even though the speed and wavelength change, the frequency does not)
    g) Refractory Index (RI) – every transparent object has a different refractory index, this is defined mathematically (Snell's Law)
        (1) Can be defined by comparing angles or wave speeds
        (2) The temperature and frequency of the wave must be controlled because changes in these will affect the refractory index
        (3) Angular Refractive Index (RI) – a mathematical comparison of the angle of incidence and the angle of refraction (RI = sin i ÷ sin r)
            (a) Angle of incidence (i) – the angle that light

strikes the medium's surface

(b) Angle of refraction (r) – the angle at which the light is refracted once it leaves the medium

(c) sin – a function of an angle

(4) Speed Refractive Index (RI) – a mathematical comparison of the speed of light in a vacuum and the speed of light in the medium (substance) (RI = speed of light in a vacuum ÷ speed of light in the medium)

h) Many materials and fluids have a known refractive index (in forensics, an unknown substance can be compared to the refractive index of a known substance, such as glass)

i) Different lenses also use the properties of refraction

(1) Convex Lenses – use the power of refraction to bend the light so that it makes an object appear larger and easier to observe

(2) Concave Lenses –use the reverse power of refraction in cameras to make large objects small enough to photograph; several lenses and their movement can be used in microscopes and the like to bring objects into focus

j) Birefringence – an object that has bends waves in more than one direction (has several refractive indexes)

6. Dispersion (a type of refraction) – when white light passes through certain media the light is refracted according to its wavelength
   a) Example – a prism breaks white light into all its wavelengths, and a rainbow of colors appears
   b) Different transparent objects have different dispersion levels
   c) The properties of dispersion are used in spectrophotometers to break apart the emission/absorption waves of certain substances for identity purposes
7. Intensity – this is a combination of the energy and height of the wave (amplitude)
   a) We see it as the brightness of light, not a change in color
   b) The intensity of light decreases with the distance traveled
8. Diffraction – a change in the direction of waves as they pass around an opening or around an obstacle in their path (diffraction is a form of interference)
   a) A light wave might appear to bend around a corner
   b) Example – water waves hitting a pier
   c) There is no change in wave speed, frequency, or wavelength (just direction)
   d) Light waves might appear to spread out after they travel through a small opening
9. Interference – when two light waves coincide, it can be either constructive or destructive (diffusion can be considered a type of interference)

a) Constructive Interference – the troughs and crests of two waves match up and the amplitude of the resulting wave increases
b) Destructive Interference – the crest of one wave passes through, or is superimposed upon, the trough of an opposing wave so the amplitude of the wave decreases

10. Polarization – the separation of different directions of light waves (a filter clarifies images due to this separation/block of specific waves)
    a) Colored lenses filter certain frequencies used in forensics to collect and observe evidence
    b) Lenses are also used in photography to clarify images
    c) Sunglasses and sunscreens block UV rays

VII. Light Properties Are Used in Forensics – technology has advanced significantly in its use of light; all the properties and behaviors of light are used for multiple purposes, including criminal investigations; light's properties are used in forensics to find, observe, and analyze evidence

A. Magnification Purposes – use the properties of refraction (lenses) to detect and observe evidence (sometimes to analyze)

1. Macro-View (magnifiers and stereomicroscopes) – usually use one convex lens and the properties of refraction
    a) Magnifying Glass – help to detect trace evidence
    b) Stereomicroscope – brings things closer so more details can be seen in a larger scale
    c) Simple Microscopes –early microscopes that are no longer used
2. Micro-View (compound microscope) – use more than one convex lens and properties of refraction
    a) A fundamental tool in the forensic laboratory
    b) A fast, affordable way to identify/compare trace evidence
    c) Used for both closer observation of the invisible and analysis of evidence
    d) Create luminescence lighting and refract the light with convex and concave lens
    e) Objectives show the powers of magnification created by the various lenses
3. Types and Techniques of Microscopy
    a) Bright Field Microscope – a basic classroom microscope that aims light toward a lens below the specimen stage
    b) Dark Field Microscope – converts a bright field microscope by using an opaque disk under a condenser lens to scatter light from the specimen; light comes from the particles on the side of the specimen, through the eyepiece, to the eye
    c) Phase Contrast – uses a phase plate to slightly increase the wavelength so that it can use light interference rather than light absorption/reflection; this allows for the imaging of transparent samples by making them appear darker
    d) Differential Interference Contrast (DIC) or Nomarski

Microscopes – use light interference rather than absorption or reflection of light to give specimens a three-dimensional appearance; use a polarizer, prism, and condenser to change the light vibration plane, and then separate and recondense light (used for biological specimens)

e) Polarized Light Microscope – use polarized filters or lenses and/or a rotating stage to show different refractive indexes of evidence in color for samples whose optical properties can vary with orientation or which have birefringence (used with fiber-, soil-, mineral-type samples)

f) Fluorescence – uses only a small set of shorter light wavelengths that are then reflected back as longer light wavelengths by phosphors found in the sample to aid in analysis

g) Infrared/Ultraviolet Light – different wavelengths of light show different characteristics of samples

h) Digital Microscopes – many microscopes are also combined with cameras using adapters (still and video) to capture enlarged images

i) Electron Microscopes – do not use light, but a beam of electrons to magnify atomic-size particles; the types of electron microscopes are transmission or scanning electron microscopes

j) Other Microscopes – there are also inverted, comparison, high and low powered, oil and water immersion, and many other variations that differ in lens, stage, use, etc.

4. Microscopic Refractive Index – comparison of the refractive index of smaller pieces of evidence when observed under a microscope
   a) Refractive Index (RI) – a mathematical comparison of the speed of light in a vacuum and the speed of light in the medium (substance)
   b) Mounting Medium – the fluid or liquid that a sample is immersed in when put on the microscope slide (possibly with a cover slide on top)
   c) Finding RI – when RI needs to be found, a mounting medium with a known RI is used and a microscope observation made
      (1) Becke Line – a dark boundary or halo around a object when it is immersed in a liquid of a different refractory index (used mostly microscopically)
         (a) If a Becke Line appears outside the object's edge, the liquid has a higher refractory index than the object
         (b) If a Becke Line appears inside the object's edge, the liquid has a lower refractory index than the object
5. Micro Colorimetry – it is hard to describe the color of any object

(fiber, paint chip, etc.) because color is very subjective; everyone interprets the reflection of light waves differently

6. Chromaticity Diagram – uses an overlay grid to assign colors numerical coordinates which quantifies the colors and makes their description more objective (developed by the International Commission of Illumination)

B. Types of Spectroscopy – a spectroscope uses prism or diffusion grating to break apart incoming wavelengths; the specific emission/absorption of wavelengths can be used to identify the unknown element in the composition of evidence

   1. Infrared (IR) Spectroscopy – detects/records absorbed wavelengths just outside the visible range of light (longer)
      a) The IR spectrum gives the most information out of all spectrophotometers
      b) Used to identify drug types and paint chips, and to test blood or urine samples
      c) Can destroy evidence
   2. Ultraviolet (UV) Spectroscopy – uses shorter wavelengths to investigate UV absorption of biological compounds and drugs in or out of the human body
   3. Reflectance Ultraviolet Spectroscopy (RUVIS) – a technique using optical filters and lenses to detect latent fingerprints on nonporous surfaces
      a) Used without dusting and can be used on evidence that has been previously super-glued
      b) Produces a detailed image that can be photographed
   4. Raman Spectroscopy – uses a laser on the sample and observes patterns of light waves that scatter
      a) Can be used to find substances beneath surfaces
      b) Determines the internal composition of bones and tissues
      c) Gives information that complements IR spectroscopy
      d) Identifies contents of packages and bottles
      e) Valuable because, unlike IR spectroscopy, Raman doesn’t destroy evidence
   5. Microspectroscopy – the microscope combines with a spectroscope for use with minute samples
   6. X-ray Diffraction/Absorption – uses smaller EM radiation (X-rays) and its diffraction (or absorption) of waves to analyze the crystal structure of samples for identification
   7. Atomic Emission/Absorption Spectroscopy – uses visible light to find the types and concentrations of elements in samples
   8. Microwave Spectroscopy – addresses the microwave region of the EM spectrum to obtain information about molecular structure
   9. Types of Spectrometry that Don’t Use Light – there are other types of technology that categorize matter into a spectrum of its components (pure elements or ions) without the use of electromagnetic radiation, using only ionic mass; but since this analysis still shows the spectrum of every physical component

in the sample, it is still referred to as spectrometry

a) Mass Spectrometry (MS) – measures the mass-to-charge ratio of charged particles to determine the ions, molecules, or elements that make up a sample's composition
b) Gas Chromatography (GC) – separates compounds into individual ions
c) GC-MS – when both are used together, the separated ions are analyzed in a spectrum by the mass spectrometer

