Penn State RET in Interdisciplinary Materials

Teacher's Preparatory Guide : GILBERT AMADI

Lab Title: Interaction of Light with Matter

Purpose: In this unit, students are expected to learn:
• How the light can be absorbed or scattered by small objects such as nanoparticles;
• How light can be used to monitor the absorption and scattering of solutions;
• How to compare light absorption, fluorescence, and light scattering; and
• Color sensitivity of the absorption, scattering and fluorescence of a materials.

Learning objectives:

- To recognize the experimental evidence for the wave nature of light.
- To understand that light travels with different speeds in different media
- To know the difference between turbidity and light absorbance
- To explore how different wavelengths interfere with different solution media
- To understand how blue, green and red) light from hand-hold laser pointers interact with different materials, including nanoparticles, fluorescence dye and milk.
- To understand the difference between absorbance and fluorescence

Time required: 2-3 periods

Level: High school

National Science Education Standards : 11-12th grade

Content Standard A
- Abilities necessary to do scientific inquiry

Content Standard B
- Structure and properties of Light
- Light Interaction with matter

• Transfer of Energy
• Light transmission, absorption, and scattering.
• Energy as a property of many substances and its association with heat.
• Light, electricity, mechanical motion, sound, atomic, nuclei, and the nature of a chemical
• Energy transfer. This lab will help students understand how light is bent into different directions as it interacts with small objects, especially those on the nanoscale (1-100nm).

California Science Education Standards

HSP PS4 1 - HST 1
HSP PS4 1 - HST 2
HSP PS4 1 - HST 3

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Teacher Background :

Rayleigh is the elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the light. Rayleigh scattering is used in this module to describe the light interference with the silver nanoparticle mixture. The particles may be individual atoms or molecules. It can occur when light travels through transparent solids and liquids, but is most prominently seen in gases. Rayleigh scattering results from the electric polarizability of the particles. The oscillating electric field of a light wave acts on the charges within a particle, causing them to move at the same frequency. The particle therefore becomes a small radiating dipole whose radiation we see as scattered light.

Fluorescence of dye is emission of light from molecules upon photoexcitation. Longer wavelength light emission is expected when the molecule is excited using a short wavelength as short wavelength light has higher energy to excite electrons of the molecule from their ground state to excited states. These excited electrons relax and return to ground states by releasing energy in forms of light.

The Tyndall effect, also known as Tyndall scattering, is light scattering by particles in a colloid or particles in a fine suspension. It is named after the 19th century physicist John Tyndall. It is similar to Rayleigh scattering, in that the intensity of the scattered light depends on the fourth power of the frequency, so blue light is scattered much more strongly than red light. An example in everyday life is the blue color sometimes seen in the smoke emitted by motorcycles, particularly two stroke machines where the burnt engine oil provides the particles.

Under the Tyndall effect, the longer-wavelength light is more transmitted while the shorter-wavelength light is more reflected via scattering. An analogy to this wavelength dependency is that longwave electromagnetic waves such as radio waves are able to pass through the walls of buildings, while shortwave electromagnetic waves such as light waves are stopped and reflected by the walls. The Tyndall effect is seen when light-scattering particulate-matter is dispersed in an otherwise light-transmitting medium, when the cross-section of an individual particulate is the range of roughly between 40 and 900 nanometers, i.e., somewhat below or near the wavelength of visible light (400–750 nanometers).

Materials:

- Wash bottle
- Ultra Silver coagulate nanoparticles
- Whole milk
- Salt
- Rodamine dye
- Green laser
- Red laser
- Blue/violet laser
- Pipettes and cuvettes
- Safety glasses
- Spoon
- Four capped glass vials
- Optical Table

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Advance Preparation:
1. http://omlc.org/classroom/scat_demo/
2. http://www.vernier.com/ (with Optics Upgrade Kit)

Safety Information: Do not point laser on any one, it might cause permanent damage. Wear your eyes goggles

Teaching Strategies:

Students should be grouped three per group

- Common Core Application:
  - Students are given reading materials on light and interaction with matter
  - Students respond to the questions from the reading materials
  - Students discuss the application of light/waves in medicine.

