The Art and Science of Light
An Interdisciplinary Teaching and Learning Experience

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Supplemental Material, Section 1:
A worksheet for students on the properties of light

Work Sheet on "The Properties of Light"

We are going to discuss the following properties of light waves.

- Wavelength
- Wavenumber
- Frequency
- Energy
- Speed

Wavelength (λ):

The wavelength of a wave is its peak-to-peak distance. Actually it is the distance between any two identical points of a light wave. Units of wavelength are units of length (meters, inches, feet, centimeters, millimeters, nanometers etc.)

The prefixes used in the SI system of units

Prefix	Symbol	Meaning	Exponential Notation
exa	E	1,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
-	-	-	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro		0.000001	10^{-6}

nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}

For visible light we will use nanometers (nm) for the unit of wavelength.

- Draw a picture of a light wave and show its wavelength on the picture.

Wavenumber $(\bar{\nu})$:

The reciprocal of wavelength is called wavenumber.

$$\bar{\nu} = \frac{1}{\lambda}$$

Therefore units of wavenumber is 1/units of length (m^{-1}, nm^{-1}, cm^{-1}, $inches^{-1}$ etc.)

Frequency (ν):

Frequency is the number of cycles per second. Units are s^{-1} also known as Hertz (Hz).

Energy (E):

Light waves pack energy. Units of energy are Joules (J), kilocalories (kcal), calories (cal).

Speed (c):

Speed of light is defined as 2.99792458×10^8 ms^{-1}.

$$c = 2.99792458 \times 10^8 \ ms^{-1} \qquad c \approx 3.0 \times 10^8 \ ms^{-1}$$

The above properties of light are related to each other by the following three equations.

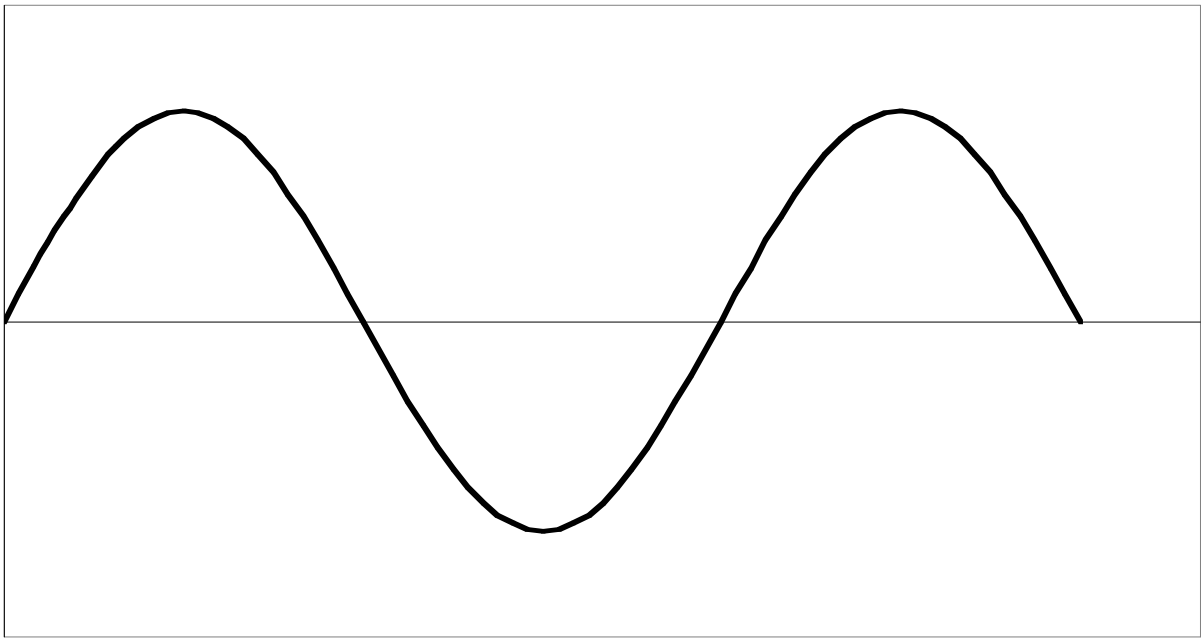
$$E = h\upsilon$$
$$c = \upsilon\lambda$$
$$\bar{\upsilon} = \frac{1}{\lambda}$$

h = Planck's constant = $6.6260755 \times 10^{-34}$ Js

THESE ARE VERY IMPORTANT EQUATIONS IN THE STUDY OF LIGHT.