C. Other Forensic Uses of EM Radiation – there are a variety of other ways light properties are used in forensics

1. Nuclear Magnetic Resonance (NMR) – radio waves and magnetic fields are used to penetrate unknowns and collect information from hydrocarbons
    a) Valuable because it is nondestructive – evidence can still be analyzed again later
    b) Can be used to analyze DNA and/or dangerous samples such as explosives
    c) A form of NMR is used to determine time of death by finding brain metabolite levels
        (1) Electron Paramagnetic Resonance – uses microwave (not radio) waves for similar purposes
        (2) X-ray Fluorescence, Neutron Activation Analysis (with infrared spectra), Inductive Couples Plasma – other examples of the many technological advances that use various forms of the EM spectrum to analyze and identify forensic evidence samples
2. Immersion Test – a transparent object (glass) is immersed in several liquids with known refractive indexes to compare the refractive indexes
    a) Glass appears to be "invisible" or disappear in liquid that has the same refractive index
    b) If the liquid has a lower or higher refractive index than the glass, the glass can still be seen (with a halo around it)
    c) Examples
        (1) Methanol RI: 1.33
        (2) Glycerin RI: 1.47
        (3) Clove Oil RI: 1.54
        (4) Pyrex Glass RI: 1.47 (would disappear in glycerin)
        (5) Lead Glass RI: 1.56 (would disappear in clove oil)
3. Other Large Scale Uses of Refractive Index
    a) Refractometer – determines the refractive index of various solids and liquids
        (1) Used to determine the identity of unknowns in forensics
        (2) Can be handheld for fieldwork or larger for a laboratory counter
        (3) Also used to determine the density of liquids and the concentrations of various components in the liquids (sugar in urine, drugs in the blood, etc.)

4. Finding the Diameter/Width of a Minute Object – Thomas Young's Double Split Patterns (interference/ diffraction of light): an experiment that showed that specific light patterns are dependent on the number of slits through which light is shown
   a) Using the known frequency of light and measurements of interference patterns you can determine the actual width of the solid that caused the light to split
   b) To find the diameter or width of an object: d = lL ÷ 10S
      (1) d = diameter of a minute object in micrometers (µm)
      (2) l = wavelength of the light (nm)
      (3) L= distance from the light source to the screen (m)
      (4) S = the average distance between bands (cm)
5. Uses of Infrared Light (Thermal Radiation) – many materials are sensitive to thermal or infrared (IR) radiation (IR waves are longer waves in the EM spectrum)
   a) Used in night vision goggles/equipment
   b) Many types of crime scene evidence are located because they will absorb visible light and show IR
   c) IR luminescence is used for many types of document analysis
      (1) Illegal Alteration
      (2) Erased Writing
      (3) IR absorption or glow from different inks
      (4) Revelation of charred document contents
      (5) Used in conjunction with other technology
6. Uses of Ultraviolet Light (Black Light)
   a) Mostly used in evidence collection
      (1) Many bodily fluids (biomolecules) fluoresce when illuminated by a source of UV light
      (2) Detection of crime scene stains such as saliva, semen, vaginal fluids, urine, and perspiration
      (3) Many times latent fingerprints will fluoresce for detection purposes
   b) UV light analysis is recommended as a first choice by the FBI for examining and identifying biological evidence
   c) Also used for authenticating signatures, paintings, and ink stains
   d) Used in the detection of trace evidence and illegal substances
   e) Used to see the light of luminol in order to find blood evidence
7. Forensic Light Source
   a) A powerful lamp with ultraviolet, visible, and infrared wavelengths of light that has many components to enhance visualization
   b) Direct lighting, such as a strong white light, is very useful to reveal trace evidence
   c) Oblique or parallel lighting will also reveal small particles
   d) Used with all types of magnifiers and microscopes

e) A multiple color band can penetrate many skin depths to reveal details of a bruise pattern
f) White light is normally used first, with other wave lengths, chemicals, goggles, polarizers, and colored lenses are used after the initial observation

8. Cameras use refraction and polarization properties (various lenses, including colored lenses) to capture permanent proof of evidence and its analysis
   a) Used in evidence collection, observation, and analysis to record results
   b) Used with
      (1) Spectroscopy
      (2) Scanning electron microscopes
      (3) Fluoresce of IR or UV radiation
      (4) Luminol (to record the chemicaluminescence of a reaction with blood evidence)

VIII. Forensics, Technology, and Evidence

A. Location and Collection of Evidence with Light – light, and all of its sources, are used to locate evidence
   1. Examples
      a) Flashlight
      b) Ultraviolet or black light
      c) Light sources with all wavelengths
      d) Colored goggles or filters
      e) Many types of digital photography

B. Observation of Evidence with Light – once evidence has been located and collected, light is used to observe it
   1. Examples
      a) Magnifying glass
      b) Microscopes (stereomicroscopes, polarizing microscopes, etc.)

C. Analysis of Evidence with Light – science has made many discoveries about light, and these are applied to analyze forensic evidence
   1. Some Examples
      a) Microscopes of all types, including electron and ion microscopes
      b) Spectroscopes – used to identify trace evidence
         (1) Emission spectroscopy
         (2) Gas and mass spectroscopy
         (3) Infrared and ultraviolet applications
         (4) Microwave, X-Ray, and nuclear forms also
   2. Mass Spectrometry – identification purposes
      a) Gas and liquid chromatography specializations

Activities

1. <u>Basic Use of a Microscope Lab</u>. Have students review how to use a microscope by completing the Basic Use of a Microscope Lab Handout.

Use the Basic Use of a Microscope Lab Key for assessment.

2. Refractive Index (RI) of Fibers Lab. Have students analyze and compare the RI of fibers by completing the Refractive Index (RI) of Fibers Lab Handout. Use the Individual Work Rubric for assessment.

   (Note: if you cannot find fiber samples in the science catalogs or cannot spare the expense, craft stores are a decent source of fibers. Any store that carries fabric will sell remnants at a reduced rate. Match the remnants to a fabric being sold on the floor to identify the type of fabric or fiber. Some stores offer free samples. Also, fluids and fiber types can differ from those in the table on the lab handout – simply look up their refractive indexes on the internet.)

3. Light Diffraction Hair Diameter Lab. Have students measure the diameter of a hair or fiber by completing the Light Diffraction Hair Diameter Lab Handout. The Light Diffraction Hair Diameter Lab Key has a sample answer that will aid assessment. The Individual Work Rubric may be used as well.

4. Spectrophotometer Use for Soil Analysis Lab. Have students analyze soils by completing the Spectrophotometer Use for Soil Analysis Lab Handout. See the Spectrophotometer Use for Soil Analysis Lab Key and the Directions for Using the "Spec 20" Spectrometer for more details. Use the Spectrophotometer Use for Soil Analysis Lab Key and the Individual Work Rubric for assessment.

5. RI of Glass by Submersion Lab. Have students determine the refractive index of glass through submersion by completing this lab. Use the RI of Glass by Submersion Lab Handout for the activity and the RI of Glass by Submersion Lab Key for preparation and assessment.