Resources:

- Omega Engineering. (2008). *Turbidity Measurement.* Retrieved November 10, 2008, from http://www.omega.com/techref/ph-6.html
- Water on the Web. (2008, January 17). *Turbidity*. Retrieved November 10, 2008, from http://waterontheweb.org/under/waterquality/turbidity.html
- http://w http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/lines paper
- http://www.nnin.org/sites/default/files/files/Moore_SlinkyvsSnakyDominator_TPG_final_0.pdf

Activities:

Warn Up: A) Draw and label paths of light depict transmission, reflection and scattering
b) Explain Raleigh scattering
c) How do we use the concept in medical applications

INTRODUCTION:

Metallic materials have small sizes like this they tend to be transparent to visible light. This is different from bulk silver and gold.
Absorption and Fluorescence:
Light shines brightly because chemicals in the water are excited. In this unit a fluorescent Rhodamin dye is introduced into a water sample where the chemicals in the dye are excited with varied laser lights (red, blue, green).
Students will learn light can be produced by energy and produced chemically. Different from nanoparticles and micrometer particles, light absorption and fluorescence are mainly due to the electronic transitions of molecules with well-defined molecule structures at the atomic/molecular level.
The varying samples created are made to explore how red and green laser light and light properties, including wavelength, differ between samples with water, milk, and dye.

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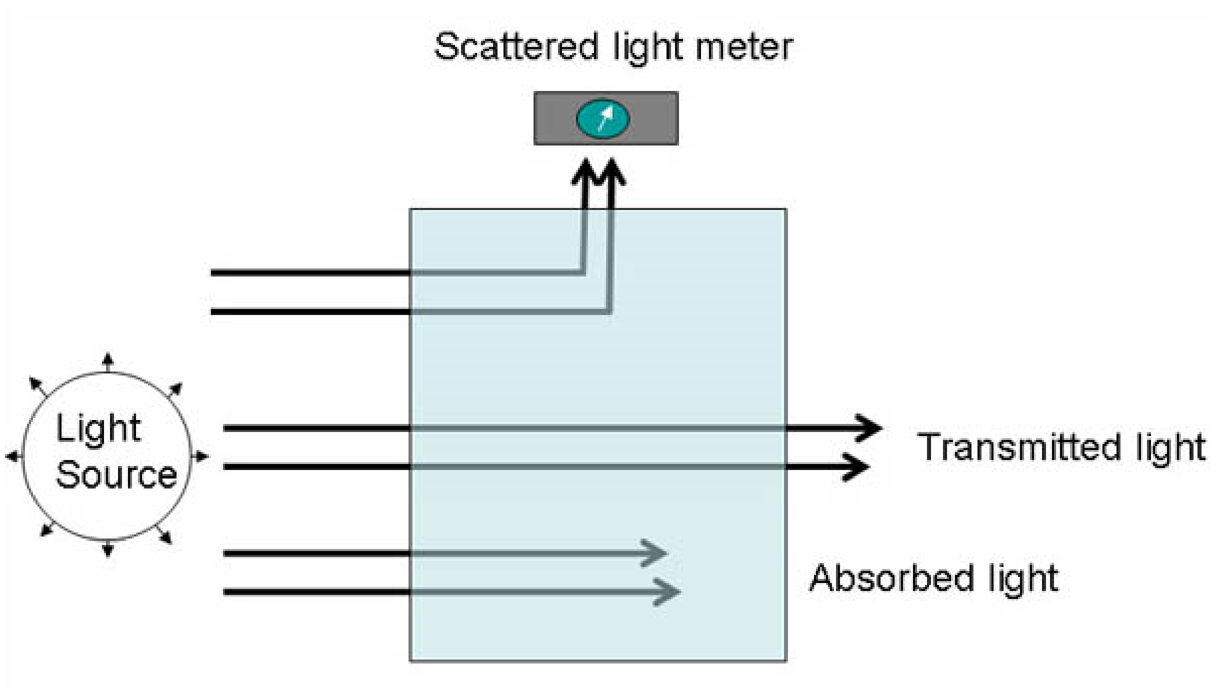
Students will learn how nanomaterials are made, how they used in every day products, and how they could potentially enter the environment. This short demonstration provides guidance as to how one might visualize different light-material interaction, and understand the underlying fundamental physics and chemistry concepts