Let us solve some problems and get familiar with using these two equations and the properties of light.

1. Use a ruler and measure the wavelength of the following wave in centimeters.



2. On top of the above light wave, draw another wave of half the wavelength and twice the amplitude. Label it “new wave”. Use a colored pencil.
3. On top of the above light wave, using a different color, draw another wave of half the frequency and the same amplitude. Label it “second new wave”.
4. How long does it take light to travel 1.5 km?
5. A radio signal takes about 2.5×10^{-3} seconds to travel from Boston to Washington D.C. Calculate the distance between these two cities.
6. A student is 5.25 feet tall. What is this height in meters, millimeters and nanometers? Which of these units is more sensible to use to measure a person’s height? (1 inch = 2.54 cm)

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Supplemental Material, Section 2:
Five "Mini-Labs"

Using the Filtergraph (20 minutes)

Work in groups o f 4

Turn on the filtergraph. Place a card on the filtergraph and look at the output. Draw a picture of this out put (what you have is a graph of transmittance versus wavelength). Draw to scale and be sure to write down the names of the axis of the graph with units. Next to the graph, write down the color on the card.

1. Repeat the above process with all the available cards. There are 9 different cards.

Homework:

2. Based on the above lab experience and the wavelengths of the visible light spectrum given below (see table below), write your own definition for "transmittance". Using the library as a resource, write a definition for "transmittance" (be sure to write down the reference you used in your lab notebook). Are there any differences between your definition and the printed definition? Discuss if any. Work with your lab team.
3. Using the library as a resource, write a definition for "absorbance". Work with your lab team.
4. Write a paragraph describing the difference between transmittance and absorbance. Work with your lab team.

The following wavelengths for the colors in the visible spectrum are provided for your reference. Please note that these are approximate values and not absolute values.

Color	Wavelength (nm)
Violet	420
Blue	470
Green	530
Yellow	580
Orange	620
Red	700

Using the Singerman Color Apparatus (15 minutes)

Work in groups of 4

In this mini-lab you will be mixing different colors and observing (with your eyes) the resulting color.

1. Turn all three lamps in the color apparatus. Insert red, green and blue color cards into the slits of the color apparatus.
2. Observe and record the individual colors with your naked eye. Also record the additive colors where two or three different colors overlap.
3. Change the intensity (there is an intensity knob on the color apparatus) of the lights and see how it affects the colors. Record your observations.
4. Repeat the above process with other color combinations. Record all observations (time limit 15 minutes).

Using Slide Projectors for Color Addition (15 minutes)

Work in groups of 4

1. You are provided with three slide projectors. Using different color slides in each one, project the images on to the wall. Record the colors.
2. Now project all three images onto one spot and see the additive color. Record your observations.
3. Use as many color combinations as time permits (time limit 15 minutes).

Using the Monochromator with white light source (20 minutes)

Work in groups of 4

Turn on the white light source. Narrow down the slits (there are two of them) so that you see a narrow, clear beam of light coming out from the monochromator. Change the wavelength dial on the monochromator and see the color of the output beam. Can you assign a wavelength (or a wavelength range) to each of the seven colors of the visible spectrum? Record your observations.

Using hand held spectrometers (30 minutes)

Work in groups of 2

You are provided with the following light sources at 5 different stations.

- White light
- Red helium-neon laser
- Green helium-neon laser
- Sodium lamp
- Neon lamp

1. Draw a sketch (naked eye observation) of each one of the light sources. This should be a rough sketch and not an artistic drawing (you may use colored pens).
2. Use hand held spectrometers to look at these light sources one at a time. For each light source, draw a picture of your observations. (Use color in your picture. Colored pens are provided at each station).
3. Be as specific as you can and record the wavelength (read from the hand held spectrometer) of each color you observe.