Photography of Physics

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by

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Abstract

The purpose of this research is to provide a visual aid in teaching physics, especially more difficult concepts, in order to make physics more accessible to non-physics communities. Using photographs and videos of simple physics experiments, the project aims to make aesthetically pleasing visual aids. The images and videos were manipulated through the use of editing software in order to make the concept behind the experiment more obvious. The thesis work explored eight different projects: single lens imaging, photography of cold atoms, a water optical fiber, refraction of light by a prism, benchtop cloud chamber particle tracks, multi-source laser interference, astrophotography, and fluorescence of olive oil. These images can be used to assist in the education of physics by creating a real world, visual representation of more abstract concepts.

Chapter 1

Introduction

When learning physics, abstract concepts can often be confusing and difficult for most people to understand. The application of formulas and equations is often demonstrated through the use of diagrams in an attempt to improve understanding, however, these diagrams can often be just as abstract as the concept itself. The purpose of this research is to go one step further in providing a visual aid for physics concepts through the use of photography. Different experiments were set up and conducted, and their results were photographed. These photographs were then manipulated either in the process of taking the photograph or afterwards in photo editing software such as Adobe Photoshop. Theses manipulated images demonstrate the concepts in a more accessible way by providing real world visuals using objects and environments that people are familiar with. These photographs will help make physics more accessible to the everyday person and assist in educating people about physics.

In addition to demonstrating concepts, an important aspect of this research is art. One of the main goals is to not only provide examples but to make the photographs as aesthetically pleasing as possible. People are drawn in by images that they find to be attractive or pleasing to the eye. If a photograph is messy and not well composed, people will tend to ignore it or move on quickly from it. The photographs for this research will be more effective when the art component of photography is combined with the capabilities of photography to capture images.

This research is influenced by the ideas of Eric J. Heller, a physics professor at Harvard University, who paints using electron flows. Professor Warren Buck in the physics department at William and Mary brought Dr. Heller's work to my attention in the early weeks of forming this research. His work is a combination of physics phenomena and art to create beautiful images of what he is researching.

Before describing the experiments, it is important to understand how a camera works. A camera is composed of a series of lenses and mirrors. The light that the camera takes in is refracted and transmitted through these lenses until it reaches the shutter. The shutter is a piece of plastic that can open and close based off the position of the shutter release button located at the top of the camera. If the shutter is open, the light passes through until it hits a sensor. This sensor gathers data to produce the image that one sees on the screen of the camera. If the shutter is closed, no light can pass. By leaving the shutter open for longer periods of time, it allows more light to pass through, which is referred to as a long exposure photograph.

Another important control on a camera is the f-stop. This controls the aperture of the camera. In an imaging system, the f/# (=focal length/ lens diameter) refers to the effective size of the lens relative to how far away the object is. This can be adjusted on a camera by manipulating the f-stop. The focal length is usually constant when using a prime lens, however it can be changed when using a variable lens. The aperture controls how much light is let in. This is what changes as the f-stop changes. Essentially, changing the size of the aperture effectively changes the lens diameter. The smaller the aperture, the less light is let in, the larger the f/#. This change also affects the depth of field, i.e. the range of distances over which an object remains in focus.

The smaller the aperture, the larger the depth of field. As the aperture increases, more light is let in, reducing the f/# and decreasing the depth of field.

This research focused on the following experiments: single lens imaging, photography of cold atoms, a water optical fiber, refraction of light by a prism, benchtop cloud chamber particle tracks, multi-source laser interference, astrophotography, and fluorescence of olive oil. These experiments will be discussed in detail below.

Chapter 2

Ray Optics “Diagram” Experiment

One of the more fundamental concepts in physics that is encountered everyday is how a light beam interacts through a lens to create an upside down, backwards image of an object. This concept is taught in classes through the use of ray diagrams (see Figure 1). Students learn to draw an arrow pointing up for the object and an arrow pointing down for the image. They learn how to draw the path of the light beams in order to determine where the image will form based off where the paths cross. However, these ideas are fairly abstract, considering the eye cannot see the actual path of light like one can see it in a ray diagram. This experiment focused on making that light path visible in a photograph so students could see how ray diagrams transfer into a more concrete scenario.

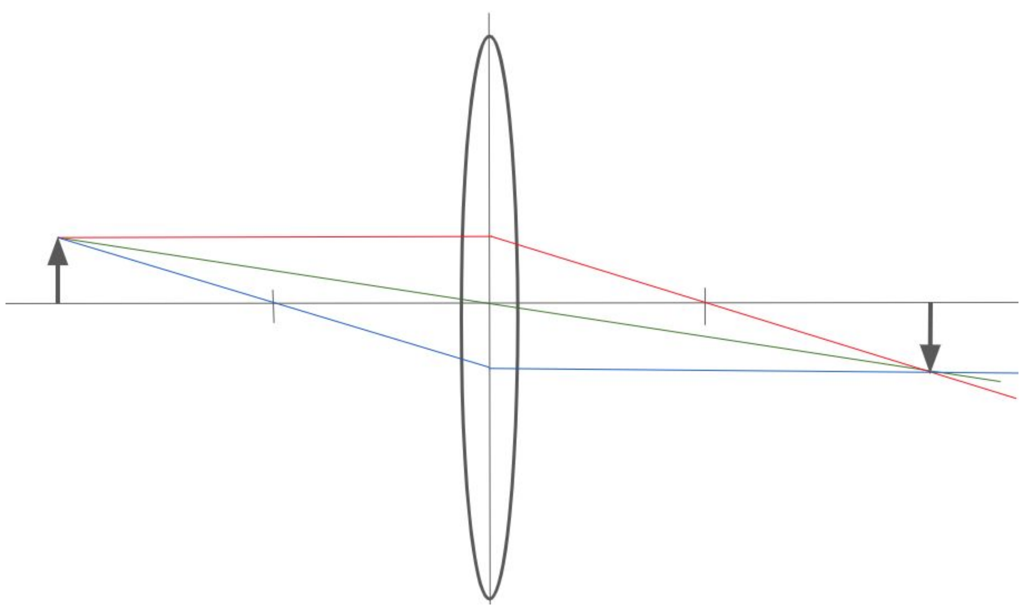


Figure 1: Ray Diagram

These photographs, in providing an example, will help further understanding of the physics concept and make physics more accessible to the general public. The experiment involved three different methods before achieving the final photograph: following the trajectory of light from a flashlight with a cardboard screen, scattering light with water mist and liquid nitrogen mist and finally using laser light produced by a diffuser. The laser through a diffuser proved to be the most successful method for capturing the path of light through the lens. First, the experiment was set up. There were two different setups used, one with a flashlight and another with a laser.

2.1 Flashlight Method:

For the first experiment (see Figure 2) a piece of paper was taped to a stand with the word "yes" written on it. Approximately 26 cm away from this piece of paper was a lens. A flashlight was placed at the base of the lens and shined towards the piece of paper. On the other side of the lens at a distance of 26 cm as well, a cardboard box was used as a screen.

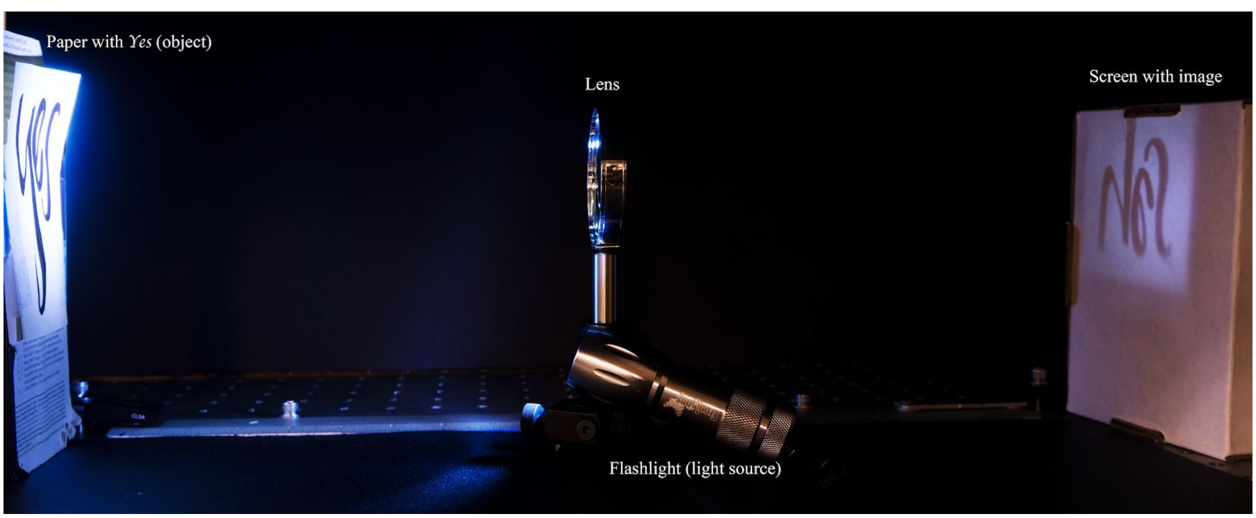


Figure 2: Flashlight set up- a flashlight is placed at the base of the lens and points in the direction of the word "yes"

Moving Screen Scheme:

The next step was to capture the light beam as it traveled out from the flashlight to the piece of paper, through the lens, and converged on the screen. The first method attempted was to use a long exposure, opening the shutter of the camera for an extended period of time, and following the path of the beam with a cardboard screen. The light would reflect off the cardboard and as the cardboard was moved, the camera would capture the path of the light. This method was only successful from the flashlight to the piece of paper. The reflected path from the "yes" paper to the cardboard could not be picked up with the long exposure on the camera.

Water Mist Scheme:

The second method was to use water mist along the path of the beam. Ideally, the light would reflect or scatter off the water droplets and be captured in a long exposure shot. A spray bottle was filled with water, which was sprayed from the flashlight to the piece of paper and from the lens to the cardboard screen. The experiment was moved outside of the lab so that the other optics equipment would not be damaged. This method faced similar problems as the first. The mist would only capture the light from the flashlight to the piece of paper.

Liquid Nitrogen Scheme:

The third method involved the use of liquid nitrogen. A bucket was filled with liquid nitrogen. Using a styrofoam cup and glove, the liquid nitrogen was scooped from the bucket with the cup and slowly poured out along the path of the light. The camera was set up a safe distance away and set to bulb mode, a way to manually open the shutter by holding down the shutter release button, for a continuous long exposure. As shown in figure 3, the liquid nitrogen caught the path of the light from the flashlight to the piece of paper and nothing else, similar to the other methods. This method, however, was more successful than the others, resulting in the most illuminated beam.