Assessments
Forensic Use of Light Exam and Key
Forensic Use of Light Technology Quiz and Key
Flame Demonstration Handout Key
Basic Use of a Microscope Lab Key
Light Diffraction Hair Diameter Lab Key
Spectrophotometer Use for Soil Analysis Lab Key
RI of Glass by Submersion Lab Handout Key
Forensic Use of Light Fill-in-the-Blank Venn Diagram Key
Discussion Rubric
Individual Work Rubric
Research Rubric

Materials
Forensic Use of Light computer-based presentation
Forensic Use of Light Fill-in-the-Blank Venn Diagram and Key
Computers with Internet access

Flame Demonstration

- Handout and Key
- Computers with Internet access

Basic Use of a Microscope Lab

- Basic Use of a Microscope Lab Handout and Key
- Compound microscope
- Glass or beaker of water
- Variety of prepared slides
- Eyedropper (plastic disposable is OK)
- Electricity Source (possible with power strips)
- Newspaper sections
- Microscope slides and cover slips
- Small scissors
- Tweezers

Refractive Index (RI) of Fibers Lab

- Refractive Index (RI) of Fibers Lab Handout
- Fiber Samples of Known Composition
- Glass slides
- Fiber Samples of Unknown Composition
- Cover slips
- Above Refractive Index Fluids
- Compound microscope
- Small beakers for fluids
- Small scissors
- Eyedropper (disposable is OK)
- Tweezers

Light Diffraction Hair Diameter Lab

- Light Diffraction Hair Diameter Lab Handout and Key
- Helium-Neon laser (also called a He-Ne laser)
- Transparent tape
- Scissors
- Index card
- Metric ruler
- Meter stick
- Binder clips
- Pencil
- Marker
- Handheld, 1-hole punch
- White paper taped on wall (legal size) or a screen to project image on

Spectrophotometer Use for Soil Analysis Lab

- Spectrophotometer Use for Soil Analysis Lab Handout and Key
- Directions for Using the “Spec 20” Spectrometer
- Spectrophotometer (Spec 20 is an example of one type that could be used in this lab)
- Unscratched cuvettes for the spectrophotometer
- 3 different soil types

– 10ml graduated cylinder
– Timer or watch for one minute intervals
– Tap water

RI of Glass by Submersion Lab

– RI of Glass by Submersion Lab Handout and Key
– Evidence bags with glass samples
– 5 – 7 test tubes
– Tweezers
– Test tube rack
– Soap
– Test tube brush
– 25ml graduated cylinder
– Samples of different oils: clove, cinnamon, castor, olive, vegetable, and isopropyl alcohol, and water

Resources

Saferstein, Richard. *Forensic Science: An Introduction.* New Jersey: Pearson Prentice Hall, 2008.

Bertino, Anthony J. *Forensic Science: Fundamentals & Investigations.* Mason, OH: South-Western Cengage Learning, 2009

Deslich, Barbara; Funkhouse, John. *Forensic Science for High School* Dubuque, Iowa: Kendall/Hunt Publishing Company, 2006

Texas Education Agency, Forensic Certification Training, Sam Houston State University

Do an Internet search for a video using the following: Flame Test 07.

Accommodations for Learning Differences

For reinforcement, students will use a Venn diagram to compare and contrast the wave and particle theory of light. Use the Forensic Use of Light Fill-in-the-Blank Venn Diagram for the activity and the Forensic Use of Light Fill-in-the-Blank Venn Diagram Key for assessment.

For enrichment, students will research and report on one of the following options:

- The many types of spectrophotometers and the ways they are used in analyzing a variety of Forensic evidence
- Quantum theory and its applications in current scientific technology.

Use the Research Rubric for assessment.

State Education Standards

Texas Essential Knowledge and Skills for Career and Technical Education

§130.295. Forensic Science (One Credit).

(2) The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:

(F) collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as calculators, spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, stereoscopes, metric rulers, electronic balances, gel electrophoresis apparatuses, micropipettes, hand lenses, Celsius thermometers, hot plates, lab notebooks or journals, timing devices, cameras, Petri dishes, lab incubators, meter sticks, and models, diagrams, or samples of biological specimens or structures;

(6) The student analyzes the evidence collected from a crime scene using scientific methods. The student is expected to:

- (E) explain properties of refractive index;
- (F) explain dispersion of light through a prism;
- (G) identify the light sources used in forensic science such as ultraviolet light;
- (H) explain the examination of trace evidence using instruments such as a spectrophotometer, stereoscope, electron microscope, and compound microscope;

(7) The student recognizes the methods to process and analyze trace evidence commonly found in a crime scene. The student is expected to:

- (A) perform continuous and light emissions laboratory procedures to identify trace evidence;

<u>College and Career Readiness Standards</u>

Science Standards

VIII. Physics

- G. Oscillations and waves
  - 2. Understand the difference between transverse and longitudinal waves.
  - 3. Understand wave terminology: wavelength, period, frequency, and amplitude.
- J. Optics
  - 1. Know the electromagnetic spectrum.
  - 2. Understand the wave/particle duality of light.
  - 3. Understand concepts of geometric optics.

Name:___________________________________Date:______________________

Forensic Use of Light Exam

______1. 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

______2. Many dyes and other hair treatments will fluoresce under a certain color (wavelength) of light. In a fluorescence microscope, a beam of light of a certain color is used. If the sample contains particular chemicals, it will absorb some of the light and then reemit light of a different color. This is called
- a) Fluorescence
- b) Effervescence
- c) Incandescence
- d) None of the above

______3. Two methods that can analyze fibers are
- a) Polarizing light microscopy and infrared spectroscopy
- b) Polarizing light spectroscopy and infrared microscopy
- c) Heat and light
- d) None of the above

______4. A forensic light source should include
- a) All wavelengths of light (including some outside of the visible)
- b) White light
- c) Black light
- d) All of the above

______5. The 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

______6. 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

______7. The speed of light passing through air is slightly

a) Slower than the speed of light passing through a vacuum, because air is slightly denser than a vacuum
b) Faster than the speed of light passing through a vacuum, because air is slightly denser than a vacuum
c) Slower than the speed of light, because air is slightly less dense than air traveling at the speed of light
d) None of the above

______8. 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 into a different part in 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

______9. One method of determining if the 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. The submersion method involves placing the glass fragment into different liquids of known refractive indexes. If a piece of glass and a liquid have the same refractive index, the glass fragment will seem

a) Larger when placed in the liquid
b) Smaller when placed in the liquid
c) To disappear when placed in the liquid
d) To reappear when placed in the liquid

______11. If the refractive indexes of several different liquids are known, the

a) Submersion method can be used to estimate the refractive index of the glass
b) Submersion method can be used to estimate the reflective index of the glass
c) Reflective method can be used to estimate the refractive index of the glass
d) Reflective method can be used to estimate the submersion index of the glass

______12. If the refractive index of the liquid medium is different than the refractive index of the piece of glass, a halo-like ring appears around the edge of the glass. This halo-like effect is called a

a) Becke quotient
b) Becke edge
c) Becke line
d) Becker edge

______13. While photographing and recording tool mark evidence, the expert searches the surface of the tool mark for bits of foreign material using
a) Digital imaging
b) Oblique lighting
c) An electron microscope
d) None of the above

______14. The dual-theory of light explains that light behaves like
a) A fire and a flashlight
b) A candle and a light bulb
c) A particle and a wave
d) An electron and a photon

______15. What causes the emission of light?
a) A photon moving down an energy level, hitting an electron
b) A wave of light
c) An energized electron moving down an energy level, hitting a photon
d) None of the above

______16. Which of the following are properties of light and describe light behavior?
a) Emission
b) Absorption
c) Intensity
d) All of the above

______17. Dispersion is when white light passes through a prism and is
a) Broken up into its individual wavelengths/frequencies
b) Broken up according to wave speed
c) A property related to interaction and refraction
d) Both a and c

______18. What property of light does a spectrophotometer use?
a) Refractive Index
b) Dispersion
c) Intensity
d) None of the above

______19. What do a compound microscope, a magnifying glass, and a camera all have in common?
a) The use of convex lenses to magnify small objects for observation
b) The use of concave lenses to magnify large objects for observation
c) The use of convex lenses to magnify small objects for observation and/or concave lenses to bring large object into focus
d) None of the above

Forensic Use of Light Exam Key

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

Name:_________________________________Date:____________________

Forensic Use of Light Technology Quiz

Directions: Match the name of each type of forensic light equipment (number) with how it works/the light property involved (capitol letter). Then also match it with a picture of the actual equipment (symbol). In other words, write the matching number, letter and symbol in the first column. (See example #1.)

Answer	Name of Equipment:	How it works/Light Property
1. D, @	**1. Magnifying glass**	**A.** When shown on hair/fiber this creates an interference/diffraction pattern that can be used to calculate the diameter of the fiber/hair
2.	**2. Refractometer**	**B.** Causes a reflection of a substance that has invisible electromagnetic waves—shorter wavelength is converted to longer wavelength
3.	**3. Spectrophotometer**	**C.** Optical filter only allows wavelengths of a certain amplitude and direction to be transferred; used with a white light source to find evidence of different wavelengths
4.	**4. Scanning Electron Microscope**	**D**. Refracts/bends light, makes object appear larger
5.	**5. Microscope**	**E.** Uses refraction of light to make an object appear bigger (optical device is thicker in the middle), or object appear more in focus (optical device is thinner in the middle)
6.	**6. Infrared Detection**	**F.** Uses one or more convex lenses and a light source to visualize trace evidence
7.	**7. Ultraviolet Light**	**G.** Compares refractive index; can be laboratory or handheld.
8.	**8. Laser**	**H.** Picks up images of objects based on their heat energy released
9.	**9. Convex or Concave Lenses**	**I.** Uses subatomic particles to light up and focus on objects, rather than lenses and white light; combines with a camera to capture images
10.	**10. Polarizing Lenses**	**J.** Calculates absorption, transmittance, and/or emission of the light of an unknown substance for the identification of the chemical composition using light dispersion

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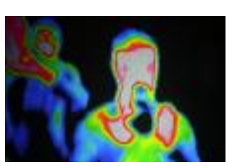
Ω 

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Forensic Use of Light Technology Quiz Key

1. D @
2. G $
3. J =
4. I %
5. F !
6. H Ω
7. B ?
8. A *
9. E ↔
10. C #

Name:_______________________________________Date:________________________

Flame Demonstration Handout

Directions:
Watch the 2 minute video Flame Test 07. Listen to the explanation, and answer the following questions. Be prepared to discuss your answers.

