**Lab Journal 1 (12%)**

**(Khai Pan, Viktor, Yaroslav)**

**Exploring the Wave Nature of Light**

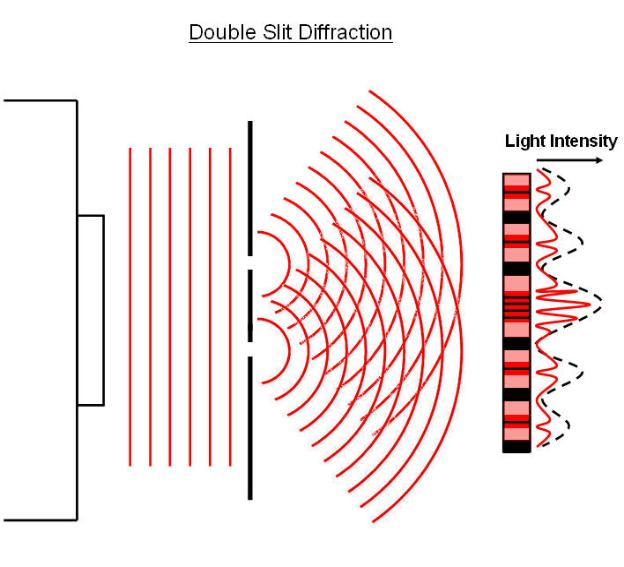
In Lab 1 you will review the ideas introduced throughout the centuries to explain observed light phenomena. You will analyze the reasons for suggesting each model and the ways to test it. You will perform interactive numerical experiments and observations and analyze them. You will also discuss practical applications of the observed phenomena.

**Part 1. Development of models about the nature of light (20 pts.)**

What is the nature of light? Is it rays, waves, or particles? Write a brief review of the development of models of light from Antiquity to Modern Times. In your work, consider the contributions of at least 4 researchers and explain the reasons (observations and/or experiments) for suggesting the models. Analyze how the model was tested. If testing was not possible at the time – how it was tested later: what the expectation was, what the observations showed, and which model of light was supported by the test results. In conclusion, state the modern understanding of the nature of light and the phenomena in which each of the models is applicable.

The definition of light refers to the transverse wave, which is an electromagnetic wave that can be seen by humans, including diffraction, which is basically a change of direction and curving of light rays diffracting of sharp objects. Light can be formed in many ways by rays, waves, particles, but most of the time, we see the light as waves and particles of matter. Light rays usually originate from the sun. Wave has a wavelength, which is a measure of the distance that light can travel in one oscillation or from crest of a wave to the following crest.

1. **James Clerk Maxwell (1831-1879):** Some 150 years ago, Scottish physicist James Clerk Maxwell experimented with light and concluded that power, magnetism and light are three distinguished characteristics of one wonder, named electromagnetism (Waldrop 289). Maxwell also discovered that light is a type of electromagnetic wave, in which later on, electromagnetic particles of wave as a component of light play important roles in our lives, even today. For instance, frequency used for radio, ultraviolet and gamma rays for X-ray, microwaves for phone’s signal, and much more. Each of these applications have been developed by different scientists, but overall, Maxwell was the person who discovered some of the modern uses of electromagnetic waves. The reason our group chose this experimentation because we found out that electromagnetic waves play a massive role in our everyday lives today and have been implemented in such current technologies as radio, microwaves, telephone communication, and much more. It is worth for us to know more about this.
2. **Galileo Galilei (1564-1642):** There were numerous scientists trying to figure out what is the fastest thing on the planet and an Italian scientist Galileo Galilei found out that it is the speed of light. The physicists cannot measure the exact speed of light as they believe it is too fast for any human reaction, however it is limited by a certain speed. The problem is that those experimentalists did not have the technology at that time to measure such speed. Furthermore, we have to thank Galilei for his development of the hypothesis that allows for the complex calculation of the speed of light that has an approximate velocity of 300000 km per hour, and once again, this is just an estimated measurement. The biggest achievement that Galileo Galilei accomplished was that he predicted that the speed of light in fact had the fastest velocity on the planet. Many physicists before Galilei have unsuccessfully tried, even used broad experiments such as calculating the time that light travels from Jupiter to a predicted point (just like the light we see from a star is the light that travels a few days before it reaches Earth). The reason our group chose this finding because we are as, human kind, only able to measure the fastest unit, which was speed of light as Italian physicist discovered. Of course, there could be something else faster, just we don’t know about it yet. Light was the basic measurement for most of the speed, velocity, and distance at that time.
3. **Thomas Young(1773-1829):** Young is well-known for his double-slit experiments, also known as diffraction of light. Young figured out that light travels in a straight line if there are no obstacles and its constant wavelength just keeps moving straight. However, whenever there’s an object, or let’s say a double-slit metal piece, light rays will diffract right after it passes the metal piece (image below). Since then, light ray will change its direction and produce light waves, which will bend outwards more after passing through two-slit openings, thus forming some type of curved wave and resulting dots of light will get darker in the middle and begin to shadow as light ray spreads more to the left and right, forming darker and brighter bands of light (dark light depends on the distance between the slits). This fascinating scientific discovery made by English physicist, Thomas Young, in 1801, became known as Young’s double slit experiment (“Thomas Young's Double Slit Experiment.”). The reason we chose this interesting experimentation because it is important to understand the outcome of light rays passing through dual-slit surface and its consequent diffraction or bending, thus creating a structure very similar to a wave. This experiment showed that light in fact had a wave-like nature and this discovery was huge compared to previous experiments and knowledge of the properties of light.