Water in a mountain stream is usually murkier, or more **turbid,** after a rainfall because the rain washes soil and other small particles into the stream. Environmental engineers and others who track the quality of drinking water measure the turbidity of the water supply using a **turbidity meter,** called a **turbidimeter.** The turbidimeter measures light scattering. Whereas in **light absorption,** colored molecules in the liquid absorb the incoming light, in **light scattering,** the incoming light bounces off of small, suspended particles, and is thus redirected away from its initial path.



A number of factors affect the scattering of light by suspended particles. The concentration and the size of the particles are two such factors. The physical characteristics of the particles are clearly important, too; for example, fat globules in milk will behave differently than dust in the atmosphere.

Another factor is the **wavelength** of the light. Blue light is scattered by the atmosphere more than red light is, which is why the sky looks blue. As sunlight passes through the atmosphere, the blue light is redirected, and we "see" it here on the ground. Sunsets are red/orange for the same reason—the sunlight has been depleted of blue colors by passing through the atmosphere.

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Procedure :

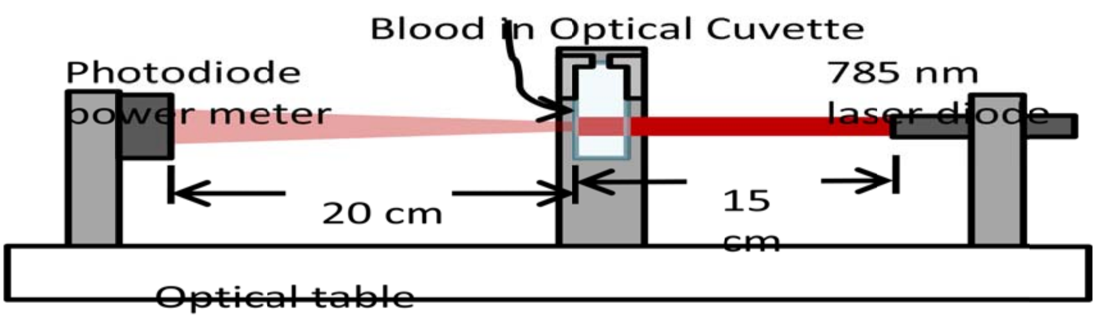
A) ABSORBANCE MEASUREMENT:

An Optical Table is set up with the cuvette mounted between the laser source and the white screen detector.

1. Fill the glass cuvette with clear water and place a white sheet of paper behind the glass.
2. Shine with the laser pointer through the water (see picture a) below). Depending on how many small air bubbles (or other particles like dust) you have in the water you might see a dim red line where the laser beam goes through the water. The bright spot on the paper is actually just red, the white spot in our picture is caused by overexposure.
3. Add a small amount of milk and stir until it is mixed. If you hold the laser so that the beam passes right below the surface you should be able to see where the beam goes.
   and added 1 cc of vitamin D milk.
4. Add more milk and see how the light pattern changes.

5. Scattering Measurement:

Repeat steps 1- 4 and replace the white screen with a camera to capture images.