Questions:
1) How could this chemical property of compounds/elements be used in forensics?

2) What causes the flames to be different colors?

Flame Demonstration Key

Note: Students will watch the two minute video and then answer the following questions. After 5 minutes reflecting on their answers, lead the class in a discussion about the properties of the flames.

1) How could this chemical property of compounds/elements be used in forensics?
Substances could be burned or held next to a flame to see what color of flame/light they emit. Based on the flame colors, the substance may be identified by referencing an index of known flame colors with the respective element or compound.

2) What causes the flames to be different colors?
Each element has a different chemical property in the way it reacts in the flame. The heat and light energy cause electrons of the atoms to become excited. Some of the electrons actually jump to a higher energy level. When these electrons fall back to their original level, light energy of a certain wavelength is released. Each individual element's atoms are specific in their excitation ability and the energy levels possible for their electrons; thus, each element releases a different wavelength of light energy (or color seen).

Note: the below table is included for reference material.

Flame Test Colors		
Symbol	**Element**	**Color**
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	Blue-green
Fe	Iron	Gold
K	Potassium	Lilac to red
Li	Lithium	Magenta to carmine
Mg	Magnesium	Bright white
Mn (II)	Manganese (II)	Yellowish-green
Na	Sodium	Intense yellow
P	Phosphorus	Pale bluish-green
Se	Selenium	Azure blue
Sr	Strontium	Crimson

Name:____Date:________________________

Basic Use of a Microscope Lab

Important: Always use the lowest objective first. Use the coarse adjustment to focus before the fine adjustment. Once focused on a lower power, it is then okay to use the next higher power and focus before moving on. Be cautious! Never use the coarse adjustment on the highest power—you will see nothing and you could crack the slide by moving the stage too close to the objective lens.

Materials Needed:

- Compound microscope
- Glass or beaker of water
- Variety of prepared slides
- Eyedropper (plastic disposable is OK)
- Electricity source (possible with power strips)
- Newspaper sections
- Microscope slides and cover slips
- Small scissors
- Tweezers

1. Label the parts of the microscope.

2. How do you calculate the power of magnification?

3. Calculate the powers of magnification for each objective lens:

Band Color	Objective Power	Eyepiece Lens Power	Power of Magnification

4. What happens to our view of an image as you increase the power of magnification?

5. Why can't you use the largest objective for some slides?

6. Try viewing the prepared slides provided by your teacher. Choose one slide and draw what you see at three different powers of magnification. Label each drawing.

Name of the specimen on the slide: ________________________________

Magnification Levels

Low Power: ________X   Medium Power: ______X   High Power: ________X

7. How do you make a wet-mount slide?

   1 – Get a clean ________________ and _______________________ from your teacher.
   2 – Place ________ drop(s) of water in the middle of the slide. Don't use too much or the water will run off the edge and make a mess!
   3 – Place the _______________ of the cover slip on one side of the ___________.
   4 – Slowly ____________________ the cover slip on top of the drop.
   5 – Place the slide on the _______________ and view it first with the lowest objective. Once you see the image, you can rotate the _________________ to view the slide with the different objectives.

8. Make a wet mount slide using the letter "e." Using the newspaper provided, cut out a lower-case letter "e." Prepare the wet slide as directed. It is very important that you place the letter "e" right-side up, as you would normally read or write the letter.

   What is unusual about this image?

   Draw what you see at three different powers of magnification. Label each drawing.

Magnification Levels

Low Power: __________X   Medium Power: _______X   High Power: _______X

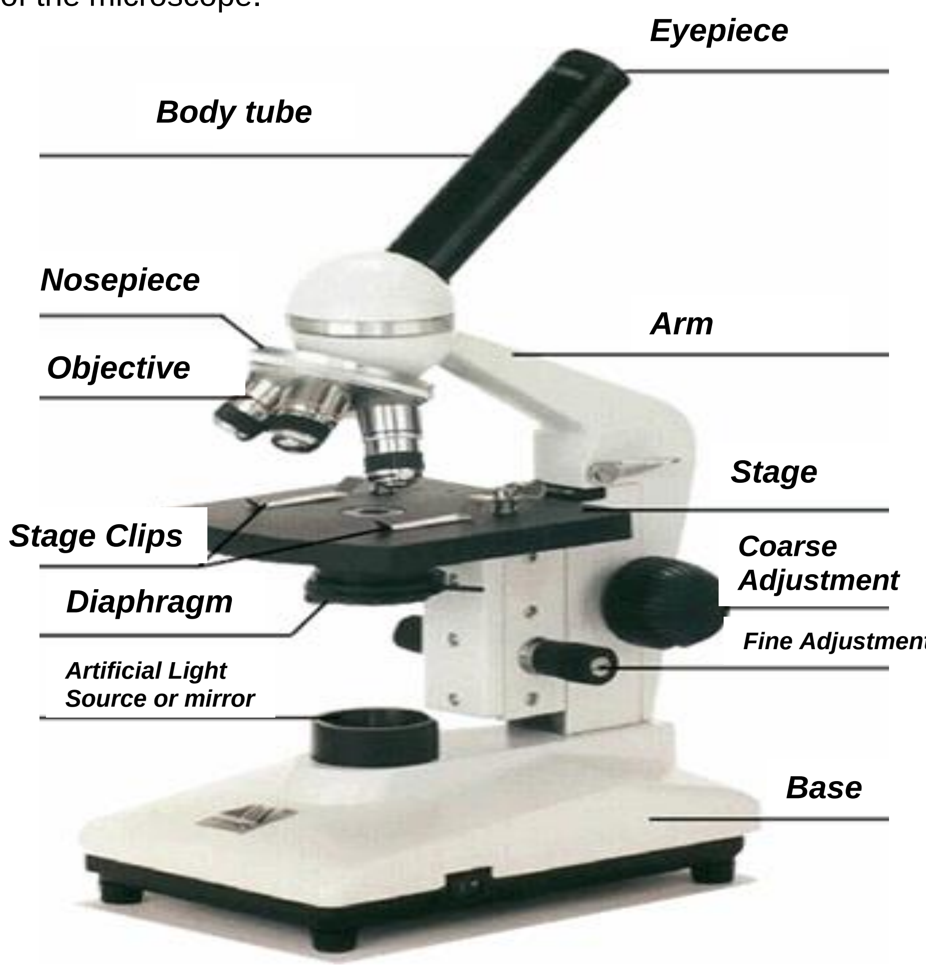
Basic Use of a Microscope Lab Key

Teacher Notes: Use microscopes from the Biology or Science Department of your school. Having a few stereomicroscopes (or dissecting microscopes) would also be useful. Ask them for some interesting prepared slides that the students can look at to get practice with the use of the microscope before preparing their own slides. Practice using the microscope. Complete this lab yourself so you can be aware of any potential issues. **Important:** Always use the lowest objective first. Use the coarse adjustment to focus before the fine adjustment. Once focused on a lower power, it is okay to use the next higher power and focus before moving on. Be cautious! Never use the coarse adjustment on the highest power—you will see nothing and you could crack the slide by moving the stage too close to the objective lens.