1. Albert Einstein (1879-1955): After series of experiments with light, A German theoretical physicist, Albert Einstein, determined that light played a critical role in the arrangement of the Universe. Einstein concluded that light was associated with matter, energy, time, and space. Upon numerous tests, the brilliant German realized that the mass of the object becomes heftier as the object gets closer to the speed of light. Therefore, as the object gets further away from the speed of light, its mass turns out to be less hefty. In edition, Einstein stated that light had elements of matter, which consisted of proton, neutron, and electron. Einstein also discovered that light was composed of small light particles, called photons, which in turn had energy. Einstein established the relationship between light’s energy and its wavelength (the distance from crest to the subsequent crest of a wave). The energy was inversely related to the light’s wavelength; hence German physicist’s conclusion was made. Einstein indicated that the smaller the wavelength of a light wave, the bigger its energy (“The Modern Theory of Light.” Sciencing, sciencing.com). Those discoveries that were made by Einstein in 1905 - became the foundation of modern theory of light. Some of the Einstein’s revolutionary hypotheses and theories even hold true, nowadays.

**Part 2. The double-slit experiment (14 pts.)**

Use the following interactive computer animation of interference of light from two small slits: <http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Youngs-Experiment>

**Describe** the experimental setup to observe interference of light: state the parameters that can be varied and the range of values for each variable, as shown in the app.

This setup consists of a laser, apertured plate and screen.

Parameters: laser color (red, green, blue)

slit width (0.00025-0.0005m)

screen distance (2.45-5.93m)

**Observe** and describe the effects of each variable on the interference pattern. **Explain** the observed effects, having in mind the approximate formula for positions of interference maxima yn:

, where n = 0, 1, 2, … are the orders of interference maxima.

When we decrease slit separation, increase screen distance or increase wavelength, distance between maximums increases. If we do the opposite, distance between maximums decreases. (because y=nλL/d. That is, distance between maximums is in direct ratio to the wavelength and distance to the screen, but in inverse ratio to the slit width)

**Discuss** possible sources of inaccuracies in the measurement and ways to improve the precision of your measurements.

1) It’s hard to measure distance to interference maxima correctly because it is small. To improve precision we can use, for example, the 5th maxima instead of the 1st.

2) Slit width is also small and hard to measure.