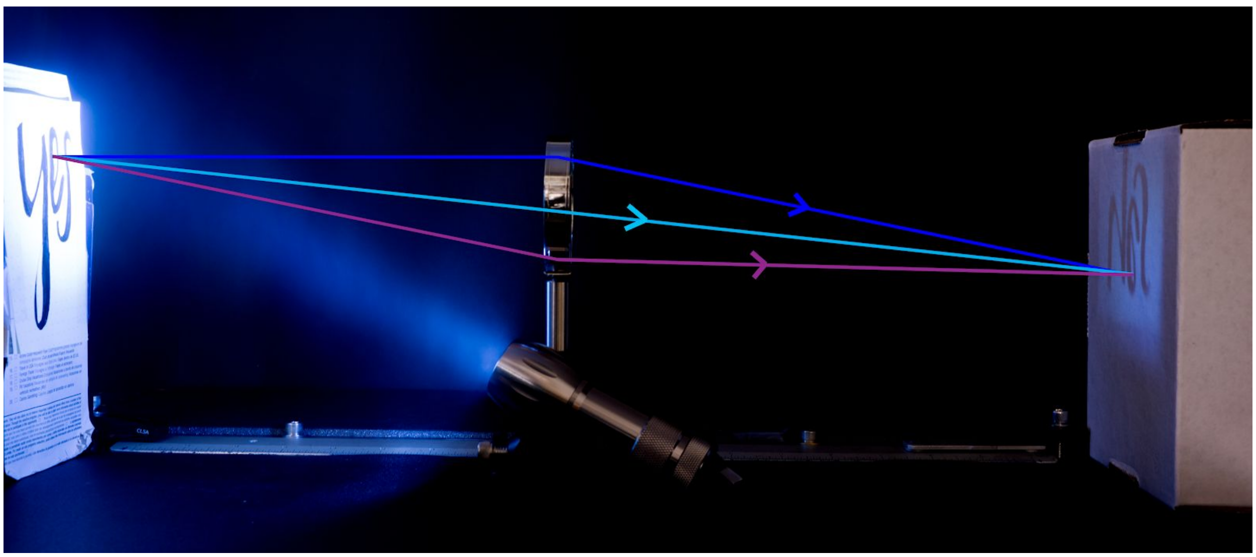


Figure 3: Liquid Nitrogen Method with Rays Drawn In

<u>2.2 Laser Method:</u>

The next method was to switch from a flashlight as the light source to a laser. A red He-Ne laser (632 nm) was set up on one side of the lens (see Figure 4).

Figure 4: Laser Set Up. A laser is pointed through two diffusers and through a lens and appears on the screen

First, the laser light is directed through two diffusers. The first diffuser was placed approximately five to ten centimeters away from the laser source, on top of a stack of books so that it was level with the laser. Two to three centimeters away from the first diffuser was the second diffuser. On this diffuser, an aluminum foil and post-it note were attached using tape. The aluminum foil was smoothed out and taped to the post-it note. The aluminum foil completely blocks any light incident on it, while the post-it note paper provides a writing surface and some stiffness. Then using a small knife, a capital "L" was cut out of the two. This "L" was centered on the diffuser to allow the most laser light to pass through it. The lens was placed roughly 26 centimeters away from the laser and the screen was placed another 20 centimeters away from the lens on the other side. When the laser was turned on, an upside down and backwards "L" appeared on the screen. The next step was to find a way for the beam to appear. This was achieved using a hand held cardboard screen with a yellow piece of paper taped to it. Ultimately, a black paper did not reflect enough light for a successful photo and a white paper would occasionally leave streaks of its appearance on the long exposure. The yellow paper made for a good in between option. The cardboard paper was held and moved back and forth between the lens and the laser. Since this side had a larger distance, it needed a long exposure for the light to appear. The left side, the side with the laser, needed a four minute exposure time. During this time, the cardboard was moved back and forth between the laser and the lens at a speed of roughly four seconds per side. A slower speed did not show up as well and created breaks in the light path. A faster speed did not allow the camera to catch as much reflected light.

On the right side of the lens, between the lens and the screen, the exposure time was less and only required one minute. The distance was smaller on this side, so it required less time. The same method was applied on this side.

Once photos of either side of the lens were captured, the two were merged together using Adobe Photoshop. The laser side exposure photo was used as the base and the screen side photo was cut at the lens and placed on top. The two were then edited to remove any lines or differences in background exposures, with the use of the blur tool as well as increasing contrast and brightness, to create a seamless looking final photograph: the final result is shown in Figure 5.

Figure 5: The Laser Method. The laser beam goes through the diffuser, letter L, and lens to appear on the screen. The beam has been made visible with the use of a hand held cardboard screen and a long exposure.

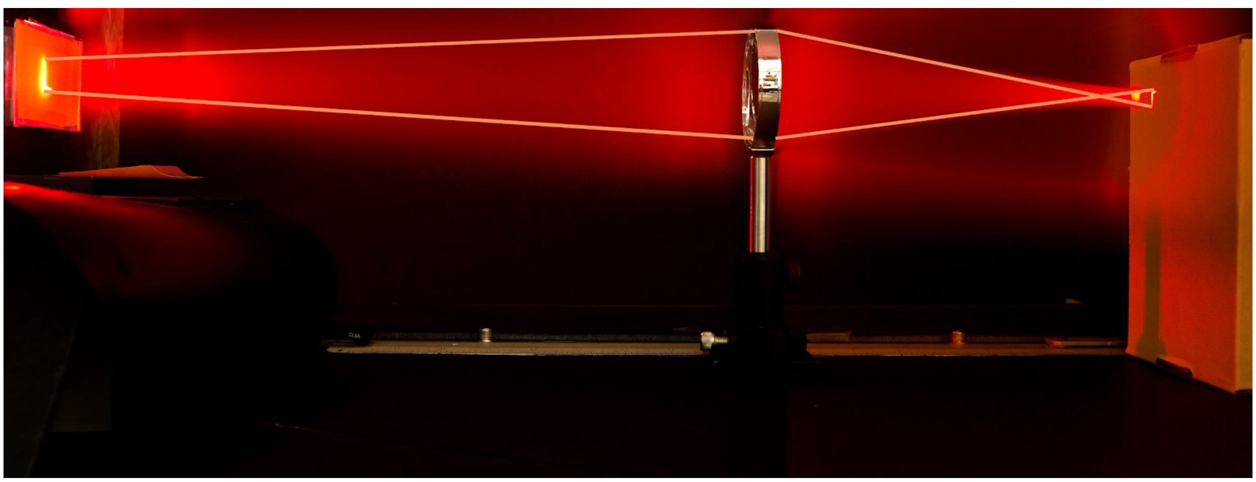


Figure 6: The Laser Method with Light Path Drawn In. Same photo as in Figure 5 but with light paths drawn in.

Figure 7: A demonstration of the forming of the upside down, backwards L

In Figure 6, the drawn in rays show the beam crossing before the L forms on the screen. This is a result of following beams from two different starting locations. If the two beams originated at the same point, then they would cross where the L forms on the screen instead.

Figure 7 demonstrates the focusing and formation of the image on the screen as it moves through space. This image was achieved by taking multiple photographs of the screen at different lengths away from the lens until the backwards, upside down L was focused. These images were then layered on one another, and the spacing was altered to allow each L to fully form. The image was then blurred to remove any lines, the contrast increased and the brightness brought down, to create the illusion of the Ls forming. The Ls photograph was placed on top of an edited version of the right side of the beamforming.

Chapter 3

MOT

The second experiment conducted to demonstrate a concept was the MOT experiment. The MOT, which stands for Magneto Optical Trap, uses three axes with counter propagating laser beams (780 nm) that cool down rubidium atoms in order to reduce their speed, a process known as Doppler Cooling. A purple light (405 nm) is used to expulse rubidium atoms that are stuck to the sides of a glass vacuum system and feed them to the MOT. The atoms then form a ball. They stay in this ball due to the extra force on them from the magnetic coils that surround the glass container.

For this experiment, the goal was to capture an image of the ball of atoms. Different types of cameras were used to experiment with quality of camera versus ability to detect the atoms. Many higher quality cameras have an infrared filters built into the lens system, which make the atoms undetectable to the camera.

The first camera, a Sony A6000, could not pick out the atom, and neither could an old digital camera. The third camera, a Canon XA25, had a switch that could turn infrared on and off. When testing the camera's capability of sensing infrared, it was able to detect the light from a remote control with both the switch on and off, however, when brought back to the lab, the camera was unable to pick up the atoms. Finally, the photograph was captured using a Galaxy S8 camera phone.

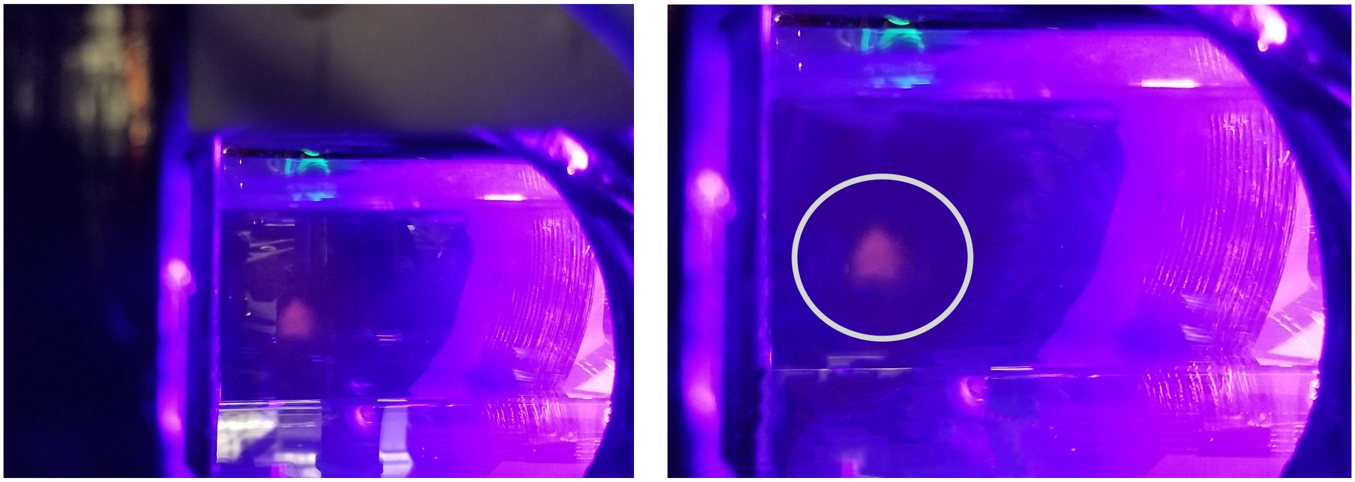


Figure 8: Unedited version of the MOT (left) compared to the edited version of the MOT (right)

Once the photograph was captured, it was edited through photoshop. The process consisted of using a stamp tool to collect color from a nearby pixel and "stamping" it on top of any reflections and distracting aspects of the image. Once the stamp tool was used to minimize distractions, a blur tool was used to remove any obvious lines. The brightness and contrast of the photo were increased as well. Figures 8 and 9 show the difference between the edited versions of the photographs of the MOT compared to the unedited versions of the MOT.