Materials Needed:

- – Compound microscope
- – Glass/ beaker of water
- – Variety of prepared slides
- – Eyedropper (plastic disposable is OK)
- – Electricity source (possible with power strips)
- – Newspaper sections
- – Microscope slides and cover slips
- – Small scissors
- – Tweezers

1. Label the parts of the microscope.



2. How do you calculate the power of magnification? **Multiply the power of each objective by 10 (because the eyepiece has 10 times the power). For example, low power is normally 10X, so the total power of magnification would be 100X.**

3. Calculate the powers of magnification for each objective lens. **This will vary according to the microscope, so generalities are given here. Also some microscopes have 4 lenses with a 65X objective.**

Band Color	Objective Power	Eyepiece Lens Power	Power of Magnification
Yellow	**10x**	**10x**	**100x**
Blue	**25X**	**10x**	**250X**
Red	**45X**	**10x**	**450X**

4. What happens to our view of an image as you increase the power of magnification? **The view will be closer, the image will be more detailed and appear 3-D.**

5. Why can't you use the largest objective for some slides? **Some slides will not focus on the largest objective because it is too close the slide will be too close to the objective lens, or because the slide shows an image that is best seen on a lower power.**

6. Try viewing the prepared slides provided by your teacher.. Choose one slide and draw what you see at three different powers of magnification. Label each drawing.

Name of specimen on slide: ________________________________

Magnification Levels

Low Power: ____***100***____X_ Medium Power: __***250***_____X_ High Power: __***650***______X

7. How do you make a wet-mount slide?

   1 – Get a clean____**slide**___and ____**cover slip**________ from your teacher.
   2 – Place _**1-3**___drop of water in the middle of the slide. Don't use too much or the water will run off the edge and make a mess!
   3 – Place the ___**top**___of the cover slip on one side of the _____**microscope slide**__**.**
   4 – Slowly ______**drop**_______the cover slip on top of the drop.
   5 – Place the slide on the _____**microscope stage**_______and view it first with the lowest objective. Once you see the image, you can rotate the __**nosepiece**________ to view the slide with the different objectives.

8. Make a wet mount slide using the letter "e." Using the newspaper provided, cut out a lower-case letter "e." Prepare the wet slide as directed. It is very important that you place the letter "e" right-side up, as you would normally read or write the letter.

   What is unusual about this image?

   Draw what you see at three different powers of magnification. Label each drawing.

Magnification Levels

Low Power: ____***100***____X_ Medium Power: __***250***_____X High Power: __***650***______X

Name:____Date:________________________

Observing Refractive Index (RI) in Fibers Lab

The halo effect seen around certain substances under a microscope is called a Becke Line. When wet-mounted or immersed in a fluid a substance a fiber (in this lab) will show its refractive index. When the Becke Line is observed on the inside of the fiber's image, the fiber has a lower refractive index than the fluid it is immersed (or "mounted") in.

When the Becke Line is observed on the outside of the fiber's surface, the fiber has a higher refractive index than the fluid. When the Becke Line is not seen, the fiber and the fluid have a similar refractive index. The refractive indexes of various fibers and fluids are known, as shown in the table below. This physical property can be used to identify an unknown fiber found at a crime scene, and also to match the fiber to one found elsewhere—this light property is used widely in forensic laboratories.

Refractive Index is also used in the identification of other substances like glass, soil, and hair, and many labs have equipment that performs the comparison automatically without the use of a technician and microscope.

Fiber	Density g/cc	Refractive Index (RI)
Cotton	1.45 – 1.6	1.53
Fiberglass	2.56	1.54
Wool	1.28 – 1.35	1.54
Acetate	1.28 – 1.35	1.54
Nylon	1.1 – 1.2	1.53 – 1.54
Silk	1.20 – 1.28	1.54
Polyester	1.35 – 1.45	1.57 – 1.60
Acetate	1.28 – 1.45	1.47
Rayon	1.45 – 1.60	1.52 – 1.54
Olefin	0.90 – 0.95	1.50 – 1.54
Acrylic (Orlon)	1.1 – 1.2	1.51

Fluid	Refractive Index (RI)
N-butyl alcohol	1.402
Olive oil (or glycerin)	1.467
Water	1.33
Castor Oil	1.482
Clove Oil	1.543
Bromoform	1.597

Materials:

- Fiber samples of known composition
- Glass slides
- Fiber samples of unknown composition
- Cover slips
- Refractive index fluids (listed above)
- Compound microscope
- Small beakers for fluids
- Small scissors
- Eyedropper (disposable is okay)
- Tweezers

Instructions:

1. Place a 1cm long length of a known fiber on a microscope slide.
2. Prepare a wet-mount of the fiber by placing one drop of a liquid with a refractive index matching the fiber's refractive index (see the chart above).
3. View the sample with a compound microscope at an appropriate magnification. You may have to pull a few filaments from the fiber so that they are more transparent (remember, that refraction only occurs if the light waves can pass through the medium).
4. If the refractive index matches exactly, the Becke Line disappears.
5. Remove the fiber with tweezers and replace it with a different fiber sample, one that has a different RI than the fluid. Note the Becke Line.
6. Repeat this several times making various wet-mounts with different fiber samples and different RI fluids.
7. Draw what you have observed with several fiber samples—label the Becke Line on each drawing. Also note on each drawing whether the RI was higher or lower than the fiber and what the possible RI of each fiber sample was.
8. Using the above chart, try to identify not only the RI of one of the unknown sample types, but also what the type of fiber is, based on its RI.

Name:_____________________________________Date:_______________________

Light Diffraction Hair Diameter Lab

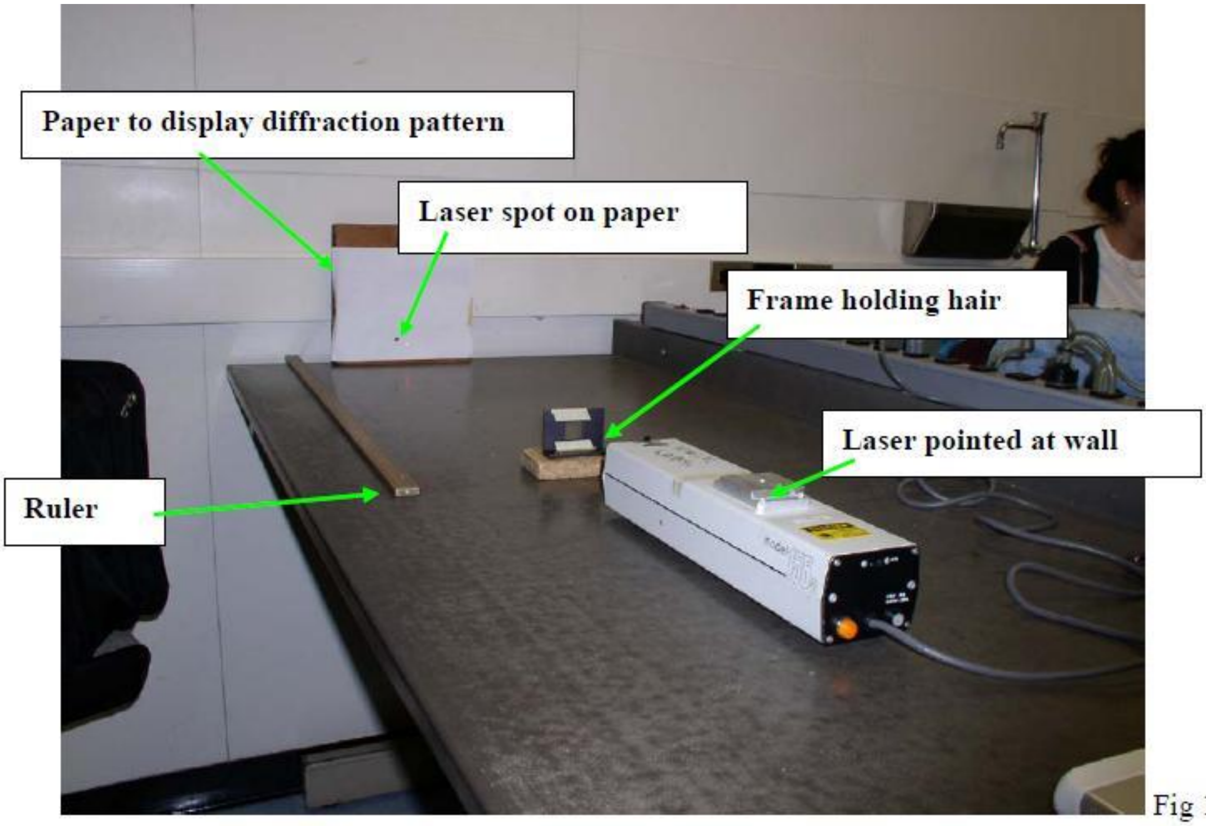


Fig 1.