**Collect data** in the table below (or draw another table, showing all necessary data). For each set of 3 wavelengths choose a slit separation and distance to screen (the app offers several possible values). Measure the distance between the central and the first order maximum, and calculate the wavelength λ in nanometers. Repeat two more times with different values of d and L. It is convenient to do this in an Excel spreadsheet, where you can insert the formula with correct conversion of units and quickly calculate the wavelengths.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Laser Light** | Slit separation, d (m) | Distance to screen, L (m) | Measured position of y1 (m) | Calculated wavelength, λ (nm) |
| Red | 0.00025 | 2.45 | 0.0066 | 673 |
| Green | 0.00025 | 2.45 | 0.0054 | 551 |
| Blue | 0.00025 | 2.45 | 0.005 | 510 |
| Red | 0.0005 | 2.45 | 0.0033 | 673 |
| Green | 0.0005 | 2.45 | 0.0028 | 571 |
| Blue | 0.0005 | 2.45 | 0.0025 | 510 |
| Red | 0.0005 | 5.93 | 0.0092 | 776 |
| Green | 0.0005 | 5.93 | 0.0072 | 607 |
| Blue | 0.0005 | 5.93 | 0.0065 | 548 |

For each colour find the average of the 3 wavelengths determined in the experiment, and round them off to the nearest integer. Enter their values in the interactive app to get feedback.

Results:

Red laser light λ = 707 nm

Green laser light λ = 576 nm

Blue laser light λ = 523 nm

**Part 3. Polarization of light. (5 pts.)**

Write a paragraph explaining what polarization of light is, and what it means for the nature of light. Describe two cases of polarization of light seen in nature, or produced by technology. Explain the mechanism of polarization in each case. Give one example of a practical application that uses polarization of light.

Polarization of light is the process of ordering the oscillations of the vector of intensity of the electric field of a light wave when light passes through some substances (in refraction) or when a light flux is reflected. Polarization is possible only in the transverse waves. So, polarization of light is a proof of the wave nature of light. Transverse wave is described by 2 directions: wave vector and amplitude vector (they are perpendicular to each other).  
Polarizer is a substance or device serving to convert natural light into a plane-polarized. Passing through the polarizer unpolarized light gives part of the energy of the electromagnetic wave to the atoms of the polarizer. That is, part of the energy of wave is left in the polarizer and energy of the resulting wave is less than the energy of an initial wave. Polarizer can be used to absorb unwanted wave.  
If we look through a polarizer at a clear blue sky at about 90 degrees from the direction to the Sun, that is, the Sun was on the side, and while the filter turns, it is clearly visible that at some filter position in the sky a dark bar appears. It means that light coming from that part of the sky is polarized. It is polarized because it has reflected from the air molecules and refracted in droplets of water.  
When the light is reflected, polarization also happens. One part of the light is reflected. Another part of the light is refracted and then reflected from the back of, for example, puddle and again refracted from the front of the puddle. That is, the reflected from the puddle light is polarized. Photographers use polaroid filters to eliminate glare.

Sources:  
https://en.wikipedia.org/wiki/Polarization\_(waves)#Transverse\_electromagnetic\_waves  
Physics in the arts. Gilbert, P. and Haeberli W. Section 1.3 Polarization

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**Part 4. Doppler Effect of Light. (5 pts.)**

All waves show Doppler effect, when the source of waves moves in respect to the observer. How is this effect observed in the case of light waves? Search for information about Doppler effect of light observed from various objects in nature. Write a paragraph explaining what is detected and how the results are interpreted.

* Doppler effect of light is basically the relationship between light wave wavelength, frequency, distance, and intensity between light waves and observer, as well as light waves and a moving object. In simple terms, whenever a wave of light, released by moving object, nears an observer or any person, the light wave’s frequency increases as the distance or wavelength shortens. Vice versa, whenever a moving object gets further away from an observer, the light wave’s wavelength increases, therefore; its frequency and strength decreases. Some of the examples of such Doppler effect of light would include the pitch of sound created by speeding ambulance or police cars getting closer to an observer, which was caused by a higher frequency of light waves (Grant 10). Policemen using radars that clock speed to catch violators of speed limits on the road, as well as on highways would represent some of the modern applications of Doppler effect (Grant 10).

At the end show your reference sources under **Works Cited in** [**MLA format**](https://seneca.libguides.com/c.php?g=498632&p=3414031)**.** **(1 pt.)**

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**Total: / 45 pts.**