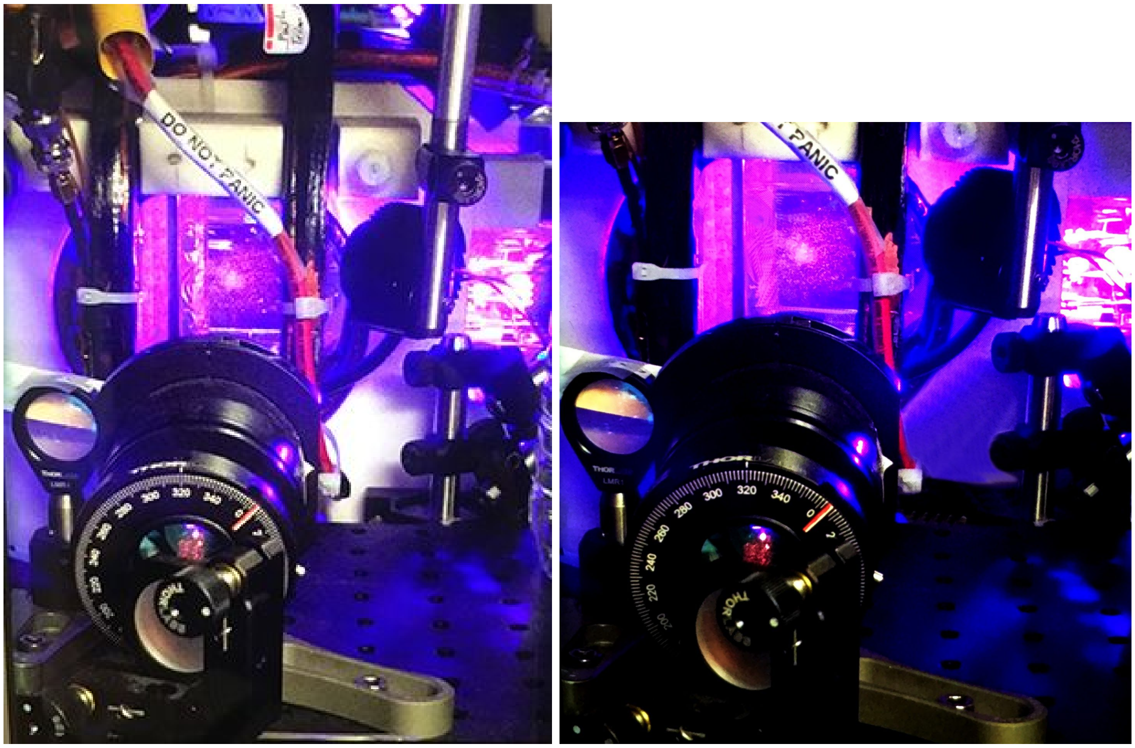


Figure 9: Unedited version of the MOT (left) versus the edited version of the MOT (right)

The next step for this experiment was to try and capture more photographs of the MOT without the purple light on (Figure 10). Another camera will also be tested out to see if the photograph quality can be slightly improved, as well as whether a long exposure photograph can be used to improve the image.

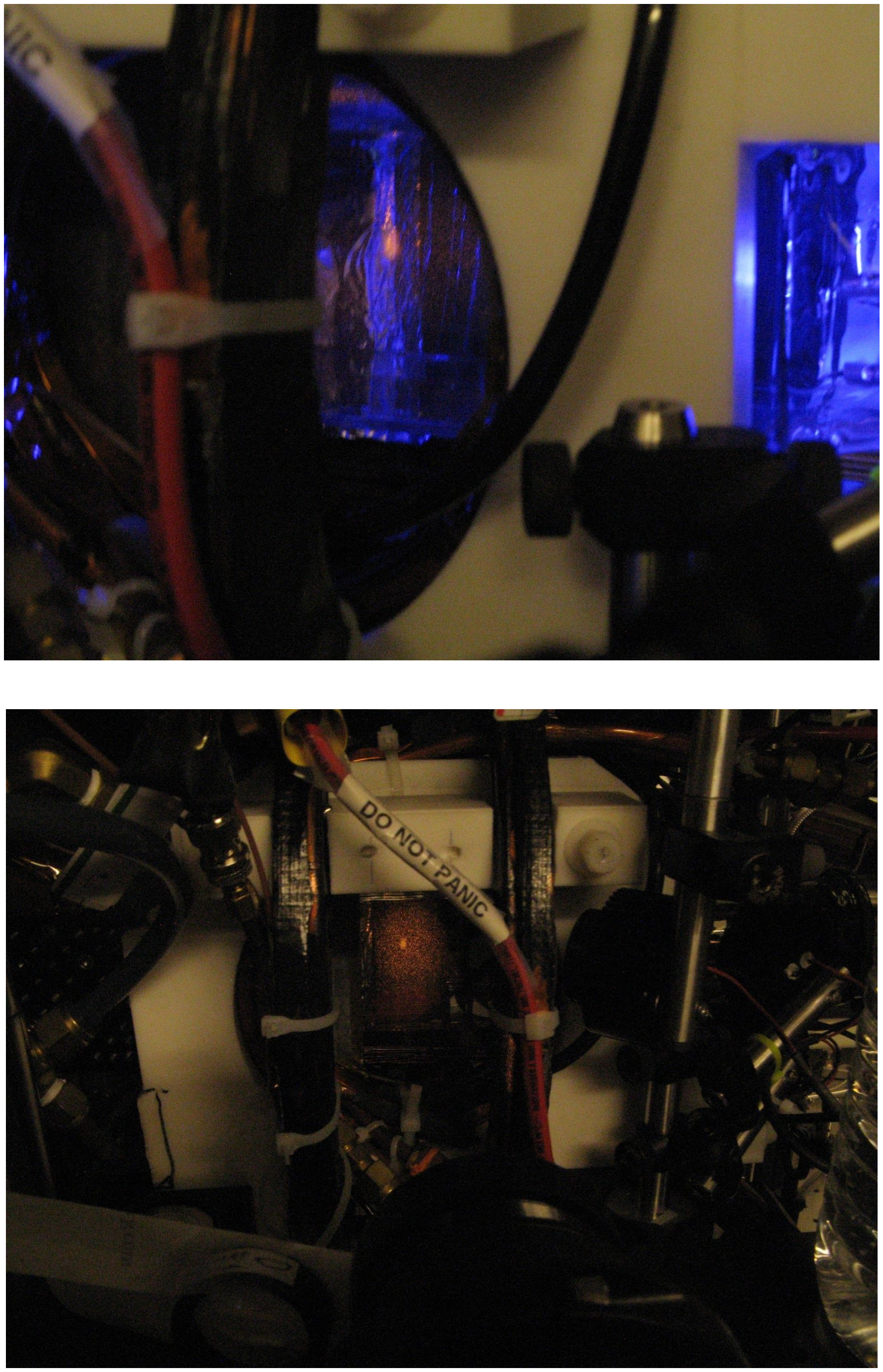


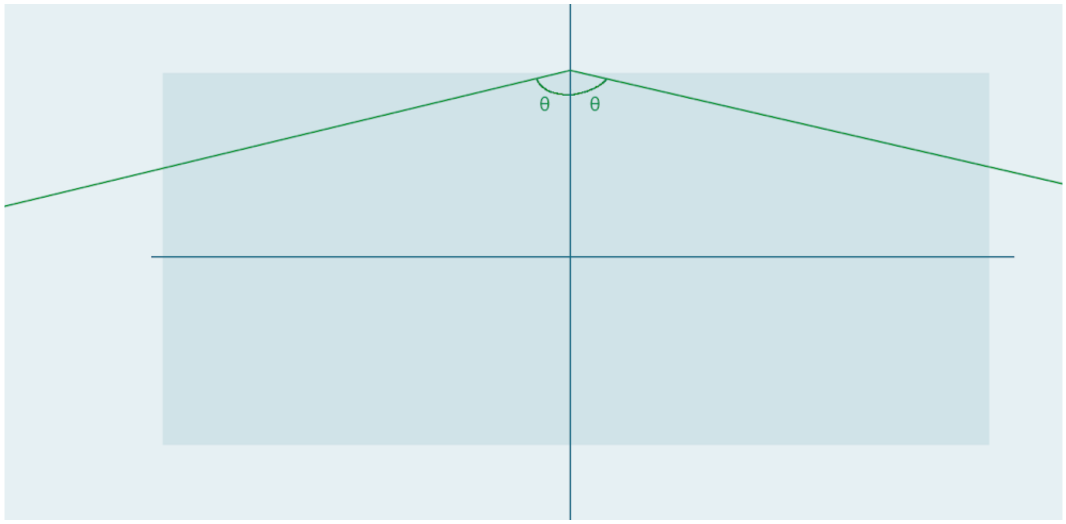
Figure 10: Unedited photographs of the MOT with minimized effects of the purple light (top) and no purple light (bottom)

This experiment demonstrates how filters and types of cameras can change how an image is viewed. Often in physics experiments, our eyes cannot detect what is actually going on in the experiment. Cameras and photography techniques are a great way to capture what our eye cannot see. This experiment helps to demonstrate the concept that while our eyes cannot detect what is happening, things can still be happening as well as how camera quality affects the resulting image.

Chapter 4

Water-based Optical Fiber

The main purpose of this experiment was to demonstrate the total internal reflection of light within the stream of water. Milk was added to the water in order to improve the visibility of the laser light. The photographs show the path of the laser as it bounces through the water. This experiment shows how an optical fiber works. Usually, the cable is made of glass or plastic instead of water, however, the results are the same. Optical fiber cables are used to carry light and information from one place to another and work more efficiently and effectively than metal. The diagrams below (Figure 11) show the physics behind total internal reflection as well as the set up of the experiment. The critical angle for total internal reflection can be calculated using the equation $n_i sin\theta_c = n_t sin\theta_t$ where n_i is the index of refraction of the water and n_t is the index of refraction of the air. The index of refraction of water is 1.33 and the index of refraction of air is approximately 1. For this experiment, the calculated expectation for the critical angle is 48.6 degrees. This angle is the minimum angle to get total internal reflection on the first bounce of the laser off the inside of the tube of water.



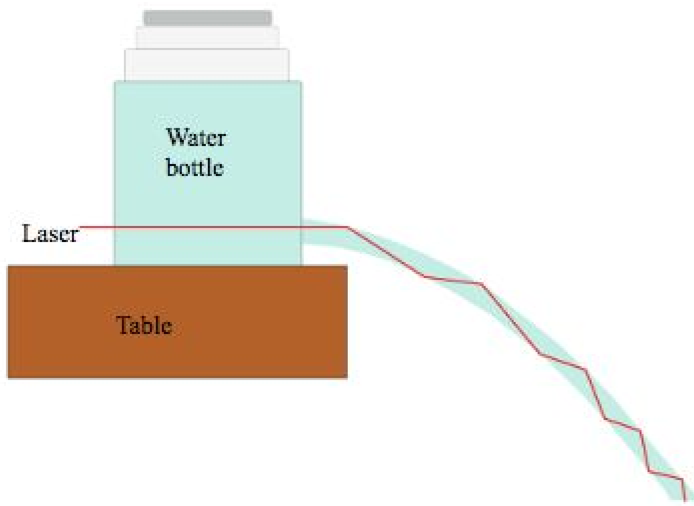


Figure 11: Diagram demonstrating total internal reflection (top) and diagram of the expected results of the experiment (bottom)

The first part of the experimental set up required a water bottle with a hole cut through on side of the bottle towards the bottom. This hole would allow a parabolic shaped stream of water to shoot out of the bottle. The hole was sanded down and cut to maximize the circular shape and smooth the plastic.

Next the experiment was set up on a rolling cart to allow movability of the entire experiment. On the middle level of the cart, a long, empty basin was placed in order to catch the falling water. A pile of books was placed on the top of the container on the side that was under the cart so that the basin would not tip over with the weight of the water. On the top level of the cart, the green laser and the water bottle were placed. The water bottle was placed on a stack of books so that the height of the laser would match the height of the water bottle's hole.

Finally, tape was placed to cover the hole in the water bottle and the bottle was filled with water. A few drops of milk were added to the water in order to improve the visibility of the lase in the water. Figure 12 shows the setup of the experiment.

Figure 12: Setup of Laser through the Bottle with Hole

After the filled water bottle was properly placed in front of the laser light, the tape was removed from the hole. The stream of water with the laser in it was photographed. One of the biggest challenges with this experiment was focusing the camera, adjusting the light settings on the camera, and taking pictures before the water levels became too low and the stream stopped.

Another challenge was finding the proper ratio of water to milk. If there was too much milk in the water, then the laser could not be clearly seen due to the cloudiness of the water. It also became difficult to accurately line up the laser with the hole in the water bottle. If there was not enough milk, then the laser would not have enough intensity to be successfully photographed.