Introduction:
Sometimes in forensics it is necessary to determine the diameter of a hair, fiber, or other object that cannot be measured by conventional means. These items can be measured by using methods of diffraction and interference known as Young's Double Slit Experiment. While Young's experiment deals with the pattern of light impinging on two narrows slits separated by a small distance, the method can be applied to an object with a small diameter as well.

Materials:

- Helium-Neon laser (also called He-Ne laser)
- Scotch or transparent tape
- Scissors
- Index card
- Metric ruler
- Meter stick
- Binder clips
- Pencil
- Marker
- Handheld 1-hole punch
- Best: white paper taped on a wall (legal size)
- Okay: a screen to project an image (just the regular white screen in the classroom will do)

Safety:
Do not shine the laser at anyone or a reflective service. Do not point the laser beam at anyone's eye or your own. Lasers can be damaging to the human eye.

Directions:

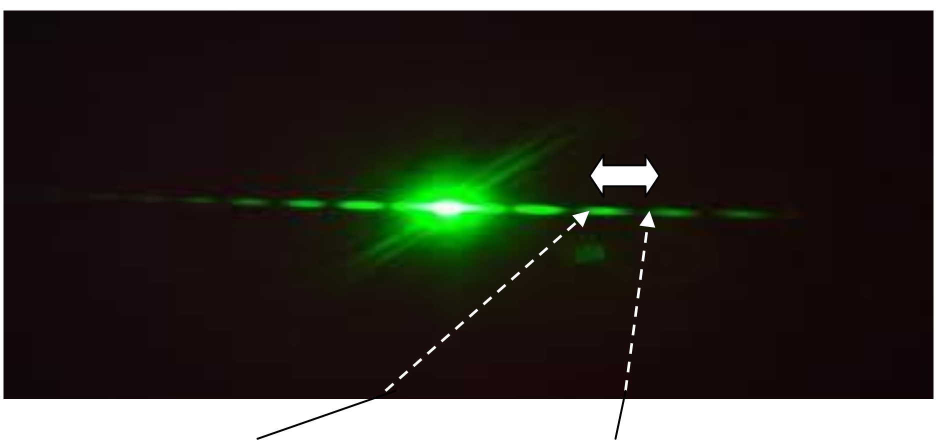
1. Using an index card, punch a hole in the center of the card (or cut a 1" by 1" inch square out of the middle of the card).

2. Tape a hair across the middle of the hole (put tape on either side of the hole to fasten the hair). Make sure that the hair is taut and that the tape does not show through the hole at all.

3. Have your teacher set up the He-Ne laser for you (the He-Ne laser should be on a stable table or cart. The laser should be about 1 - 2 meters from the screen/paper on wall. The laser needs to be very steady and shining in the middle of the screen).

4. Arrange the hole so that the hair is lined up with the middle of the laser beam—the beam is shining directly on the hair (see the photo of the setup—the photo shows the laser on the wall instead of on the screen. Use binder clips sideways to hold the index card in place, instead of the wooden frame. It may be necessary to move the laser up and down rather than adjusting the index card).

5. You should be able to see a pattern of alternate light and dark images of the hair projected on the screen. You might need to darken the room. Refer to this diagram (your light might be red, instead of green). Now gather the data you will need to carry out your equation.



Beginning of the dark-band to the Beginning of the next dark-band

6. Precisely measure the distance between the start of the light beam and the screen (in meters).

7. Best: Use a piece of paper for your screen so that you can carefully mark the light and dark band boundaries with a pencil. Then un-tape the paper and take it to a desk. Fill in the light lines with a marker and then use a ruler to measure the distance in centimeters from the *beginning of the first dark band* to the *beginning of the next dark band* (see the arrows above for an example).

   Or: On the projected screen pattern, accurately measure the distance (in centimeters) between the *beginning of the first dark band* and the *beginning of the next dark band*.

On the paper or on the screen get this measurement for several dark band distances on both sides of the center light; then average these numbers to get a typical measurement between bands.

8. Carry out the mathematic equation below to solve for the diameter of the hair in micrometers. Show all your work for the equation to get full credit.

9. Measure the difference in hair diameters between at least two students. Compare hair diameters between someone with thick/coarse hair and someone that has fine hair.

10. The equation to be used to find the diameter of the hair is: $d = \frac{I\ L}{10S}$

    d = diameter of the hair in micrometers (µm)
    I = the wavelength of the light source (for a He-Ne laser it's 635 nanometers)
    L= the distance from the light source to the screen in meters (m)
    S = the average distance from beginning dark band to beginning dark band (centimeter (cm))

Lab Questions:

1. What are the two hair diameters that you calculated?

2. How do they compare according to the texture of the students' hair?

3. What two properties of light wave disruption properties is this lab demonstrating?

4. Define these two wave properties.

5. Describe how this test would be used in a Forensic Lab.

Light Diffraction Hair Diameter Lab Key

Math Problem Example:

L: distance from light source to screen is 2.23 meters

I: average distance from bands is 4.3 centimeters

$$d = \frac{635 \text{ X } 2.23^*}{10\ (4.3)}$$

d = 32.93 micrometers (μm)

* Other problems of this type show the conversion of all of the units to meters and more complicated math/averaging. This data gathering process and mathematical equation has been simplified, and it still works well.

Name:____ Date:____________________________

Spectrophotometer Use for Soil Analysis Lab

Materials:

- Spectrophotometer (Spec 20 is an example of one type that could be used in this lab)
- Unscratched cuvettes for the spectrophotometer
- 10ml graduated cylinder
- Tap water
- 3 different soil types
- Timer or watch for one-minute intervals

Instructions:

1. Calibrate the Spec -20.
   - Use the empty cuvette
   - Set the wavelength to 300 – 500
   - Set the transmittance to 100%
   - Match the white line of the cuvette with the plastic line on the sample holder
   - Calibration must occur before each sample is measured

2. Put 2ml of soil into the cuvette.
   - Use a 10ml graduated cylinder to measure the soil
   - Observe and record the color and texture on the data table

3. Add 7ml of water to the cuvette.
   - Shake for 20 – 30 seconds
   - Observe and record the appearance with water while shaking
   - Immediately put the cuvette into the Spec 20
   - Start the timer and note percent transmittance quickly for start data

4. Note percent transmittance at 1-minute intervals for 10 minutes.

5. Use the table on the next page to distinguish the particle size and soil type. Convert percent transmittance to size of particles.

Grain Size Scale Table :

Size of Particle (in mm)	Number of Sieve Series	Texture Type/Name
3.35	6	Very coarse/gravel
2.00	10	Very coarse/gravel
0.850	20	Coarse/sand
0.425	40	Medium/sand
0.250	60	Medium fine/sand
0.150	100	Fine/silt
0.075	200	Very fine/silt
0.038	400	Very, very fine/clay
0.002		Very, very, very fine/clay

6. Repeat for each sample.

7. Graph the data with a line graph (time is the x-axis).

% Transmittance Recorded Every Minute															Analysis	
Sample	**Color**	**Texture**	**With water**	**Start**	**1 min**	**2 min**	**3 min**	**4 min**	**5 min**	**6 min**	**7 min**	**8 min**	**9 min**	**10 min**	**Particle Size**	**Soil Type**
#1																
#2																
#3																
Mix of 2																

1. Which soil type had the highest percent transmittance after 10 minutes?

2. What does percent transmittance mean? How does this relate to soil particle size?

3. How could this test be used in a CSI lab?

Spectrophotometer Use for Soil Analysis Lab Key

Objectives:

- To understand how to operate a spectrophotometer.
- To understand that a spectrophotometer can emit light from a controlled wavelength.

Notes:

- The spectrophotometer can either measure the transmittance of this light through a substance OR measure the absorption of this light by the substance.
- Transmittance and absorption levels are always opposite of each other.
- With a spectrophotometer, you can determine what wavelengths a substance will transmit, and what wavelengths it will absorb.
- The more dense (opaque) a substance, the more it will absorb, rather than transmit, wavelengths. The less dense (more transparent) a substance, the less it will absorb, but the more it will transmit, wavelengths.
- Water alone without the soil should have almost 100% transmittance of all wavelengths.
- The goal of this lab is not to be exact in your guess of particle size of the soil.
- Time will affect the amount of transmittance.

Teacher Instructions: (please see further enclosed directions for using the Spec 20 Spectrometer)

1. Gather 3 types of soil samples with different textures (some smaller grains like clay, medium grained like potting soil, larger grained like sand).
2. Having a Spec 20 machine for each lab table is the preferred method.
3. Care should be taken so that soil samples do not scratch the cuvettes (scratched cuvettes will interfere with light transmission).