Research Set up that will be modified for the classroom

Cleanup :

- Students turn off all lasers
- Students return all used solution to designated containers
- Students return aprons and goggles
- Students clean tables

Student Worksheet 1: Milk Solution Absorbance Worksheet 1

Lasers: (wave length)

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1, 1 ml solution				
Beaker 2, 2ml solution				
Beaker 3, 4 ml solution				

Worksheet 2: Rodamine dye/Absorbance

RODAMINE DYE/ Absorbance Worksheet

Lasers: (wave length)

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1, 1 ml solution				
Beaker 2, 2ml solution				
Beaker 3, 4 ml solution				

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Worksheet 3: Salt/ Absorbance

MILK SCATTERING

Lasers: (wave length)

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1, 1 ml solution				
Beaker 2, 2ml solution				
Beaker 3, 4 ml solution				

RODAMINE SCATTERING

Lasers: (wave length)

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1, 1 ml solution				
Beaker 2, 2ml solution				
Beaker 3, 4 ml solution				

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SALT/ SCATTERING

Lasers: (wave length)

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1, 1 ml solution				
Beaker 2, 2ml solution				
Beaker 3, 4 ml solution				

STUDENT WORKSHEET- LESSON REVIEW

All About Light—Notes Outline

The speed of light is _______________ in space. In glass, light slows down to ______________.

Light wave wavelengths go from about ______________ to about ______________ in length.

A nm, ______________, is ______________ meter, which is one ______________ of a meter.

When light strikes an object, it will do one of several things:

1. It can be ______________; it is ______________ to the object (mainly as ______________).
2. It can be ____________________, meaning it ______________ the object.
3. It can be ____________________, or _________________ the object.

______________ objects ______________ allow light to pass through; they ______________ or ______________ it all. ______________ objects can be seen ______________, but not ______________; they ______________, ______________ and ______________ the light.

______________ objects allow ________ of the light to __________, so they can be seen through ______________.

White light is made up of ______________________________. A _______________ splits the light into its ________________________ colors.

We see the color of light that is being _______________ by an object.

A blue object is _______________ blue light and _______________ all the other colors. A black object absorbs _______________, and reflects _______________. A white object _______________ all light and _______________ none.

The three ____________________ colors of light are: _______________, _______________ and _______________.

Light and Reflection

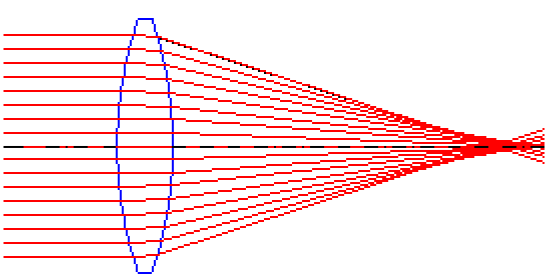
_______ types of reflection of light:

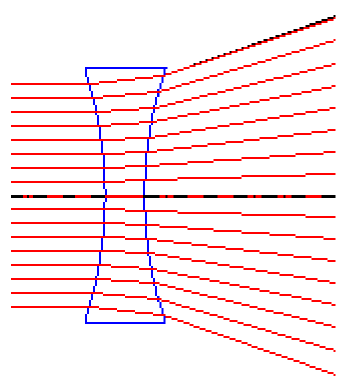
- _____________ diffusion occurs when light strikes a _____________ surface causing you to see an _____________ on the surface because most or all of the reflected light _____________ your eyes. Example: a _____________ displays regular reflection, and with a _____________ (flat) mirror, you see an _____________, _____________ -size image. Curved mirrors change the _____________ of the image.
- With _____________ reflection, a _____________ surface _____________ the light in many different _____________ so that not all of it reaches your _______, and you _______ see a reflection.

Light and Refraction

Light _____________ as it goes from space into air, water, or solids. Why? Because the _____________ get in the way.

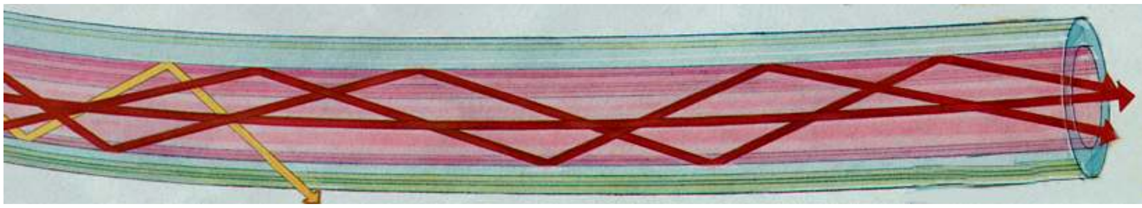
A _____________ is a clear, curved _____________ object used to bend light. ➘_____________ lenses _____________ light and can form an _____________.





______________ lenses ______________ light rays. ⬉

When light strikes a boundary between two _____________ materials at the correct _____________, all the light gets _____________. This is called total _____________ reflection and it is how _____________ work. It allows the _____________ of light to travel great _____________ over _____________ paths. ➜



Lasers

The word "lasers" stands for "light ___________ by stimulated ___________ of ___________." Lasers use ______ wavelength of light so that all the ___________ and ___________ line up. Because they are all lined up, they do not ___________ with each other and ___________ the light out like white light.

Students Worksheet- Lesson review Answers

The speed of light is 300,000 km/s in space. In glass, light slows down to 197,000 km/s.

Light wave wavelengths go from about 400 nm to about 700 nm in length.

A nm, nanometer, is 1×10^{-9} meter, which is one billionth of a meter.

When light strikes an object, it will do one of several things:

4. It can be absorbed; it is transferred to the object (mainly as heat).
5. It can be reflected, meaning it bounces off the object.
6. It can be transmitted, or go through the object.

Opaque objects do not allow light to pass through; they absorb or reflect it all. Translucent objects can be seen through, but not clearly; they absorb, reflect and transmit the light.

Transparent objects allow almost all of the light to pass through, so they can be seen through clearly.

White light is made up of all the colors of the rainbow. A prism splits the light into its component colors.

We see the color of light that is being reflected by an object.

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A blue object is reflecting blue light and absorbing all the other colors. A black object absorbs all light, and reflects none. A white object reflects all light and absorbs none.

The three primary colors of light are: red, green and blue.

Light and Reflection

Two types of reflection of light:

- Regular diffusion occurs when light strikes a smooth surface causing you to see an image on the surface because most or all of the reflected light reaches your eyes. Example: a mirror displays regular reflection, and with a plane (flat) mirror, you see an upright, same-size image. Curved mirrors change the shape of the image.
- With diffuse reflection, a rough surface scatters the light in many different directions so that not all of it reaches your eyes, and you do not see a reflection.

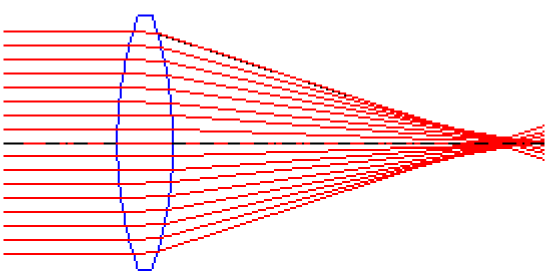
Light and Refraction

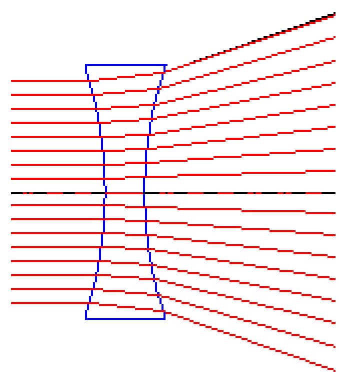
Light slows down as it goes from space into air, water, or solids.

Why? Because the atoms get in the way.

A lens is a clear, curved transparent object used to bend light.

Convex lenses converge light and can form an image. ↙





Concave lenses diverge light rays. ↖

When light strikes a boundary between two transparent materials at the correct angle, all the light gets reflected. This is called total internal reflection and it is how fiber optics work. It allows the transmission of light to travel great distances over curved paths. ↓

Lasers

The word “lasers” stands for “light amplification by stimulated emission of radiation.”

Lasers use one wavelength of light so that all the crests and troughs line up.

Because they are all lined up, they do not interfere with each other and spread the light out like white light.

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