The images were then uploaded into Adobe Photoshop and enhanced. The brightness and contrast were adjusted in order to make the green laser more visible. The final results (Figure 13) show the laser refracting in the stream of light. I have drawn in yellow lines to better show the path of the light in one image. The third image demonstrates the total internal reflection by including the axis and path of light as well as the critical angle.

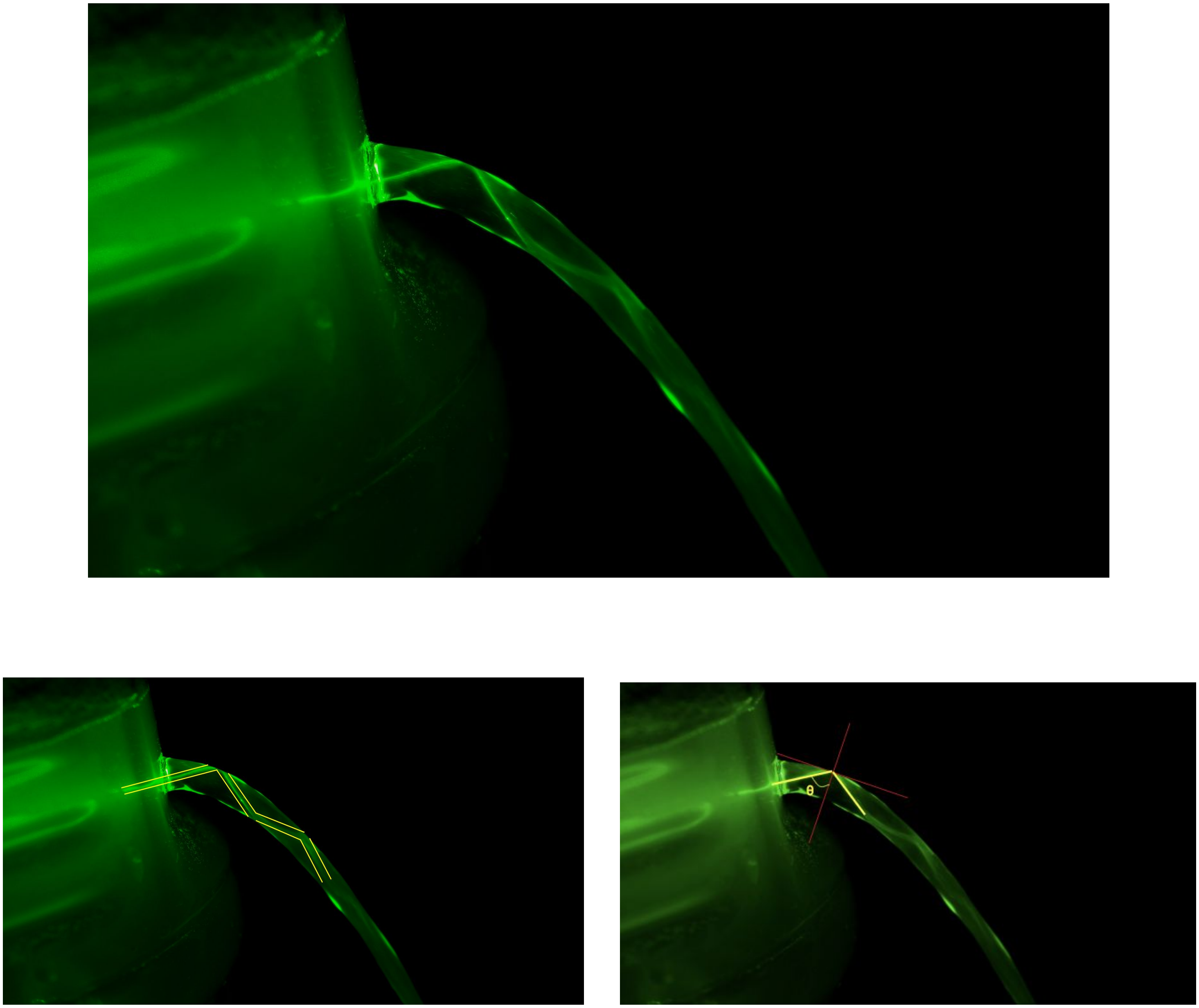


Figure 13: Edited photograph of the laser traveling through the stream of water

Bottom left photograph shows added yellow lines, bottom right shows the total internal reflection

The finalized images were then used to measure the critical angle. Using an angle measuring tool in Adobe Photoshop, the reflection angle at the water-air interface was found to be 55 degrees, somewhat larger than the minimum (critical) angle of 48.6 degrees needed to ensure total internal reflection.

The purpose of this experiment was to use photography to capture an image of a laser internally reflecting through a stream of water in order to demonstrate how fiber optic cables work. Using a green laser and water bottle with a hole, the experiment was conducted. Milk was added to the water to improve the visibility of the laser. Images were taken and edited in order to maximize the effectiveness of the photograph.

Chapter 5

Newton's Prism Experiment

Another interesting phenomenon that happens in the world can be demonstrated in Newton's Prism Experiment. The concept behind this experiment is that white light is composed of different colored light. By breaking up this white light in a prism, the various rainbow colors can be seen. People often see this happen after it rains when rainbows form in the sky. Figure 14 demonstrates the physics behind Newton's Prism experiment.

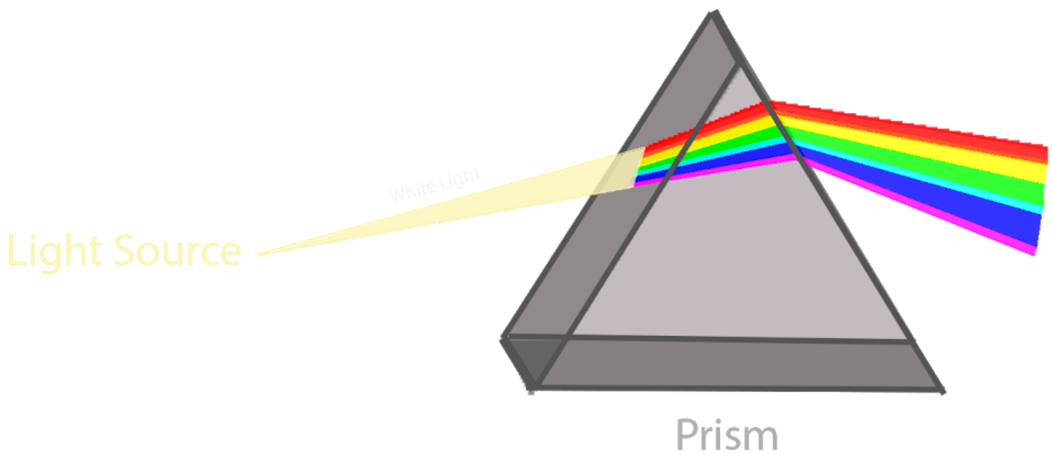


Figure 14: Diagram of white light hitting a prism and dispersing into color

5.1 First Setup

There were two different setups used in this experiment. The first one (Figure 15) was simpler and involved a flashlight, a prism, and a piece of paper. The flashlight was taped to a stand and the prism was placed on a pile of books with white paper on the top in order to level out the prism and light source. A cardboard screen was placed on the edge of the pile of books. The prism was then angled correctly to maximize the visibility of the color as well as to improve the focus.

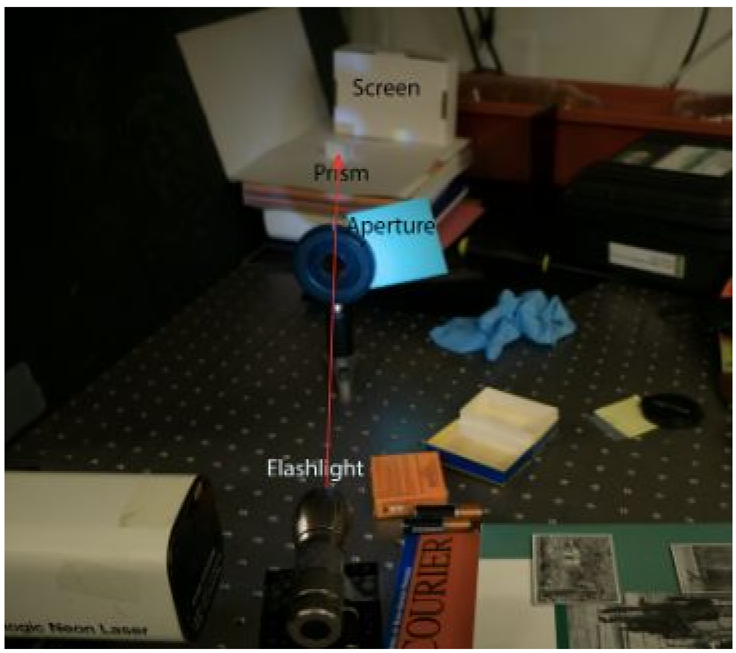


Figure 15: The first setup for Newton's Prism experiment

5.2 Second Setup

The second setup (Figure 16) was more complicated. The flashlight was lined up with an aperture like device in order to reduce the beam of light. The light was then bounced off of a mirror in order to angle it towards a second aperture and finally through the prism onto the cardboard screen. The purpose of this new setup was to increase the distance between the light source and the prism. This distance would generate a narrower more collimated white light beam, however the overall power of the beam would decrease. This narrow beam helps to ensure that the colors overlap less, which creates more defined and brighter colors.

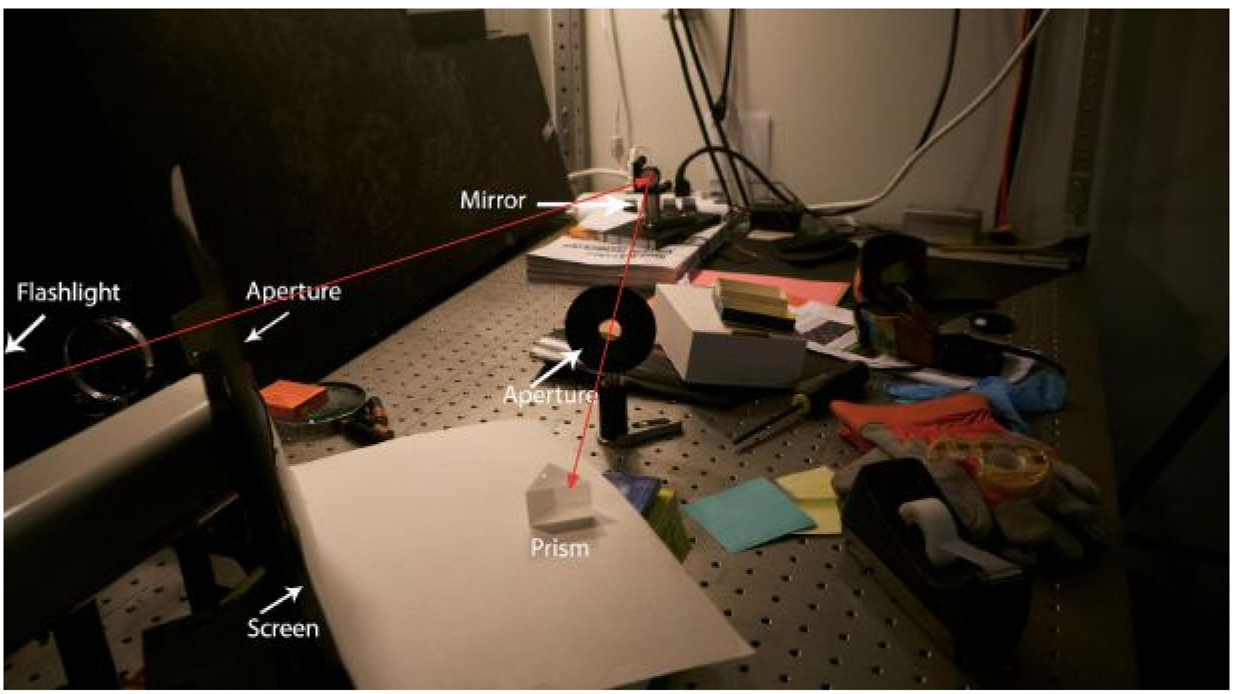
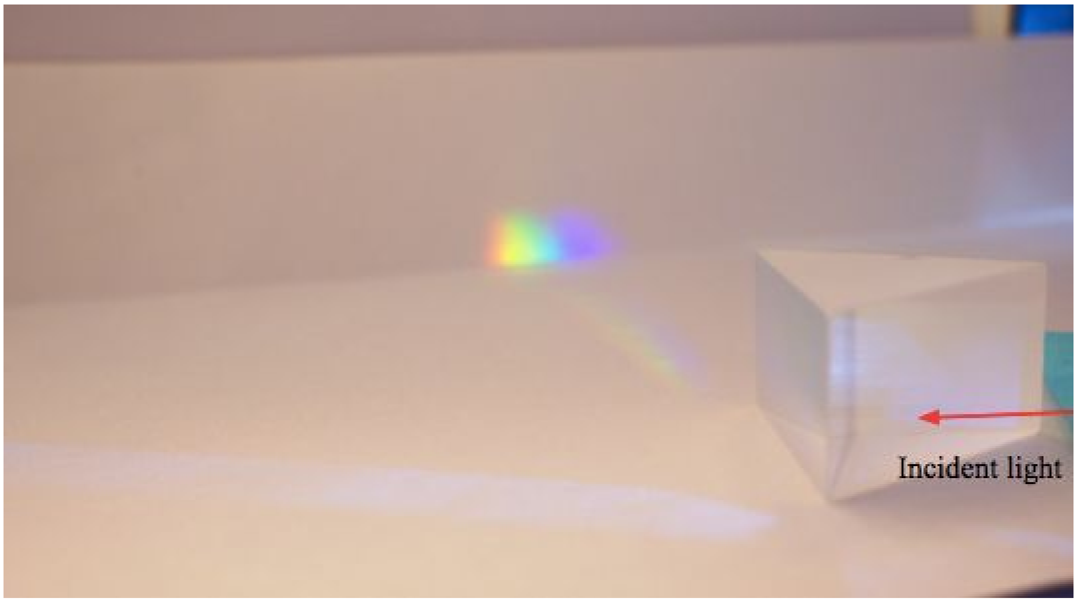


Figure 16: the second experimental setup for Newton's Prism

For both experiments, photographs were taken of the entire set up, as well as just the rainbow results. The second experiment, due to the set up, was more difficult to photograph the white light, prism, and colored light. So for the second set up, most photographs taken were of just the rainbow formed. The images were then edited to improve the concept. The brightness and contrast were adjusted as well as the different levels of the colors in order to make the photograph look cleaner. Figure 17 shows the final results for the first prism experiment.

Figure 17: Photographs of white light hitting the prism and creating a rainbow

The second set up resulted in a brighter and more defined rainbow that could be seen on the paper traveling to the screen better. Figure 18 shows these results.



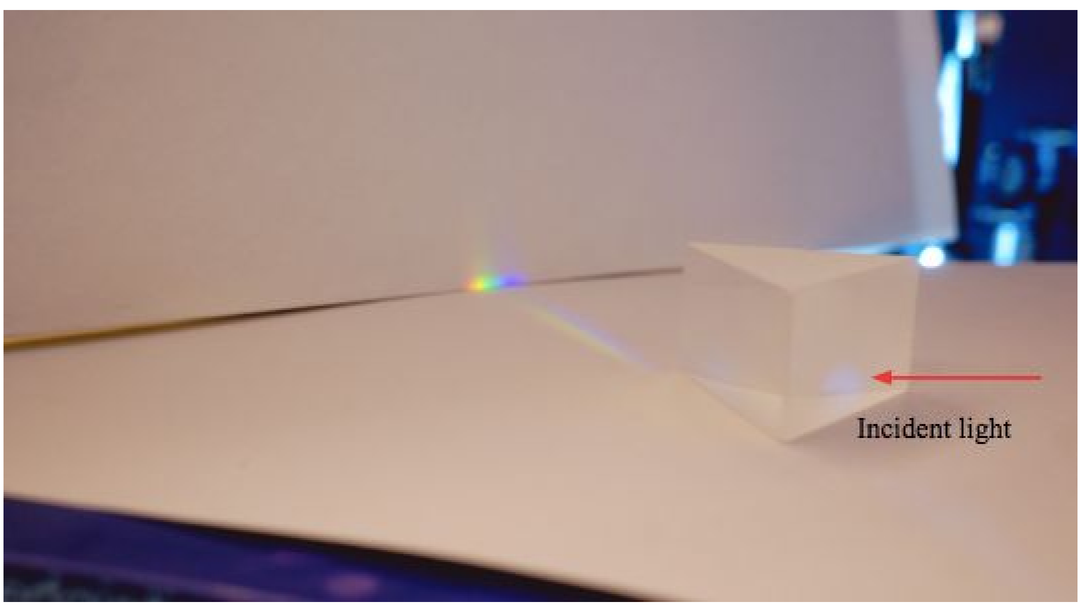


Figure 18: Photographs of the results from the second experimental setup

Using a prism, this experiment showed how white light is composed of different colored light. The white light was broken into these different components. Two different setups were used and their results were photographed. These photographs were edited by increasing the brightness, contrast, and levels in order to improve the color and neatness of the photographs.

Chapter 6

Cloud Chamber Experiment

The cloud chamber experiment's purpose was to provide a way to view the different tracks that different particles leave as they move through vapor. Particles are constantly moving around in the world, however, humans do not see any of it. Physics classes often discuss particles, so this experiment helps to visualize these different particles. The main focus were electrons, alpha particles, and muons.

The experiment was set up on a multilevel rolling cart. A plastic bin full of ice and cold water was placed on the middle level. A tube and power cord were placed in the icy water. These both connected to a machine placed on the top level. The machine was composed of a round, empty base with a glass lid. Construction paper had been place around the inside of the base. Rubbing alcohol was poured into the base and the lid was placed back on top. There was a small round hole in the lid where a metal prong could sit. After the machine was turned on, the alcohol would be soaked up into the paper. It would travel towards the top of the base by capillary action. Since the bottom of the base was significantly colder than the top, a temperature gradient would occur. The alcohol, as it traveled through the temperature gradient from top to bottom, created a cloud-like vapor. Once the radioactive prong was inserted, electrons and other particles would travel through the vapor and their trails would be visible. Figure 19 below shows the different layers of the cloud chamber.

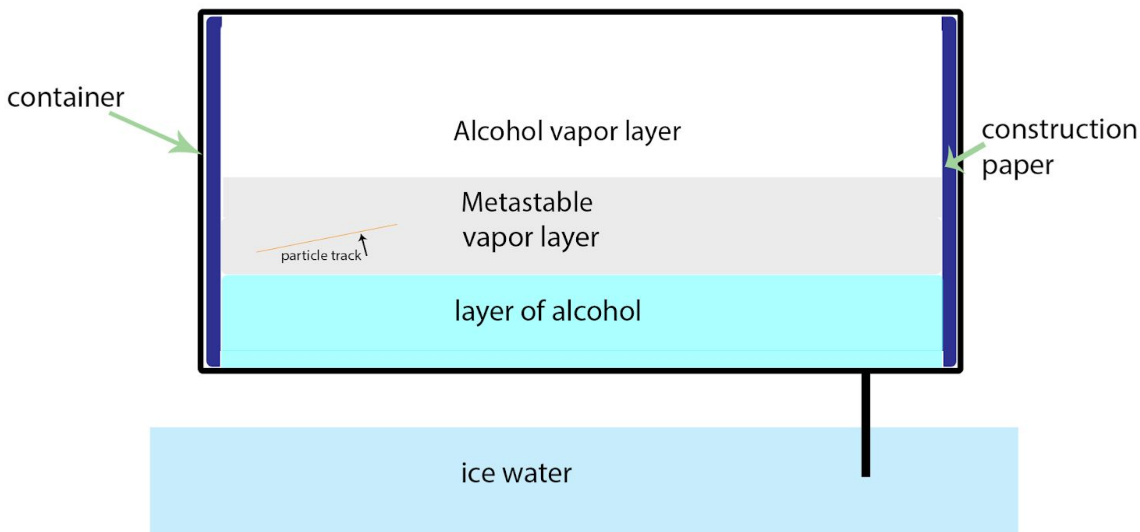


Figure 19: Diagram of the layers within the cloud chamber

The different charged particles that moved through the metastable vapor would ionize the alcohol, producing small nucleation centers for droplets to form around and these leave tracks behind. These tracks could be seen and categorized. If the track was not straight (i.e. wandering), it was an electron; if the track was narrow and straight, it was a muon and if the track was thick and straight, it was an alpha particle or proton (Figure 20).

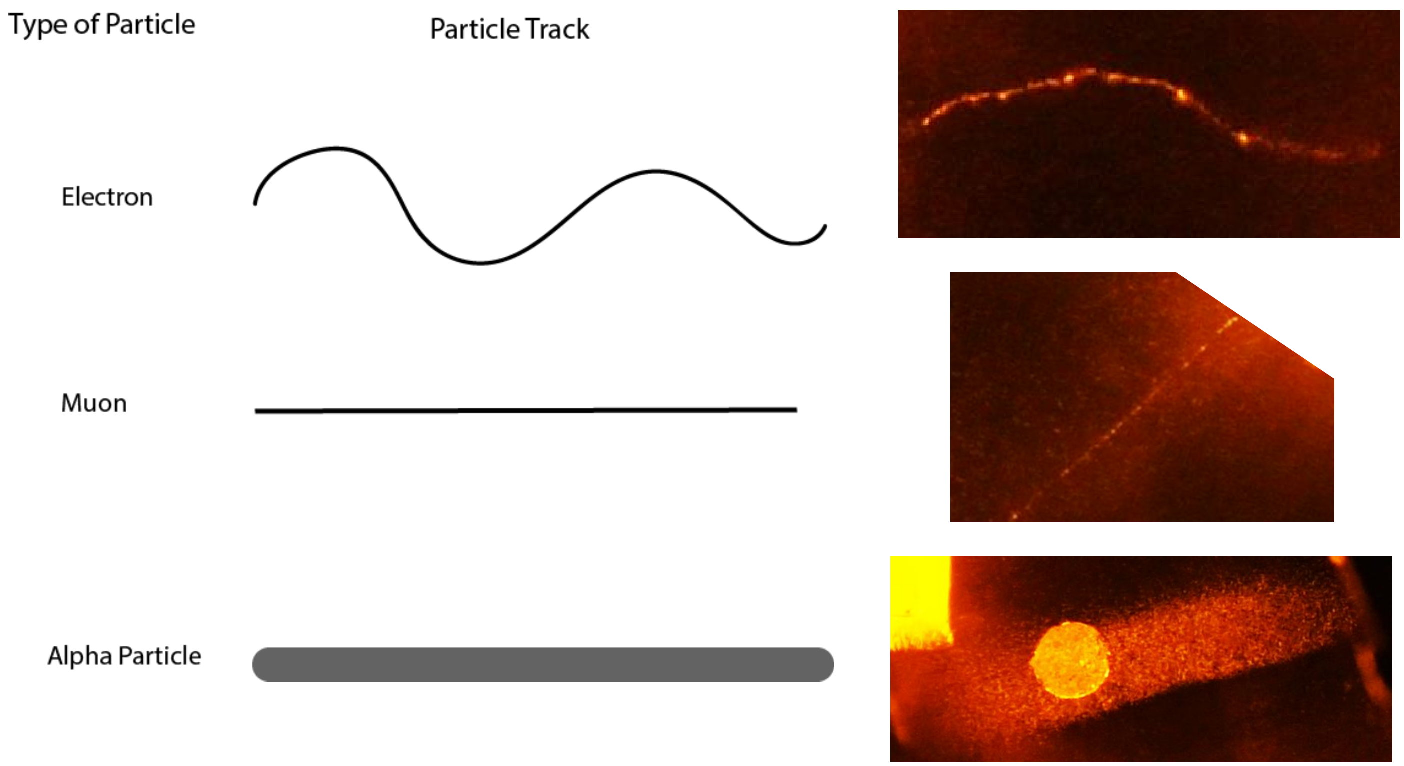


Figure 20: Diagrams and photographs of the different tracks of the particles

There were two different probes that were inserted into the cloud chamber. The first one was not radioactive, so the various particles that could be seen were all from the environment (Figure 21). The second probe was radioactive, so there were more particles, creating a visually exciting cloud chamber.

For this experiment, the best way to capture what was happening was to use video. Several videos were taken as different prongs were placed into the base and moved around. After the videos were taken, they were uploaded into Adobe Premiere and stabilized to minimize any shaking of the camera. These videos were then uploaded into Adobe Photoshop as several different stills. Each still was examined and the stills with visible paths of electrons were kept. The rest were deleted. The remaining stills were copied and pasted on top of one another to create one image with a significant number of paths in order to demonstrate the experiment in photographic form.

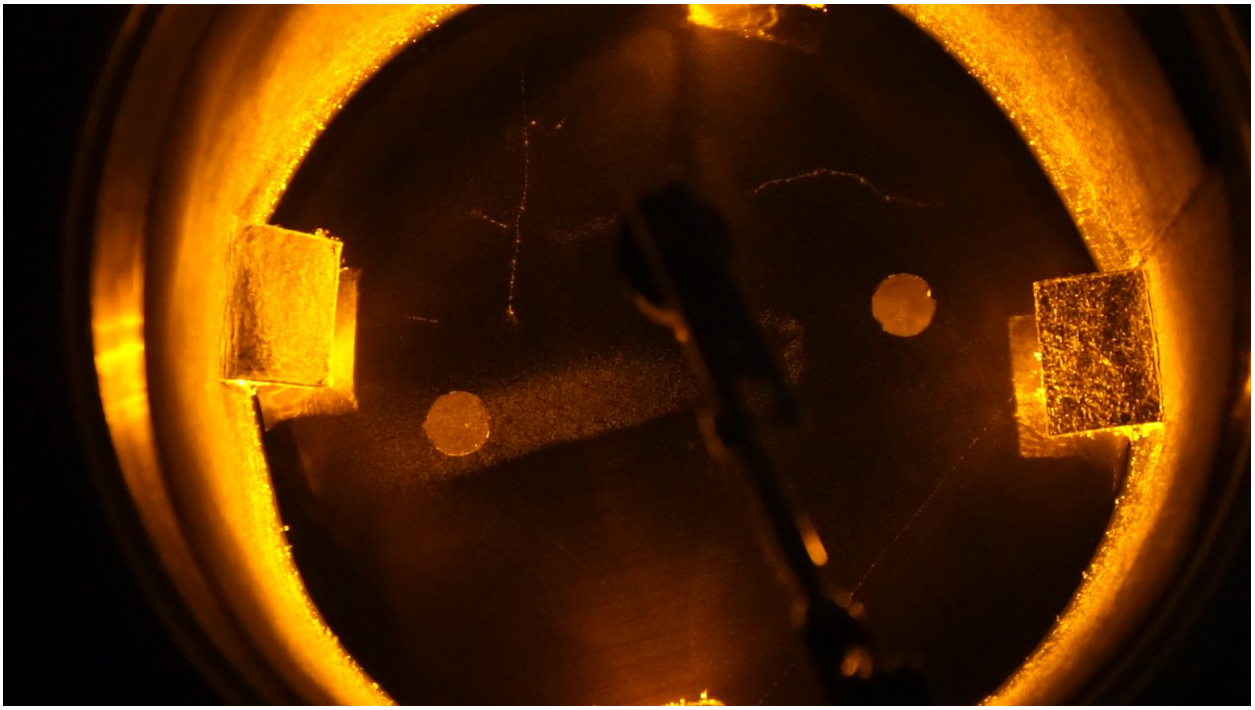


Figure 21: Edited image of the particle tracks in the cloud chamber

This experiment used a combination of photography and videography to capture electrons, muons, and alpha particles as they moved through a metastable alcohol vapor created by a temperature gradient. Both naturally occurring particles and then later particles from a radioactive Pb-210 probe were captured in videos that were converted to images. These photographs show how particles are all around in the atmosphere as well as provide a visual for the different movements of different particles.

Chapter 7

Five Source Interference

The purpose of this experiment was to explore how adding more points changed the interference pattern. This experiment is a further exploration of the double slit experiment, which is commonly done in undergraduate level physics labs. The double slit experiment demonstrated that light can behave as a wave. Figure 22 shows a diagram of the double slit experiment.

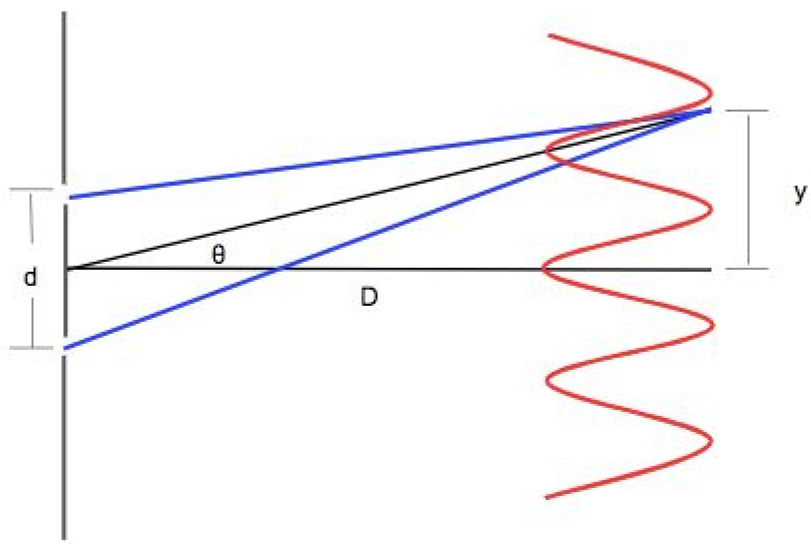


Figure 22: A diagram of the double slit experiment

The size of the fringes of the interference pattern could be calculated using the following formula $y_{bright} = \frac{m\lambda D}{d}$ where y_{bright} is the position of the bright fringes, *m* is the order of interference, λ is the wavelength of the light, *D* is the distance from the holes to the interference pattern, and *d* is the distance between the holes. For this set up, the expected value for the size of fringes would be approximately one centimeter. The order of interference for this calculation was one, the wavelength of the laser was 632 nm, the distance *D* was approximately eight meters, and the distance between the holes was 0.5 millimeter.

There were two different setups used in this experiment, however the second set up was used to extend the path of the laser. For the first setup, the laser was placed on one side of the aperture. A piece of tinfoil with a certain number of small holes was attached to the aperture. The laser was aligned with the holes to maximize the brightness of the laser on the other side of the aperture. The interference pattern could then be seen on the far wall, which was approximately six to seven meters away.

The second setup (Figure 23) was used to extend the path of the laser in order to make the laser more diffused to enable it to go through more points. The laser was placed perpendicular to the aperture and facing away from it. A mirror was placed and angled to reflect the laser light onto a second mirror that was located within the same line as the aperture. The second mirror was then adjusted so the laser would go through the holes located on the aluminum foil. Then the interference pattern could be seen on the same wall.

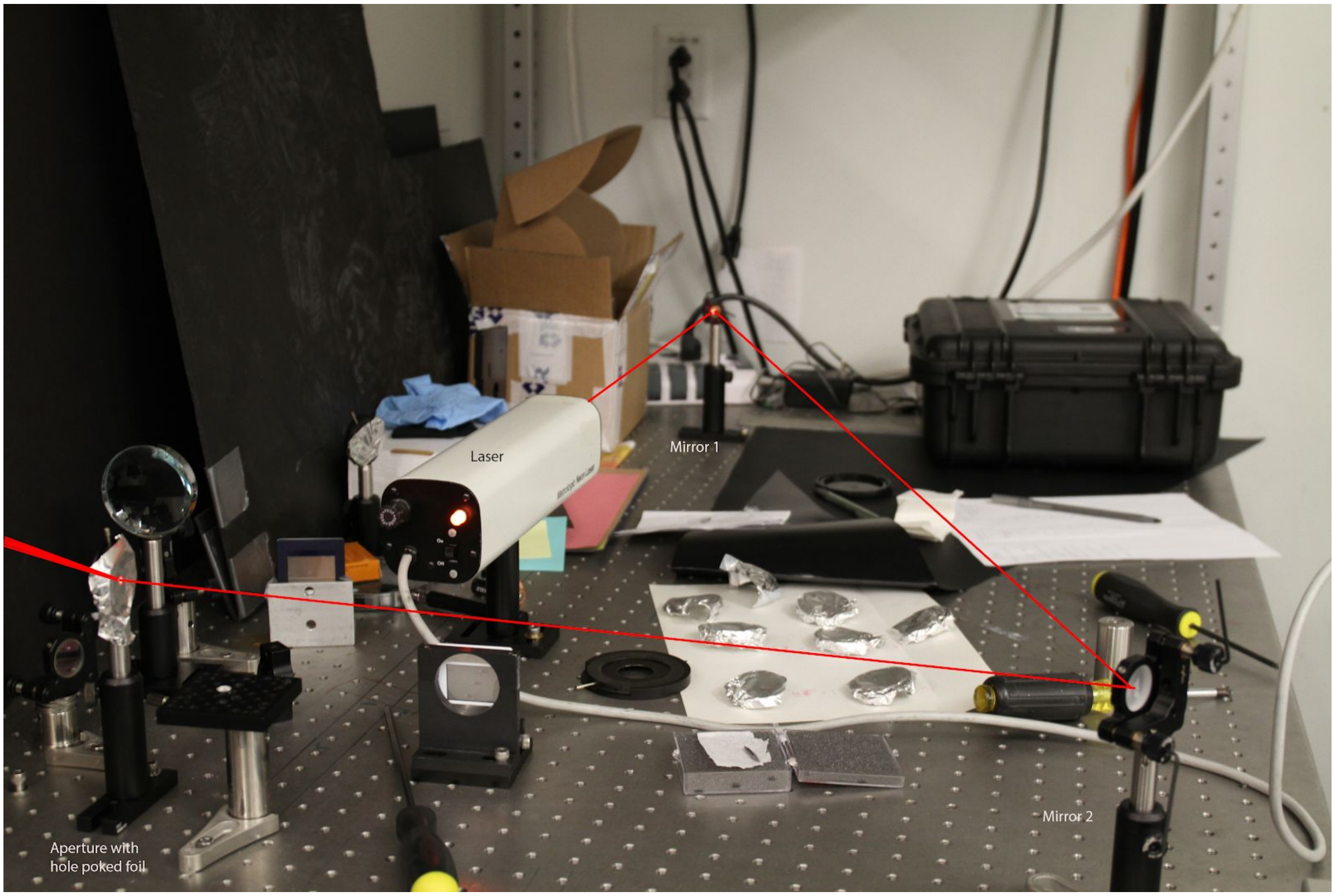


Figure 23: The second experimental setup for the multi source interference experiment

The next aspect of the experiment involved creating the holes in the aluminum foil. The first attempted structure was a double hole. Two small dots were poked into the foil using a thumbtack. The foil was then placed in front of the laser. Figure 24 shows the interference pattern. The expected size of fringes was one centimeter and the results were approximately a centimeter.

Figure 24: The double slit interference pattern

Next, three holes were poked into a new piece of foil in a triangular shape (Figure 25) then four holes (Figure 26) and finally five holes were attempted.

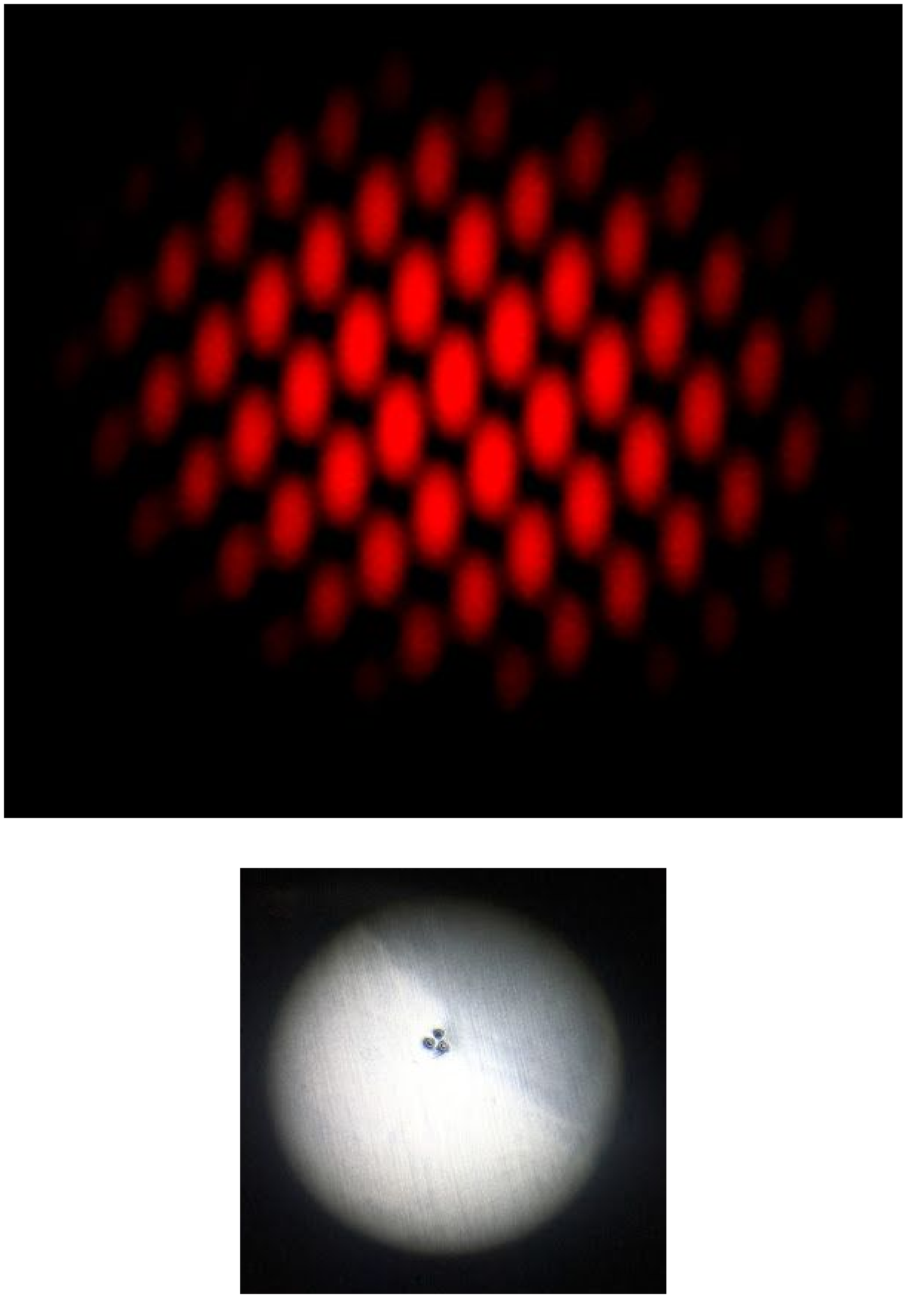


Figure 25: 3 hole interference pattern

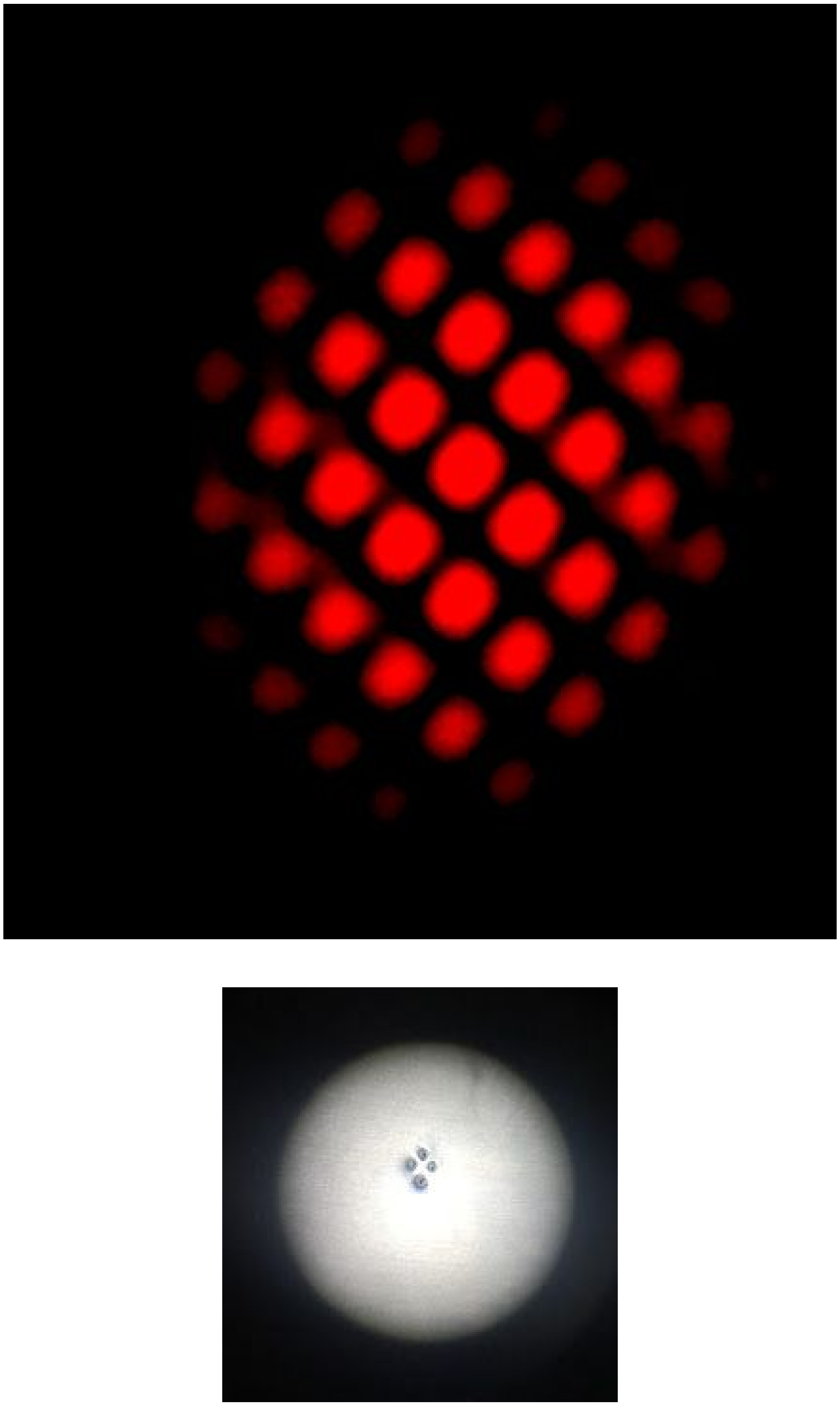


Figure 26: 4 holes interference pattern

The five hole experiment was run twice. The second attempt involved making the holes smaller and farther apart. The interference patterns changed from the first trial (Figure 27) to the second trial (Figure 28).

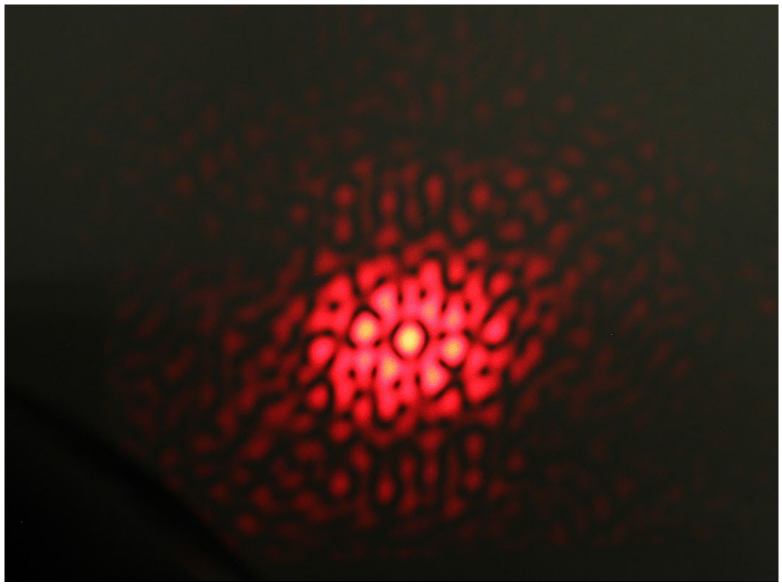


Figure 27: the first trial of the five holes interference pattern

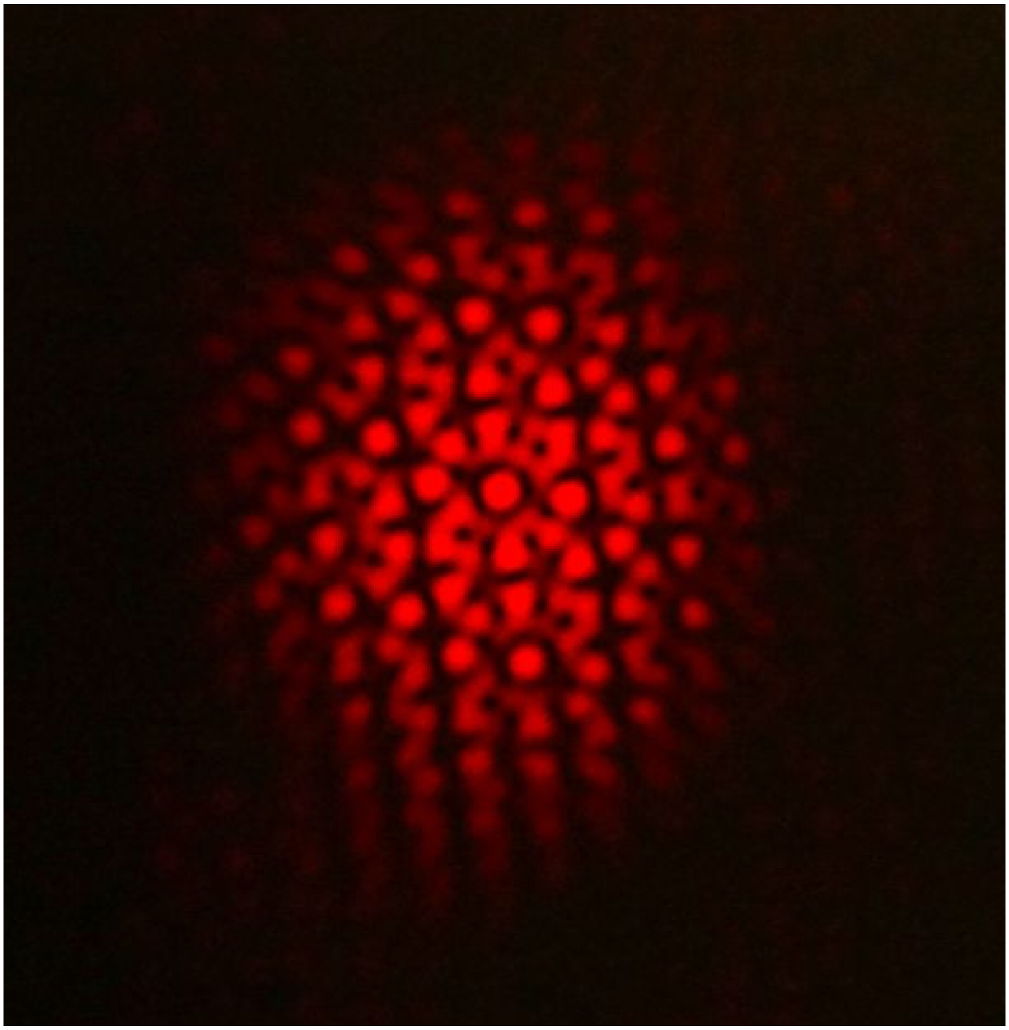


Figure 28: the second trial of the five holes interference pattern

This experiment explored the different resulting interference patterns when more slits were added. Starting with a double slit experiment and slowly working up to five holes, the results of each new holed foil were captured. The orientation as well as spacing and size of holes affected the results of the interference pattern. The photographs were edited slightly to increase the brightness and improve the contrast in order to make the patterns more visible. The five source experiment had two different results.

Chapter 8

Star Tracks

If anyone stares up at the night sky for long enough, they will notice that the stars are moving across the sky. The purpose of this experiment was to use long exposure to show the tracks of the stars as the earth rotates. This was accomplished by setting a camera was a high powered zoom on a tripod pointed at various constellations and opening the shutter for five to ten minutes for smaller tracks.

First, a darker area with a clear sky was needed to see the stars and minimize light pollution. The camera was then set up on the tripod and focused on the night sky. A timer was set within the camera's long exposure bulb mode settings. The shutter opened and the long exposure began. Exposure times varied from five minutes to ten minutes depending on how light from outside sources was affecting the photograph. Once the image was taken, it was uploaded into Adobe Photoshop where the levels and brightness were manipulated to bring out any dim or hidden stars (Figure 29).

Figure 29: Long Exposure of the Stars

One of the biggest problems with this experiment was finding a clear night to see the stars. Once there was finally a clear night, other problems involved the balance between exposure time to capture more stars while minimizing light pollution and over exposing the photographs.

While photographing the stars, a few pictures of the moon were captured as well. These pictures were also edited and the contrast adjusted to improve the image (Figure 30). Over time, more photographs could be taken to show the phases of the moon.

Figure 30: Photograph of the moon

While the purpose of this experiment, to capture star tracks as the earth rotates, was achieved, there is still more potential to further the experiment. Some possibilities include visiting a darker area with less light pollution, waiting till Andromeda is visible in the night sky and capturing photos of the galaxy, and using longer exposures to capture longer tracks.

Chapter 9

Fluorescence of Olive Oil

When laser light is shown through certain liquids, the color of the light changes due to the fluorescence of the liquid (Figure 31). The purpose of this experiment was to demonstrate that a green laser light while travelling through olive oil appears red.

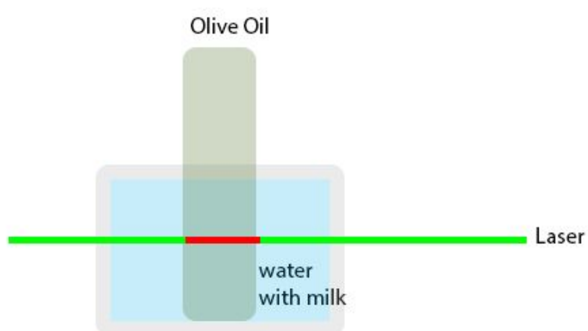


Figure 31: Diagram of a laser changing color in olive oil

First, the labels were taken off of the various olive oil bottles in order to maximize visibility of the laser. The bottle of olive oil was then placed in a clear bowl filled with milky water. The laser was turned on and aligned to optimize visibility within the olive oil and water. Photographs were taken at various angles. The images were then uploaded to Adobe Photoshop and the contrast, brightness, and levels were adjusted (Figure 32).

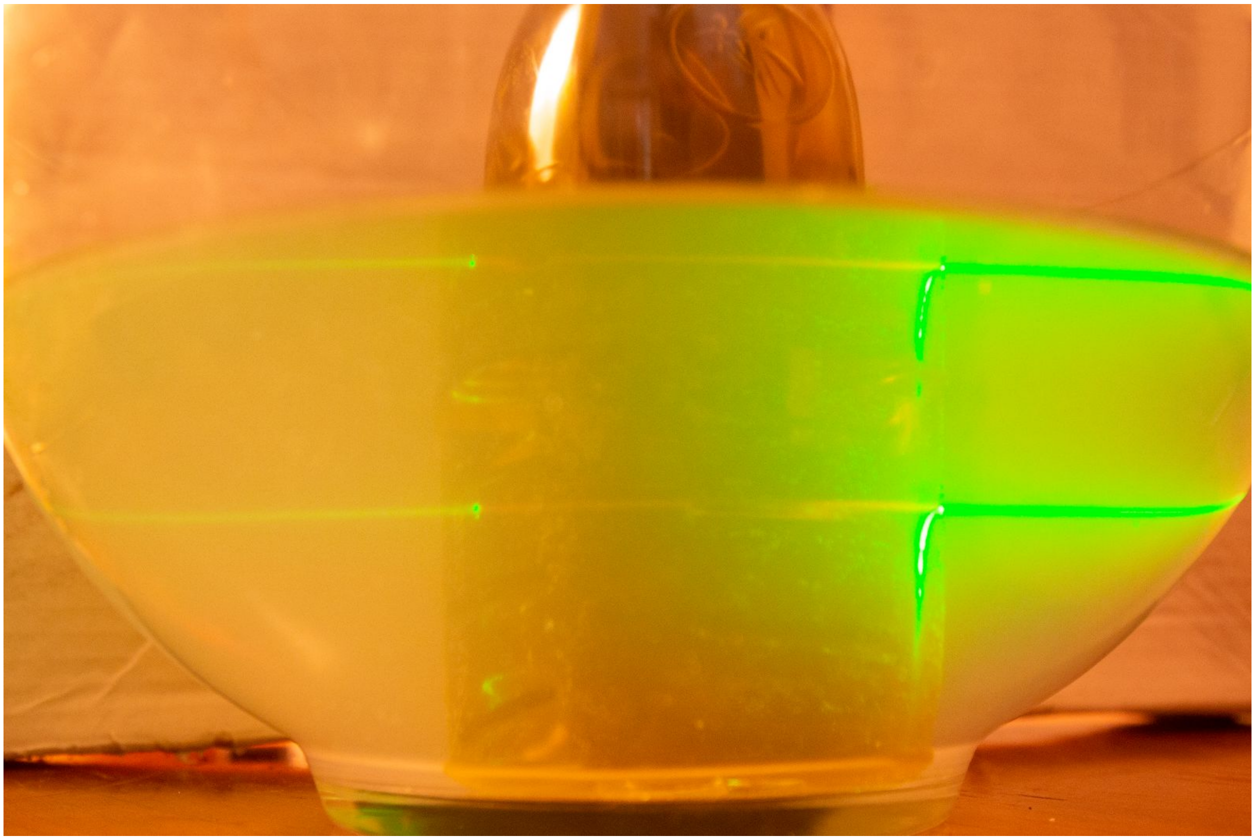


Figure 32: Laser travelling through water and olive oil demonstrating the fluorescence of olive oil

Since the olive oil is already a dark yellow color, it is difficult to see the red color of the laser as it passes through the oil. Another struggle with this experiment was balancing showing the original green color of the laser while maintaining the ability to see the laser in the oil. Notably, the top laser beam appears to be the total internal reflection of the bottom beam (there was only one laser beam) off of the water's surface.

The different types of olive oil resulted in variations in color and intensity of the red light. Extra virgin olive oil had the most visible and red light. This was the oil used in the photographs.

The laser did change to a reddish color in the olive oil and the images were captured, although they were not as clear as desired. The purpose of this experiment was achieved, however future research could expand and improve the experiment and final images.

Chapter 10

Conclusion

The purpose of these photography experiments was to use photography to demonstrate concepts of physics in a more concrete way to further understanding of these concepts amongst the general public. The first experiment conducted was an optic experiment that demonstrated the path light travels as it goes through a lens. Once the experiment was set up using a laser through a diffuser, the photograph was taken and edited to achieve a clear, cohesive image of a concrete example of a ray diagram. The ray diagram was overlaid on top of the final photograph to demonstrate their similarities. The second experiment in the series explored the effect of camera quality on the ability to view laser-cooled atoms: The lower the quality of the camera, the more likely it will be able to pick up infrared. The third experiment was the water fiber experiment which demonstrated total internal reflection by shooting a laser through a stream of water and capturing the movement of the laser. The images were edited to improve visibility of the laser as it reflected through the stream. The next experiment, Newton's prism experiment, demonstrated the composition of white light by using a prism to disperse the different colored light. A flashlight was used as a light source and reflected off of a mirror in order to gain more distance between the light source and prism. Photographs were taken and edited in order to make the colors brighter and more visible. The fifth experiment was the cloud chamber experiment, which showed the particles' tracks as they moved through the vapor. Both naturally occurring particles and later particles from a radioactive probe could be seen in the cloud chamber. Videos and photographs were taken and edited. The next experiment was the five source laser experiment. This experiment explored the different interference patterns that resulted when more holes were added to the aluminum foil. The size and spacing of these holes changed the interference patterns. The next experiment was to explore the rotation of the earth by capturing long exposure photographs of the stars moving across the sky. This was accomplished by taking ten minute long exposures of the stars and editing the images to improve the quality of the photographs. This experiment could be further improved with longer exposures taken in areas with less light pollution. The last experiment was the fluorescence of olive oil. As the green laser was sent through the olive oil, it appeared red. Images were captured, however there was room in this experiment to improve the quality of the images.

The next steps for this experiment are to branch out into other major physics concepts and set up experiments to photograph that will demonstrate those concepts. Future endeavors include beam splitting, capturing a photograph of the galaxy Andromeda in order to show its size in comparison to objects such as the moon or nearby trees, and furthering exploration of fluorescence of different liquids. Another way to explore fluorescence could be to combine the methods of the water fiber with the fluorescence to attempt to see the movement of the red laser in a stream of olive oil.