Student Instructions:

1. Calibrate the Spec 20.
   – Use the empty cuvette
   – Set wavelength to 300 – 500
   – Set the transmittance to 100%
   – Match the white line of the cuvette with the plastic line on the sample holder
   – Calibration must occur before each sample is measured
2. Put 2ml of soil into the cuvette.
   – Use a 10ml graduated cylinder to measure the soil
   – Observe and record the color and texture on the data table
3. Add 7ml of water into the cuvette.
   – Shake for 20 – 30 seconds
   – Observe and record the appearance with water while shaking
   – Immediately put the cuvette into the Spec 20
   – Start the timer and note percent transmittance quickly for start data

4. Note percent transmittance at 1-minute intervals for 10 minutes.
   Teacher Note: Results will vary because of differences in the soil samples. Generally, the more transmittance there is, the larger the particles. The less transmittance, the smaller the particles.
5. Use the table below to distinguish the particle size and soil type. Convert percent of transmittance to size of particles.

Grain Size Scale Table :

Size of Particle (in mm)	Number of Sieve Series	Texture Type/Name
3.35	6	Very coarse/gravel
2.00	10	Very coarse/gravel
.850	20	Coarse/sand
.425	40	Medium/sand
.250	60	Medium fine/sand
.150	100	Fine/silt
.075	200	Very fine/silt
.038	400	Very, very fine/clay
.002		Very, very, very fine/clay

6. Repeat for each sample.
7. Graph the data with a line graph (time is the x-axis).

Analysis	% of Transmittance Recorded Every Minute															
Sample	**Color**	**Texture**	**With water**	**Start**	**1 min**	**2 min**	**3 min**	**4 min**	**5 min**	**6 min**	**7 min**	**8 min**	**9 min**	**10 min**	**Particle Size**	**Soil Type**
#1																
#2																
#3																
Mix of 2																

1. Which soil type had the highest percent transmittance after 10 minutes? **Coarser soil, like sand, should have the most transmittance after 10 minutes. Finer soil, like clay, should have the least transmittance after 10 minutes**

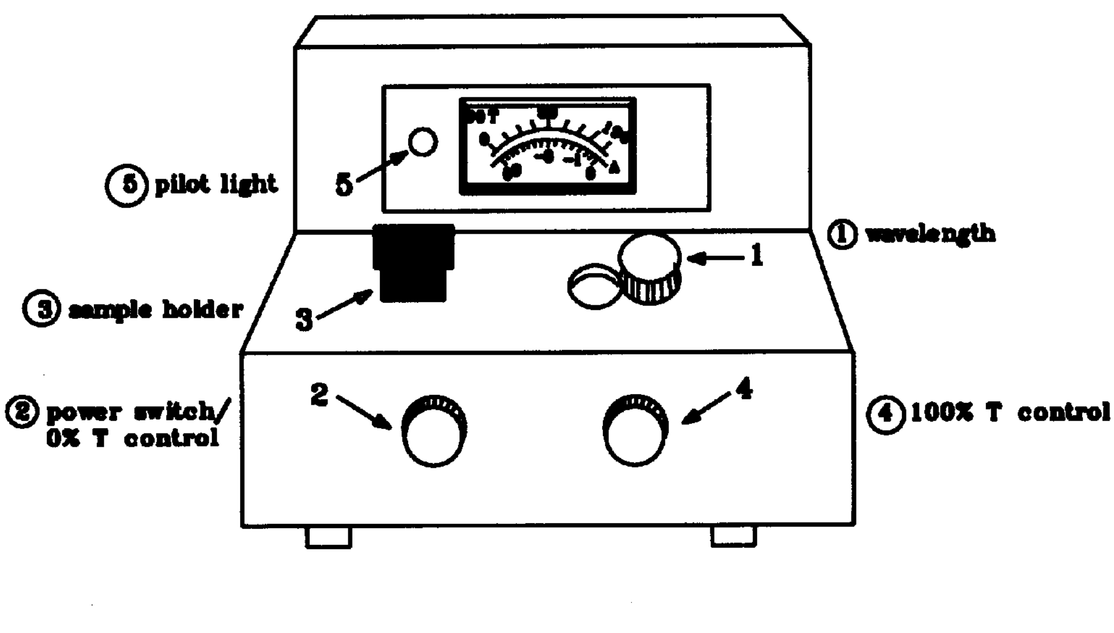
2. What does percent transmittance mean? How does this relate to soil particle size? **Percent transmittance is related to what wavelengths get through the material. The higher the transmittance, the more waves come through, and the less solid areas there are in the cuvette. So probably, over time, transmittance will become higher as particles settle out.**

3. How could this test be used in a CSI lab? **A forensic scientist could extrapolate that similar soils would have similar transmittance and absorption ratings at similar time intervals. Good preliminary match of soil types.**

Directions for Using the "Spec 20" Spectrometer

Any spectrophotometers (specometer) will be similar (calibration before using each sample is a must).

1. Turn the power switch on and allow 5 minutes for warmup.
2. Set the instrument to the desired wavelength.
3. Adjust the instrument needle to read 0% on the Transmittance scale by turning the lower left-hand knob. Be sure the cover of the cuvette holder is closed. Rinse a colorimeter tube (cuvette) with "blank" solution and then fill about two-thirds its capacity. Wipe and polish the lower half of the cuvette with a tissue. Keep your fingers off the lower part of the tube. Raise the cover and insert the cuvette into the cuvette holder as far as it will go. The vertically etched line at the top of the cuvette should line up with the indicator line at the top of the plastic cuvette holder. Close the cover so outside light does not affect the phototube.
4. Adjust the needle to read 100% Transmittance by turning the lower right-hand knob.
5. Remove the cuvette containing "blank" and repeat step 2, readjusting the lower left-hand knob if necessary.
6. Reinsert the "blank" cuvette and repeat step 4, readjusting the right-hand knob if necessary.
7. Rinse and then fill a second cuvette with the first standard solution. Record the absorbance reading, estimating to 3 decimal places. Continue with other samples. Check the settings of the instrument frequently to ensure that the needle has not drifted from the original settings made in steps 2 and 4.



Name:________________________________Date:______________________

RI of Glass by Submersion Lab

Directions:
Determine the refractive index of glass by submersion in different liquids. The following tables are included as a reference.

Source of glass	Refractive Index
Borosilicate glass	1.47
Automotive headlight glass	1.47 – 1.49
Television glass	1.49 – 1.51
Pane window glass	1.49 – 1.51
Bottle glass	1.51 – 1.52
Eyeglass lenses	1.52 – 1.53
Quartz glass	1.54 – 1.55
Lead glass	1.56 – 1.61
Cubic zirconium	2.14
Diamond	2.42

Liquid	Refractive Index
Cinnamon oil	1.62
Clove oil	1.54
Castor oil	1.48
Vegetable oil	1.474
Olive oil or glycerin	1.47
Isopropyl alcohol	1.37
Water or methanol	1.33

Materials:
- 5 – 7 test tubes
- Test tube rack
- Test tube brush
- Tweezers
- Soap
- 25ml graduated cylinder

Evidence Bags:
Three evidence bags containing glass should be ready for your use.

Instructions:
1. Prepare the test tubes with about 10ml of the each of the above liquids (your teacher may have other liquids and you will be given their refractive indexes).
2. Test each piece of glass in each type of fluid with tweezers. The glass will seemingly disappear in the fluid that has a matching RI.
3. Use the matching RI to determine what type of glass your evidence is.

Questions:

1. Based on the results of your submersion test, record the estimated refractive indices for each of the glass fragments.

   The Refractive Index (RI) of the Crime scene glass = ________

   The Refractive Index (RI) of the glass from Suspect 1 = ________

   The Refractive Index (RI) of the glass from Suspect 2 = ________

2. What would you consider to be some experimental errors using this method?

3. What could you do to improve the reliability of this experiment?

4. Is your match conclusive? Why or why not?

5. Why would glass from the crime scene matched to a suspect be considered class evidence?

6. Explain the refraction of light. Include in your answer the following:
   - Two different mediums
   - Light velocity
   - Density

7. A refractive index of olive oil is equal to 1.47. It is calculated as a ratio between what two numbers?

RI of Glass by Submersion Lab Key

Teacher's Tips:

- Pea-sized glass fragments work well.
- Set up a demonstration rack for clove and castor oil and perhaps cinnamon oil as they are expensive for student use.
- Test tubes with oil are difficult to clean, so you may want to use the same tubes from one lab period to the next. After use, clean them with soap and a test tube brush, turn them over in the rack and let them drain thoroughly.
- The lowest refractive index in which the glass disappears will be the closest to the refractive index for that sample of glass. Some sample values follow. Borosilicate glass in olive or vegetable oil works well, as does quartz in clove oil.

Source of glass	Refractive Index
Borosilicate glass	1.47
Automotive headlight glass	1.47 – 1.49
Television glass	1.49 – 1.51
Pane window glass	1.49 – 1.51
Bottle glass	1.51 – 1.52
Eyeglass lenses	1.52 – 1.53
Quartz glass	1.54 – 1.55
Lead glass	1.56 – 1.61
Cubic zirconium	2.14
Diamond	2.42

Liquid	Refractive Index
Cinnamon oil	1.62
Clove oil	1.54
Castor oil	1.48
Vegetable oil	1.474
Olive oil or glycerin	1.47
Isopropyl alcohol	1.37
Water or methanol	1.33

Materials:

– 5 – 7 test tubes
– Test tube rack
– Test tube brush
– Tweezers
– Soap
– 25ml graduated cylinder

Evidence Bags:
Before the lab, three evidence bags containing glass need to be prepared for each team. At least one of the glass fragments of Suspect 1 or 2 should match the glass fragments in an evidence bag.

The evidence bags should be sealed using the proper chain-of-evidence format. The bag should be sealed with the name or initials of the crime scene technician. The name should be signed across the interface of the bag and the tape. The Chain of Possession form should have at least one name, date, and time entered before the student receives the evidence bag.

Instructions:

1. Prepare the test tubes with about 10ml of the each of the above liquids (your teacher may have other liquids and you will be given their refractive indexes).
2. Test each piece of glass in each type of fluid with tweezers. The glass will seemingly disappear in the fluid that has a matching RI.
3. Use the matching RI to determine what type of glass your evidence is.

Questions:

1. Based on the results of your submersion test, record the estimated refractive indices for each of the glass fragments.

   The Refractive Index (RI) of the Crime scene glass = ________

   The Refractive Index (RI) of the glass from Suspect 1 = ________

   The Refractive Index (RI) of the glass from Suspect 2 = ________

2. What would you consider to be some experimental errors using this method?
   Answers may vary. Possible sources of error include
   a. **Using the same piece of glass to test in the different solutions**
   b. **Washing the glass piece may alter the evidence**
   c. **Not having large enough pieces of glass**
   d. **Not thoroughly cleaning the glass prior to submersion**

3. What could you do to improve the reliability of this experiment?
   Answers may vary.
   a. **If enough evidence was available, use a different piece of glass before doing each submersion test.**
   b. **Try to find pieces of glass that are all approximately the same size.**
   c. **Repeat the submersion test and check that you got the same results.**
   d. **Confirm your findings with other members of the class.**
   e. **Have more solutions with different refractive indexes to be able to more closely determine the refractive index.**

4. Is your match conclusive? Why or why not?
   Answers may not be conclusive if the glass fragment did not disappear and remained slightly visible. That would mean that the refractive index of the solution was not exactly the same as the refractive index of the glass.

5. Why would the match of glass from the crime scene to a suspect be considered class evidence?
   The glass may not be unique. For example, bottles (juice, milk, etc.) manufactured by the same company could all have glass at the same refractive index. The glass fragment of the trophy case could be the same as the glass fragments from a different window.

6. Explain the refraction of light. Include in your answer the following:
   - Two different mediums
   - Light velocity
   - Density

   Refraction of light is referred to as the bending of light as it passes from one medium through another. The bending occurs because of a difference in density between the two mediums. If one medium is denser than the other, the velocity of light slows down, resulting in the bending of the light.

7. A refractive index of olive oil is equal to 1.47. It is calculated as a ratio between what two numbers?
   The refractive index of olive oil is calculated as a ratio between the speed of light in a vacuum and the speed of light through olive oil.

Name:____ Date:________________________________

Forensic Use of Light Fill-in-the-Blank Venn Diagram

Directions: Compare and contrast the two theories of light.

__Wave Theory__

Light acts like a __________.

Light waves are called ______________ waves.

____________ is the distance from the crest of one wave to the next.

The entire range of known light waves is called the ____________ spectrum.

The _________ of light is 3.0 X 10^8 m/s.

As wavelength _______, wave frequency decreases; they are inversely related.

Other examples of waves are: _______ and water.

The speed of light wave formula is wave speed = ___________ x ____________.

Both

Light transfers or carries __________.

Light travels in a ___________.

Color of light has to do with the __________ of the wave or the electron.

We see light that is ________ not absorbed.

________ of light is the bending of light.

Some light is _____________to the human eye (like ___violet, ___red, & ___rays) but is used in the analysis of evidence for forensics.

Light properties are used in many forms of light technology like ______________ ______________ and ______________

__Particle Theory__

Light acts like a _________.

Light particles are called _________.

Photons transfer their energy to __________.

Energized electrons jump up one _______ and then move back down to their original ________ level.

When the electron moves back down, this releases a certain _________ that is individual for every _______ and can be used to identify __________elements.

The photon theory of light is also known as _________ physics.

Forensic Use of Light Fill-in-the-Blank Venn Diagram Key

Directions: Compare and contrast the two theories of light.

Wave Theory

Light acts like a **wave**.

Light waves are called **electromagnetic** waves.

Wavelength is the distance from the crest of one wave to the next.

The entire range of known light waves is called the **electromagnetic** spectrum.

The **speed** of light is 3.0 X 10^8 m/s.

As wavelength **increases**, wave frequency decreases; they are inversely related.

Other examples of waves are: **sound** and water.

The speed of light wave formula is wave speed = **wavelength** x **frequency**.

Both

Light transfers or carries **energy**

Light travels in a **vacuum**.

Color of light has to do with the **frequency** of the wave or the electron.

We see light that is **reflected** not absorbed.

Refraction of light is the bending of light.

Some light is **invisible** to the human eye (like **ultra**violet, **infra**red, & **X-**rays) but is used in analysis of evidence for forensics

Light properties are used in many forms of light technology like **microscopes**, **spectrophotometry**, **refractometers**, and **lasers**. **(answers may vary)**

Particle Theory

Light acts like a **particle**.

Light particles are called **photons**.

Photons transfer their energy to **electrons**.

Energized electrons jump up one **energy** and then move back down to their original **energy** level.

When the electron moves back down this releases an certain **color** that is individual for every **element** and can be used to identify **unknown** elements.

The photon theory of light is also known as **quantum** physics.

Name____ Date________________________________

Discussion Rubric

Objectives	4 pts. Excellent	3 pts. Good	2 pts. Needs Some Improvement	1 pt. Needs Much Improvement	N/A	Pts.
Participates in group discussion						
Encourages others to join the conversation						
Keeps the discussion progressing to achieve goals						
Shares thoughts actively while offering helpful recommendations to others						
Gives credit to others for their ideas						
Respects the opinions of others						
Involves others by asking questions or requesting input						
Expresses thoughts and ideas clearly and effectively						
Total Points (32 pts.)						

Comments:

Name______________________________________ Date_______________________________________

Individual Work Rubric

Objectives	4 pts. Excellent	3 pts. Good	2 pts. Needs Some Improvement	1 pt. Needs Much Improvement	N/A	Pts.
Follows directions Student completed the work as directed, following the directions given, in order and to the level of quality indicated						
Time management Student used time wisely and remained on task 100% of the time						
Organization Student kept notes and materials in a neat, legible, and organized manner. Information was readily retrieved						
Evidence of learning Student documented information in his or her own words and can accurately answer questions related to the information retrieved						
***Research/Gathering information (if relevant)** Student used a variety of methods and sources to gather information. Student took notes while gathering information						
Total Points (20 pts.)						

Comments:

Name_______________________________________ Date____

Research Rubric

Objectives	4 pts. Excellent	3 pts. Good	2 pts. Needs Some Improvement	1 pt. Needs Much Improvement	N/A	Pts.
Question/goal Student identified and communicated a question or goal of the research						
Research/Gathering information (if relevant) Student used a variety of methods and sources to gather information. Student took notes while gathering information						
Conclusion/Summary Student drew insightful conclusions and observations from the information gathered. Information is organized in a logical manner						
Communication Student communicated the information gathered and summary or conclusions persuasively. Student demonstrated skill in the use of media used to communicate the results of research						
Reflection Student reflected on the importance of the research and its potential application						
Total Points (20 pts.)						

Comments: