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Holography in the Secondary Physics Curriculum

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Holography in the Secondary Physics

Curriculum

(TITLE)

BY

Stephen P. Hogan

THESIS

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IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
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2016

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Abstract

This paper presents a unit plan for effective implementation of a holography learning activity in the secondary science physics classroom. The study of holography has traditionally been limited to collegiate optics courses due to financial and physical constraints. Recent developments in the technology of holographic film has eliminated these two limiting factors. Recent secondary educators who have introduced holography with their secondary science classes have completed the activities, without much discussion or explanation regarding the scientific principles that allow the phenomenon to occur. In this paper we develop a foundational unit plan that finishes with holography as the pinnacle activity, which a secondary physics teacher can complete in a twelve day progression. The foundations of the unit plan incorporate instructional activities on topics including multidimensional wave interference, simple atomic theory and quantum effects. The implementation of this holography unit was completed during the Spring 2016 semester in the AP Physics 1 course at Oak Forest High School (OFHS). Twelve students of that course participated in the unit plan and feedback and assessment information is presented.

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My original physics mentor, Damian Simmons, for instilling creativity in me when the lack of curricular resources requires a teacher to be innovative in accomplishing goals.

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Introduction

The Next Generation Science Standards (NGSS) as released in 2013, were the result of a motivation to improve the scientific education of the nation's students from multiple stakeholders. NGSS was developed by a alliance of the National Science Teachers Association, the National Research Council, the American Association for the Advancement of Science, and twenty six adopting state educational bodies. The standards are "rich in content and practice, arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked scientific education" (NGSS, 2013).

With the opening initiatives of NGSS there is compelling drive to improve the scientific reasoning and problem solving skills of today's students for 21st century academic and workplace demands. Recent global scientific literacy tests show that the average U.S. student is lagging behind his or her peers in developed nations (Miller, 2007). In an ever increasing global market, all students need critical thinking skills in order to compete in more demanding job markets. In order to foster this growth of reasoning capabilities in today's students they need instructional activities that challenge them to process the information presented to them and apply it to many aspects of their societal lives. In the science classroom the way to accomplish this is through a strong curriculum of experimentation. Hands-on manipulation of the material presented aids tactile learners and increases active learning.

The rationale for developing this unit plan is that many secondary physics courses lack a tactile based laboratory activity on three dimensional holograms. Quite often high school teachers skirt around the physical concepts which build the foundation of holograms, but stop short of embracing and including them into their curriculum. The few teachers that have had students produce holograms in class demonstrate them as a way to engage their students in a unique and exciting activity, but many times fall short in explaining the science behind what enables their images to be produced and recorded. The goal of this unit plan is to present a guide for any physics educator to successfully incorporate holograms, including the scientific basis of their formation, into the secondary science curriculum. Holograms should be included in secondary curriculum due to their applicability in areas such as interferometry, structural stress simulations, monetary security, and digital cryptography.

The pilot study of this unit plan is for the AP™ Physics 1 (trigonometry-based) course section of OFHS (IL) to complete the listed activities after the AP Physics 1 examination on 3 May 2016, until the conclusion of the school year on 20 May 2016. As the students in this gifted course have this additional free time, it was appropriate to implement these lessons during that closing interval of the school year. The duration of this pilot study is twelve school days with fifty five minutes of instruction time per day. During that time students were presented with instructional activities on the foundations of interference of waves, quantum phenomena, photochemistry, resolution, illumination which are all aspects involved in the production of three dimensional holograms.

Before venturing into the designs of this unit plan, it is essential for the reader to understand that this was simply a plan that fit a specific time frame and academic level of student. The sequence of activities are designed to offer a method of introducing holography into the curriculum of a willing teacher. It is likely that some modifications will be necessary in order to meet the diverse needs and limitations present in the average physics teacher's classroom and curriculum.

Literature Review

The motivating drive for improvements in science education in the U.S. populace of the 20th century has its roots based in the global crises of World War II (WWII) and the subsequent Cold War. At 4.1 trillion dollars (inflated 2011 estimate), WWII was the most costly war to date for the nation (Daggett, 2010). The conflict consumed nearly 40% of the nation's gross domestic product for the duration of the war which does not even account for rather large human cost. At those financial levels, governmental leaders were searching for a swift end to the double front conflict and invested heavily in the advancements of science for a solution. That scientific investment namely in the Manhattan Project, eventually paid off in the development of nuclear arms, which ultimately convinced the Japanese to cease their aggression in the Pacific (Dickson, 2007).

The conflict was immediately replaced by the Cold War. The remaining global powers (England, France, Soviet Union and the U.S.) divided up the European continent among their competing ideological differences according to geography. The Eastern bloc was composed of communistic governments under Soviet influence, while Western european nations held on to their democratic and capitalistic principles. In a silent battle, the two differing viewpoints attempted to best each other in their influence upon other nations and technological advances. Another manifestation of the Cold War was both sides trying to develop superior nuclear bomb technology both in quantity and quality. That battle spilled beyond the limitations of the planet, as the Soviets successfully launched the orbiting Sputnik satellite in 1957 (Dickson, 2007).

Sergei Korolev's orbiter at a mere 184 pounds had a tremendous impact upon the American psyche. In a clear sky with the sun at the correct angle, one could see it traversing with the naked eye view horizon to horizon. Any amateur short wave radio enthusiast with the correct equipment could hear its radio beeping pattern. Suddenly it was clear to many that the United States was behind the Soviets in the space and technology race. (Dickson, 2007). Not only did the Soviets beat the Americans into space, but they likely had the rocket technology to launch nuclear warheads at their enemies as well. Sputnik exposed a national security threat to the public. The United States, embarrassed by its shortcomings, needed to catch up in order to adequately defend itself and survive (Powell, 2007).

National policymakers, realizing the need for reform, looked at science education as a way to match and surpass the Soviets and formulated committees to tackle the problem. Priority was given to educating the nation's youth with the most contemporary educational practices of the time. This would help in preparing the nation to face any challenge that would be launched from its eastern adversary for the next three decades or more. Thus the National Science Foundation, which was founded in 1950 to advance American progress in science, had its budget raised from 3.5 million dollars in 1952 to 40 million dollars in 1957 and to 133 million dollars in 1959. With that budget increase NSF greatly accelerated the development of national laboratories for research. It also accompanied the billion dollar National Defense Education Act of 1958, which provided funding at all levels of education for four years (Powell, 2007).

The Physical Science Study Committee was born out of this time of conflict. Concerns about the national scientific manpower in comparison to the Soviets was gripping the country with Nicholas DeWitt's 1955 publication *Soviet Professional Manpower*. Within it DeWitt spelled out that the Soviet's technical education programs were, by large margins, out pacing the United States educational initiatives (DeWitt, 1955). This acknowledgment spurred the national policymakers to set up the PSSC as a way to reform and revitalize physics education to catch the Soviet Union in technical expertise. The committee was made up of distinguished faculty at prestigious schools, such as Jerrold Zacharias of M.I.T., and various corporate leaders in technology. From the committee new experimental labs were presented as kits, that provided a new vision to educate mid-century science students (Rudolf, 2006). Those lab kits transformed science courses from study of practical orientation (ie. "How does a refrigerator or toaster work?") to a focus of basic research and inquiry with a conceptual foundation ("What principles are used to cool or heat things?"). K–12 science students started to question and study more cause and effect relationships in the variables that are involved in a specific scientific experiment (Powell, 2007).

Science education is just as intertwined in the humanities as it is in the basics of mathematics. C.P. Snow in the heart of the cold war of 1959, coined that the worldview of education was brought down to "Two Cultures" (Snow, 1993). One which had a firm foundation of the scientific worldview and the other viewpoint of a literary sense based in the humanities. Though science was universal across content areas due to its ability to have repeatable tests that prove its applicability. From this relationship there was a contemporary incentive from the 1980s to 1990s in relating society and science. The goal of science education is to foster the growth of scientifically literate students who could understand the relationships between Science, Technology, and Society (termed STS) (Hollenbeck, 2003).

The STS method of learning incorporates the Constructivist Learning Model (CLM) which includes:

- Student thinking drives an individual lesson or an entire unit.
- Designing content plans to fit the interest and ideas presented by students.
- Allowing for collaboration between students for effective cooperative learning strategies.

- A facilitator-role for the instructor, which fosters autonomy for students to drive their own learning in the classroom and allows for, and even demands, more individualized instruction.
- Students mutually assist each other in their learning, as much as the teacher would in a direct learning environment.

By incorporating the STS constructivist methods in science courses, teaching and learning will turn quite dynamic in the classroom. Students will effectively learn science by physically doing it and can relate their learning experiences to his or her peers. Inquiry should be facilitated and guided by the instructor to maintain the objective goals of the lesson, but students can tackle the challenges and direct their own learning upon that in-class activity. (Hollenbeck, 2003).

Using inquiry in the science classroom can be quite effective for students to be motivated in mastering the concepts behind the objectives of the lesson. Student groups in a case study were broken down into predetermined categories such as explorers (students who are independent and self-reliant), directors (students who would like to have assertive impact on other people), coordinators (students who act on social relations in a group), and accurators (students who appreciate cohesive and organized work habits). During laboratory assignments students were aligned in groups composed with one student from each category. Groups completed a series of twelve cross-curricular inquiry labs. Those science inquiry activities led to an increase of 23% conceptual retention in directors, 19% in explorers, 16% in coordinators and 12% in accurators. The researchers found that inquiry based learning allows students to learn necessary adapting strategies for dynamic work environments (Skoda, et al, 2015).

Guided inquiry as a pedagogical tool in the K-12 classroom is seen as a effective method that encourages for students to learn scientific practice to further gain their respective conceptual knowledge of the material. This idea is prevalent throughout the Next Generation Science Standards as defined by the National Research Council in 1996:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NGSS, 2013).

Through guided inquiry, learners of science place an emphasis on developing explanations and rationale through scientific observation. Learners would then evaluate their collective explanations with their peers, with respect to alternative conclusions, to deduce the most likely rationale. After determining the most likely explanation through collaboration, learner groups would then formulate their ideas, communicate and present their proposed conclusions. Organizing the guided inquiry learning structure with these feedback loops can prove highly beneficial in introductory science courses (Banerjee, 2010).

Incorporating feedback loops into the laboratory discussion allows the student to actually learn as scientists. Researchers at University of Illinois at Urbana-Champaign learned that the undergraduates enrolled in introductory science courses held little merit for the learning experiences that the lab experiments provided. The six bar graphs in Figure 1 shows that many students found laboratory experience lacking in aiding their success in the course compared to lecture or homework activities. (Selen, 2016).

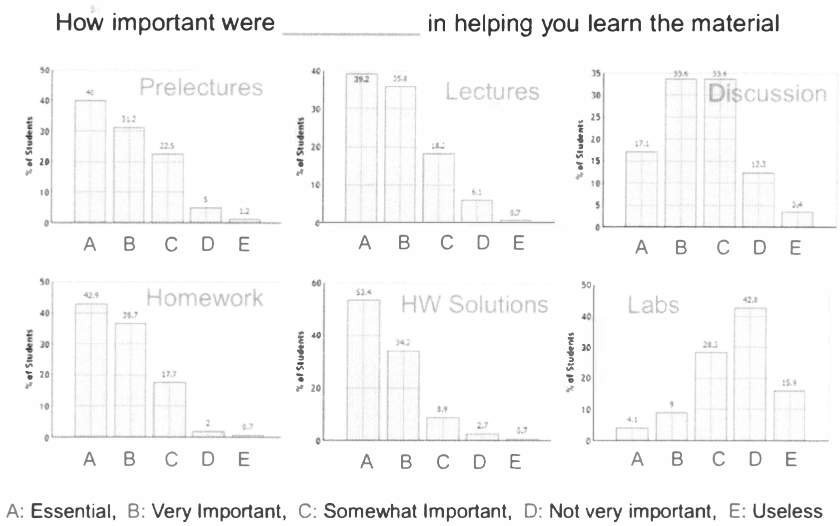


Figure 1: University of Illinois undergraduate student responses on the effectiveness various strategies in learning course's material (Selen, 2016).

The undergraduate students' thoughts on the effectiveness of laboratory experiences were further confirmed from research by Carl Wieman and N. G. Holmes (2015) at Stanford University. A third of the students in an introductory physics course at Stanford University elected to enroll in the laboratory sections associated with the course. Performance was measured between students who took the laboratory section and those that simply enrolled in the lecture alone from data at the final examination. Students who enrolled in the laboratory sections had a normalized difference within 1% of the final exam scores of those who chose not to enroll with an uncertainty of 2% (Wieman and Holmes, 2015). Clearly the benefits for students to complete the laboratory experiments associated are not reflected in their overall exam scores and their effectiveness has to be questioned.

Mats Selen (2016) and his research team at the University of Illinois decided to invest time and dedication into a laboratory that was more meaningful to the learning process. They started incorporating an Investigative Science Learning Environments (ISLE) in their introductory courses (Etkina, 2010). These learning environments allow a feedback loop that would allow students to tackle laboratory tasks and challenges in a similar manner as actual scientists as modeled in Figure 2.

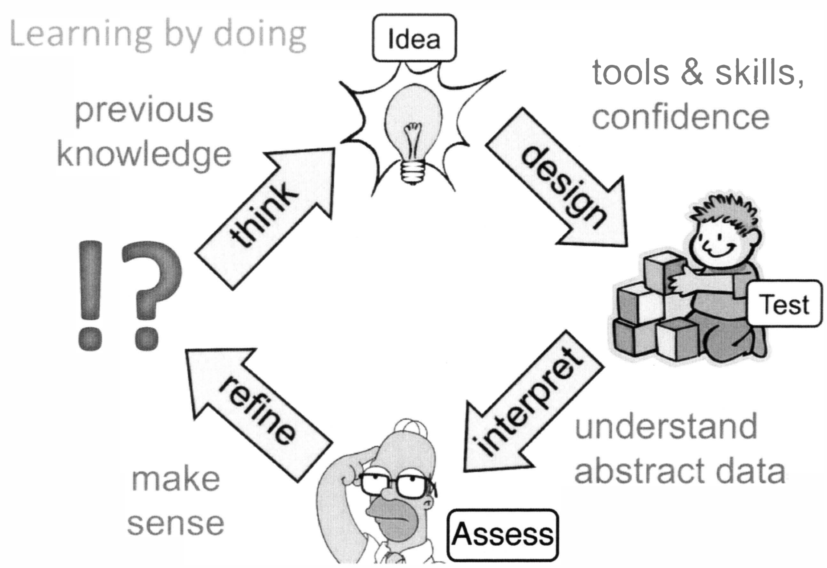


Figure 2: Selen's scientific comprehension feedback loop modified from Etkina's resarch (Selen, 2016)

Students first are provided with a laboratory challenge where they need to rely on previous knowledge to determine an idea to solve the challenge. They would design a method with the tools available to them to test their strategy. Students then obtain data and interpret their results and assess them through personal reflection to determine whether the results make scientific sense. The entire process allows them to refine their preconceived thoughts if they were conflicting with the end results. Strangely enough the feedback loop is quite similar to how young children learn as well. Toddlers would not realize the future consequence of playing with fire if they had not been curious about the flame and experienced burning themselves first. With the expected result that the fire causes pain to the touch, the child deduces that the aesthetically pleasing flame should not be tinkered with by their hands. Selen and his research team are redefining their introductory physics labs to be reflective of this learning process with their new IOLABS (Selen, 2016).

Guided inquiry in holographic experiments for the K–12 levels has been relatively limited due to physical and financial limitations. In the past a dark room was typically required, with a vibration damping table top surface which can cost a significant amount. Still there have been a few educators who have explored holography with their students at the K-12 level. Pedagogically it presents an appealing optic effect but usually the presentation only skims the scientific principles behind their production. A high school physics instructor, Robert Latham (1986), discusses that light holography could be used to teach the principles of wave properties and interference in simply one unit (Latham, 1986). Tung Jeong of Lake Forest College, further explains that holography “combines meticulous laboratory techniques with extremely elegant formal theory,” that can truly explain the major foundations of modern geometrical and physical optics (Jeong, 1975).

Due to the high cost of incorporating holograms at that time, Latham located a local competitive newspaper grant to apply for improving science curriculum and won the grant based upon his plans to use lasers and holograms with his high school students. Latham’s grant invested in the Metrologic Sandbox Holography and Physical Optics Laboratory set – the latter was not necessary for completing the holograms, but Latham intended to use the supplementary set to further demonstrate to his students that certain variables have observable effects upon created interference patterns. To construct the sand boxes he purchased sand bags, molding, slabs of particle board, and simple construction hardware. The construction of Latham’s sandbox is shown in Figure 3. To further dampen the vibration that may be present upon the experiments, a rubber floating innertube that Latham used for leisure float trips down the James River was placed underneath the sandbox (Latham, 1986).

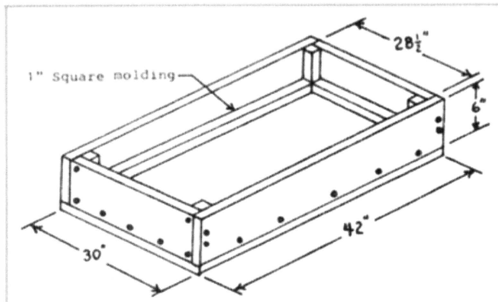


Figure 3: Schematic for the sandbox construction as detailed from Latham's Metrologic™ Holography Kit (Latham, 1986)

Before introducing the activity to his students, Latham and his lab assistant dabbled in the lab setup themselves. They encountered some issues with Metrologic's lack of support in the instructions for novice holographers and the recommended settings were unusable for 15 pieces of film. Through a trial and error process, Latham and his assistant were able to produce visible holograms, but they were still 'dark' by any set of professional standards. Latham attributes that to the low power of the laser (0.8 mW) and a short depth of field of the holograms they attempted to produce, but nonetheless the holograms were still presentable to the students.

Figure 4: Students setting up their equipment in the sandbox for a simple transmission hologram (Latham, 1986).

Latham began his instruction of holography immediately after interference of light waves (as the topic is already within his course curriculum) and subsequently discussed with his students simple atomic energy theory, spectroscopy and a conceptual discussion in Fourier Transforms in a one day lecture. The following day they prepared student groups for the lab setup and groups were organized with members into the following roles: group leader, setup supervisor, timer and developer. In Figure 4 a student group is shown which models Latham's arrangement. In the end, the images that students produced in their groups had three dimensional properties, but they were still rather dark.

To evaluate this student project, Latham surveyed his students for their assessment of the hologram activity successes and failures. With some expected variance Latham found his students found the activity quite enjoyable. They appreciated an activity that required a meticulous procedure and that results in something outside the norm of their typical science experience. The end result was a very contemporary form of technology that they could take home with them as a souvenir. Many claimed that they enjoyed the hands-on experience that was a higher ordered multi-day lesson, which makes it much more memorable. Students told other students about the experience and as thus, Latham found the enrollment in his physics course increasing for the following year.

Latham did not find that the hologram activity was without any flaws. The setup required a rather large investment in time for curriculum and preparation. Further he would have preferred the resulting holograms to not be so difficult to see as they were particularly dark. Bleaching improved the results, but due to the caustic characteristics of the chemicals involved (potassium dichromate and sulfuric acid) this would only be a step for a well trained teacher, removing another step for the students to get their hands dirty. The instructional activity was expensive without the help of the newspaper grant. Tallying up the expense of the Metrologic Kits, sand, hardware construction materials and supplementary film would total around $400 [approximately $1100 in 2016] (Latham, 1986).

Scratch or abrasion holography is a way possibly to introduce holograms in a rather cost effective manner as it requires very little materials outside of what can be purchased at the local hardware store. The making of this hologram by hand would not require a darkroom, isolation table, costly labor or a massive stockpile of photochemicals to process. Willam Beaty of the University of Washington, noticed when walking through a parking lot a three dimensional hand floating on the hood of a car. Due to a polishing mitt from the local car wash detailer, the mitt left millions of parallel abrasions in the surface of the car's paint due to the un-smooth characteristics of the polishing mitt as shown in Figure 5. Beaty described this as a 'scratch' hologram and it acts similarly to a rainbow hologram – found on apparel licensing or as a security feature on a credit card. As pictured the hologram can be viewed under normal white light illumination, rather than with a monochromatic laser point source, that would be necessary for a transmission hologram. Each scratch would act as a light scatterer on a curved line that produces astigmatic images that can be real or virtual of a point source at a distance (Beaty, 2003).

Figure 5: Three dimensional handprints of a polishing mitt scratch into the engine hood of a car as observed by Beaty (Beaty, 2003).

As light impinges upon the surface, it will reflect from each "scatterer" (abrasion). The abrasion then acts geometrically as a reflective diffraction grating, creating virtual images from different viewpoints of observation from the surface. This reflection of light off the surface of the scatterer creates what Beaty describes to be as a hollow conical scatter. As shown in Figure six, among the x-y plane there is a curved line scatterer, with the center of the curve at $\boldsymbol{C}$ and radius $\boldsymbol{r}$. Distant light source PS shines light upon the scatterer abrasion, and each ray incident upon the scatterer reflects into a hollow cone. The angle of the conical reflection is dependent upon the swept angle $\boldsymbol{\alpha}$ and the axis of that cone would be tangent to the arched scatterer. The second figure shows how a virtual arc would be created if the conical scattered reflections would interfere with one another due to the same abrasion (Beaty, 2003).

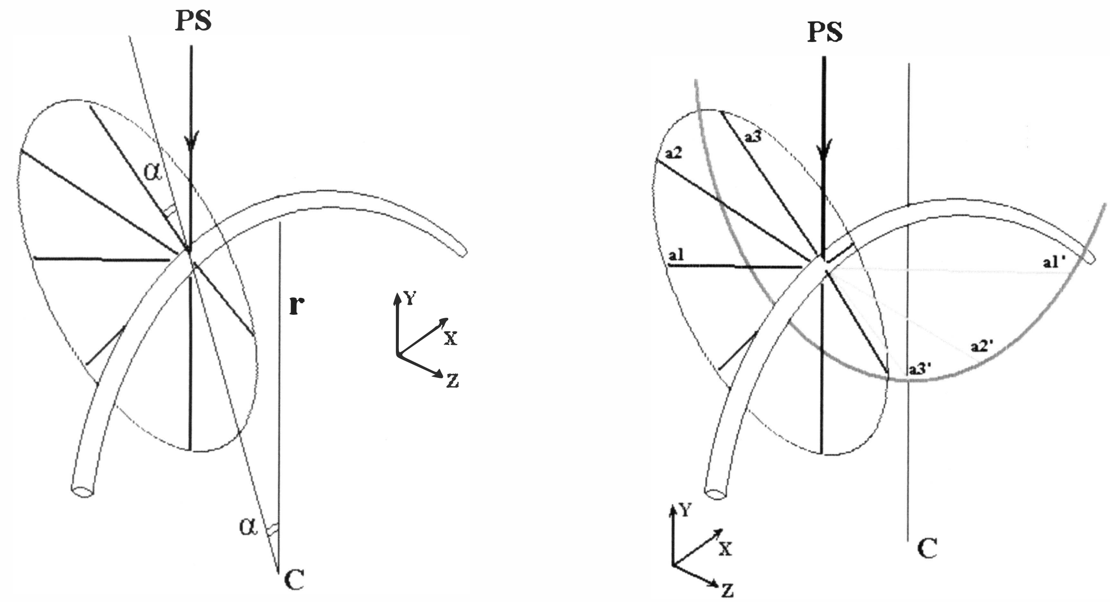


Figure 6: Single scratch abrasion detailing the hollow conical reflection of the scatterer and its possibilities in three dimensional interference (Beaty, 2003).

Figure 7 shows that the observer position affects how the image will be viewed from multiple rays being emitted from the distant light source. Through stereopsis observers may possibly perceive two virtual images. As placing the observer's two eyes at **O1** and **O2**, they would observe ellipse formation of the hollow cone in Figure 6 (a1', a2', a3'). The observer then looks through the scratch abrasion, as the curved scatterer will somewhat behave like a slit aperture. The slit will block the vertical extent of the elliptical image locus and the observer's eyes will only see a bright spot located at point position P. There exists another viewable point on the ellipse image that is in the positive side on the z-plane that is not viewable. It may be viewed if the orientation is flipped so that the observer's eyes are on the other side of the x-y plane upon the scatterer. Thus the scatterer then can form a reflection-form image on one side of the plane and a transmission-mode image sent to the other, which is holographic optics by convention. If one views from directly above the scratched surface the image would seem to have a depth below the surface as shown by position C. Viewing the scratch from different observer positions, will allow the image to be viewed as outside the surface located at position P (Beaty, 2003).

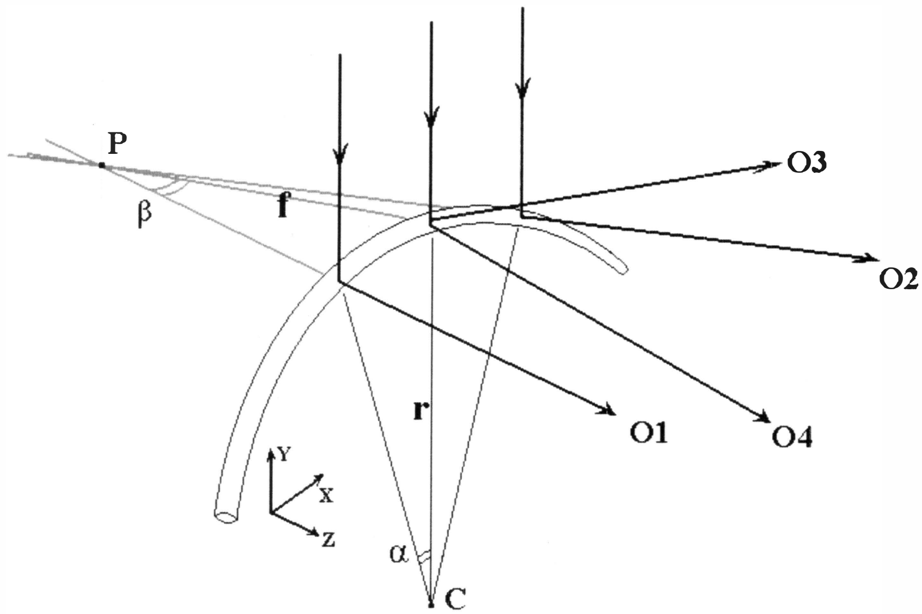


Figure 7: Multiple observer orientations upon the abrasion to show multi-dimensional depth to the perceived images (Beaty, 2003).

It is expected that scratch holograms likely function in a similar manner to traditional holograms. The array of abrasions upon the surface scatter the conical reflections into an interference pattern. Upon viewing the abrasions into a light source like the sun this returns the original object that the array of scratches originated from. There is likely a function, similar to Fourier Transforms of holograms, that allow the three dimensional image to return (S. Daniels, personal communication, July 7, 2016)

The unit plan originally contained the intention to implement a module on scratch holograms into the classroom. Not having the resources to locate and supply Metrologic's sandbox kit and associated film, nor having a dark room of any kind at OFHS, the implementation of three dimensional holograms was going to be the abrasion kind. Upon further research new developments have been happening in the advancement of novice holographic films, such as Litiholo's C-RT20 instant holographic film with associated hologram kits (Chiaverina, 2010).

Chiaverina also realized that completing even simple transmission holograms required a sandbox or vibration damping table, an expensive laser source, high quality beam splitters, perhaps lens equipment and chemicals for development. Litiholo's new film (C-RT20) is self developing "Instant Hologram" film, which makes the whole development process reminiscent of Polaroids™ during the pre-digital era of film. The active components on the film plate are fully consumed during exposure and the film is also no longer sensitive to any exposed light. As a result, one can immediately view their newly produced hologram. Also remarkable about the film is that it is quite 'forgiving' in producing holograms for the novice holographer. No longer would a formal dark room be required, but merely having a 'darkened' room (shades drawn, and room lights powered off) would be sufficient enough to allow the instant film plate to produce a decent hologram. The kit setup is merely placed upon a desk without use of a costly isolation table or cumbersome sandbox (Chiaverina, 2010).

The characteristics of Litiholo's entry model hologram allow science teachers to include hologram production as a valuable learning activity with their students. This new system was within reach of the resources at OFHS and it was decided to include it as an additional module on holography.

Curricular Rationale of Unit Plan

The presented topics in this paper are connected into the curriculum of AP Physics 1 and 2 courses as defined by the College Board™. Superposition and interference of waves is actively studied in the AP Physics 1 course as curricular requirements for the cumulative college board exam held every May. A conceptual presentation of diffraction is also included as a mere vocabulary definition of the wave behavior. Quantum atomic theory is included in the subsequent AP Physics 2 course, which some of the students will enroll in for the following academic year. Introducing these topics at the end of AP Physics 1 will motivate students to continue and enroll in AP Physics 2. There's also quite a few students in this course who might enroll in AP Chemistry of which quantum atomic theory and photochemistry might be useful topics to become familiar with as well.

As the State of Illinois presses forward with implementation of the Common Core learning standards, the science subsidiary of those would be the Next Generation Science Standards (NGSS). For the NGSS this unit plan would satisfy the following standard:

> **HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.***
>
> *The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea (NGSS, 2013).

The unit plan module meets this standard in the following factors:

- Determining the width separation from a double slit aperture with a laser source.
- Determining the quantum effects that the absorption light waves have upon a simple atom.
- Using photographic film to determine optimum light resolution from a camera.
- Utilizing holographic film to capture three dimensional images.
- Presenting a chosen special topic on the science and applications of light waves to the class.
- All of these will be technically communicated to the instructor with supporting data and rationale.

Methodology

This unit plan was incorporated in the spring semester of OFHS's 2015-16 academic calendar in the AP Physics 1 course. This course is open to any student who has passed Honors

Physics First, the pre-requisite course or has prior permission from the instructor. The subject group this year consisted of ten (10) sophomores, two (2) juniors and fifteen (15) seniors for a total enrollment of twenty seven (27) students.

Due to the curricular constraints of the course, the unit plan was scheduled for the time frame from the administration of the college board examination on Tuesday, May 3 to the last day of school on Thursday, May 19. During this time various students in the course were excused from class due to other scheduled AP examinations. Attendance on any given day was rather erratic due to these absences.

The fifteen senior students in the course were dismissed from school on Tuesday, May 10. Although those students did participate in the foundation activities on days which they did not have an AP examination scheduled, they were not present for the conclusion of the unit plan. As such they did not submit course work for the final project of light, nor complete any holography laboratory activities. Those activities were limited to the twelve students who remained in the class until the conclusion of the calendar year–students in the tenth and eleventh grades. These students are also eligible to enroll in AP Physics 2 the following year.

All students were provided with release forms to be signed by their parents or guardians before the unit plan commenced (see Appendix Section). The science department supervisor of Bremen High School District #228 approved the objectives of the unit plan before implementation in the classroom.

Necessary Pre-Knowledge (3 school days)

In order for students to understand the concepts behind holography, they will need a solid foundation in the physical concepts of the interference and diffraction of waves. In the AP Physics 1 curriculum set forth by the College Board™ both concepts are covered in the curriculum currently. General superposition of waves is an essential component in a one dimensional sense. Students are expected to know the behavior of waves as they pass through barrier openings. Both concepts are detailed in the sound unit of study for the AP Physics 1 curriculum (0 days).

Going beyond the scope of one dimensional interference with simple superposition, a connection into two dimensional sources would be the next curricular step. Through classroom demonstrations and lecture, students would be exposed to what happens whenever two wave sources cause disturbances within a medium. Emphasis would be placed upon studying the nodal and anti-nodal pattern of two dimensional interference. Further discussion its changes with respect to source wavelength, distance between sources and the resulting fringe pattern at different distances from the two interfering wave sources (1 day).

Young's single and double slit experiment would be discussed combining the wave behavior of two dimensional interference and diffraction. Demonstrations and lecture and discussion of the phenomenon tied to the founding concepts would be discussed during the course of one class hour. The following day, students would complete a laboratory experiment regarding the variables of the wave behavior involved in Young's slit experiments. Traditionally student groups would be provided metallic templates with varying slit sizes and distances to mimic the variables for the experiment, completing the analysis to see the effects on the fringe patterns developed on a screen. For a student engagement activity, it is always beneficial to determine the width of the students' hair as an continuation of the experiment as well. The students can compare that result to the metallic strips that were experimented upon during the traditional lab experiment (2 days).

Comprehending Film Technology (1.5 - 2 school days)

The standard AP Physics 1 curriculum does not cover photon emission and absorption or hydrogen energy levels. Conveniently for the students at OFHS the prerequisite course for AP Physics 1 – Honors Physics First – distinctly has a formal unit on quantum electron jumps as well as Bohr's atomic model for hydrogen. Building upon that conceptual foundation, an informal discussion of film technology could be developed to eventually aid students in understanding how a chemically treated glass plate can eventually create a hologram.

Depending on how well the students retained the material from the quantum unit from the previous school year, it may be necessary to review key concepts of that phenomena before diving into film technology. A simple quick lecture and discussion in class of those concepts would pull out that information (time cost 0.5 to 1 school day). Afterwards, students could learn about film technology and photosensitive materials in a guided style web quest activity where they are exposed to a quick overview on the background of film as well as its overall history. In the same web quest they would be asked to make a connection between the absorption of the photons scattered off an object and how the photosensitive film changes due to the exposure of the light (1 day).

Fourier Transform (1 school day)

Fourier transforms are a major component of the theory of how hologram technology truly occurs upon a glass plate. Unfortunately a full comprehensive discussion into Fourier transforms requires extensive calculus knowledge. At OFHS this creates a limitation as only a handful of the students enrolled in AP Physics 1 are typically concurrently enrolled in AP Calculus AB, which is only first semester university level calculus. Fourier transforms are more complex math than would be covered in the first semester university level calculus. The challenge then is to expose students to purely the conceptual aspects of Fourier transforms as they relate to holography, without diving into full detail of the calculus involved.

The objective here is tying the transforms to Young's double slit experiment. The maxima and minima fringe pattern developed by Young's double slit experiment upon a viewable screen matches closely with the graph of the mathematical cardinal sine (sinc) squared function. If a slit pattern is modeled after that viewable fringe pattern, the new slits placed at the exact same distance from the viewable screen will reproduce the original slit pattern that produced the first pattern. This conceptual foundation (neglecting the mathematics) will help explain the effects of the fringe pattern upon holographic glass to produce a three dimensional image of a given object. To portray these concepts to the students, a simple demonstration showing the eventual return of the original slit pattern and a guided discussion of the overall process reinforcing two dimensional interference and diffraction will forge toward the mathematical models regarding holography (1 day).

What is a Hologram? (1 school day)

With a foundation built regarding the scientific concepts and mathematical models involved, a culminating discussion into the science of holography could tie the major ideas together. During a classroom lecture, a teacher could perform a demonstration of showing the properties of monochromatic light with an incandescent light bulb radiation versus a pure laser through a diffraction grating. Next students could see how the monochromatic light of a split laser beam will interfere with itself as reflected upon a screen. A probing question could be asked then to the class, what if the screen was replaced by a piece of glass film? What would the 'picture' upon the film truly represent? As class closes, students would be guided into the question: If one of the beams incurred diffuse reflection off an object, how would that affect the interference pattern upon the glass plate?

Holography Activities (2 school days)

The capstone of the unit plan is to complete the guided inquiry labs on three dimensional hologram production and the science behind what makes them work. Two types of holography would be investigated in the unit plan. The first is a simple scratch (abrasion) hologram upon an optical surface, such as plastic, as designed by Stephen Benton in 1968, and discussed in Beaty (2003). Afterwards the students would make a traditional transmission hologram upon a glass plate. For the first scratch lab, the main objective is to determine the interference of reflective waves upon the optical surface in order to create the simple three dimensional image. Students are provided with a four by six inch piece of clear acrylic plastic from the local hardware store, a double tipped compass, and their choice of different patterns to arc scratch with their compasses upon the plastic. Looking at the holograms in the outdoor sunlight they would be able to see a similar three dimensional image a basic design that is similar to a simple rainbow hologram. Students fill out a summary questionnaire which probes their understanding of the optics behind the image that they view upon the scratched plastic. The following school day, students create a traditional transmission holograms upon emulsified glass film. The objective is for the students to see the connections between the previously discussed optics behavior and Fourier transforms and the monochromatic light reflected off the physical object versus the direct light from the laser upon the glass. Conveniently the cost in time and funds have been greatly reduced by laboratory kits. Seeking a grant funds from Bremen High School faculty association, possible student transmission hologram kits could be either provided from Litolo $99 or Integraf for $169 per each kit.

Student Research Presentations (3 school days)

At the conclusion of the unit plan students were assigned to groups of two to complete an oral presentation on extension topics based on holography or light optics. Groups were asked to research topics of their choice from a list provided from their instructor. Presenting their research in seminar format, students discussed with their class peers the scientific concepts involved in each chosen topic. Students were assessed in their coverage and performance on each topic via a supplied rubric.

Student Evaluations

To determine the efficacy of the unit, students were requested to complete a survey about their learning experiences. Survey questions are measured on a numerated scale of student agreement regarding specific aspects of the learning activities. Also included on the evaluation would be open ended responses regarding the strengths, weaknesses, and ways to improve the activities for future classes of AP Physics 1. Concluding the survey, students will be asked to self assess their own expected grades for the unit plan.

Day One Lesson Plan

Lesson Objective and Goals:
Students need to correlate the scientific principles of simple interference and superposition into two dimensional analysis. They need to define and identify nodal and anti nodal lines of interference due to two point sources of waves.

Lesson Materials Needed:
Projector Ripple Tank [from Arbor Scientific $49.00 #P7-7260], Interference Pattern Templates, Wet Erase Markers, Associated worksheets and handouts located in Appendix A.

Perceived Lesson Challenges:
It is a challenge for some students in the secondary setting to visualize models in a multidimensional method. Some students will need guidance and various methods to conceptualize the interference in this manner. The ripple tank demonstration should be able to help in this regard at the beginning of the class activity.

Key Physics Concepts used in this Lesson:

Superposition	Interference
Wavelength	Frequency
Phase Shift	Nodal / Anti-Nodal Lines

Classroom Time Span (~55 mins total):
~5 min. Intro review discussion on what is interference and superposition. Have the students redefine each in an open forum with their peers.
~10 min. Discuss single source pattern waves using a ripple tank on the overhead projector. Key points of discussion is that ripple waves travel in all directions from the source at a constant speed.

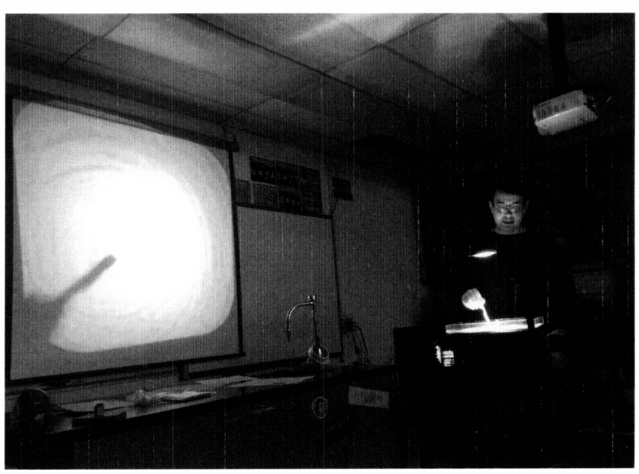


Figure 8: Class Discussion of Single Source Waves

~15 min. Discussion of double source pattern waves using the overhead projector and the Interference pattern templates overlapped. Key points of discussion would be the concepts of the nodal and anti-nodal line interference patterns.

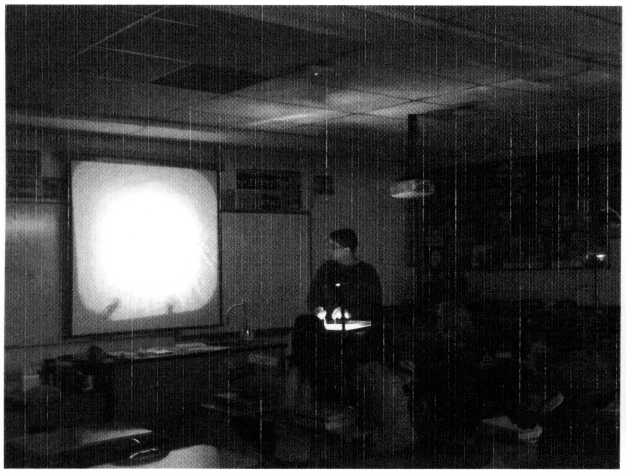


Figure 9: Discussion of Double Source Waves

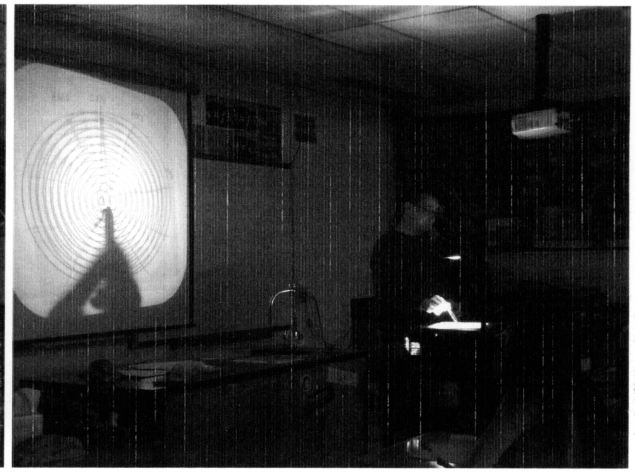


Figure 10: Discussion of Double Source Wave Interference

~25 min. Student Work on path difference measurement lab between two oscillating sources. Students will perform a percent error analysis on their results.

<u>Lesson Assessment:</u>
Student groups will also turn in their worksheets at the completion of the lesson for my assessment on the knowledge gained during the measurement activity lesson. The answer key is also provided in this days lesson.

<u>Evening Homework:</u>
Finish the phase difference measurement lab and its summary questions. Determine the percent error of the data driven results.

Day Two Lesson Plan

<u>Lesson Objective and Goals:</u>
In this lesson, students need to apply interference concepts to light waves and identify diffraction of light though small barrier openings. They will also determine the relationship between slit distance, screen distance, wavelength of light and their relationship to fringe patterns on a screen.

<u>Lesson Materials Needed:</u>
Monochromatic Laser; Diffraction Grating; 2D Interference Pattern Templates; Digital Projector; Associated worksheets and handouts located in Appendix B.

<u>Perceived Lesson Challenges:</u>

The relationships of how the slit distance and wavelength of light affects the fringe distance can be challenging to some high school students. Adequate discussion and example demonstrations of slit differences and different laser beams of light should likely help clarify any issues.

Key Physics Concepts used in this Lesson:

Superposition	Interference
Wavelength	Frequency
Phase Shift	Young's Double Slit Experiment
2D Fringe Pattern	

Classroom Time Span (~55 mins total):
~5 min. Review two dimensional interference pattern with Ripple Tank demonstration.
~5 min. Discuss and review diffraction. Usually going out in the hallway and screaming works for high school level students. It is an example that sound does travel around barriers easily while light waves do not. The students could hear the scream in the hallway through the open doorway, but they cannot see its source.
~5 min. Review safety aspects of using a laser source correctly and the notion that they should never be shone into any person's eyes.
~35 min. Conduct the powerpoint presentation on Young's double slit experiment, which proved beyond Huygen's principles that light has wave like properties.
~5 min. Introduce sample double slit problems and distribute homework.

Lesson Assessment:
Students will complete their summary worksheets at the end of the lesson for my assessment on the knowledge gained during the lecture. With the summary worksheet the answers are provided in brackets. Thus students can self assess their own learning.

Evening Homework:
Students will complete the Young's Double Slit Problems Worksheet which is due the following day.

Day Three Lesson Plan

Lesson Objective and Goals:
Students will apply the equations and relationships of Young's Double Slit Experiment in a practical manner to determine the width of their hair. They will analyze their results to compare with their peers and rationalize why certain students might have thicker hair than in comparison to others.

Lesson Materials Needed:
Monochromatic Laser, Diffraction Grating, Metersticks or Foot-long Rulers, Associated worksheets and handouts located in Appendix C.

Perceived Lesson Challenges:

It is likely easier for students with longer hair of course to pull out a sample of their hair to use in the experiment. Anyone with short hair (crew cuts, flat-tops) to complete the experiment for their own purposes, as it is a challenge to disturb the laser light to cause an interference fringe pattern. In an unusual twist, students who have it, previously used their leg hair strands.

<u>Key Physics Concepts used in this Lesson:</u>

Superposition	Interference
Wavelength	Frequency
Phase Shift	Young's Double Slit Experiment
2D Fringe Pattern	

<u>Classroom Time Span (~55 mins total):</u>

~5 min. Review previous night's homework and their respective answers from the Young's Problems Worksheet.

~5 min. Discuss and introduce the day's lesson plan and student objectives. Model as an example that interrupting a monochromatic laser beam with a strand of hair can cause a fringe pattern upon the white board.

~45 min. Student groups conduct and collect their data for their respective strands of hair plucked from their heads. They measure the fringe patterns caused from the separation of the laser beam due to the interruption. After collecting their data, the rest of the classtime they use the fringe pattern equation with small angle approximation (tan $\theta \sim \sin \theta \sim \theta$) to determine the width of the separation of light which is equivalent to the widths of their hair strands. Through guided questions in the lab, students will have a conceptual discussion among their own groups which student has the widest hair strands and what would make their hair different than their peers. Afterwards, students complete summary questions regarding the mathematics of Young's double slit experiment on the opposite side of the laboratory worksheet.

~Optional: If one has the correct set of calipers, you can confirm the hair width from the lab data to that with the accepted value from the calipers.

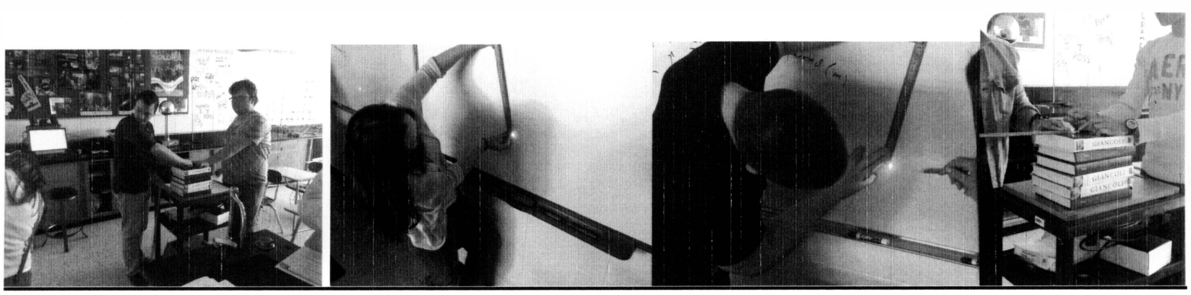


Figure 11: Students collecting laser fringe data

<u>Lesson Assessment:</u>

Data will be collected from the experiment and students are expected to analyze it and determine the width of the hair that causes the interference patterns of light. Students would be assessed in their ability to take accurate data as a team and analyze it correctly to complete the summary questions.

Evening Homework:
Students will complete their analysis of the lab data and the summary Young's double slit problems on the opposite side of their lab worksheet, which is due the following day.

Day Four Lesson Plan

Lesson Objective and Goals:
Students will be introduced to the concepts of Bohr's model of the atom – that photons of light can be released or absorbed from electron orbitals in packets of quantized energy. This is an important aspect of how photosensitive film works and functions.

Lesson Materials Needed:
LED Light Array Tower [$79 from Arbor Scientific #P2-7125], Spectral Tube Power Supply 115V [$205 from Edmund Optics # 71-559], Class set of diffraction gratings, hydrogen, neon and mercury gas spectral tubes for demonstrations, Overhead digital projector for presentation, Associated worksheets and handouts located in Appendix D.

Perceived Lesson Challenges:
Students at our school were introduced to the physics of color during their ninth grade honors physics course. It might be a challenge for them to remember that combined spectra mix to make certain colors of light (for instance mercury which is a light blue hue is a mixture of many colors).

Key Physics Concepts used in this Lesson:

Electrons	Nucleus
Energy orbits	Frequency
Wavelength	InfraRed, Visible & UltraViolet spectrum
Photon	Planck's Equation

Classroom Time Span (~55 mins total):
~5 min. Review discussion on the aspects of the hair width lab from Day three's lesson plan resulting fringe patterns on the whiteboard.
~45 min. Lesson presentation keynote on the Bohr's model of the atom. Discussion would focus upon the photon emission and absorption through the quantized energy leaps. Planck's equation would be introduced as the energy contained in a photon of light. Make sure to show in demonstration the light spectra of the gas tubes to the students, with the class set of diffraction gratings. They can be compared to the pure color spectra of the sample gases in the template. In the future lessons of the unit plan, photochemical film would be connected to these concepts for the absorption of images traditionally in silver halide crystals.
~5 min. Close the lecture with a question and answer session that the students may have regarding the concepts discussed.

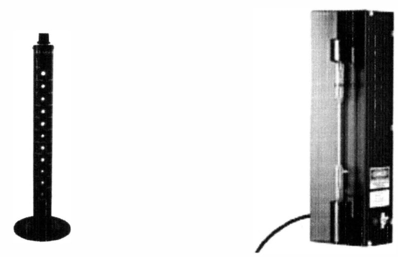


Figure 12: LED Light Array & Spectral Tube Power Supply

Lesson Assessment:

Students will complete their summary worksheets at the end of the lesson for my assessment on the knowledge gained during the lecture. With the summary worksheet the answers are provided in brackets. Thus students can self assess their own learning.

Evening Homework:

Students will complete their summary worksheet entitled “The Bohr Atom” which will be collected for assessment the following day.

Day Five Lesson Plan

Lesson Objective and Goals:

Students will be apply the knowledge gained from the previous lesson’s introduction on Bohr’s model of the atom to a simulated lab coordinated from the PhET™ interactive animated laboratory program through the University of Colorado-Boulder.

Lesson Materials Needed:

Computer laboratory checkout or personal computing devices for the students to complete the simulated activity. Associated worksheets and handouts located in Appendix E.

Perceived Lesson Challenges:

As decent as the animation is, it is still essential to have a summary discussion at the end of the lesson to make sure students are observing what they should be taking away from the activity. When the photons of light are being absorbed by the electron orbiting the nucleus, they should know that specific quantum leap occurs and the electron is energized to another orbit. This is a key component in this lesson to understand how film technology functions with photosensitive materials.

Key Physics Concepts used in this Lesson:

Electrons	Nucleus
Energy orbits	Frequency
Wavelength	InfraRed, Visible & UltraViolet spectrum
Photon	Planck’s Equation

Classroom Time Span (~55 mins total):
~5 min. Review discussion on the aspects of the Bohr's model of the atomic structure and quantum phenomena of the electron.
~45 min. Students complete the Bohr's model of the atom laboratory simulation packet. They will collect data and analyze it according to the packet's instructions. When completed collecting their lab students will finish the summary questions on what they observed during the laboratory activity.
~5 min. Summary discussion of key concepts presented during the laboratory simulation, focusing on the quantum effects of photons being absorbed by the associated electrons.

Lesson Assessment:
Assessment will be completed by students taking accurate data in their laboratory packets and with sound reasoning answer the conceptual summary questions which follow data collection.

Evening Homework:
Students will complete the analysis questions to the laboratory packet and they are to be turned in the following day.

Day Six Lesson Plan

Lesson Objective and Goals:
Students will become familiar with the inner workings of a photographic film loaded camera and the scientific concepts which allow photosensitive film to permanently record images due to light exposure variables. This will be completed through an online webquest activity.

Lesson Materials Needed:
Computer laboratory checkout or personal computing devices for the students to complete the simulated activity. Associated worksheets and handouts located in Appendix F.

Perceived Lesson Challenges:
Although it is not far into the digital age, some secondary level students have never even seen or heard of photographic cameras before. The teacher will need to actively monitor students as they complete the webquest focused questions and provide feedback as necessary. It is essential to formulate a connection from Bohr's model of the atom activity with quantum phenomena to photochemistry.

Key Physics Concepts used in this Lesson:

Electrons	Photon
Energy orbits	Camera
Wavelength	Photographic Film
Photochemistry	Film Speed
Aperture	Shutter
Base	Gelatin

Classroom Time Span (~55 mins total):
~5 min. Review discussion on the aspects of the Bohr's model of the atomic structure and quantum phenomena of the electron.
~45 min. Students complete the webquest activity finding the answers to the probing questions of the associated worksheet. Through the activity based upon the information found at http://www.howstuffworks.com/ they will discover what causes photographic film collect and permanently store information due to the quantum phenomena of typically silver halide crystals upon the film.
~5 min. Summary discussion of key concepts presented during the webquest, focusing on the photochemistry of film layers.

Lesson Assessment:
Assessment will be completed by students finding the key information regarding camera technology through the webquest. With sound reasoning, they will answer the conceptual summary questions which follow the guided questioning research.

Evening Homework:
Students will complete the analysis questions to the webquest and they are to be turned in the following day.

Day Seven Lesson Plan

Lesson Objective and Goals:
Students will determine which level of light illumination that results in the best resolution of images as judged by a photography resolution template.

Lesson Materials Needed:
Fuji Instax™ Mini 8 Camera [$79.90 through Amazon.com], Instax Mini film - 10 Sheets x 5 packs [$38.49 through Amazon.com], Resolution Chart [$13.95 through Amazon.com], Lab Stand with clamps, 4 Desktop Lamps with 40W light bulbs at 380 Lumens each, Bausch & Lomb Binocular Microscope [on loan form Eastern Illinois University, but similar used models can be found on Ebay.com for approximately $30-$70].
Associated worksheets and handouts located in Appendix G.

Perceived Lesson Challenges:
This lesson will need substantial oversight from the instructor as the students complete the lab. For time constraints, it would be recommended that the laboratory stations are pre-setup with the cameras safely secure in their stands and the placard is placed at its location approximately 0.6 m from the lens of the Instax cameras – which is recommended as the minimum distance by the manufacturer. For the best resolution data, it is further recommended that the minimum distance is maintained as the students attempt to determine the resolution values. After the students collect their data, they will need instruction to what they should be observing underneath the Bausch & Lomb microscope.

Key Physics Concepts used in this Lesson:

Illumination	Resolution
Magnification	Photochemistry

Classroom Time Span (~55 mins total):
~5 min. Review discussion on the concepts of photochemistry during the previous webquest activity.
~45 min. Student groups take their data through the laboratory setup with the instant cameras. They should choose someone with a steady hand to push the shutter button and collect their data. They organize their data according to the data chart on the lab handout, which gradually increases from 40W to 180W of combined illumination upon the resolution placard. With their pictures, groups will determine the optimal illumination power from the microscope and when the color distinction of the center wheel of the placard starts to become apparent.
~5 min. Summary discussion of key concepts presented during the laboratory, focusing on the relationships between illumination, resolution and the distinction of color for the laboratory set ups.

Lesson Assessment:
Assessment will be completed by students taking accurate data with their instant cameras, determining the quality settings for resolutions for the templates. Finishing off the lab, they should answer the summary questions with reasoning skills that supports their findings.

Evening Homework:
Students will turn in their laboratory packets (with supporting pictures pasted and summary answers determined) by the following class day.

Figure 13: Students taking resolution data with lab setup.

Day Eight Lesson Plan

Lesson Objective and Goals:
Students will begin research today upon the special light and optics topics as discussed on the handout.

Lesson Materials Needed:
Computer laboratory checkout or personal computing devices for the students to complete the simulated activity. Associated worksheets and handouts located in Appendix H.

Perceived Lesson Challenges:
This lesson activity certainly does not only cover a single day, but multiple days. It culminates in a final presentation on a topic choice of the student to his or her peers in the class. The teacher must keep up to date on all students to maintain appropriate progress to project ending.

Key Physics Concepts used in this Lesson:
Refer to handout, but all topics deal with advanced study into light and optics and not only limited to simply holography.

Classroom Time Span (~55 mins total):
~5 min. Introduce the project topics, parameters and requirements for students. Students will determine if they would like to work as a group up to three students and which topic upon the list is of special interest that they would like to explore further.
~50 min. Students announce their topics to the teacher and begin their research to present to the class. Typically workspace and computer consoles are provided the school's library staff. Therefore students can use a variety of different resources to collect their research and formulate the outlines to their presentation. The span of this activity is a full school week. Students are responsible to continue progress on their research and project development.

Lesson Assessment:
Students will be assessed via the associated rubric which is attached to the backside page on the topic handout worksheet.

Evening Homework:
Students are responsible to continuing their own research of the material topic choice as they progress towards the presentation due date.

Day Nine Lesson Plan

Lesson Objective and Goals:
Students will produce a 3D scratch hologram as instructed and determine the basics concepts behind how they are formed.

Lesson Materials Needed:

1/8" inch thick plastic sheet cut into 3" x 5" pieces [purchased an 11" x 21" acrylic sheet from the local hardware store for $6] ; Classroom set of mathematical compasses that are pre-loaded with double needles [borrowed from OFHS Math Dept] ; Masking Tape ; Scratch Hologram Template ; Access to sunlight

Perceived Lesson Challenges:
In completing the scratches across the acrylic sheets, students will need to make pretty light abrasions with their compasses. Too often students gouge the surfaces with scratches that are too deep. Also students have a troublesome time trying to maintain arc scratches with equal radii on their acrylic surfaces. It is recommended to demonstrate the scratch techniques to the students before they potentially waste a sheet of acrylic.

Key Physics Concepts used in this Lesson:

Illumination	Scattering
Resolution	Interference

Classroom Time Span (~55 mins total):
~5 min. Introduce the activity and objective to the students. There are various online tutorial videos that students can observe sample scratch holograms being produced. The same video can be looped as well throughout the time when students complete their holograms.
~50 min. Students complete their scratch holograms according to the instructions on the laboratory handout. Once students are completed with their scratches they can see the results of their abrasion holograms outside in the sunlight. The classroom of 419 at OFHS has an external door and thus its easy access. It might be a challenge in other classrooms and if so, even a cell phone flash light can work as a point source light to see the abrasion reflections.

Lesson Assessment:
Assessment will be completed by students completing their scratch holograms and answering the summary questions stated on the handout. Namely they should postulate that the scratches cause scattering of the incident light beams and the scattering of the light over multiple scratches will cause an interference pattern with one another.

Evening Homework:
Students will turn in their laboratory worksheets (with supporting pictures pasted and summary answers determined) by the following class day.

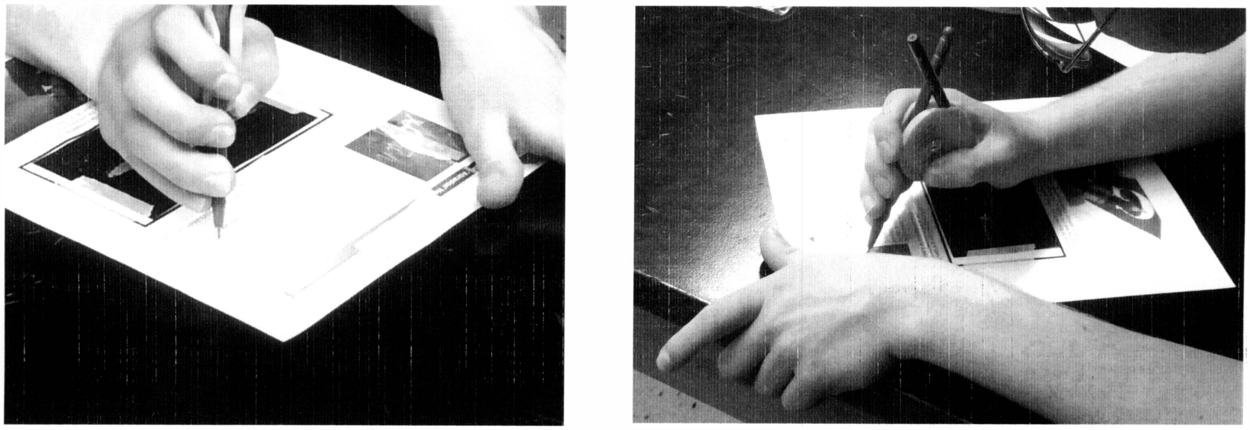


Figure 14: Students completing the scratch hologram lab.

Day Ten Lesson Plan

Lesson Objective and Goals:

Students will combine the background concepts of holography: quantum effects, interference, resolution, to understand how the technology of producing holograms in a keynote presentation.

Lesson Materials Needed:

Overhead digital projector, Presentation software, Associated worksheets and handouts located in Appendix I.

Perceived Lesson Challenges:

At this point the students completed a fast crash course on various core topics of holography, which typically last a week each (minimum) in the AP Physics 2 curriculum – the subsequent year's elective course. Thus there might be some uneasy conceptualization of the ideas presented and how they fit in the scheme of holograms. Today's lesson's aim is to iron out those challenges and explain why the unit had investigations of those concepts in the overarching project of producing a hologram.

Key Physics Concepts used in this Lesson:

Illumination	Scattering
Resolution	Interference
Frequency	Wavelength
Quantum Phenomena	

Classroom Time Span (~55 mins total):

~5 min. Show and discuss the characteristics of the hologram produced during the summer of 2015 at the physics labs of Eastern Illinois University. It is a reflection hologram and can be viewed in simply white light. Pass around to the students so they observe the hologram glass plate itself.

~50 min. Keynote discussion on the concepts of holography. Discussion on the history of holograms and the basics of their setup and the concepts of light waves . Explain during the diagram setup that holograms are truly the permanent record of quantum interference upon a film plate. See attached file slides.

Lesson Assessment:
The assessment of this lesson will be determined on Day 11, when students will be using the concepts and skills gained during this discussion to complete the Holography lab the following day.

Evening Homework:
As we will be making our holograms with the Litiholo™ kits tomorrow, students are to bring in small miniature objects of their choice (no larger than a matchbox car) to produce their custom hologram.

Day Eleven Lesson Plan

Lesson Objective and Goals:
Students should be able to describe the essential steps in producing successful 3D Transmission holograms through guided inquiry. (Optional) Students can develop a procedure in producing a reflection hologram that could be seen in white light concluding the laboratory experience.

Lesson Materials Needed:
Litiholo Hologram Kits [$99.99 from Litiholo.com] ; Although the kits come with little Matchbox™ style toy cars, students can bring in their own personal miniature sized objects to make their own holograms from if they choose ; Each hologram kit comes with ten (10) C-RT20 2” x 3” instant holographic film plates [additional can be ordered at $64 per 20 plates at Litiholo.com] ; Laboratory room that can turn relatively dark with minimal ambient light. If windows are located in the laboratory, closing the shades should be sufficient. Associated worksheets and handouts located in Appendix J.

Perceived Lesson Challenges:
At this point the students completed a fast crash course on various core topics of holography, which typically last a week each (minimum) in the AP Physics 2 curriculum – the subsequent year’s elective course. Thus there might be some uneasy conceptualization of the ideas presented and how they fit in the scheme of holograms. Today’s lesson’s aim is to iron out those challenges and explain why the unit had investigations of those concepts in the overarching project of producing a hologram.

Key Physics Concepts used in this Lesson:

Illumination	Scattering
Resolution	Interference
Frequency	Wavelength
Quantum Effects	

Classroom Time Span (~55 mins total):

~5 min. Review concept foundations of holography with the students. Have a discussion regarding why the students studied the separate phenomena of multi-dimensional interference patterns, quantum effects, photochemistry, and illumination and resolution of light.
~50 min. Students complete the laboratory as detailed in the handout. It is recommended due to the limited supplies of instant film provided by Litiholo, that the instructor helps guide and facilitate the student groups' steps through the process. It is a challenge to make sure that the laser diodes are correctly docked in their mounts as the groups set up their labs. Also, student group setups should be pre-checked by the instructor to insure that enough illumination of the light is apparent upon the film plate area and the object involved in the experiment. The timing of the exposure (~12 min) might need to be completed simultaneously between groups depending upon the setup of the classrooms. In the classroom at OFHS Room 419, it is necessary to complete this step simultaneously due to all the ceiling lights connected to a single wall switch. Lastly, it would be wise to mention to the students the delicate nature of the lab kit components make the pieces particularly fragile. Students should handle the kit components with extreme care during assembly.

Lesson Assessment:
Completion of laboratory handout questions that are coordinated per each step of the experimental procedure. They will also be rewarded with extra credit if they write a successful procedure to complete a reflection hologram.

Evening Homework:

Finish the answering the probing questions of the laboratory procedure, where students determine why the setup of the transmission holography lab allows their experiments to be successful.

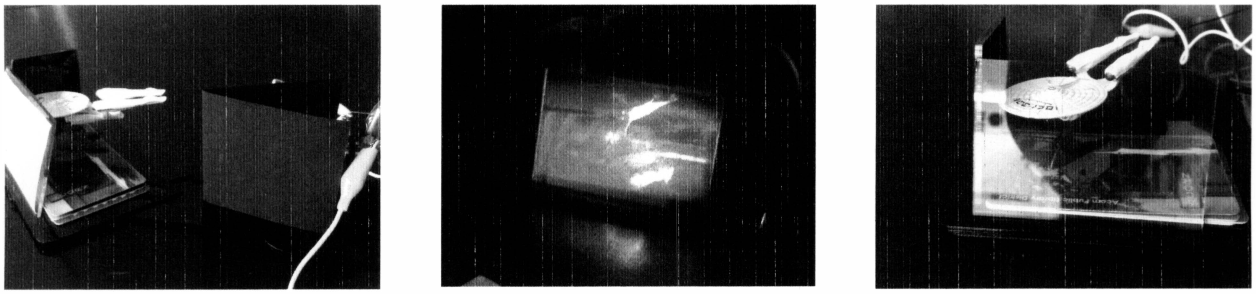


Figure 15: Setup and completion of a three dimensional transmission hologram for a Starship Enterprise™ figurine.

Figure 16: Mr Hogan disappointed by three broken mounting spine brackets after delivery of Litiholo™ Holographic Kits

Day Twelve Lesson Plan

Lesson Objective and Goals:
Students will present the findings of their research on chosen special topics to their classroom peers in a 7-10 minute presentation.

Lesson Materials Needed:
Overhead digital projector, Presentation software, Associated worksheets and handouts located in Appendix K.

Perceived Lesson Challenges:
Students should have had by this point in time a full week to work on their research outside of class and organize a presentation. At this academic level, students either master or still struggle with presenting a topic orally to the class with clear slide structures, professional use of backgrounds, and logically organized discussions from opening to closing. Also, students have variance in their ability to not simply read off the slides verbatim, as well as hitting the targeted time interval of 7-10 minutes. All of these are categorized as scores in the presentation rubric.

Key Physics Concepts used in this Lesson:
Varies per chosen topic, but all presentations would be a discussion of light behavior or phenomena in some aspect. Review topic choices in the Appendix Section.

Classroom Time Span (~80 mins total):
~60 min. The elongated classroom time compared to the previous days in the unit plan is due to the fact that this day is a final examination period. The longer class time would be beneficial for seven student groups to fit their presentation intervals within the same day.
~20 min. If time permits, as a class we would attempt to get an additional exposure of holograms completed.

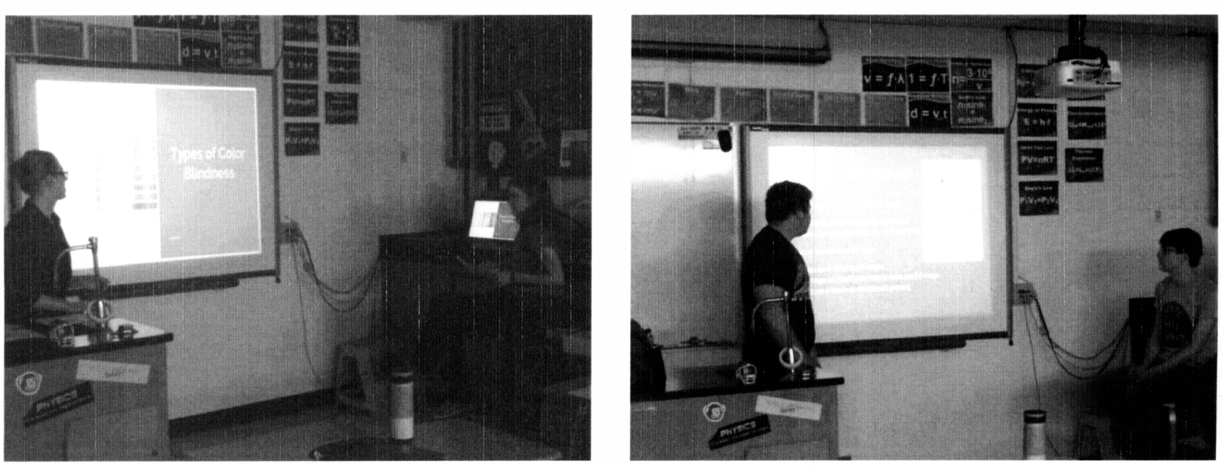


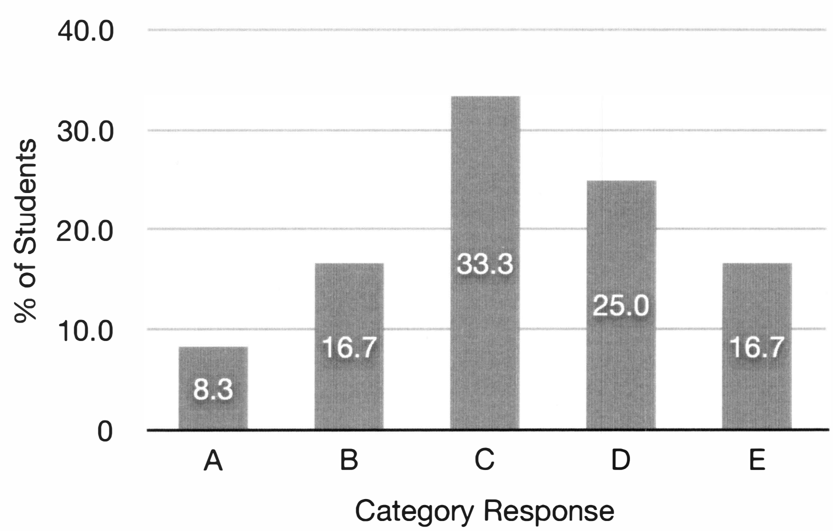
Figure 17: Students Presenting Chosen Special Topics

<u>Lesson Assessment</u>
Completed per rubric as stated in the appendix section. Students were provided with rubric before researching their topic, thus if they adequately prepared themselves prior to presenting students should be able to self assess what their score would be as a prediction.

Survey Results

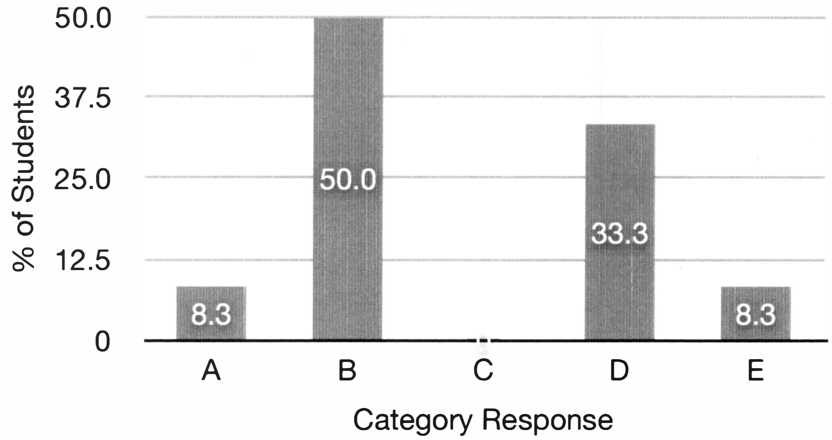
The sample size for this study precludes significant statistical analysis and results. Due to limitations as discussed in the methodology section, unfortunately we could not involve more students that would provide an amount of participants that would be statistically significant. Nonetheless, the remaining students' interests and opinions were surveyed at the conclusion of the unit plan to determine whether the program should be continued for subsequent years. If so, would any particular modifications be necessary to improve its pedagogical delivery. The twelve students were asked the following list of questions. In the first eight questions, the students assess how well they agree with the listed statement on a five category scale.

The pacing of the holography unit was appropriate.

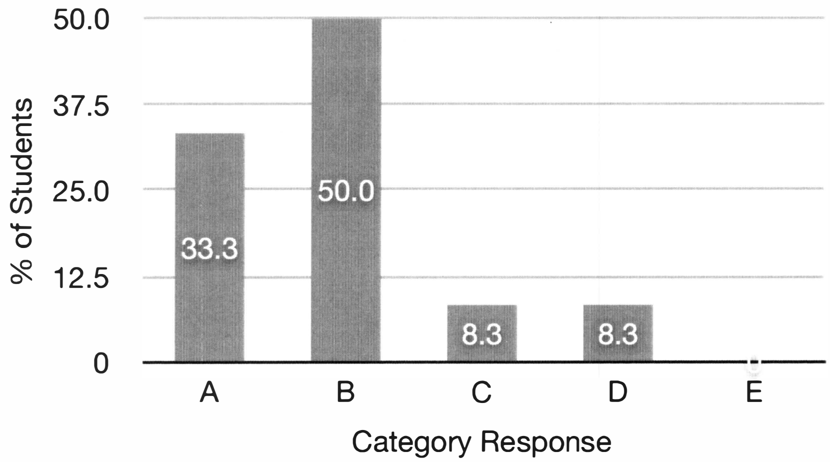


(A - Strongly Agree, B - Somewhat Agree, C - Neutral, D - Somewhat Disagree, E - Strongly Disagree)

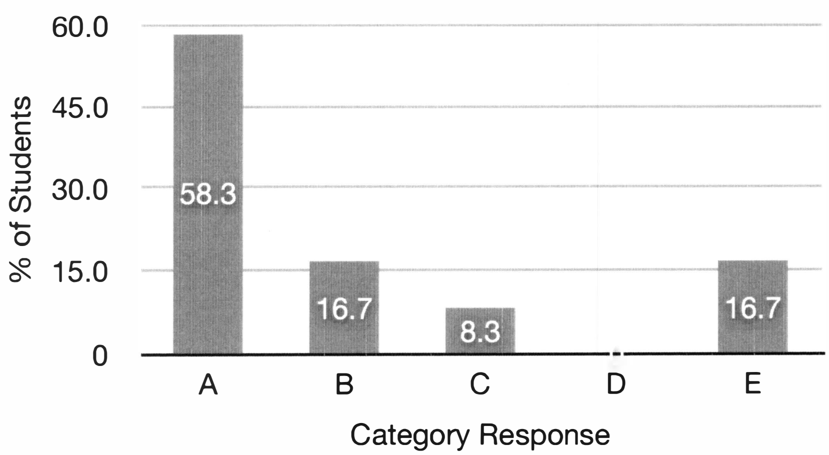
The tasks of the in-class activities were not challenging to understand.



Mr. Hogan guided us through the investigation appropriately.

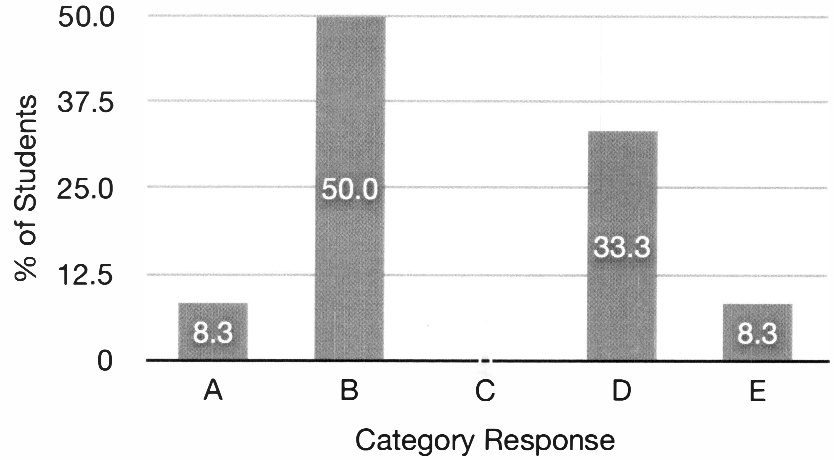


I preferred completing this unit project instead of having a traditional final exam administered.

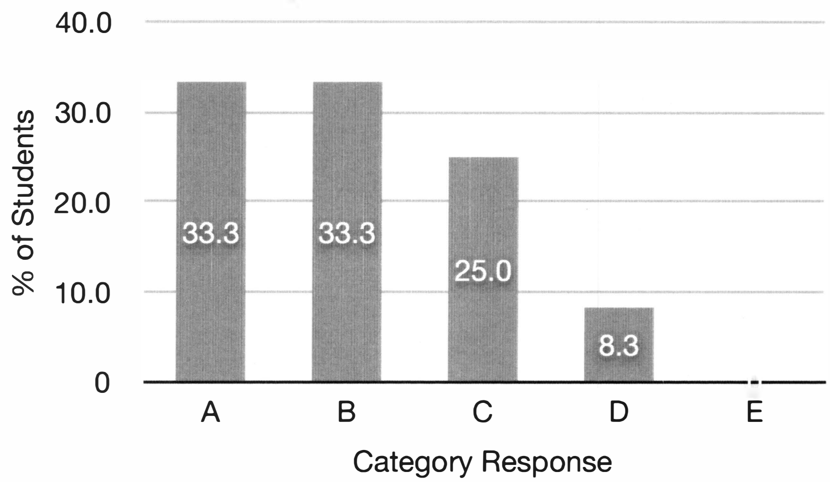


(A - Strongly Agree, B - Somewhat Agree, C - Neutral, D - Somewhat Disagree, E - Strongly Disagree)

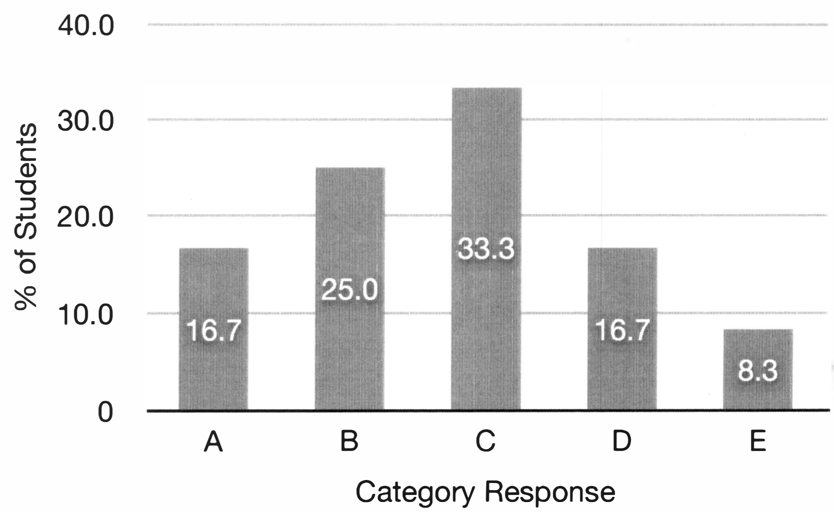
This unit provided me with an appropriate grasp of wave interference.



This unit provided me with an appropriate grasp of quantum effects & simple atomic theory.

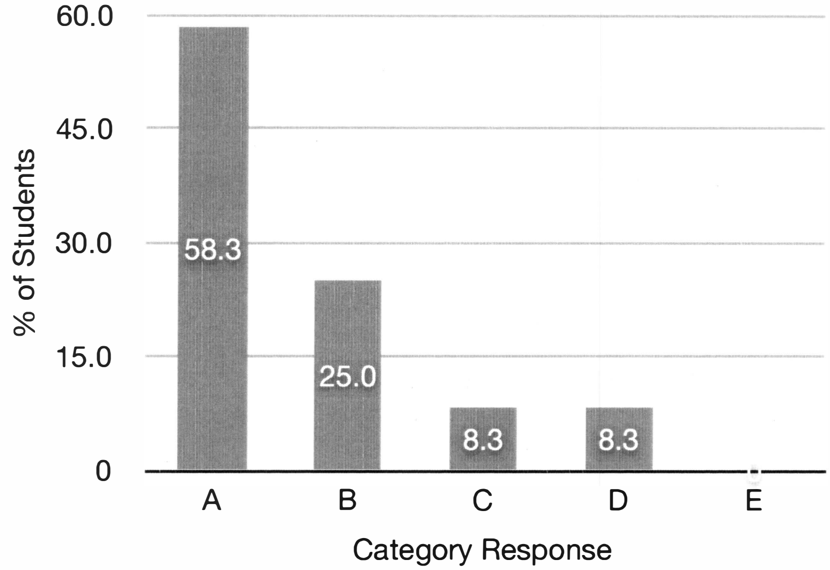


I can see connections from this unit to real world applications.



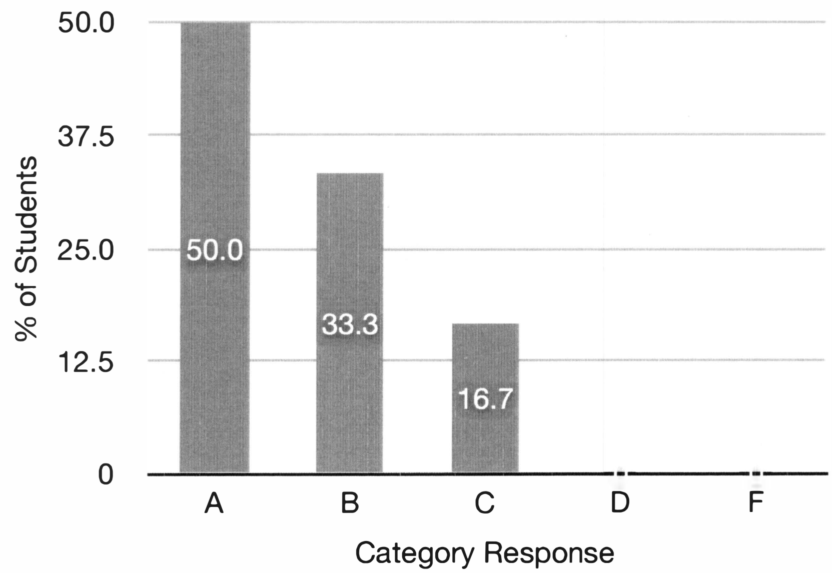
(A - Strongly Agree, B - Somewhat Agree, C - Neutral, D - Somewhat Disagree, E - Strongly Disagree)

Overall I enjoyed learning about holography and the scientific concepts behind them.



(A - Strongly Agree, B - Somewhat Agree, C - Neutral, D - Somewhat Disagree, E - Strongly Disagree)

What letter grade do you expect to receive for the holography unit at its conclusion?



The final three optional questions from the survey were open ended from the students' own perspectives. The student reponses follow the questions in bullet form. Any repeating statements of similar nature in topic, were truncated to the same single statement with a multiplier applied.

1. Is there anything in particular (lesson, learning activity) that you enjoyed most in completing this final unit project?
   - "Making the 3D Hologram on the last day was exciting" (x 4)
   - "The photography lab was pretty neat with the instant cameras" (x 2)
   - "The progression of labs from one topic to the next"
   - "The special topic presentations were pretty diverse and informative"
   - "Seeing how all the previous lessons fit in to the overall holography lab"
2. Is there anything in particular (lesson, learning activity) that you enjoyed the least in completing this final unit project?
   - "Wish we had more time on the material and labs" (x3)
   - "I was a little confused as it seems that the material was presented too quickly" (x2)
   - "We did not have a chance to try the reflection hologram"
   - "I do not like talking in front of class, so I did not appreciate the presentation requirement"
   - "I wish this topic was in the textbook, could have been helpful for review"
3. Anything that Mr Hogan should modify to make improvements in the unit plan for subsequent years?
   - "Complete the unit plan with more time" (x4)
   - "Allow more time each for the scratch holography and main holography lab" (x2)

Conclusions

The holography unit plan had noticeable positive characteristics, as well as aspects which would need improvement on for future years. From the survey, students seem to have appreciated completing this unit plan instead of having a final examination administered to them at the conclusion of the year. The students seemed confident about their expected grades at the conclusion of the unit. Making holograms at the final day of the unit plan seemed to have increased their curiosity and excitement. Many seemed pleased that the topic was outside of the ordinary for many high school science labs and also highly technical in nature.

A noted improvement would be increasing the laboratory time frame for scratch holograms. Reviewing Coughlin's experience implementing scratch holograms in his middle school science classroom, his students had four class periods to eventually master the art of producing them. Over that extended time, his students realized the proper techniques in order make the holograms apparent to the ordinary observer. Maintaining constant radius scratched arcs upon the plexiglass as well as a scratch that did not gouge the surface, were the two main factors in producing decent observable holograms. By the fourth class period Coughlin's students were readily reproducing scratch holograms with confidence (Coughlin, 2010).

According to the unit plan time interval, the students at OFHS only had one day to complete their scratch holograms. Completing the array of scratches upon the plexiglas definitely requires an investment of the majority of the class hour. By the time students had completed their hologram designs, only one student's scratch hologram produced an identifiable image, leaving the others bewildered and frustrated. The budget of time in the class hour and the unit plan did not allow the students any more attempts in class on the scratch holography. The students were told that they could continue to work on the holograms after school if they wished to do so, but few decided to do so. They did appreciate the one student's example as a completed scratch hologram.

Students were only able to get one exposure in the final class period for a transmission hologram. As pictured in the eleventh day lesson plan, three spine brackets were shipped broken from Litiholo. After reorganizing the groups into lab kits that did not have broken pieces within them, the experiment took over half of the class period to set up correctly. It was necessary to inspect all groups to make sure the laser diode was mounted correctly, that the glass plate was leaning on its support, and that the object was correctly oriented. The beam of light needed to have enough exposure on the glass as well as the object, as pictured in the holographic lab in the appendix section.

After all groups had set up their holographic kits correctly, the lights were shut off for about fifteen mins for students to expose their setup to the laser beam. It was quite remarkable that the students could keep quiet and still in total darkness for that length of time. As these are gifted students in the AP program, a certain level of trust is present which probably does not exist with other courses. After the fifteen minutes, students removed their objects and in its place upon the viewing orientation was a three dimensional transmission hologram. Many were excited to see this image, considering the lack of success in the scratch hologram, and the students were excited to try the challenge of a reflection hologram. Unfortunately the class period ended at that time and students were dismissed to their next course.

Clearly each hologram making class period did not allow enough time for the students to complete the activities to their own satisfaction. An improvement in the unit plan could be simply adding more time to each lab experiment. The challenge is where could another day be afforded within the unit plan. The entire allotment of class days between the AP Physics 1 exam and the conclusion of the school year is twelve days, no more no less. In order to add more class time to the hologram experiments, that extra time must be pulled from instructional time of the core concepts of holography.

In itself that would cause another issue as already students were responding in their surveys that not enough time was provided to master optical wave interference, simple atomic theory and quantum effects. All these topics have their own separate units within the subsequent course, AP Physics 2, where students spend nearly a week of class time mastering each one. Challenging the students to comprehend the objectives of each topic in a day or two was not enough time for comprehension. As a result some students as reflected in the student surveys felt rushed. Before they felt comfortable with a formal grasp on one fundamental topic the class moved on to the next topic. Which leads into another possible improvement upon the delivery of this unit plan. Due to the defined curriculum in AP Physics 2, holography could be completed even as a review topic in that course if the course is available. The students already mastering the core concepts, so that they should be able to tackle holography with confidence. Looking back on what they learned in the course, they might easily see the connections of holograms to wave interference, quantum effects and simple atomic theory. Unfortunately at OFHS the AP Physics 2 course has yet to exist due to enrollment trends currently. Students who elect to take the course will need to enroll in a traveling section located at nearby Tinley Park High School instead.

Still this unit plan had few expectations and they were likely met through the learning process. The original strategy for holograms at the secondary level was simply to expose the students to an application that they have never observed in a science classroom. Quite often, holograms are simply a topic of study for collegiate physics courses who have the financial and physical means. As one student noted, the study of holograms are not even a topic mentioned within the supplied AP Physics textbook. It could be simply assumed by many authors that the topic is not covered in secondary science curricula. The study of holograms would probably have been passed over for the students of OFHS if there were not any recent developments in instant holographic film technology.

With various educational initiatives, it is the essential for a science educator to provide students with strong tactile learning experiences. Completing a previously unattainable hands-on lab activity for students at this age level simply accommodates that initiative. Lastly, some of the students will be taking AP Physics 2 as a subsequent course. For learning about holography through this unit, they likely are more prepared for the associated units of study in that class. Therefore even if the class was short on time due to calendar limitations, the students still found this unit on holography valuable and enjoyable to their learning process.

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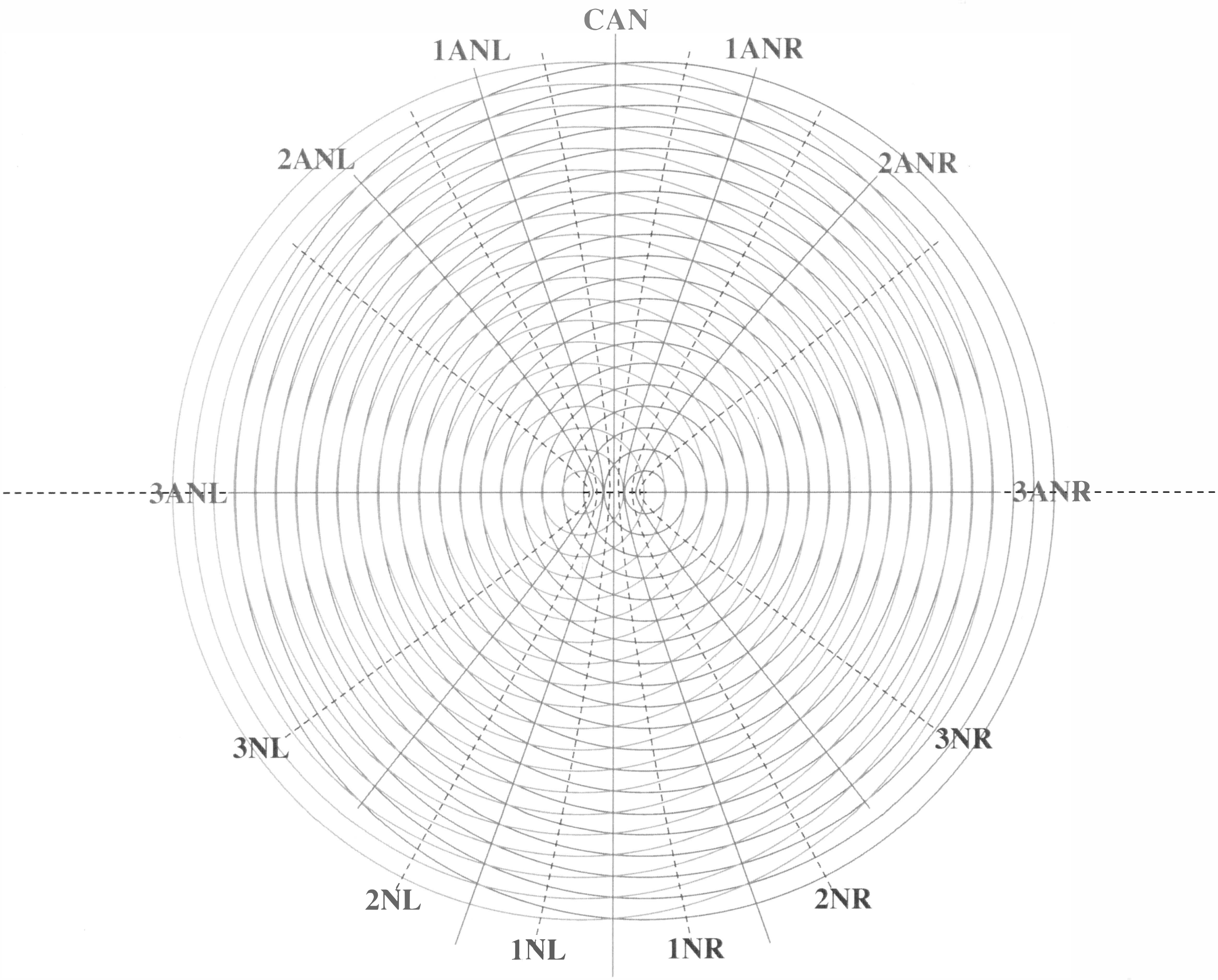
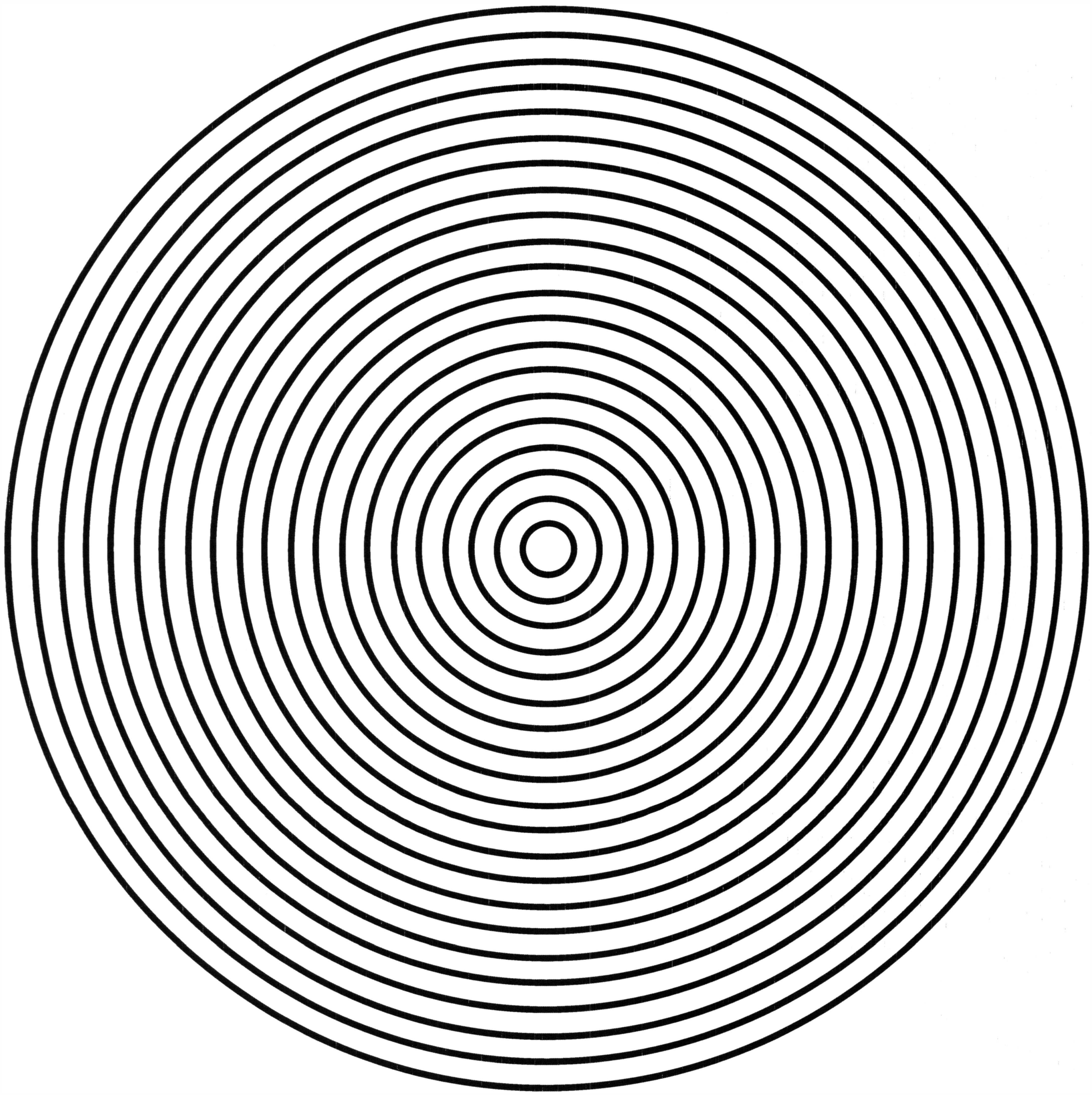
Appendix Section

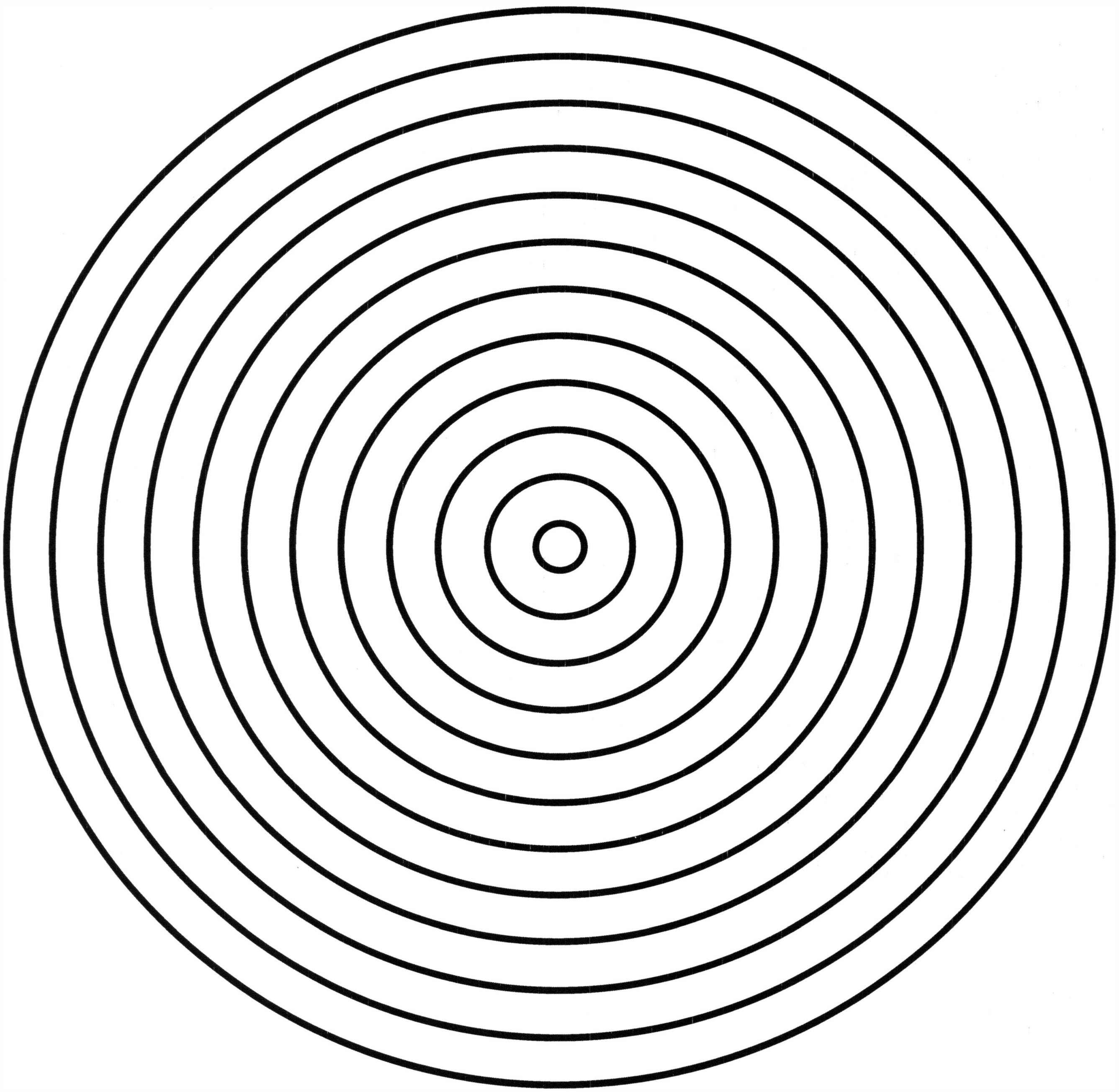
Appendix A.1 2D Interference Template



Appendix A.2 Single Source Wave Pattern (f_0)

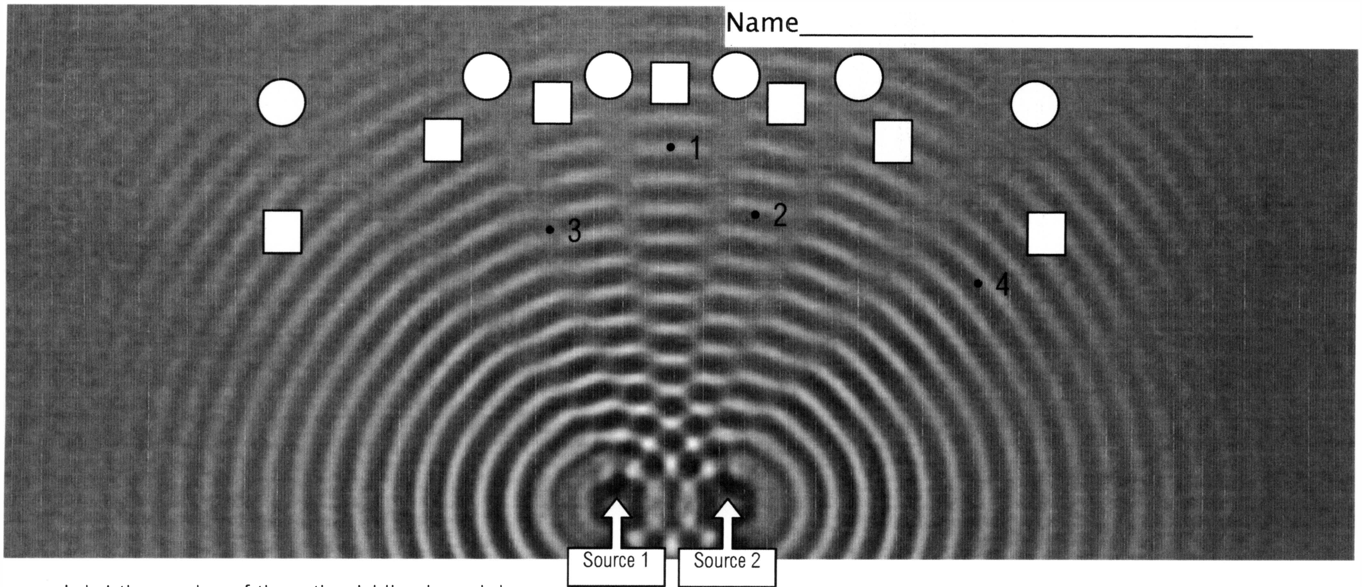


Appendix A.2 Single Source Wave Pattern ($f_0/2$)



Appendix A.4 Double Source Interference Pattern Analysis Worksheet

Name________________________________



Label the number of the antinodal line in each box on the diagram above.
Label the number of the nodal line in each circle on the diagram above.

Use a ruler for the following measurements:
What's the distance from Source 1 (S1) to point 1? ____________cm
What's the distance from Source 2 (S2) to point 1? ____________ cm
What's the difference in these distances? ___________cm

What line of a typical 2D interference pattern is point 1 on? ____

What's the distance from Source 1 (S1) to point 2? ____________cm
What's the distance from Source 2 (S2) to point 2? ____________ cm
What's the difference in these distances? ___________cm

What's the path length difference (Dd) for all points on this line of the interference pattern? _______________λ

What's does that make λ for this interference pattern? _____________cm

What's the distance from Source 1 (S1) to point 3? ____________cm
What's the distance from Source 2 (S2) to point 3? ____________ cm
What's the difference in these distances? ___________cm

What's the path length difference (Dd) for all points on this line of the interference pattern? _______________λ

What's does that make λ for this interference pattern? _____________cm

What's the distance from Source 1 (S1) to point 4? ____________cm
What's the distance from Source 2 (S2) to point 4? ____________ cm
What's the difference in these distances? ___________cm

What's the path length difference (Dd) for all points on this line of the interference pattern? _______________λ

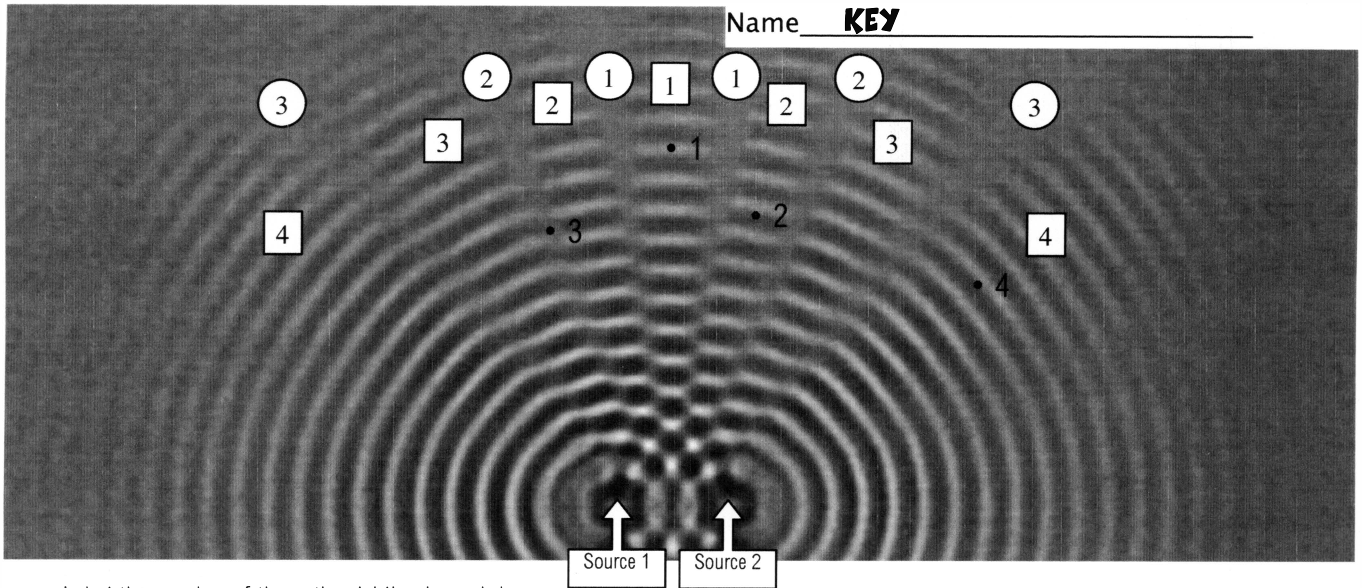
What's does that make λ for this interference pattern? _____________cm

What is the average for all of your λ values? ______________ cm
Measure the wavelength directly from the picture using a wave at the bottom edge of the picture. ______________ cm
(HINT: Measure several wavelengths, then divide by the number of wavelengths to get a more accurate value!)

What's your percent difference? ((Difference/Average)*100) ______________ % difference

Appendix A.5 Double Source Interference Pattern Analysis Worksheet Key

Name KEY



Label the number of the antinodal line in each box on the diagram above.
Label the number of the nodal line in each circle on the diagram above.

Use a ruler for the following measurements:

What's the distance from Source 1 (S1) to point 1? 4.9 cm
What's the distance from Source 2 (S2) to point 1? 4.9 cm
What's the difference in these distances? 0 cm

What line of a typical 2D interference pattern is point 1 on? CENTRAL ANTI-NODE

What's the distance from Source 1 (S1) to point 2? 4.9 cm
What's the distance from Source 2 (S2) to point 2? 3.8 cm
What's the difference in these distances? 0.6 cm

What's the path length difference (Dd) for all points on this line of the interference pattern? 1 λ

What's does that make λ for this interference pattern? 0.6 cm

---

What's the distance from Source 1 (S1) to point 3? 3.9 cm
What's the distance from Source 2 (S2) to point 3? 4.3 cm
What's the difference in these distances? 0.4 cm

What's the path length difference (Dd) for all points on this line of the interference pattern? 1.5 λ

What's does that make λ for this interference pattern? 0.3 cm

---

What's the distance from Source 1 (S1) to point 4? 5.7 cm
What's the distance from Source 2 (S2) to point 4? 4.4 cm
What's the difference in these distances? 1.3 cm

What's the path length difference (Dd) for all points on this line of the interference pattern? 3 λ

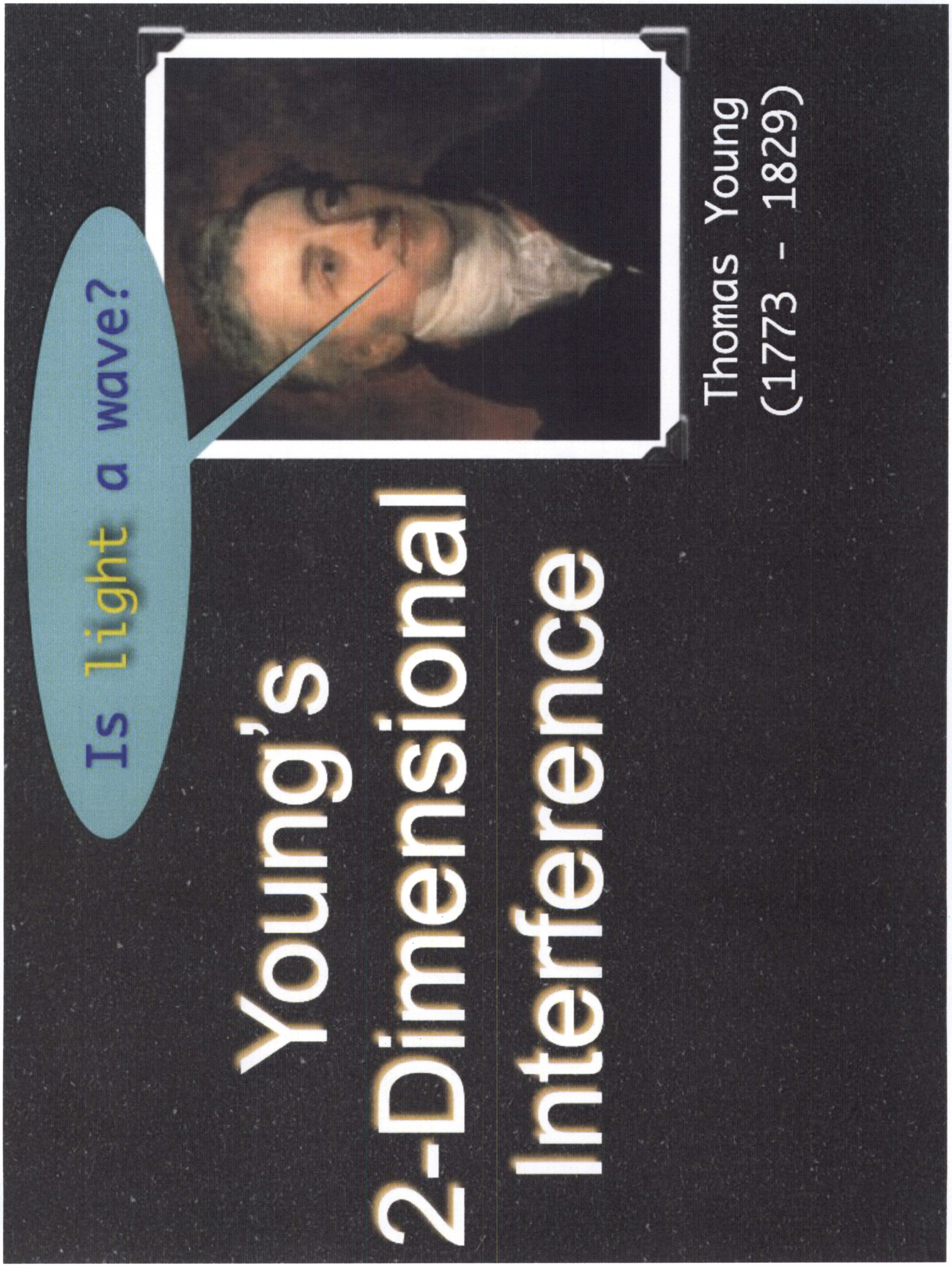
What's does that make λ for this interference pattern? 0.4 cm

---

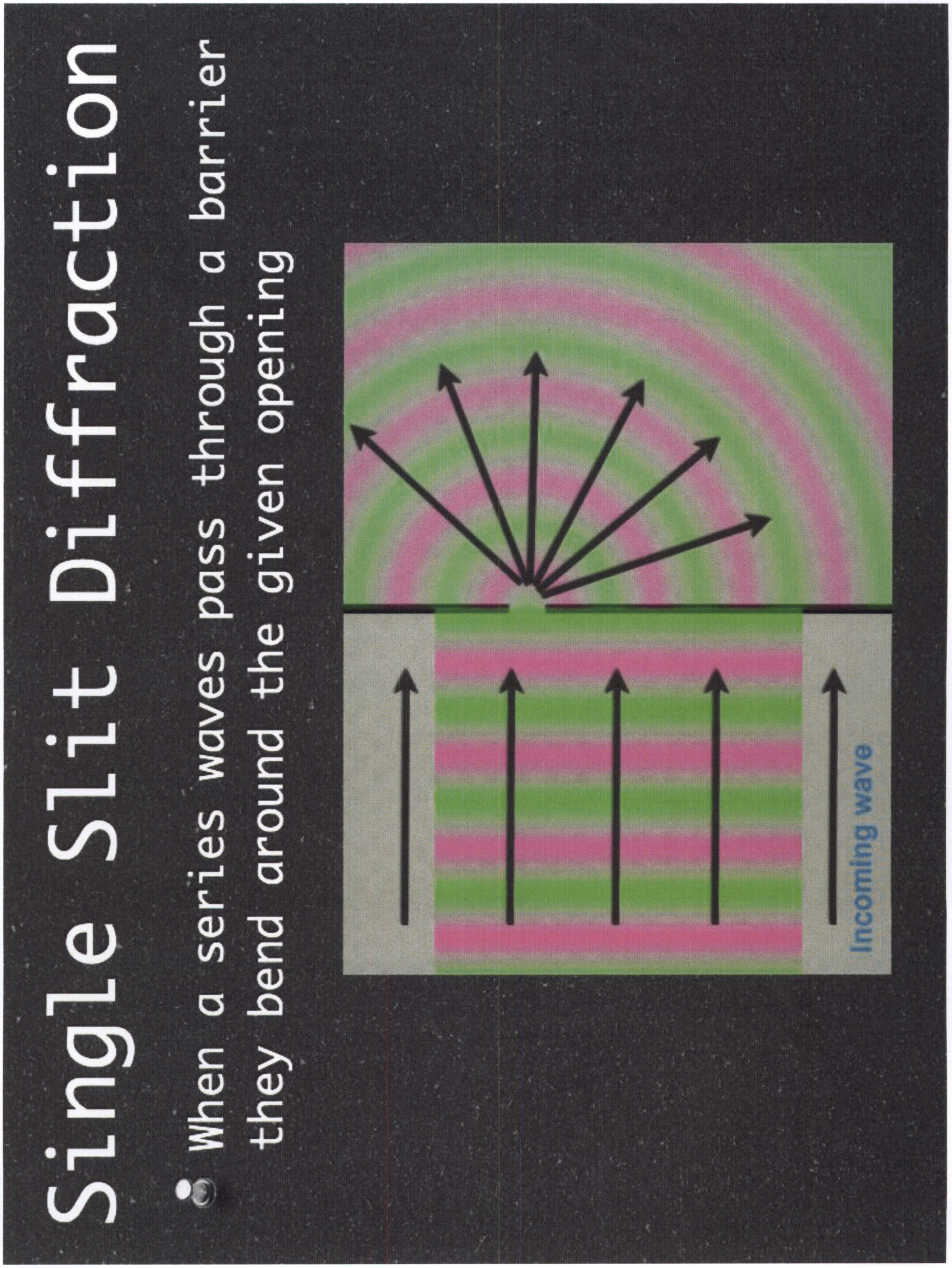
What is the average for all of your λ values? 0.433 cm
Measure the wavelength directly from the picture using a wave at the bottom edge of the picture. 0.44 cm
(HINT: Measure several wavelengths, then divide by the number of wavelengths to get a more accurate value!)

What's your percent difference? ((Difference/Average)*100) 2.3 % difference

Appendix B.1 Young's Double Slit Experiment Keynote



Appendix B.1 Young's Double Slit Experiment Keynote



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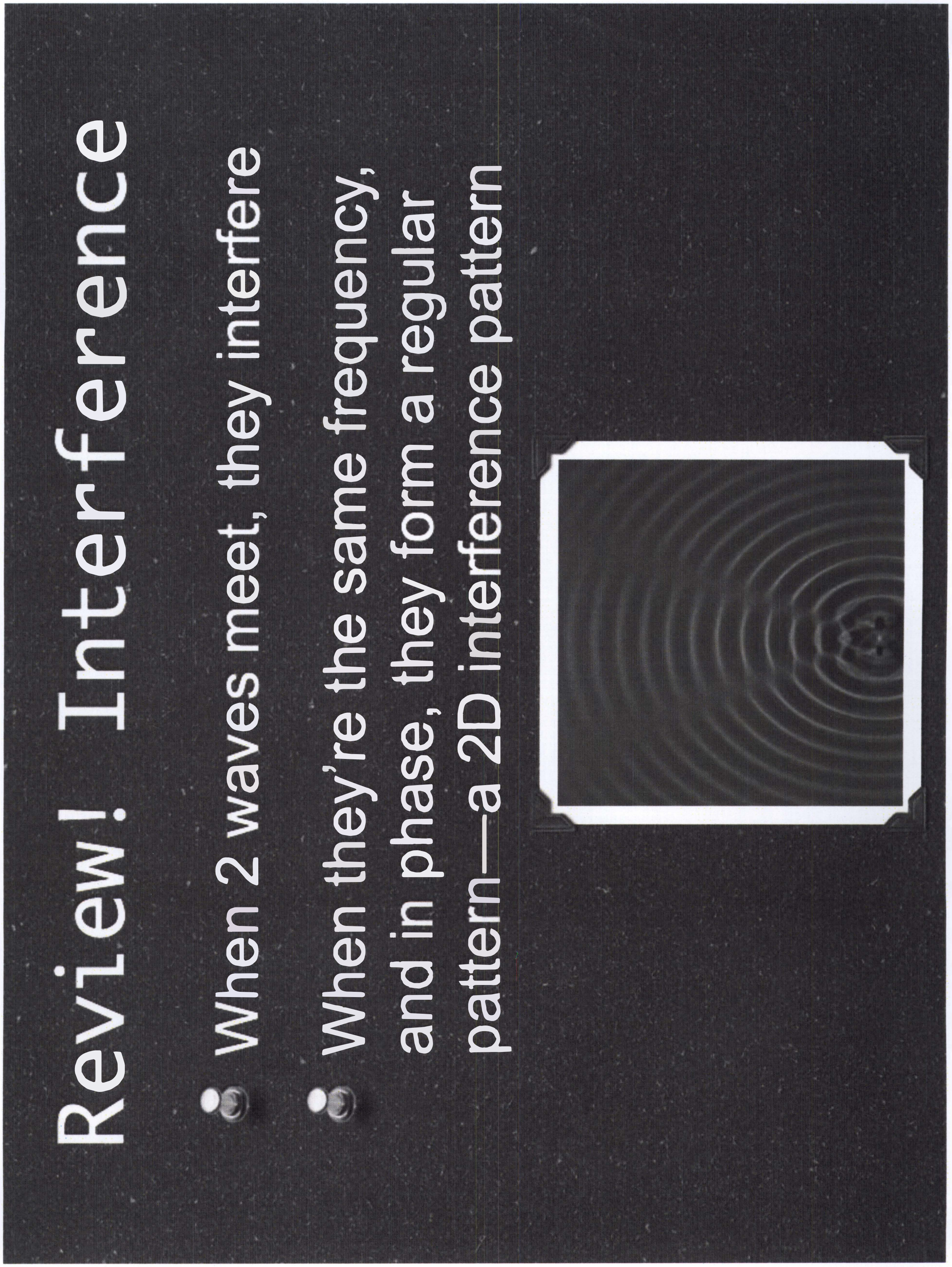

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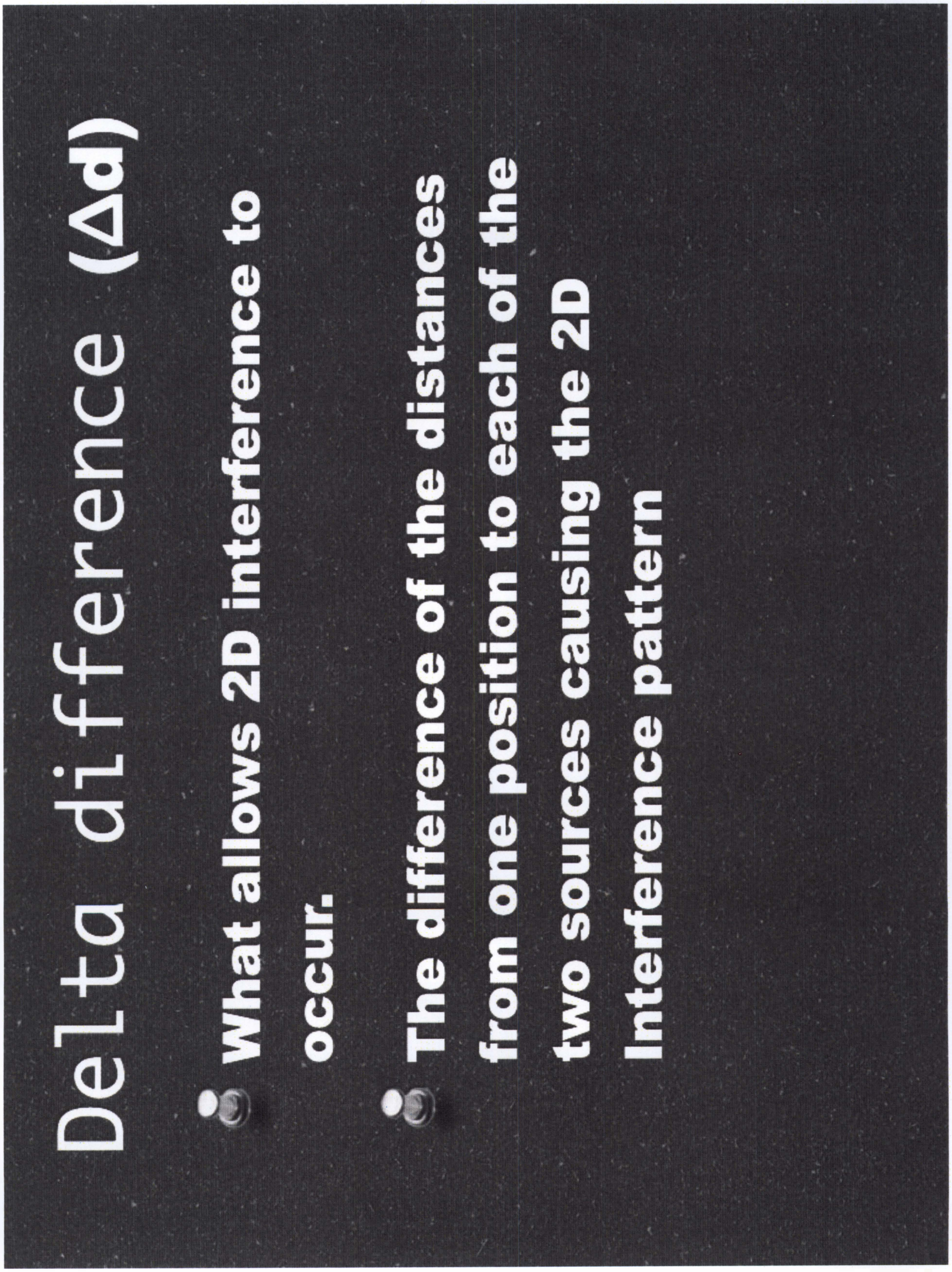

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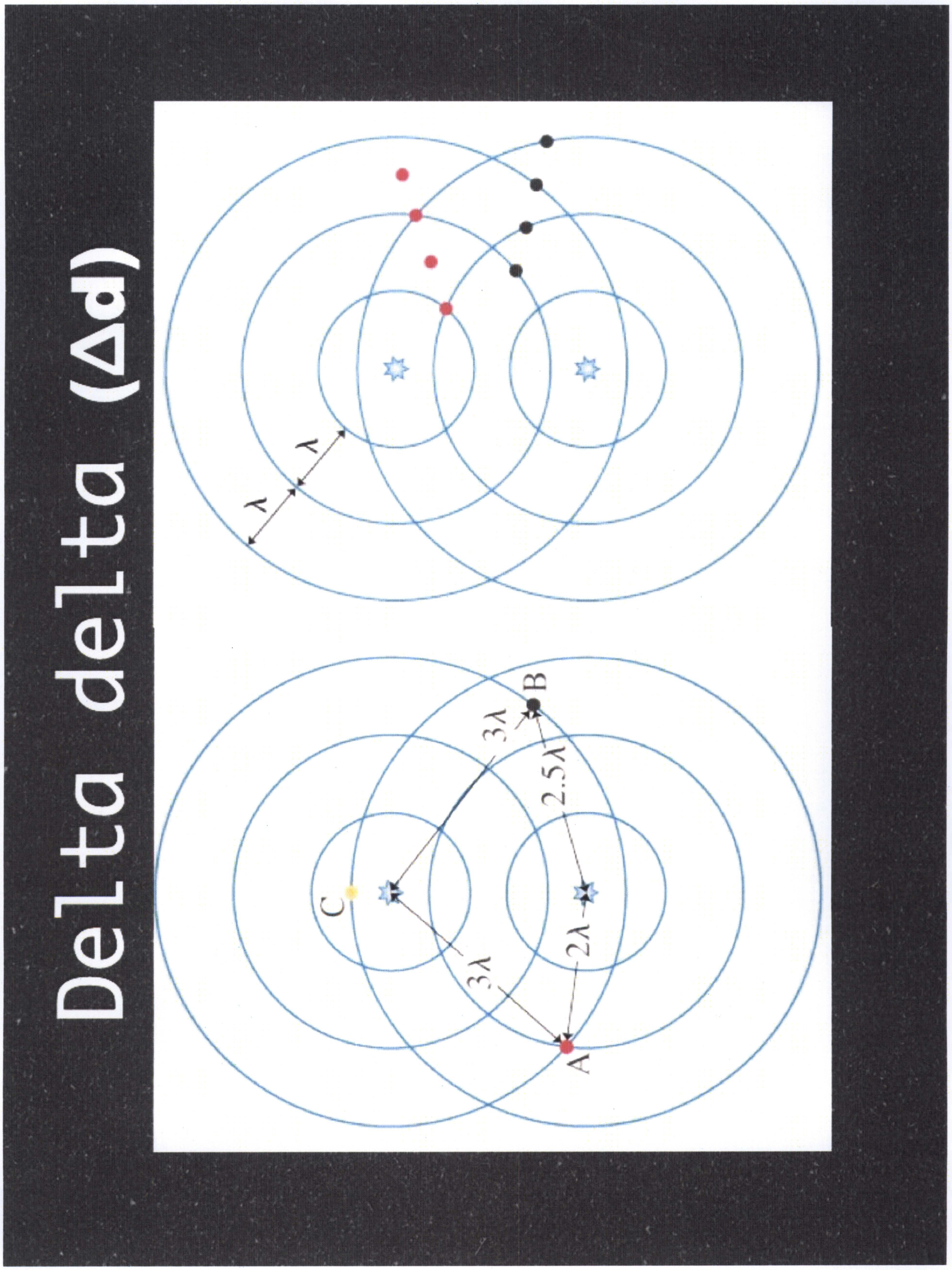

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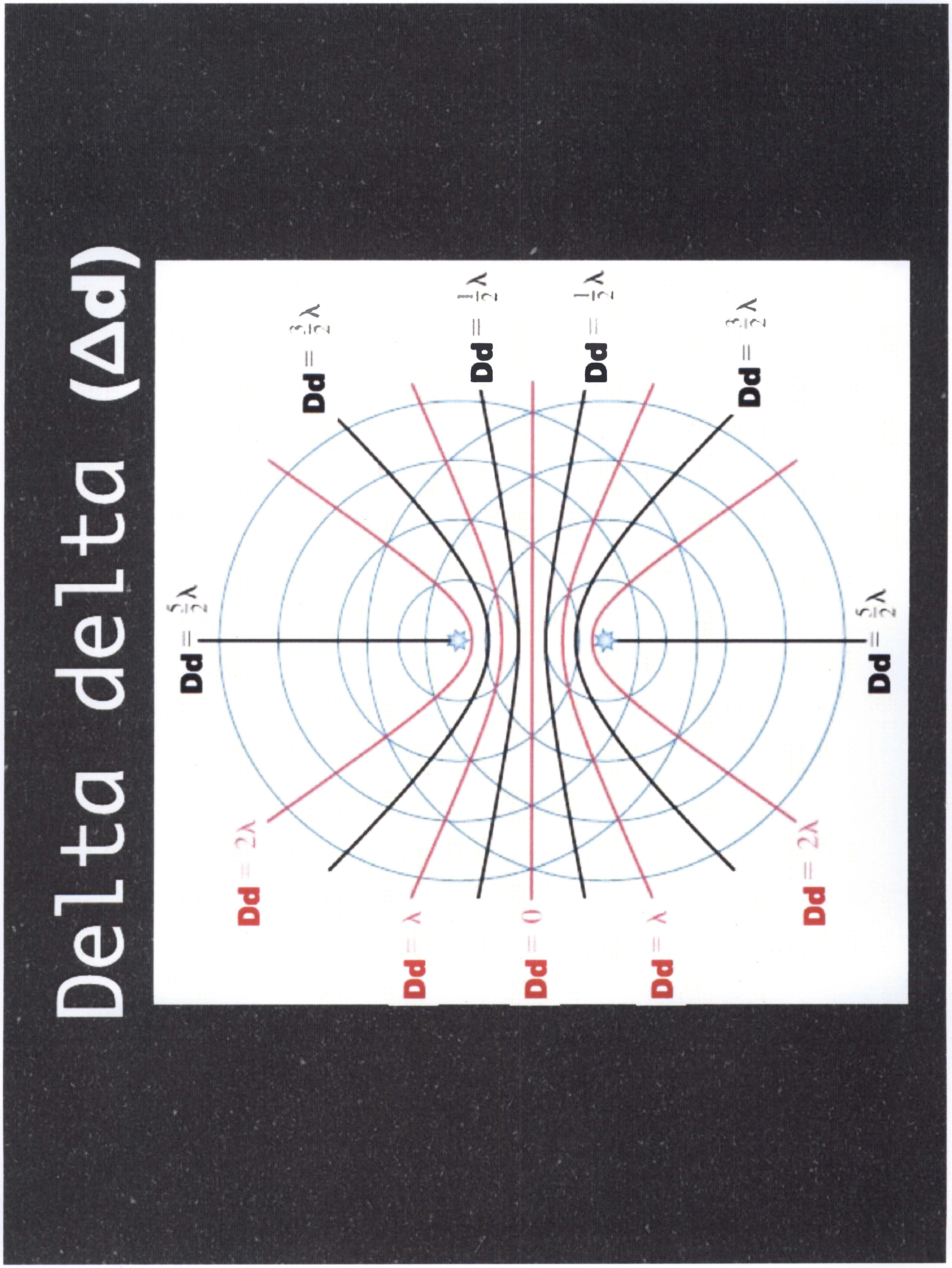

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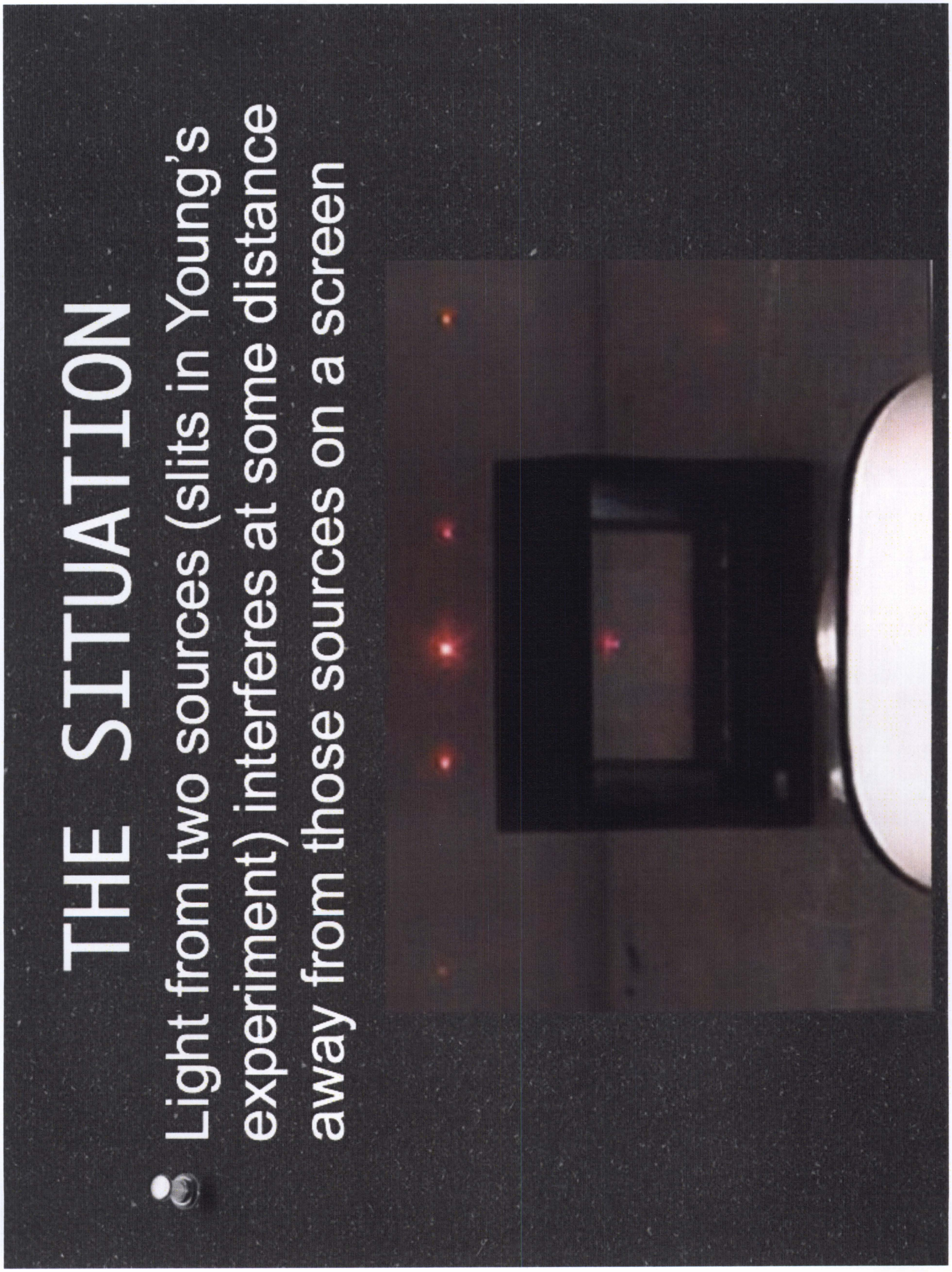

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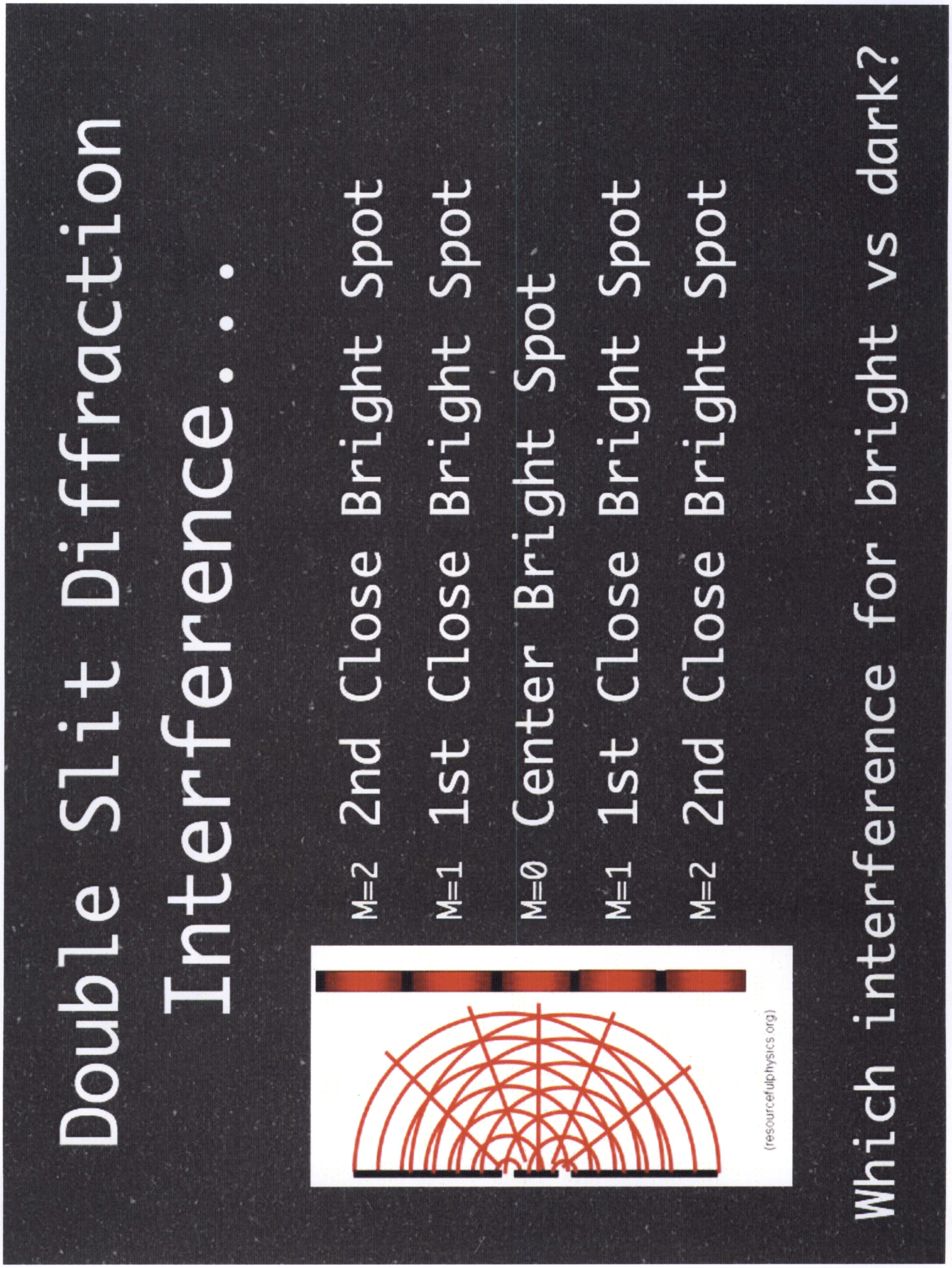

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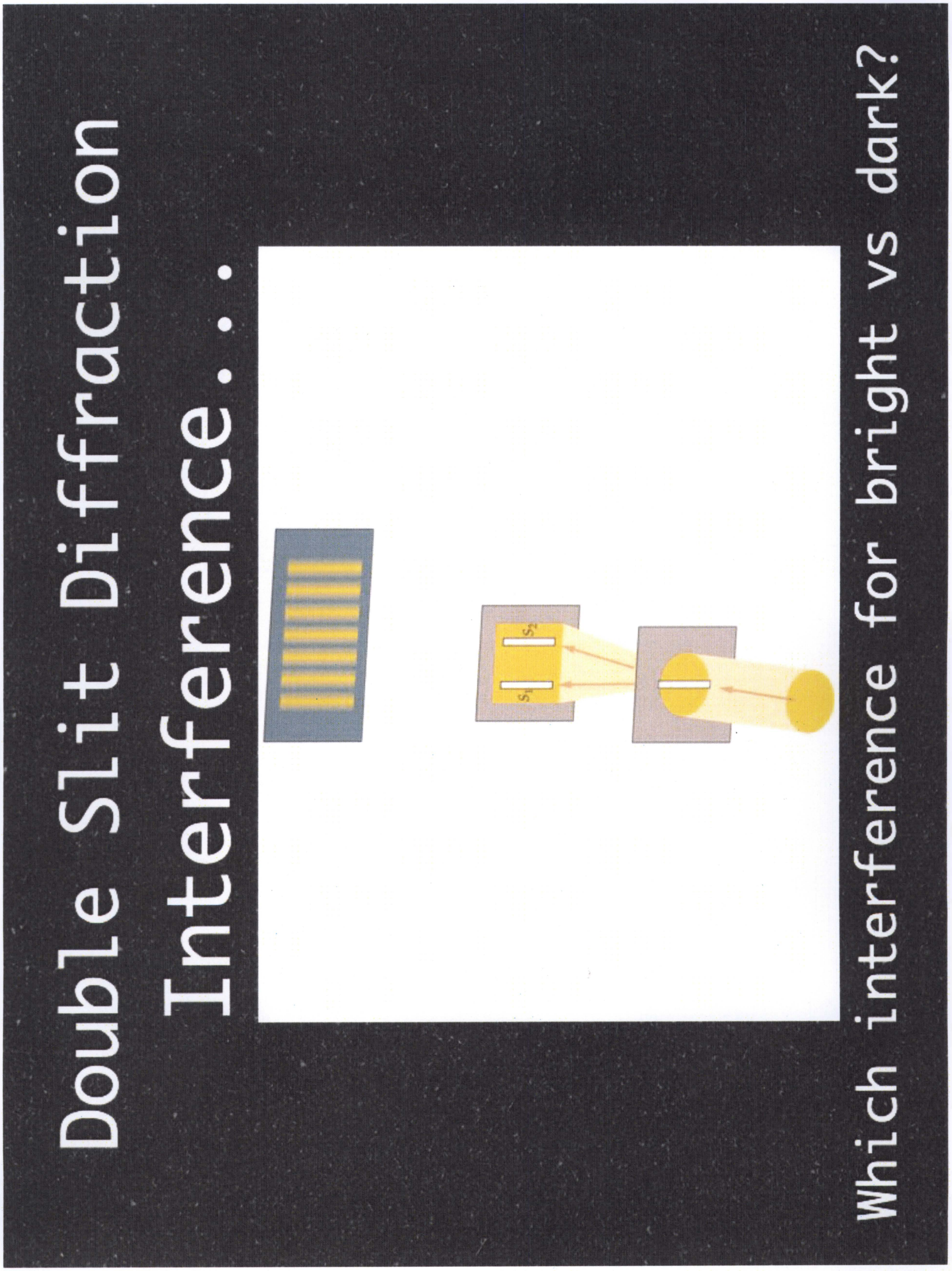

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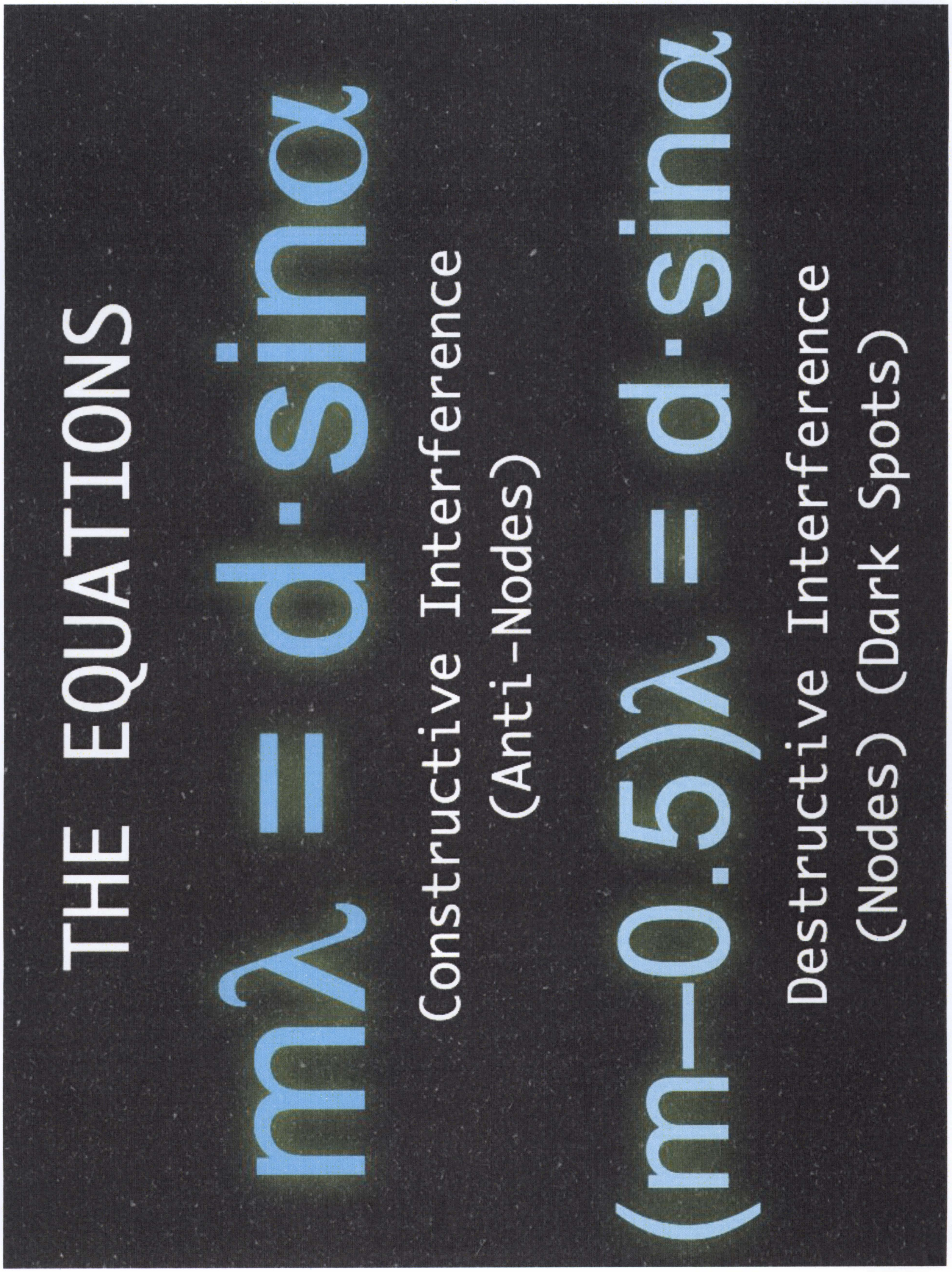

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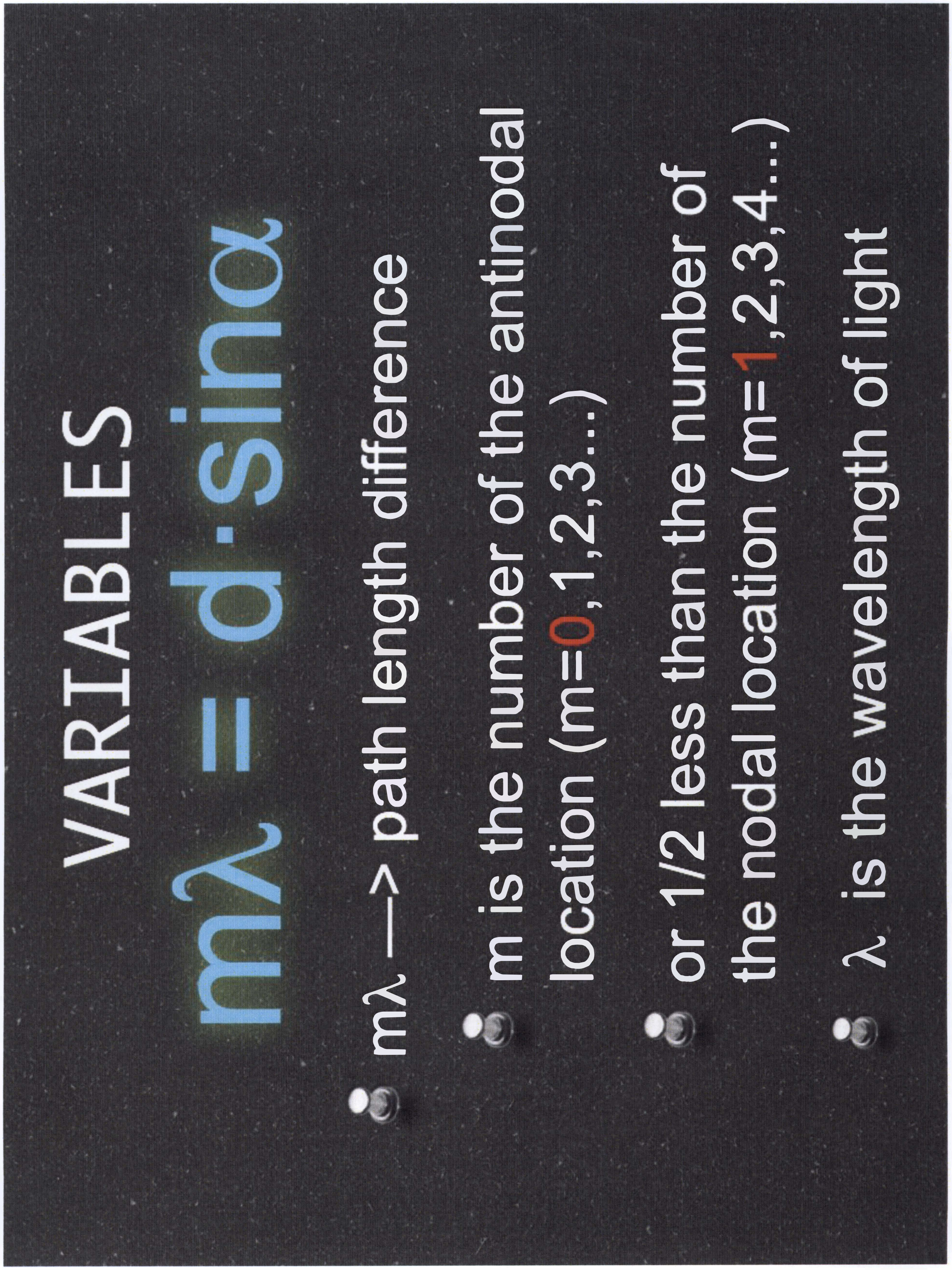

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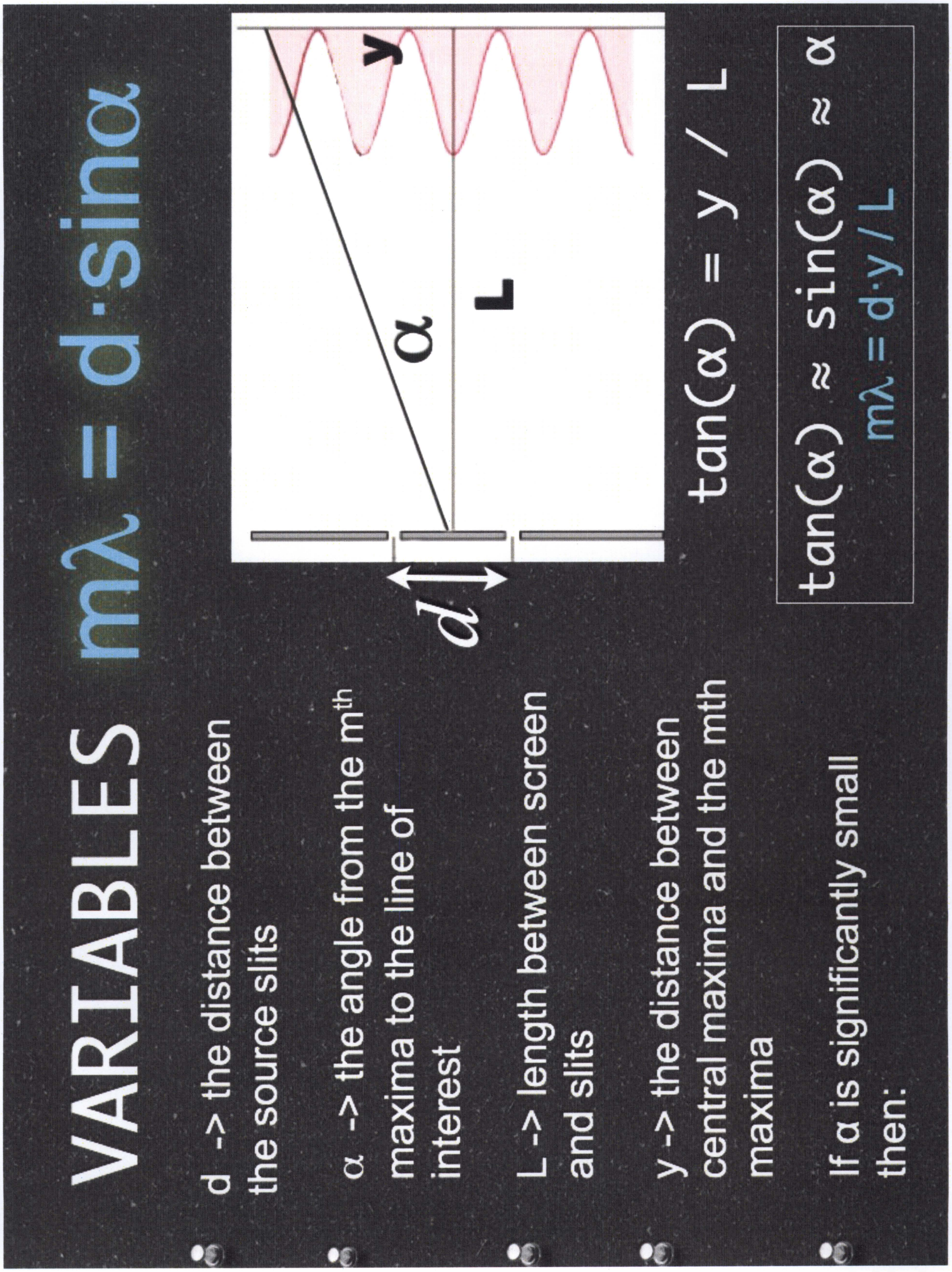

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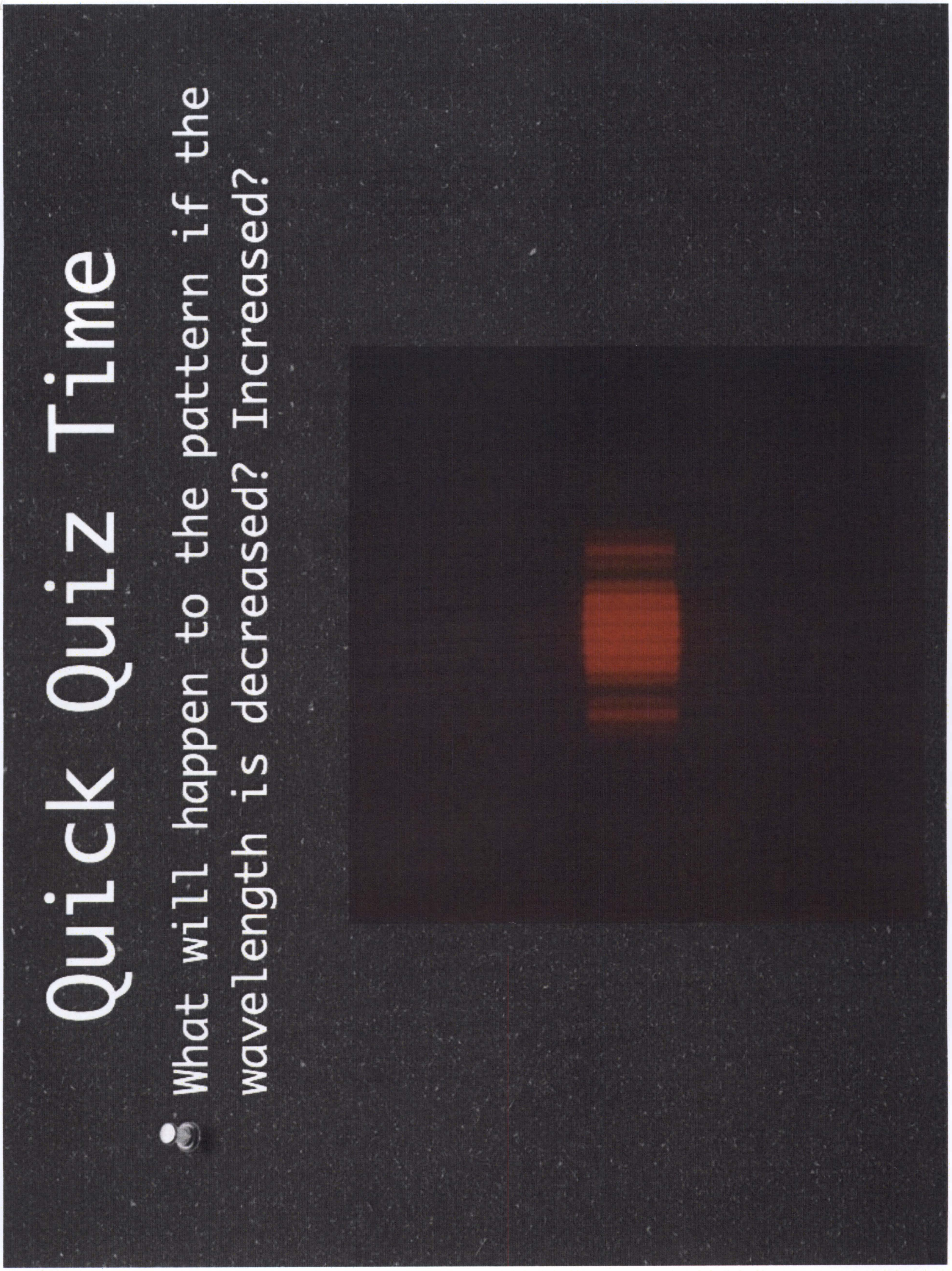

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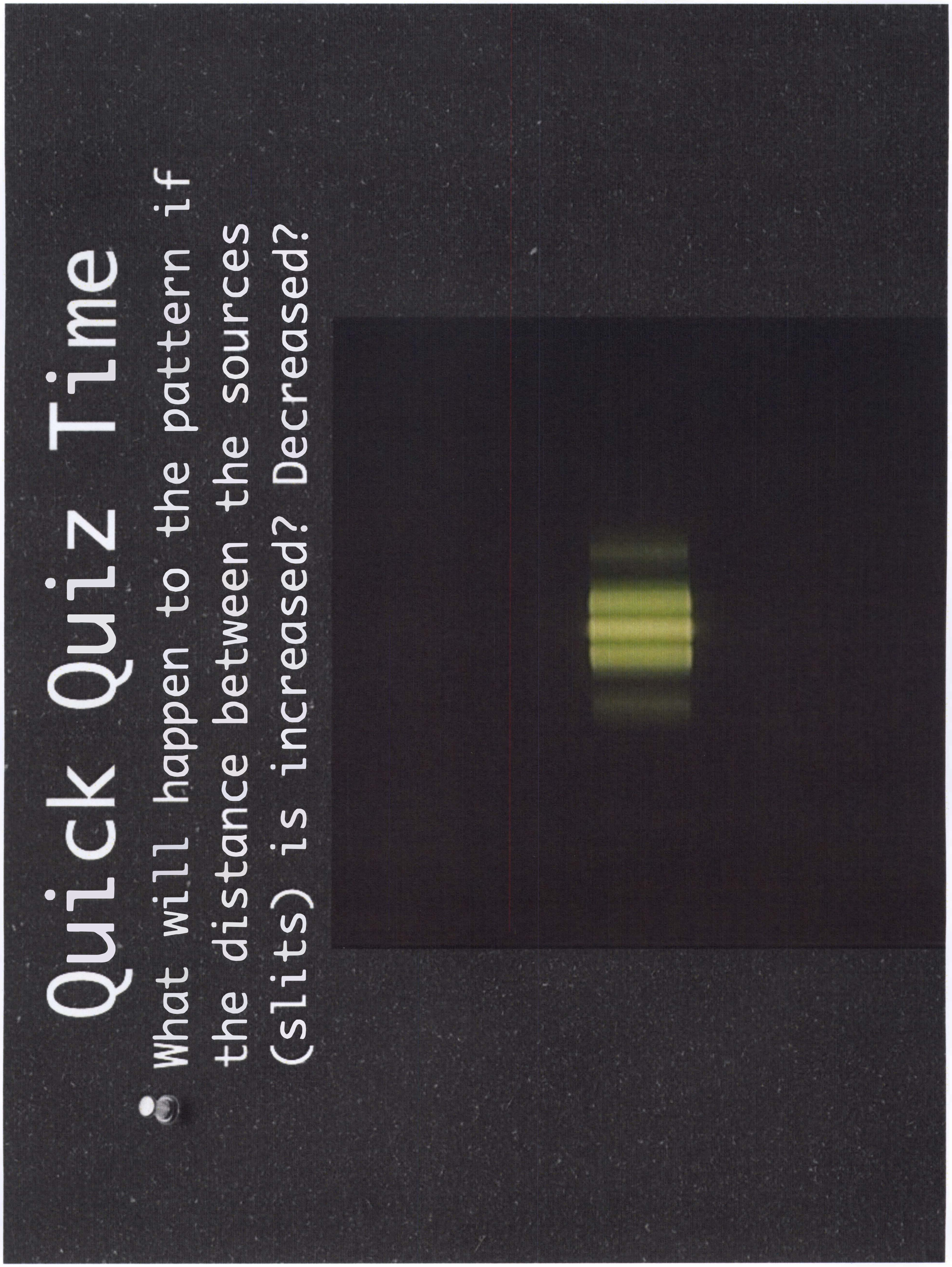


Appendix B.1 Young's Double Slit Experiment Keynote

Appendix B.1 Young's Double Slit Experiment Keynote

Appendix B.2 Young's Double Slit Worksheet

Young's Double Slit Problems

Answer the following equations assuming that the fringe patterns of light are approximated to be small angle approximations. All of the quantitative questions have answers in [brackets], so you may check your own work for accuracy.

1. Hold one hand close to your eye and focus on a distant light source through a narrow slit between two fingers. Describe the pattern that you see.

2. Monochromatic light falling on two slits 0.016 mm apart produces a fifth order fringe at an 8.8° angle. What is the wavelength of light produced? [4.9×10^{-7} m]

3. The third order fringe of 610 nm light is observed at an angle of 18° when the light falls on two narrow slits. How far apart are the slits? [5.9 μm]

4. A parallel beam of light from a He-Ne laser, with a wavelength 656 nm, falls on two very narrow slits 0.060 mm apart. How far apart are the fringes in the center pattern on a screen 3.6 m away? [3.9 cm]

5. Light of wavelength 680 nm falls on two slits and produces an interference pattern in which the fourth order fringe is 38 mm from the central fringe on a screen 2.0 m away. What is the separation of the two slits? [0.14 mm]

6. If 720 nm and 660 nm light passes through two slits 0.58 mm apart, how far apart are the second order fringes for these two wavelengths on a screen 1.0 m away? [0.2 mm]

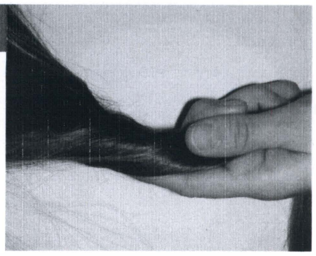
7. What happens to the diffraction pattern of a single slit if the whole apparatus is immersed in (a) water, (b) a vacuum, instead of air.

8. Monochromatic light falls on two very narrow slits 0.048 mm apart. Successive fringes on a screen 5 m away are 6.5 cm apart near the center of the pattern. Determine the wavelength and frequency of the light. [6.2×10^{-7} m ; 4.8×10^{14} m]

9. In a double slit experiment, it is found that blue light of wavelength 460 nm gives a second order maximum at a certain location on the screen. What wavelength of visible light would have a minimum at the same location? [613 nm]

Appendix C.1 Hair Width Lab

How Thick Is My Hair?



How thick is your hair? How does it compare to your lab partner(s) hair? For this experiment, you will need to donate a strand of hair in the name of science! You will then be using your hair to cause a double slit interference pattern on the wall, which will allow you to calculate the thickness of your hair!

Data and Analysis:

1. Using the classroom interference set-up, measure the distance from the laser light source to the chalkboard (screen).

L = ____________________

2. Obtain the wavelength of the laser light. (HINT: What color is it? Look back at your notes or textbook if necessary!)

λ = ____________________

3. Hold your hair in from of the laser beam, creating a double slit pattern. Your lab partner can then measure the distance (y) from the center maxima to any subsequent mth bright spot surrounding the center maxima. You will need to measure two bright spots, one being the first ordered maximum, the other measurement being any other maximum of your choice. Be sure to control your 'm' value

m = ______________ y = ____________________

m = ______________ y = ____________________

4. Perform two calculations to determine the thickness of your hair (both calculations should give approximately the same result). Show all work, and then take an average of the two for the acceptable value.

Conceptual Questions (look in notes from keynote to help you!):

1. How does the thickness of your hair compare to the thickness of your lab partner's hair? Determine the difference and who's the winner. Talk amongst yourselves and try to figure out why they have thicker hair (genetics, hair product usage, overexposure to the sun, etc.)

2. How would the interference pattern appear different in our lab, if you used a volumizing shampoo in your hair?

3. How would the interference pattern appear different in our lab if your hair got damaged, stripped, and thinner?

4. If we used a violet colored laser instead of the one we used how would that change the interference pattern?

Appendix C.1 Hair Width Problems

Young's Double Slit Experiment Practice Problems

Review the following summary problems for tonight's homework assignment. All answers are given in [brackets] for you to self assess your own work. For all problems you may assume small angle approximations of the diffracted light.

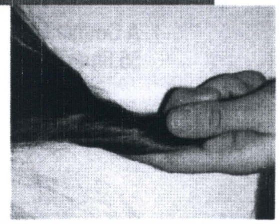
1. A double slit apparatus (d= 15 μm) is used to determine the wavelength of unknown green light. The first bright spot is 55.8 mm from the center bright spot on a screen that is 1.6 m from the slits. What is the wavelength of the light? [5.23 x 10^{-7} m]

2. A yellow-orange source from a sodium lamp of wavelength 596 nm is aimed at two slits separated by 1.9 x 10^{-5} m. What is the distance from the center bright spot to the first bright spot if the screen is 0.6 m from the slits? [18.8 mm]

3. In an experiment a fantastic physics student uses a laser with a known wavelength of 632.8 nm. The student places the screen 1.1 m from the double slits and finds the first bright spot to be 65.5 mm from the central bright spot. What is the slit separation distance? [1.06 x 10^{-5} m]

Appendix C.1 Hair Width Lab Student Sample

How Thick Is My Hair?



How thick is your hair? How does it compare to your lab partner(s) hair? For this experiment, you will need to donate a strand of hair in the name of science! You will then be using your hair to cause a double slit interference pattern on the wall, which will allow you to calculate the thickness of your hair!

Data and Analysis:

1. Using the classroom interference set-up, measure the distance from the laser light source to the chalkboard (screen).

L = ______ m

2. Obtain the wavelength of the laser light. (HINT: What color is it? Look back at your notes or textbook if necessary!)

λ = 686×10^{-9} m

3. Hold your hair in from of the laser beam, creating a double slit pattern. Your lab partner can then measure the distance (y) from the center maxima to any subsequent mth bright spot surrounding the center maxima. You will need to measure two bright spots, one being the first ordered maximum, the other measurement being any other maximum of your choice. Be sure to control your 'm' value

m = 1 y = ______ cm (0.00__)

m = 2 y = ______ cm (0.0125)

4. Perform two calculations to determine the thickness of your hair (both calculations should give approximately the same result). Show all work, and then take an average of the two for the acceptable value.

$m\lambda = d\left(\frac{y}{L}\right)$

$1(686 \times 10^{-9}) = d\left(\frac{.003}{1.48}\right)$

$686 \times 10^{-9} = d(0.002)$

$d = 0.000343$ m

$m\lambda = d\left(\frac{y}{L}\right)$

$2(686 \times 10^{-9}) = d\left(\frac{0.0125}{1.48}\right)$

Conceptual Questions (look in notes from keynote to help you!):

1. How does the thickness of your hair compare to the thickness of your lab partner's hair? Determine the difference and who's the winner. Talk amongst yourselves and try to figure out why they have thicker hair (genetics, hair product usage, overexposure to the sun, etc.)

2. How would the interference pattern appear different in our lab, if you used a volumizing shampoo in your hair?

3. How would the interference pattern appear different in our lab if your hair got damaged, stripped, and thinner?

4. If we used a violet colored laser instead of the one we used how would that change the interference pattern?

Appendix C.1 Hair Width Problems Student Sample

Young's Double Slit Experiment Practice Problems

1. A Double Slit apparatus (d= 15 μm) is used to determine the wavelength of unknown green light. The first bright spot is 55.8mm from the center bright spot on a screen that is 1.6 m from the slits. What is the wavelength of the light?

$m\lambda = d\left(\frac{y}{L}\right)$

$1\lambda = 15\times10^{-6}\left(\frac{0.0558}{1.6}\right)$

$\lambda = 15\times10^{-6}(0.034875)$

$\lambda = 0.000000523$ m

2. A yellow-orange light from a sodium lamp of wavelength 596 nm is aimed at two slits separated by 1.9 x 10^{-5} m. What is the distance from the center bright spot to the first bright spot if the screen is 0.6 m from the slits?

$m\lambda = d\left(\frac{y}{L}\right)$

$1(596\times10^{-9}) = 1.9\times10^{-5}\left(\frac{y}{0.6}\right)$

$\frac{596\times10^{-9}}{1.9\times10^{-5}} = \frac{y}{0.6}$

[illegible] $= \frac{y}{0.6}(0.6)$

$y = 0.01882$ m

3. In a double-slit experiment a fantastic physics student uses a laser with a known wavelength of 632.8 nm. The student places the screen 1.1 m from the slits and finds the first bright spot to be 65.5 mm from the central bright spot. What is the slit separation distance?

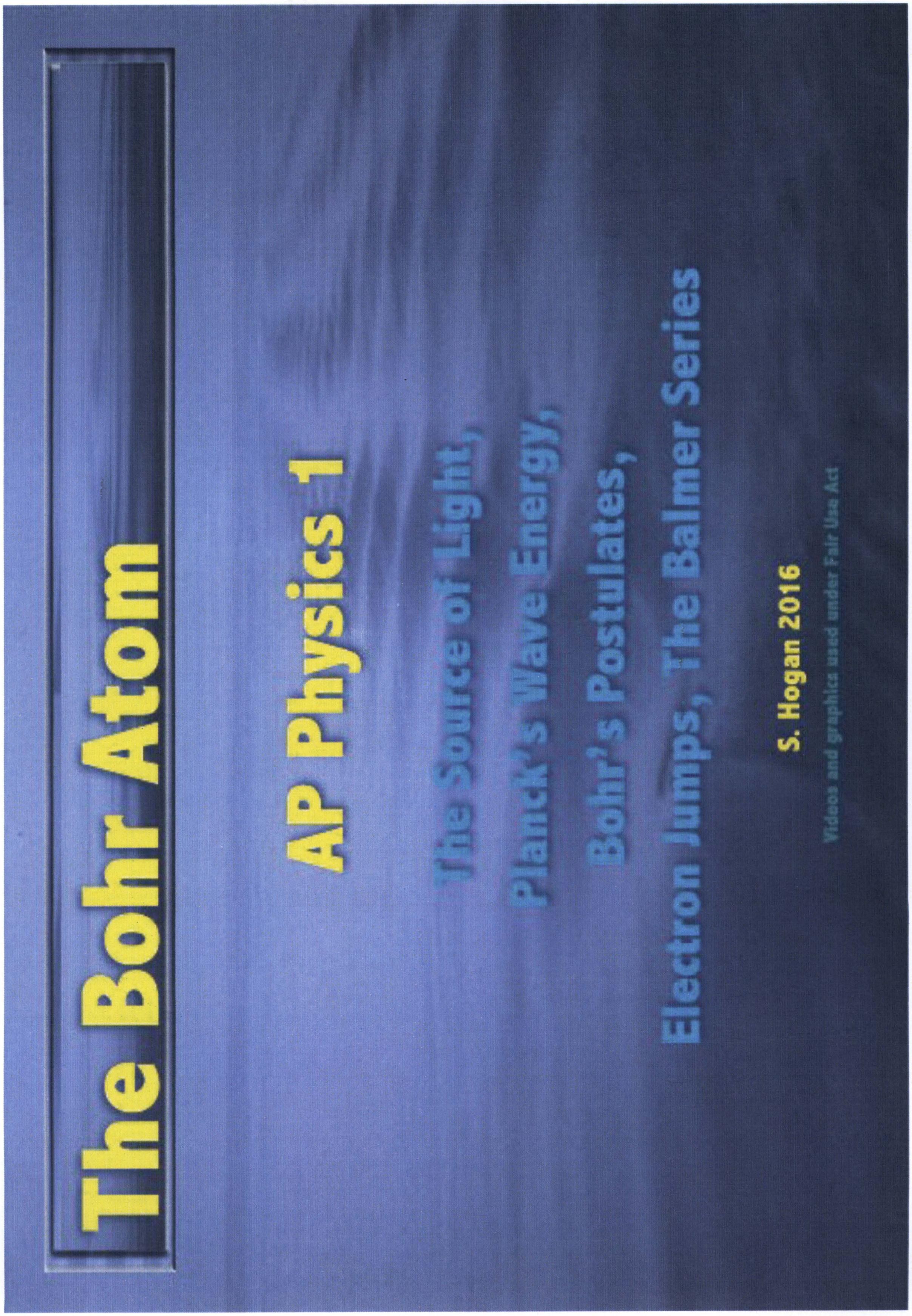
$m\lambda = d\left(\frac{y}{L}\right)$

$1(632.8\times10^{-9}) = d\left(\frac{65.5\times10^{-3}}{1.1}\right)$

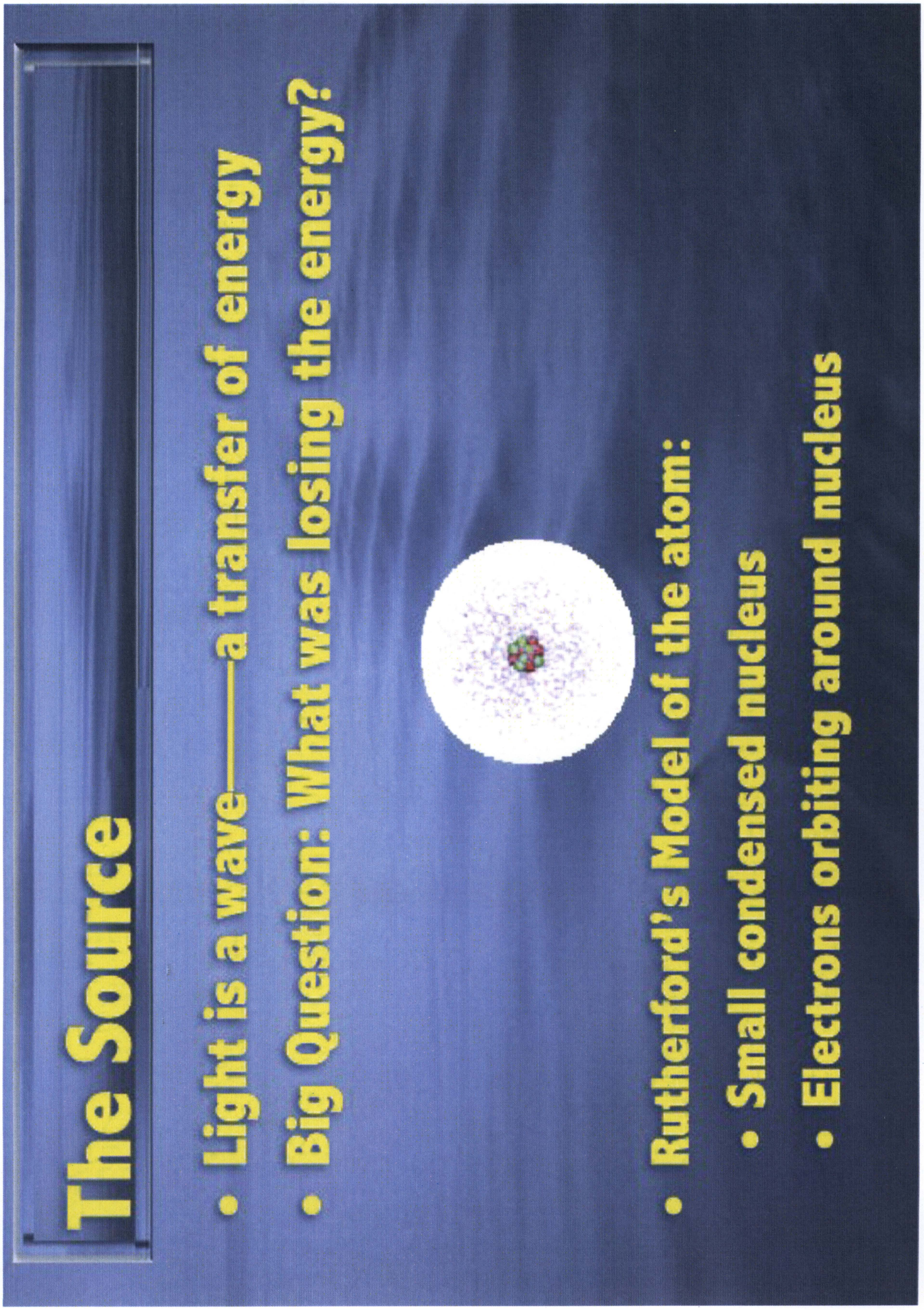
$632.8\times10^{-9} = d(0.0595454555)$

$d =$ [illegible] m

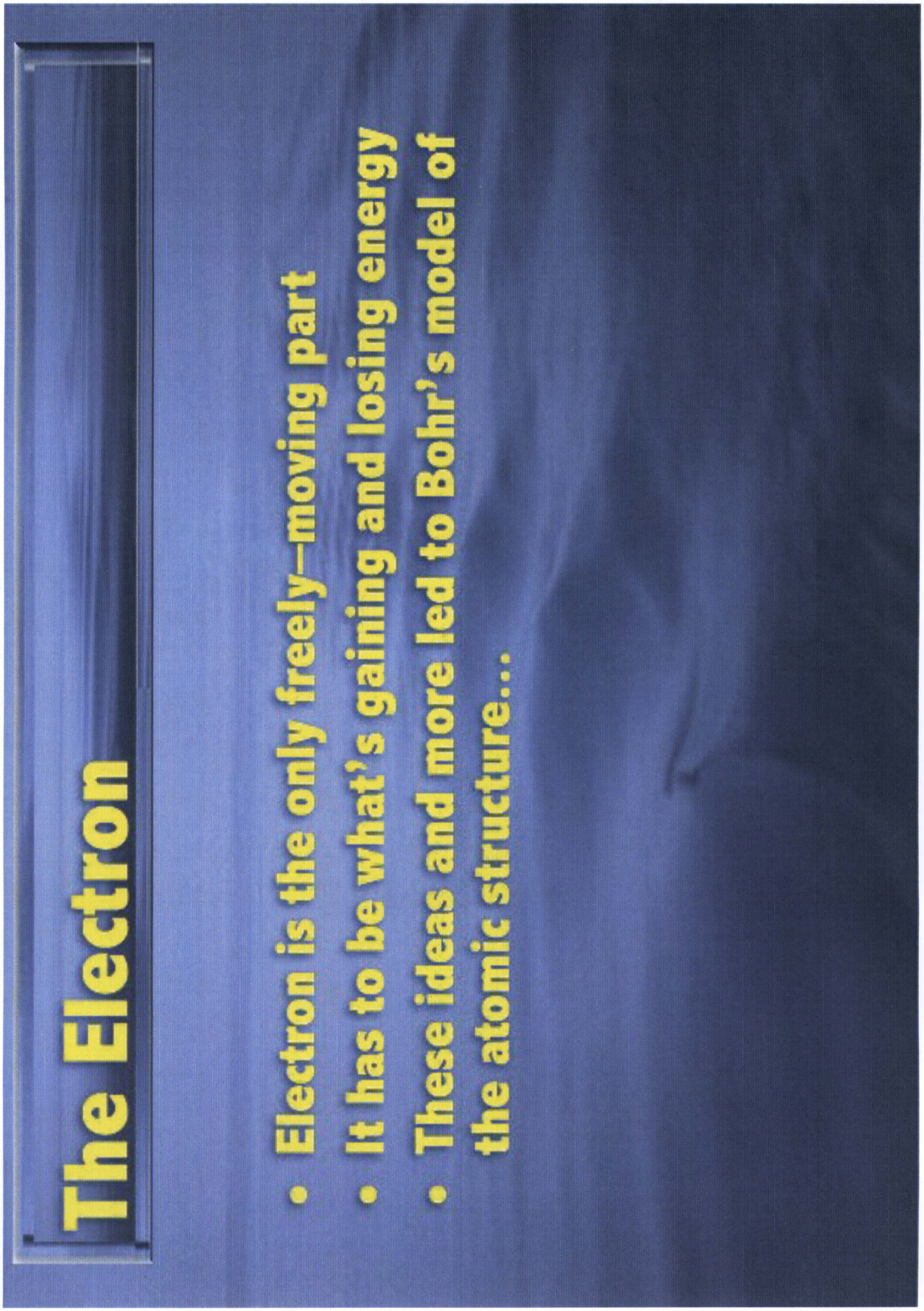
Appendix D.1 The Bohr Model Keynote



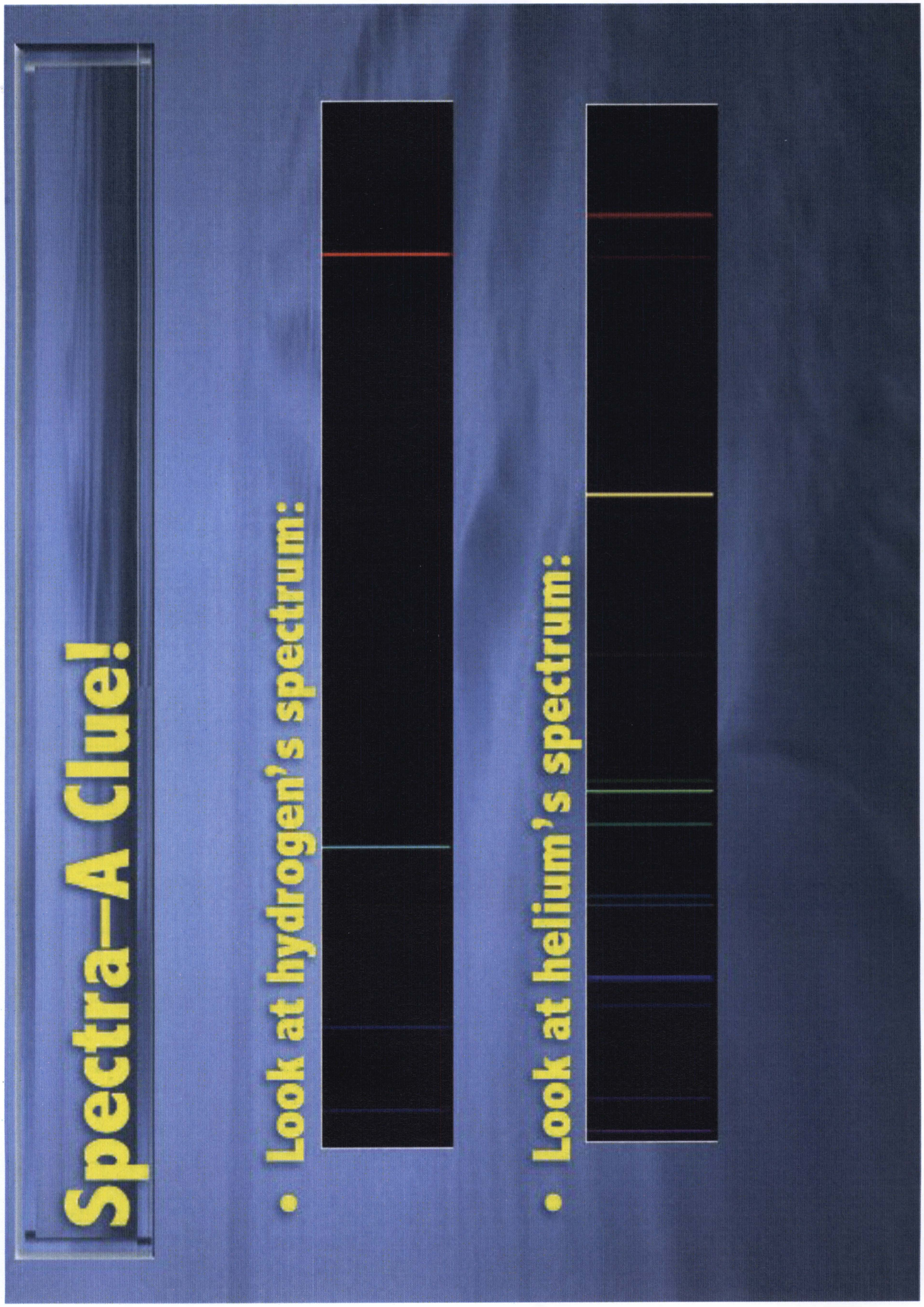
Appendix D.1 The Bohr Model Keynote



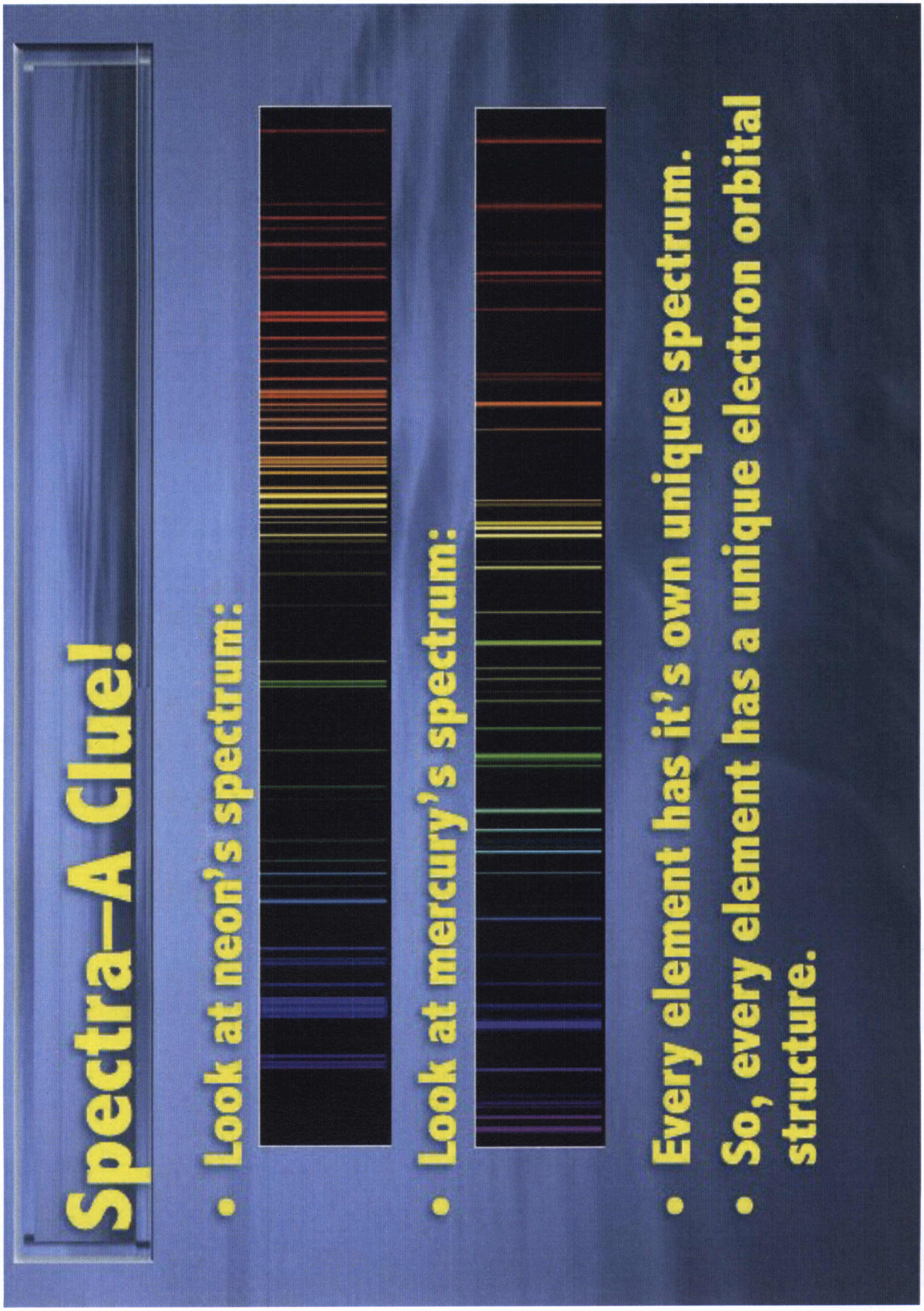
Appendix D.1 Appendix D.1 The Bohr Model Keynote



Appendix D.1 Appendix D.1 The Bohr Model Keynote



Appendix D.1 Appendix D.1 The Bohr Model Keynote



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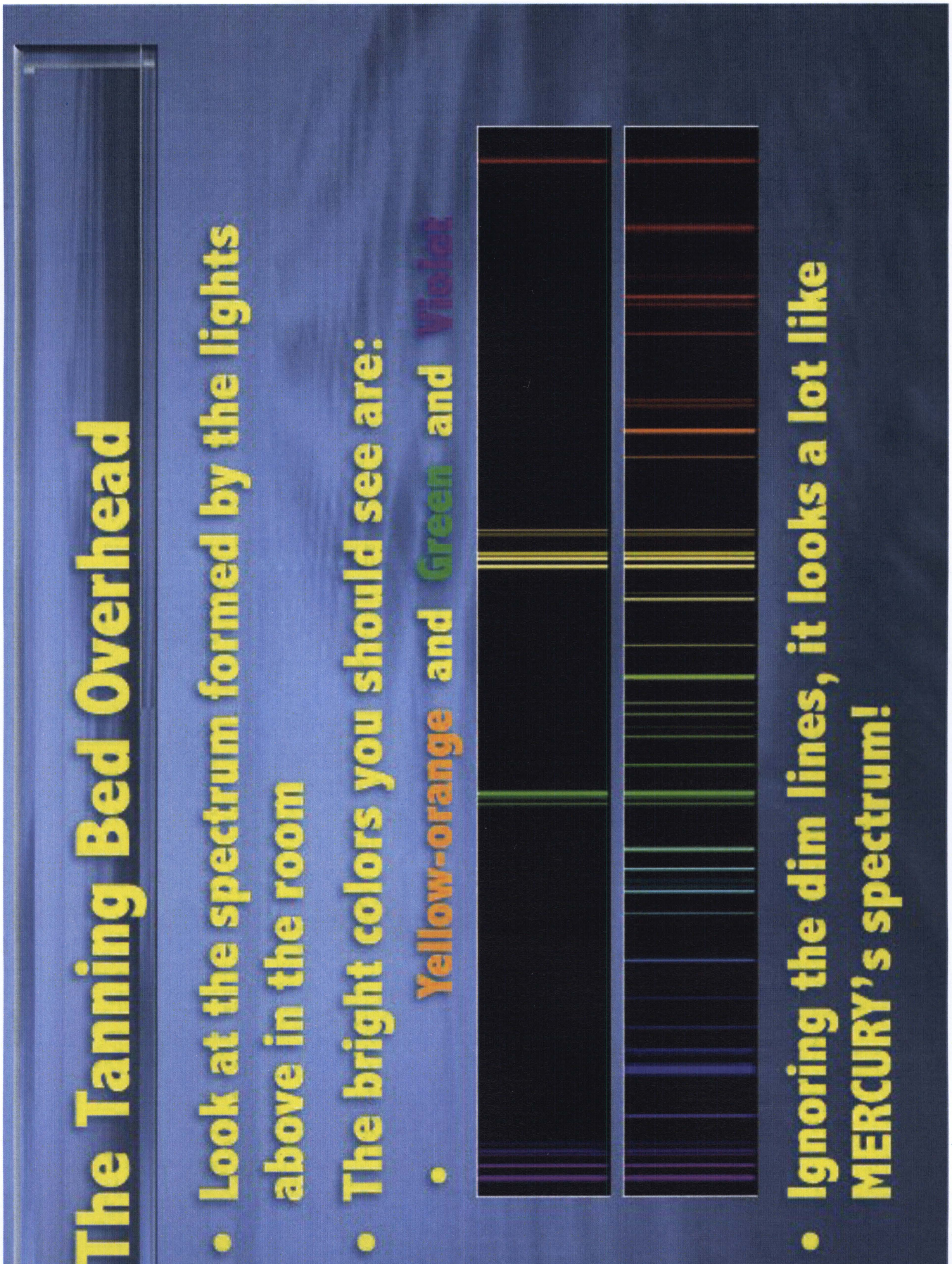

Appendix D.1 The Bohr Model Keynote

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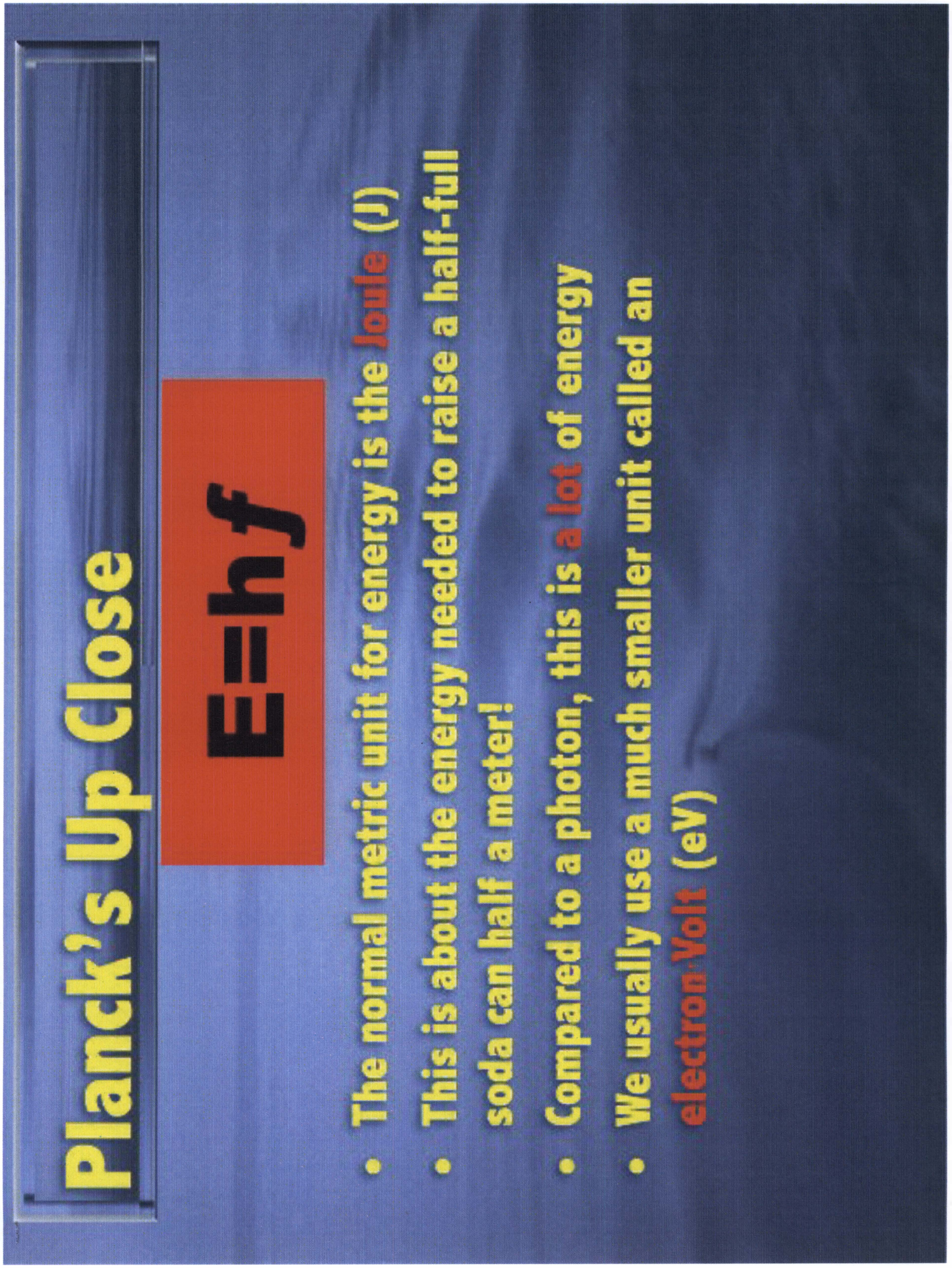

Appendix D.1 The Bohr Model Keynote

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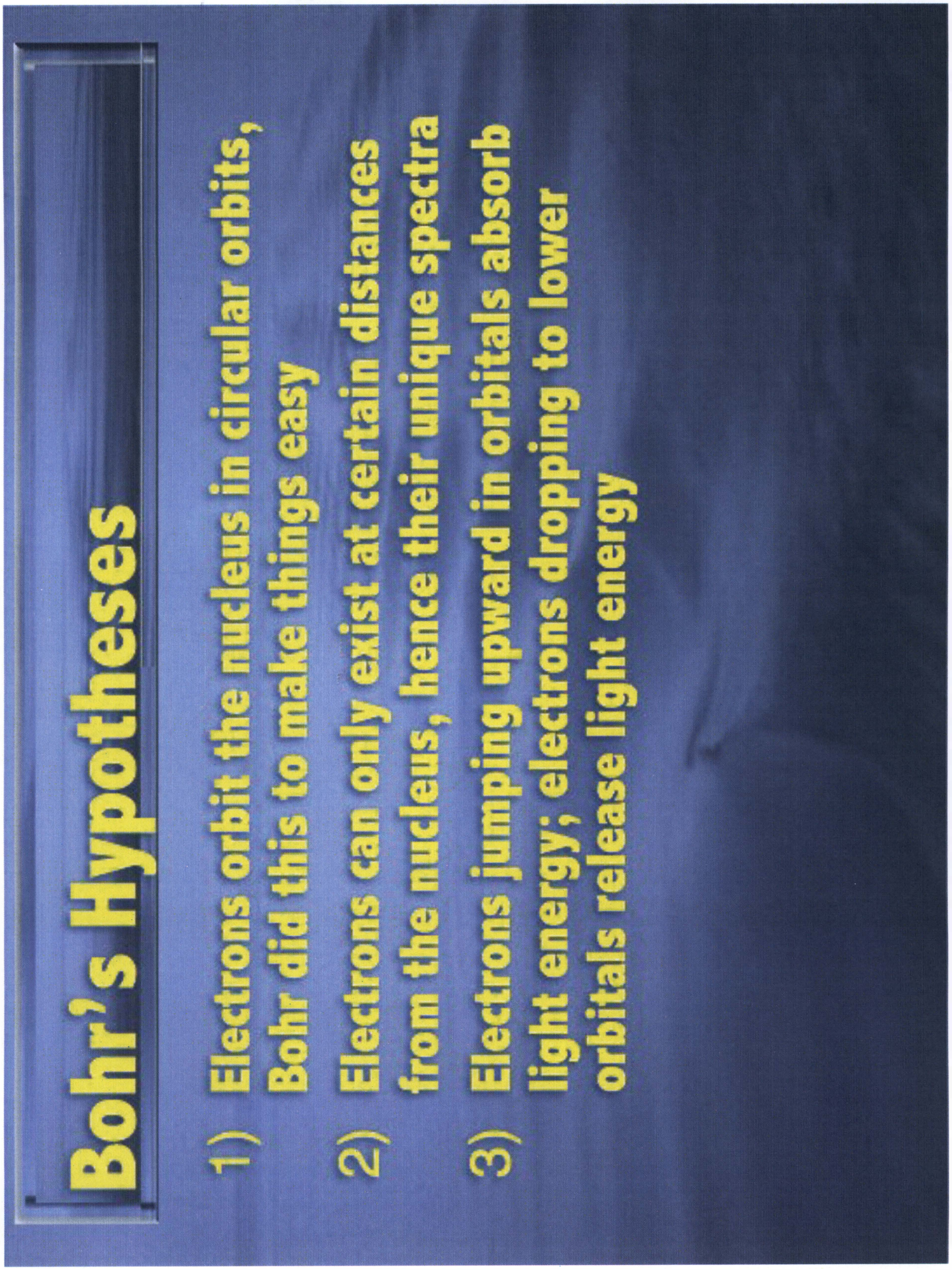

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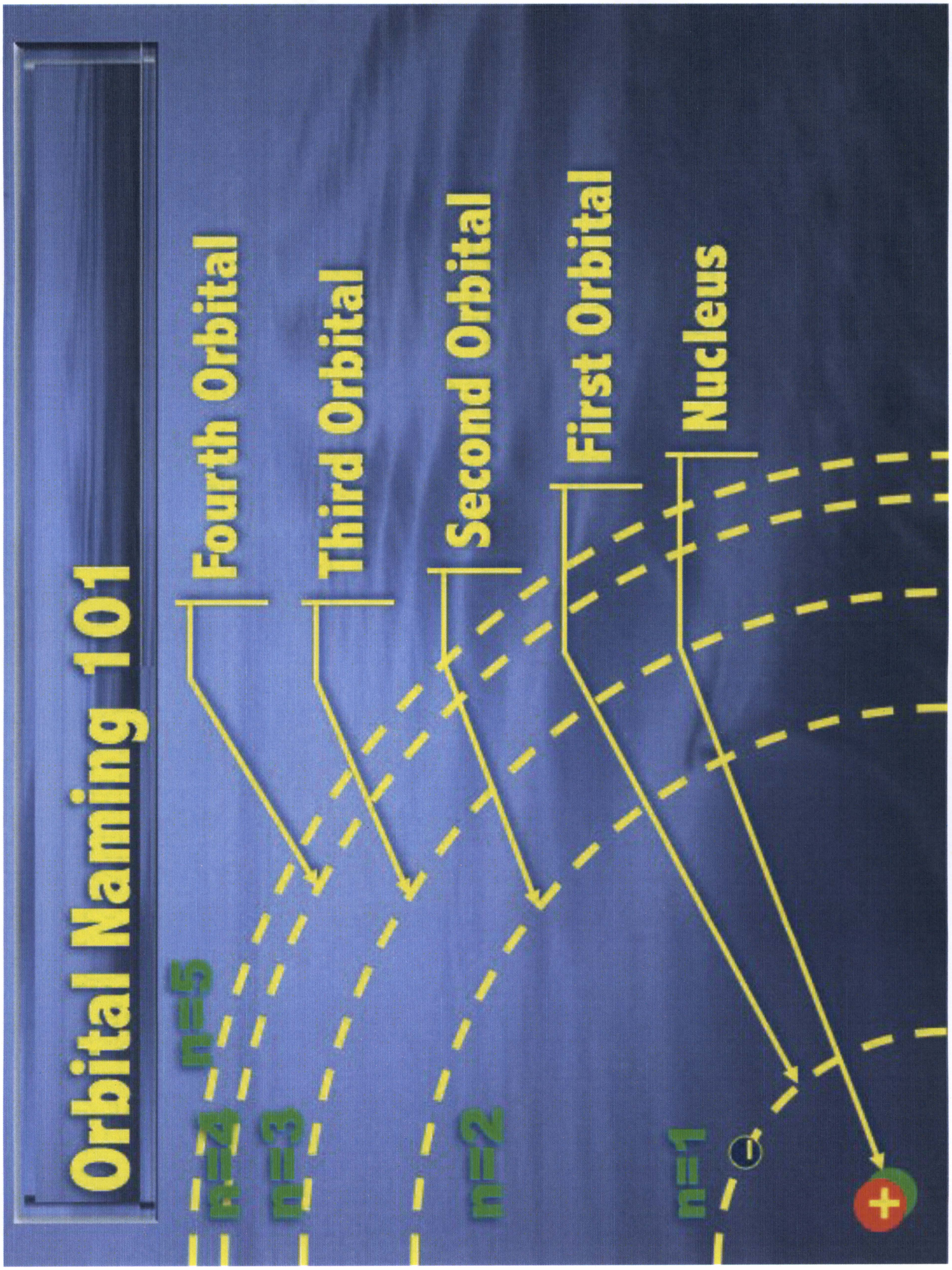

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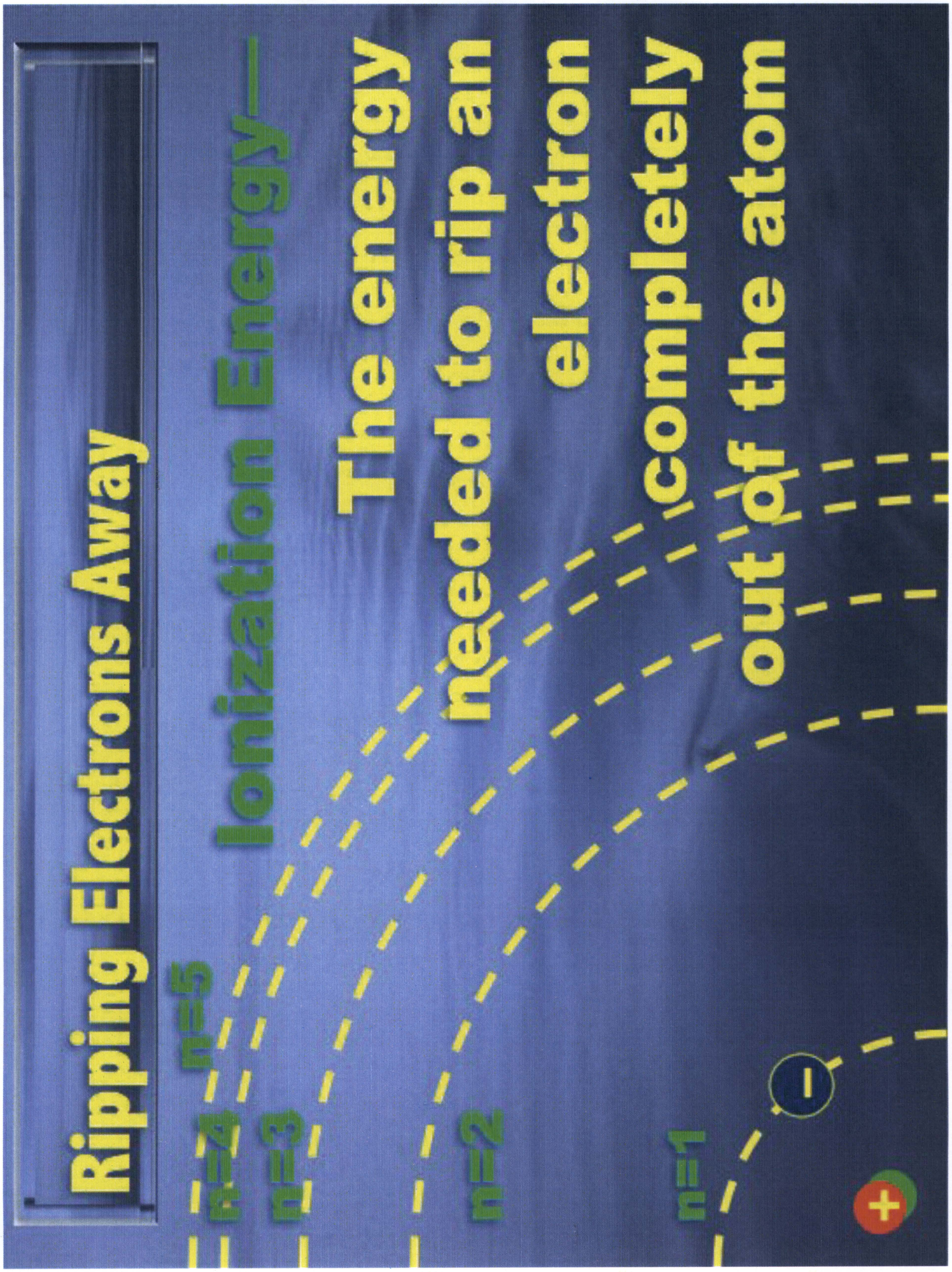

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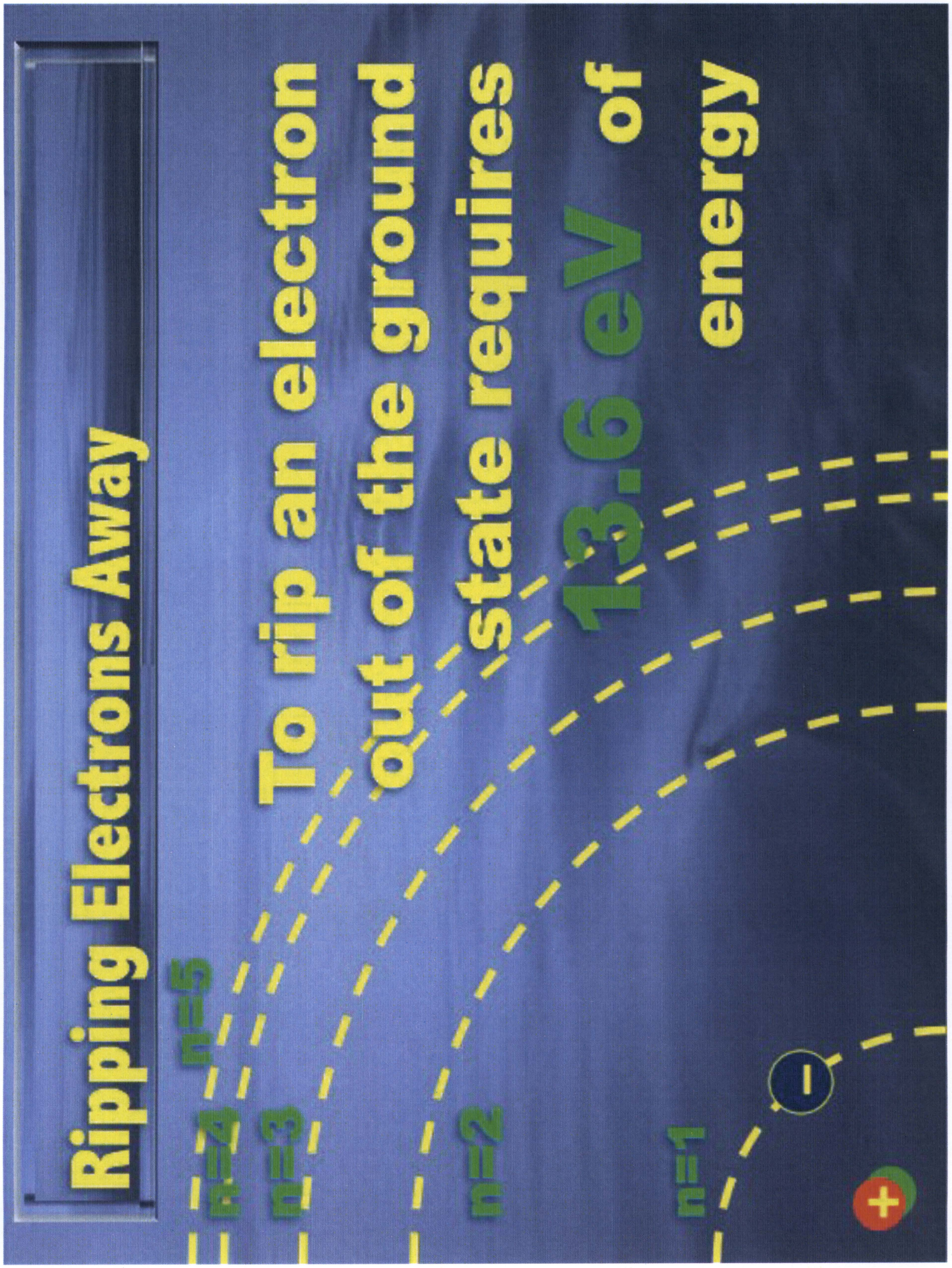

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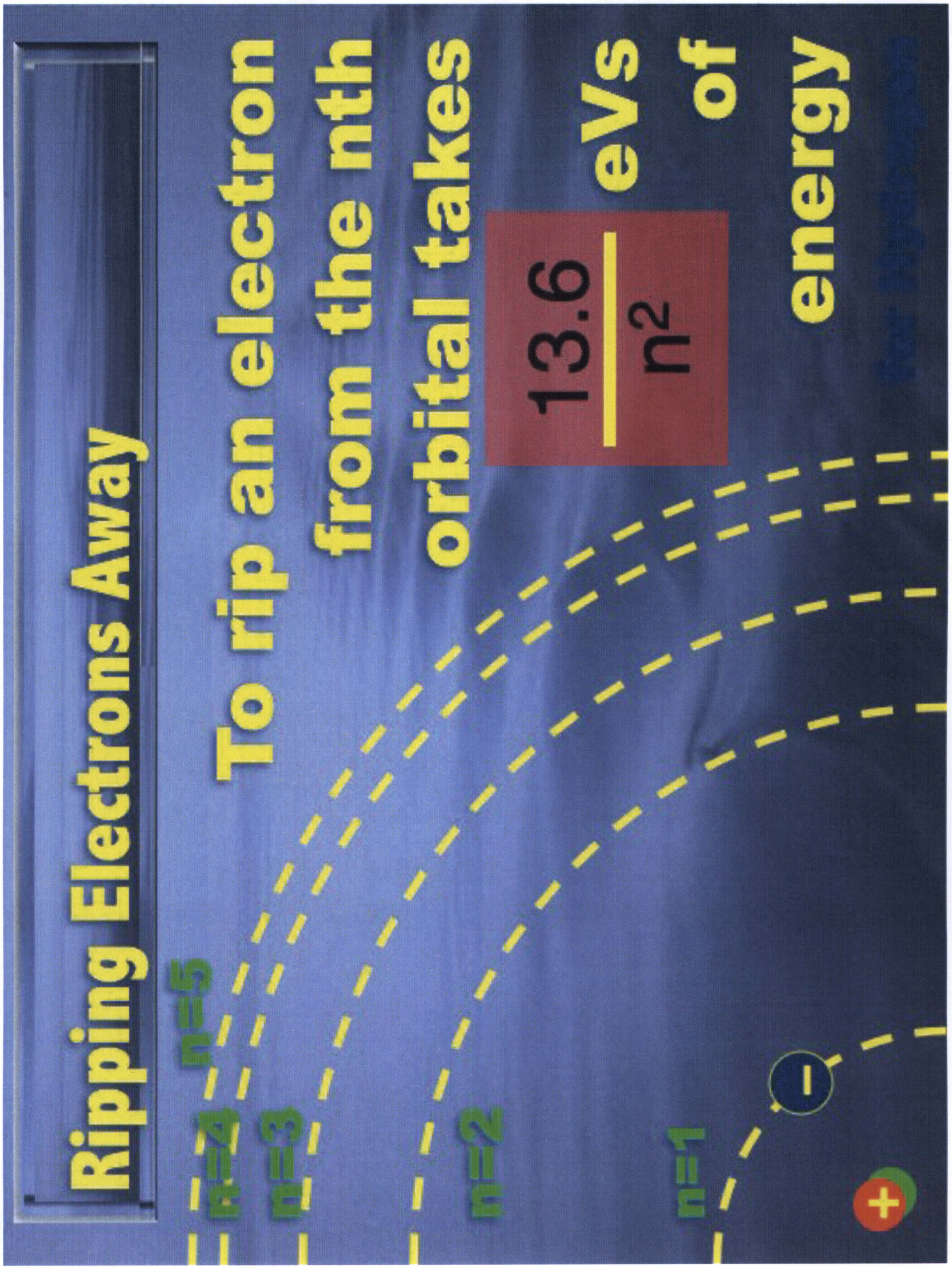

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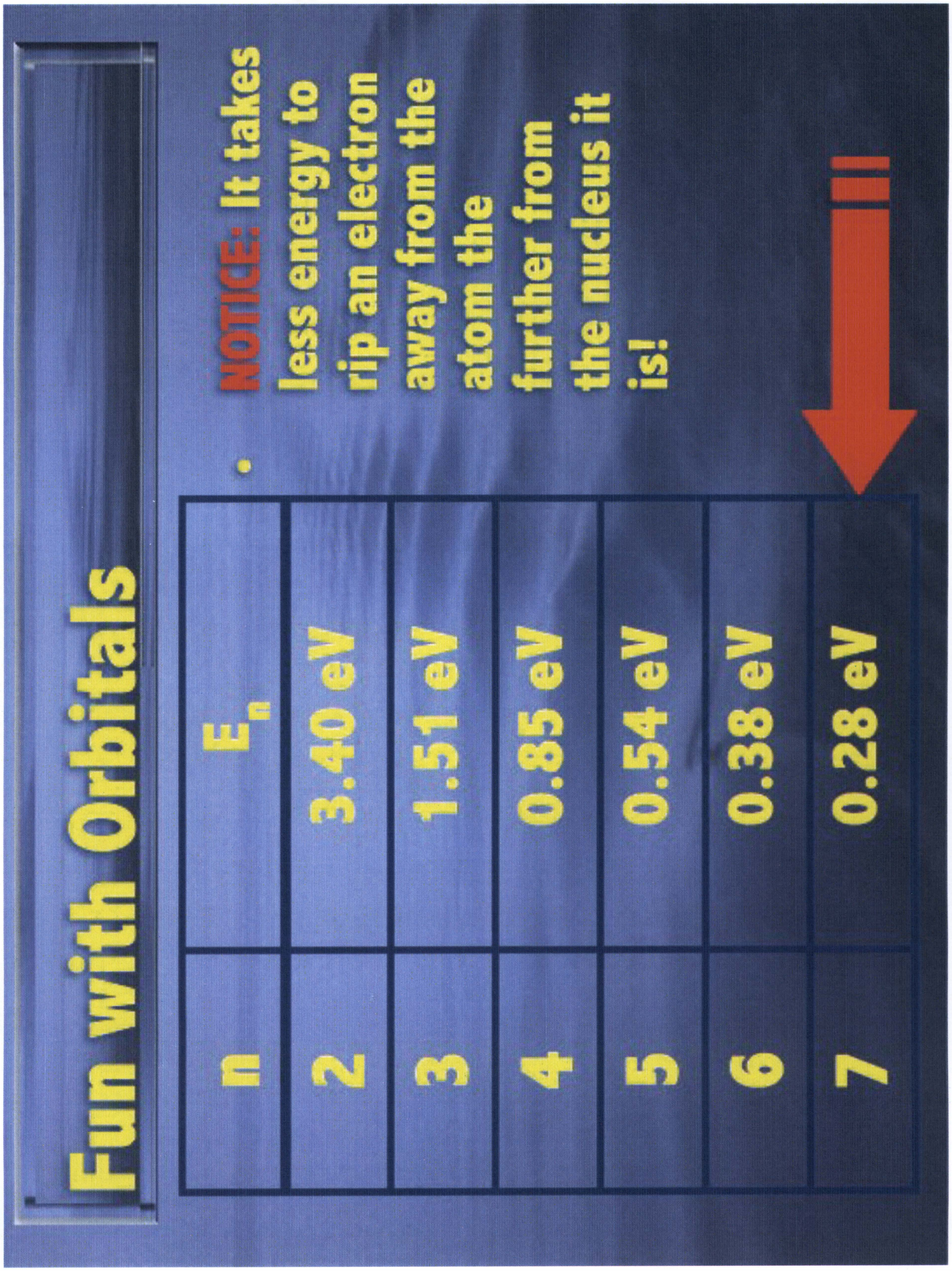

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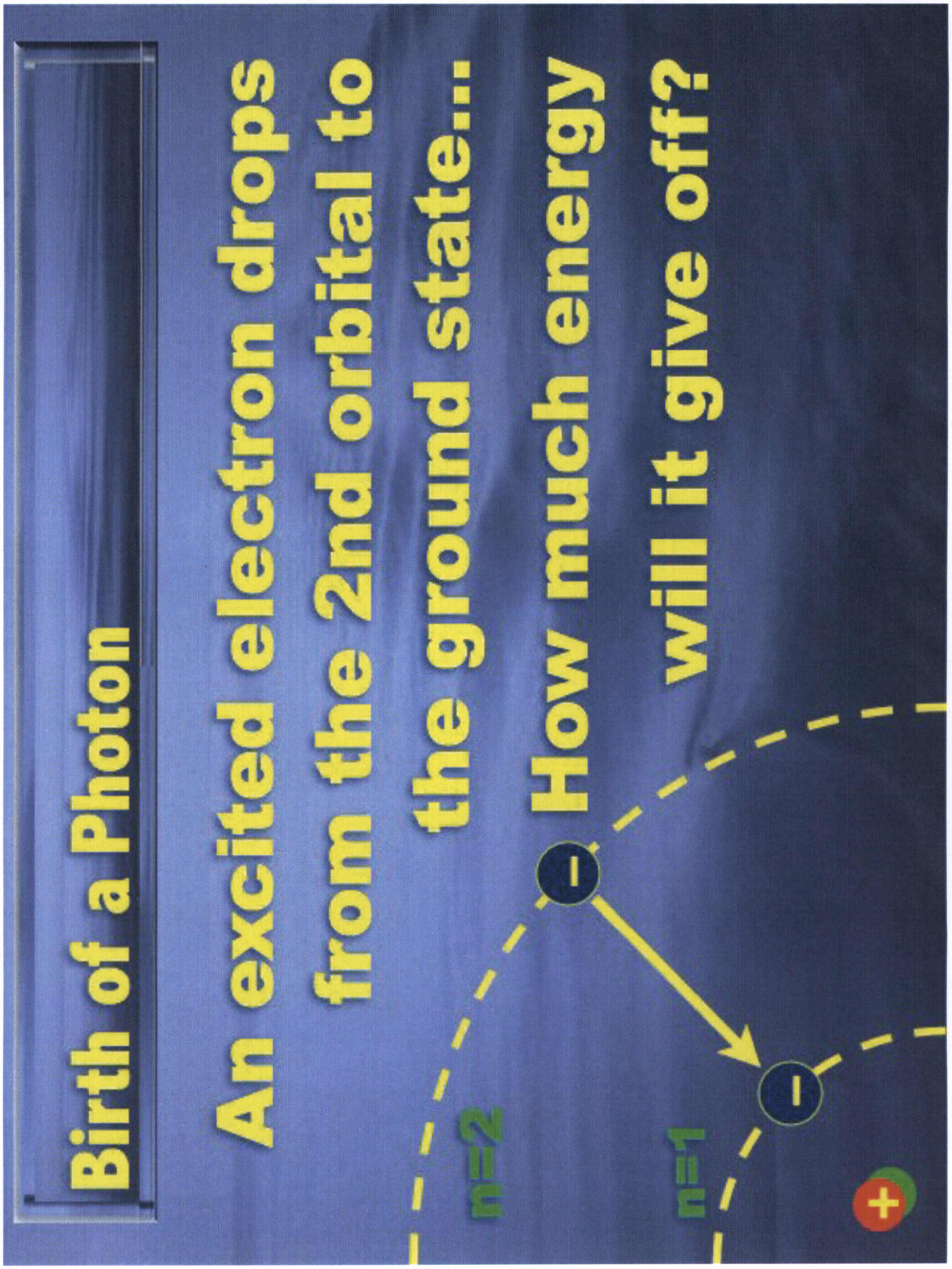

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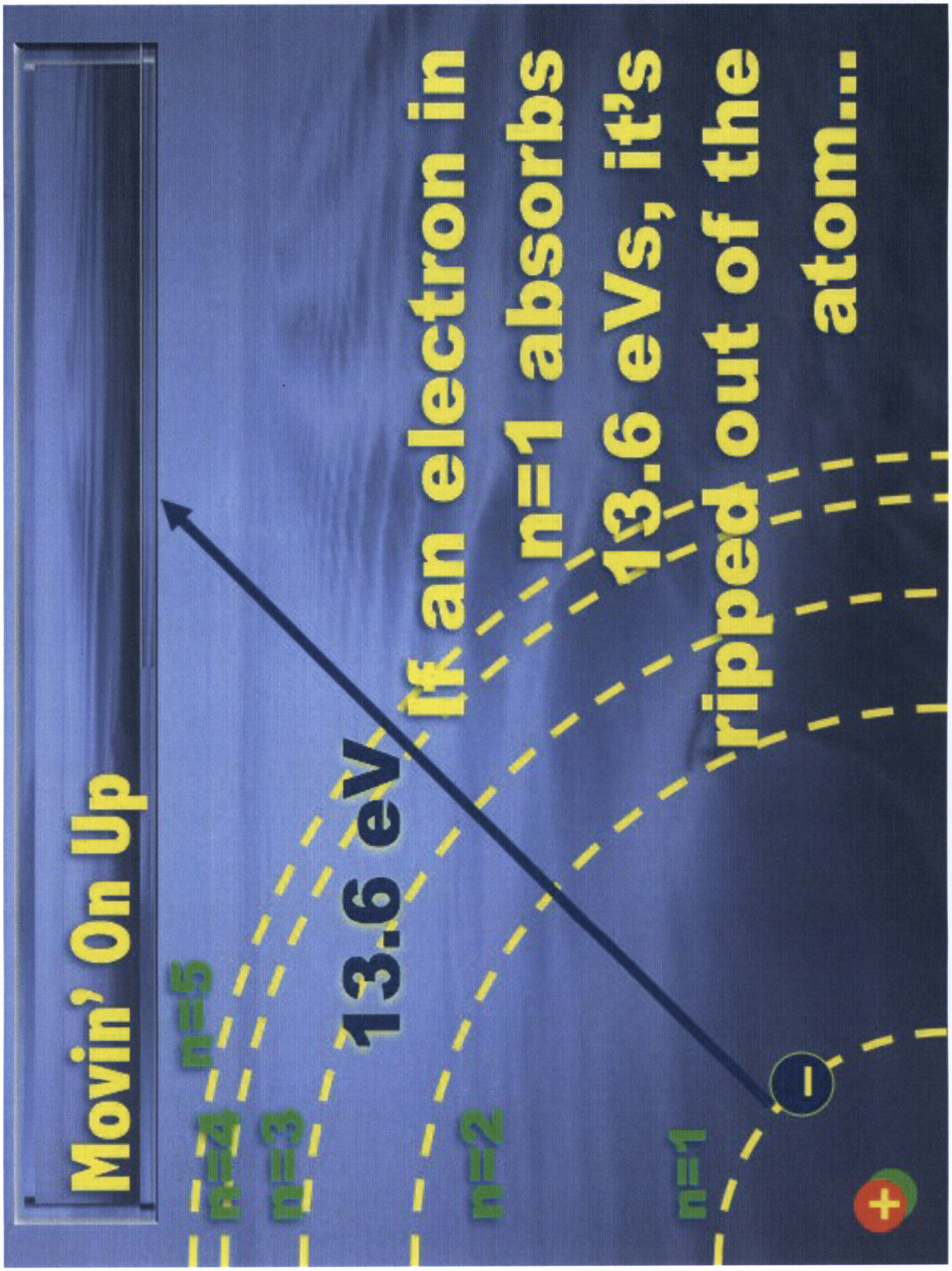

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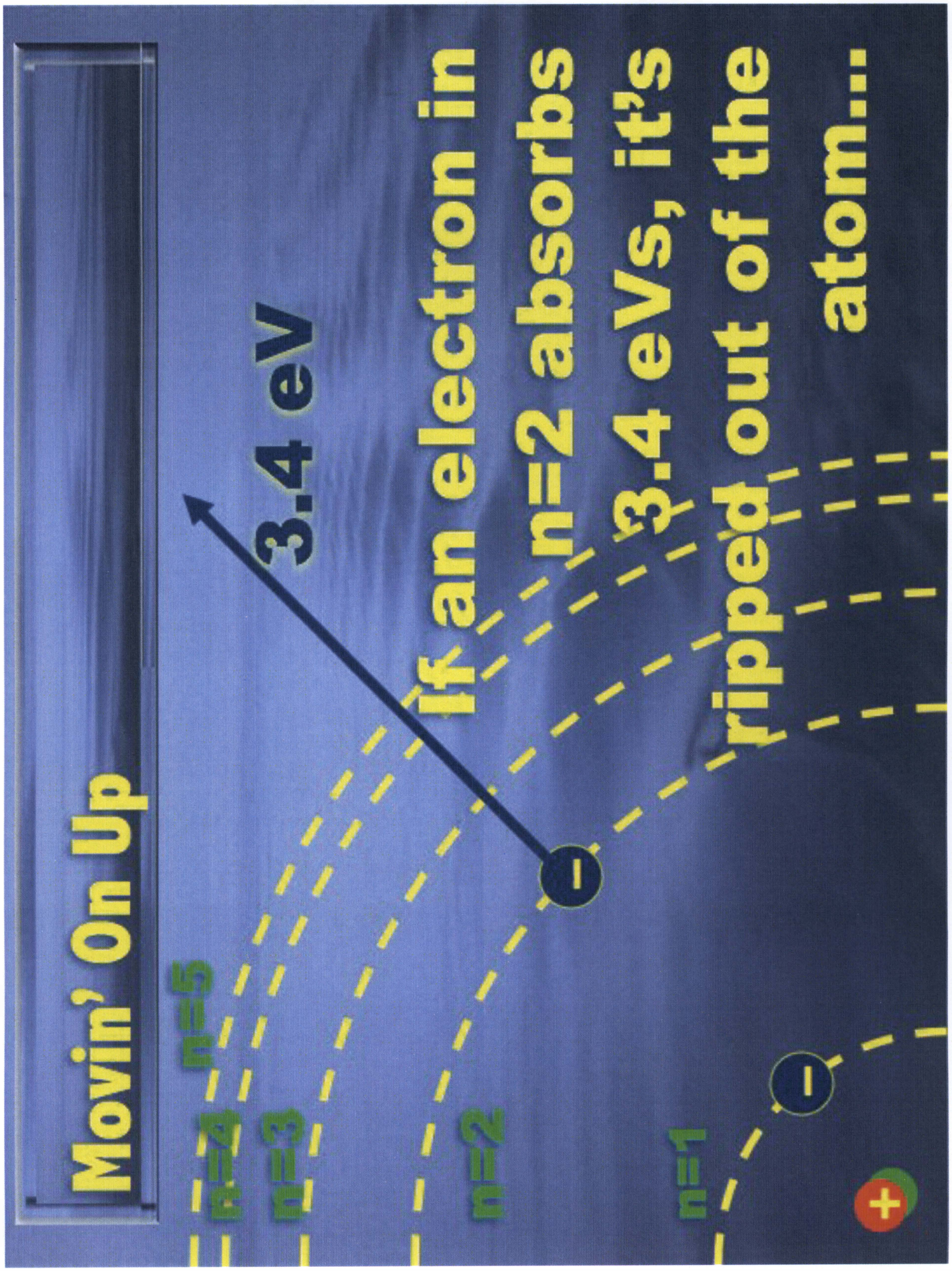

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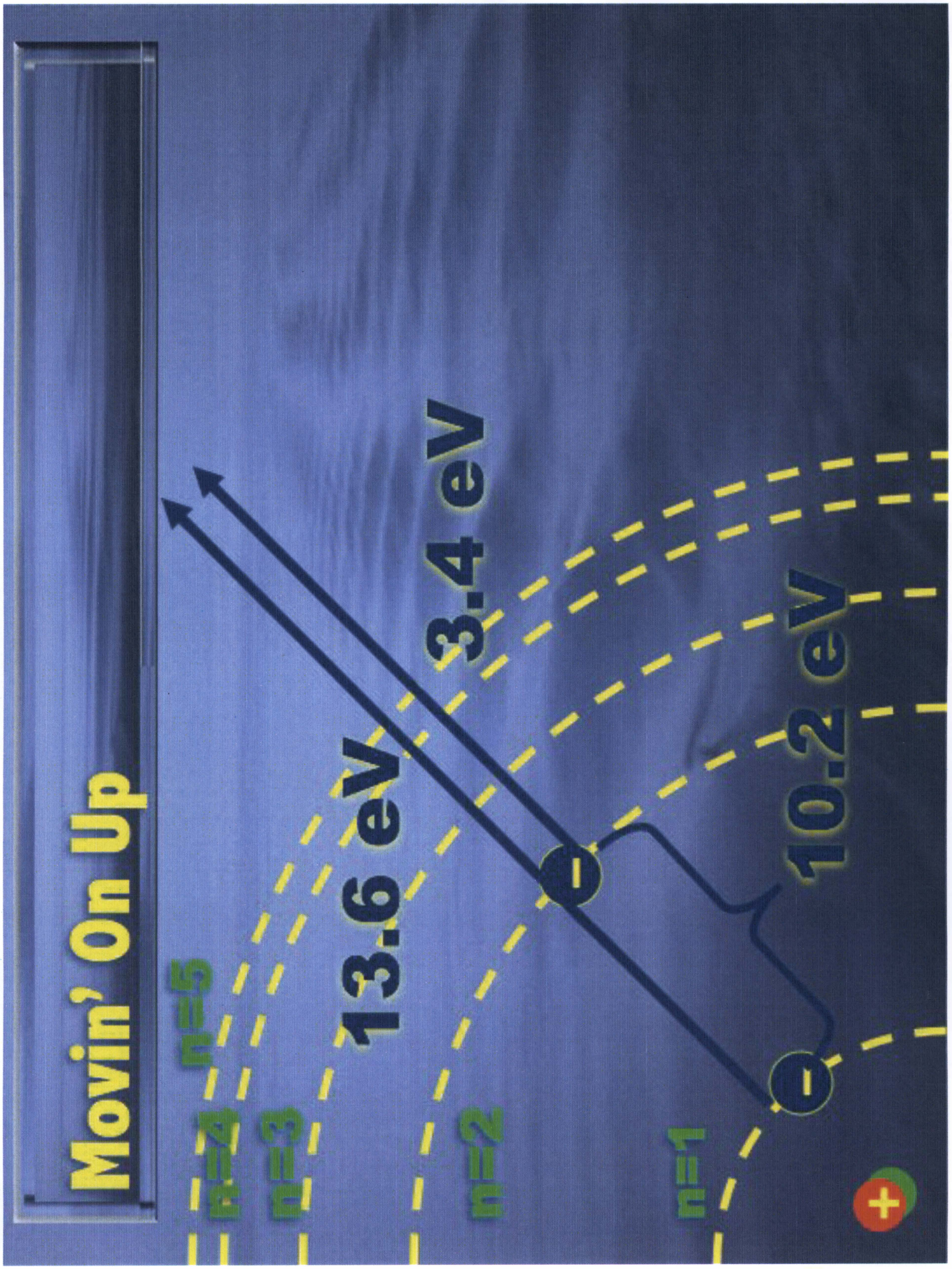

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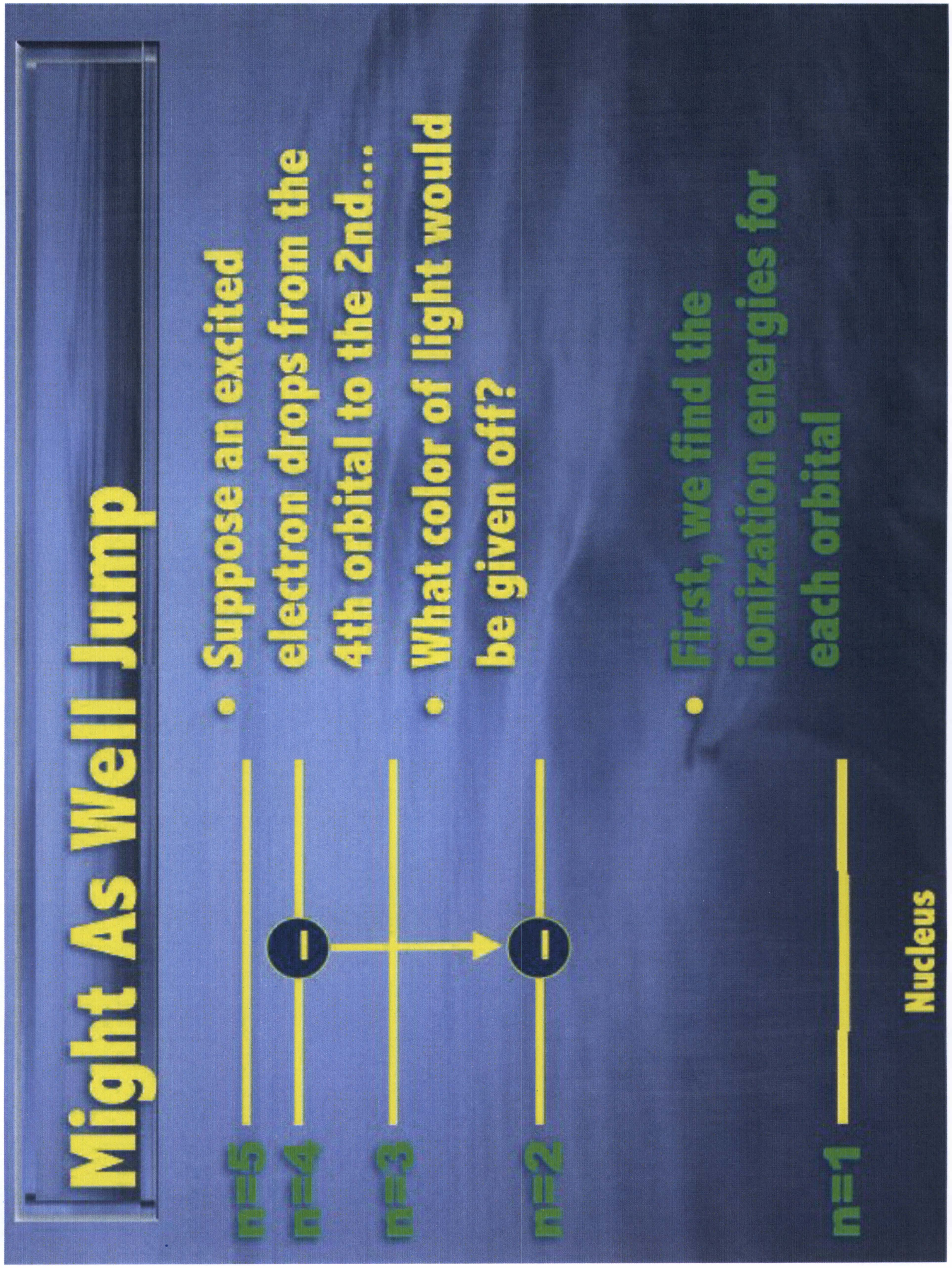

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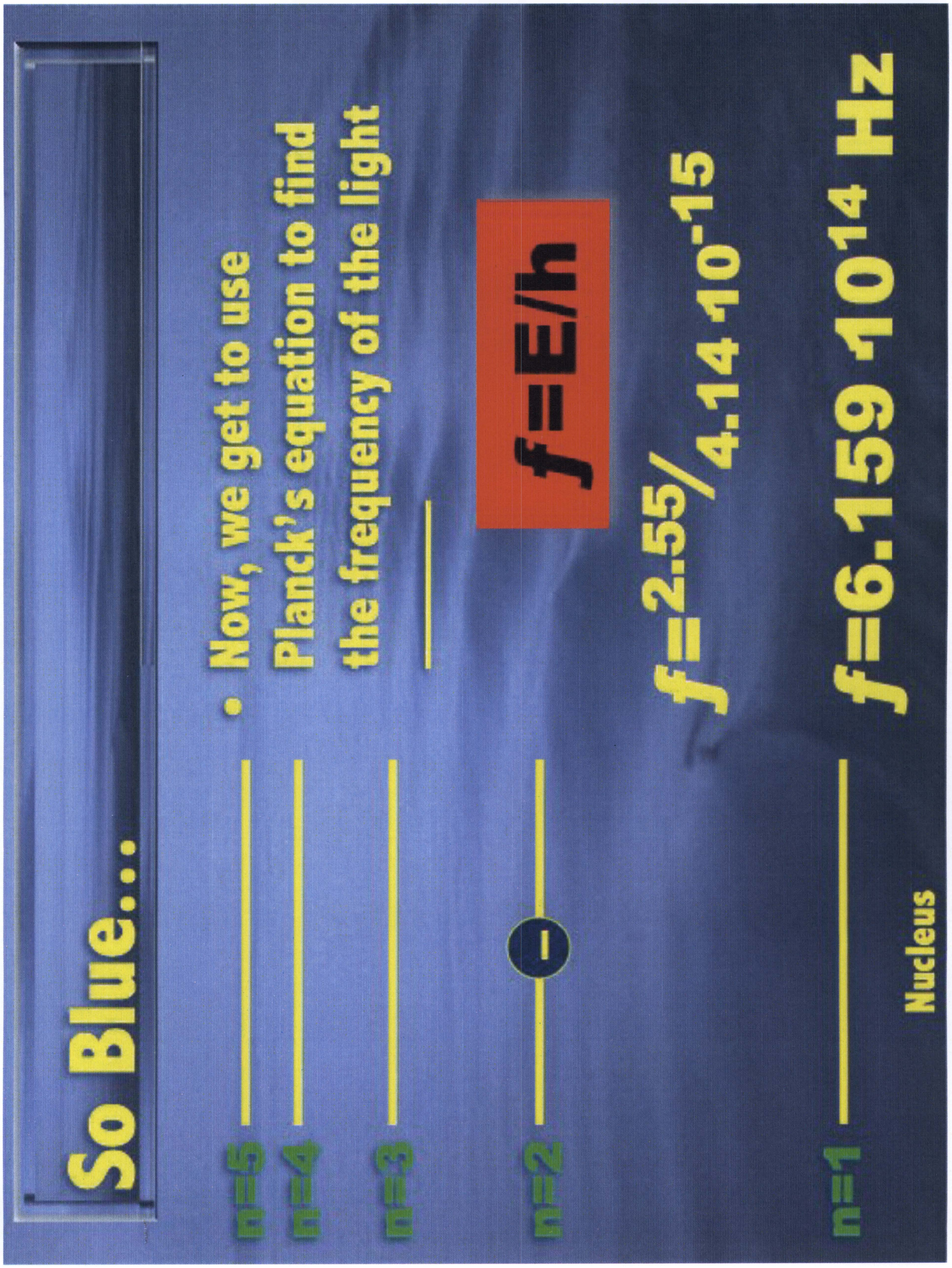

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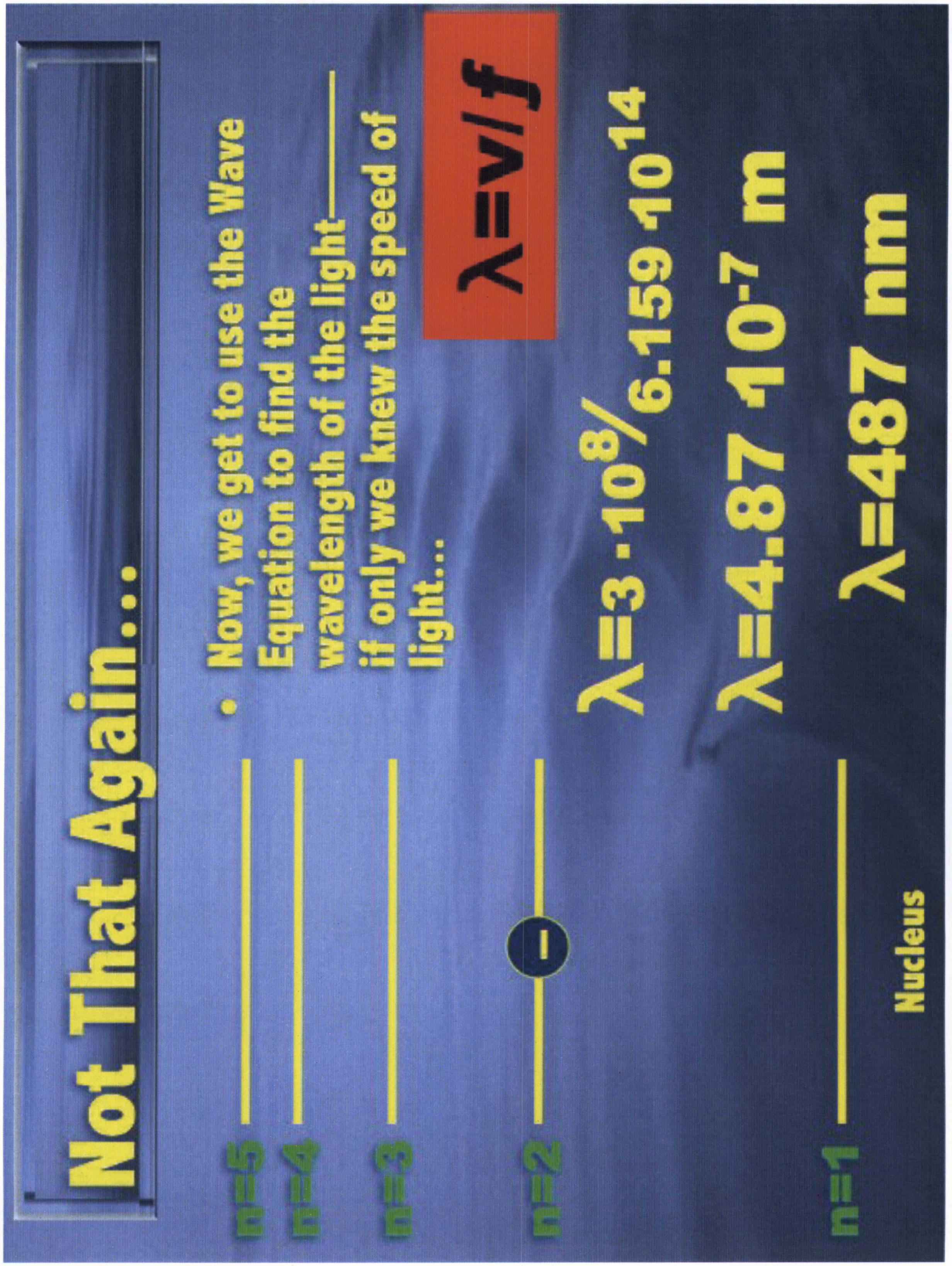

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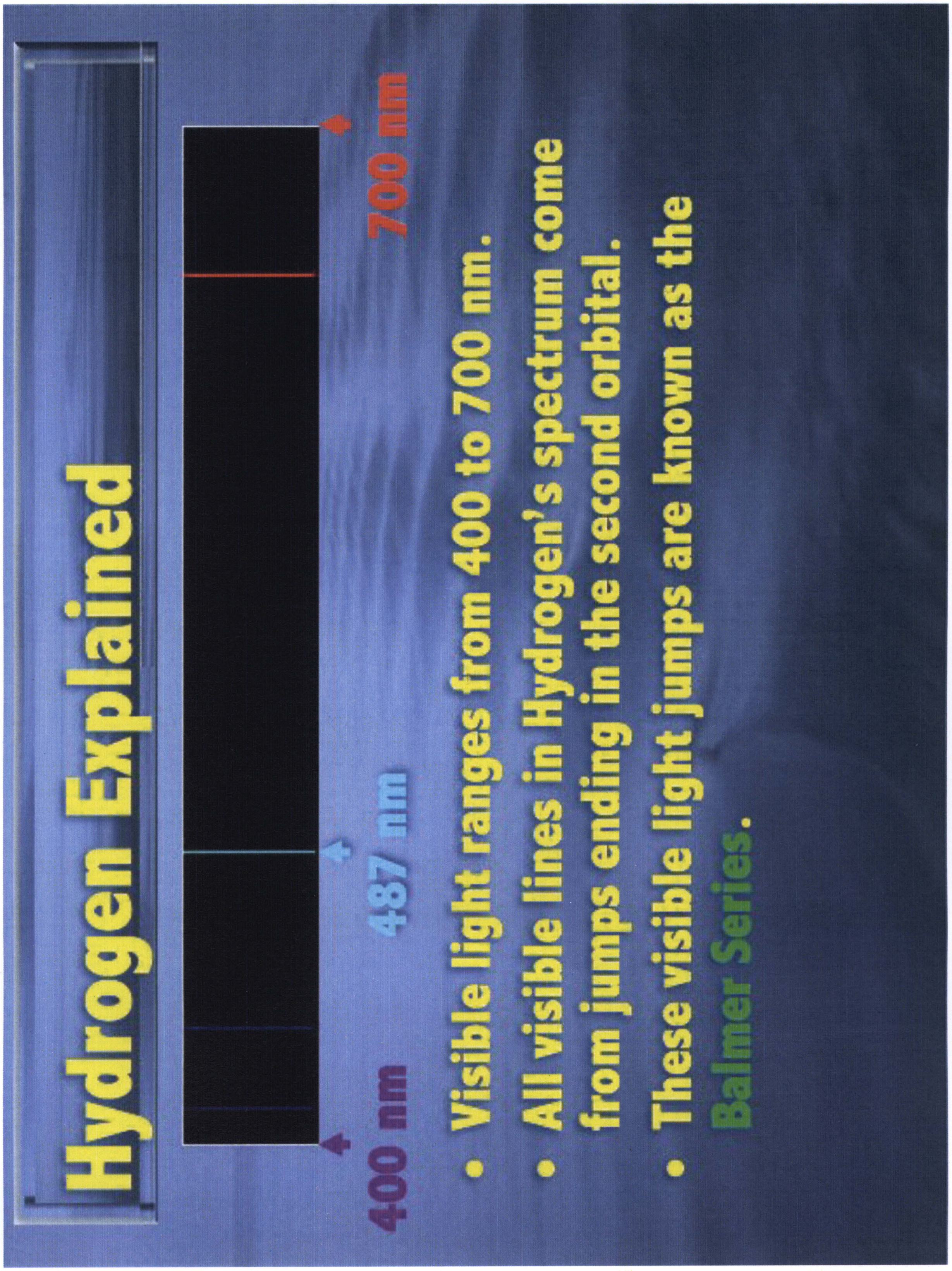

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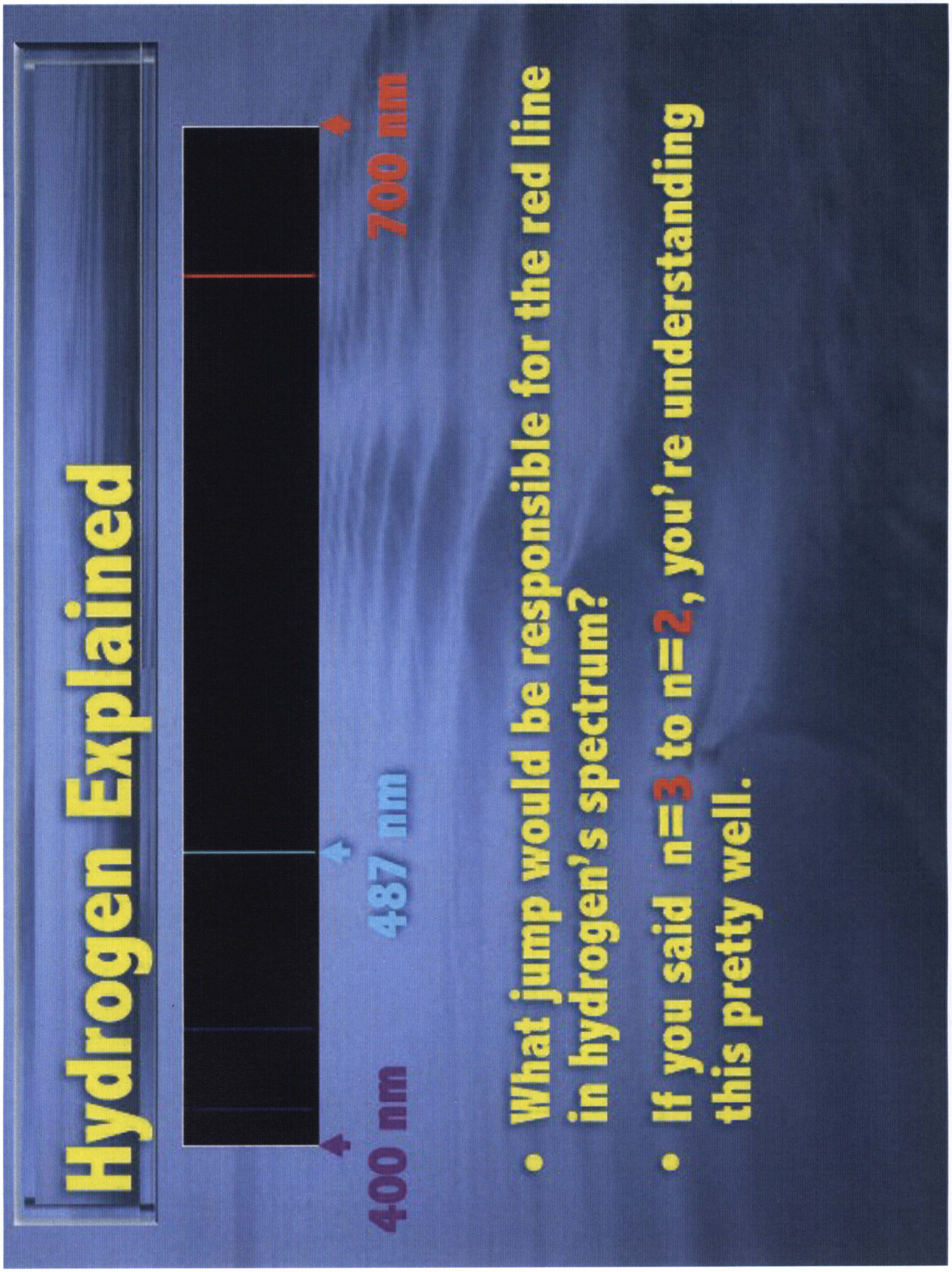

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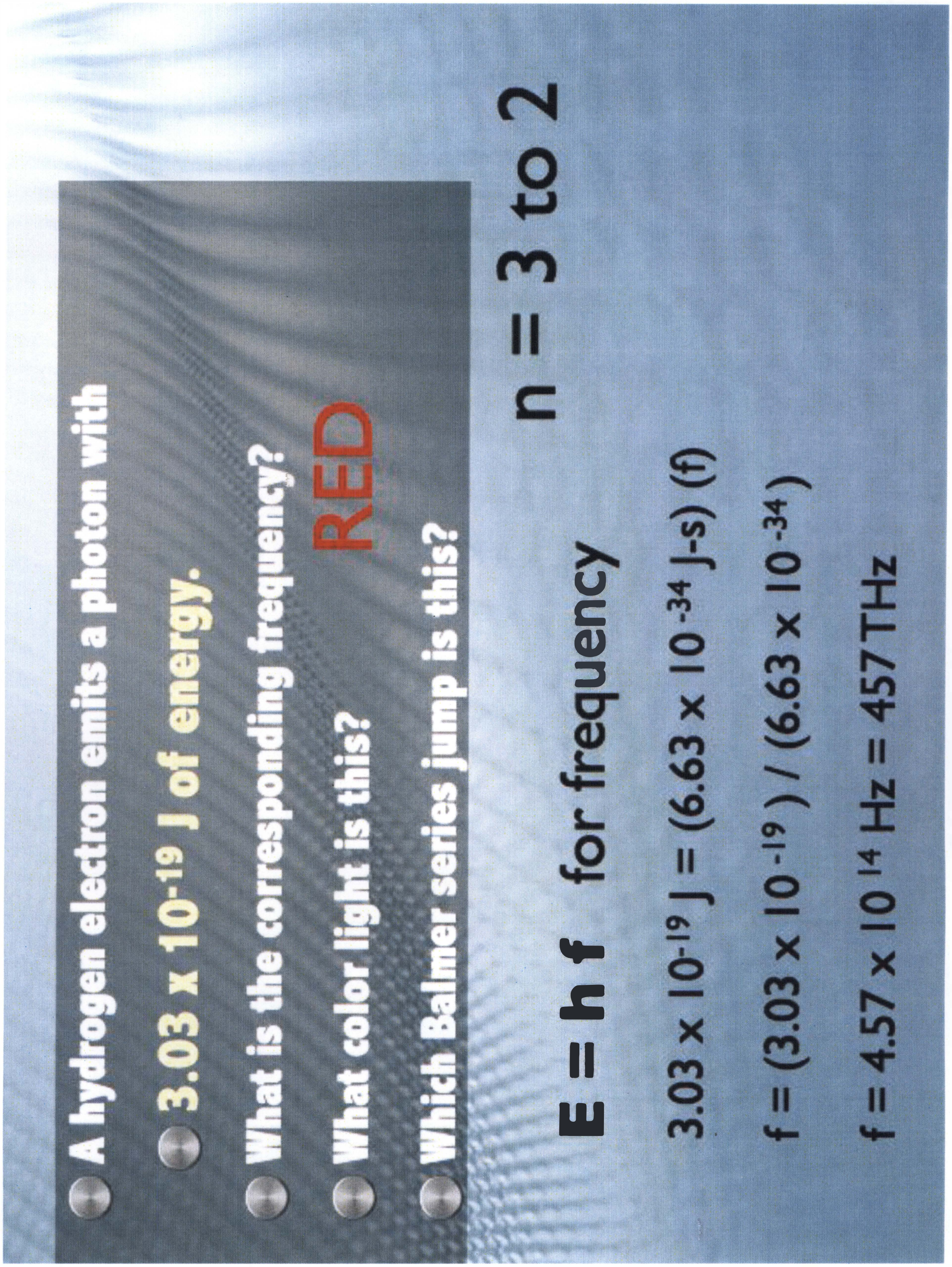


Appendix D.2 The Bohr Atom Practice Worksheet

THE BOHR ATOM WS

1. Determine the wavelength and frequency of light emitted when an electron in a hydrogen atom makes a transition from the 5^{th} excited state to the 1^{st} excited state.

2. When an electron is removed from an atom, the atom is said to be "ionized." The energy of the electron is then considered to be zero. How much energy would be required to ionize an electron from the 3^{rd} excited state in a hydrogen atom? What frequency of light (if all of its energy was absorbed by the electron) would be required to ionize an electron in the ground state of a hydrogen atom?

3. What is the energy of a photon that will raise an electron from the ground state to the 2^{nd} excited state? What color photons would be released if the electron jumped from the 2^{nd} excited state to the 1^{st} excited state, and then returned to the ground state?

4. What is the maximum wavelength of light that will ionize an electron in the ground state of a hydrogen atom?

5. A photon of wavelength 103 nm is emitted from a hydrogen atom. What two states must an electron have jumped between to create this photon?

6. Suppose titanium atoms, which have a work function of approx 4.33 eV, behave a lot like hydrogen atoms ($E \approx 1/n^2$). What color of light would be emitted by an electron in a single-electron titanium atom that dropped from the 3^{rd} orbital to the ground state?

Appendix D.2 The Bohr Atom Practice Worksheet

THE BOHR ATOM WS KEY

1. Determine the wavelength and frequency of light emitted when an electron in a hydrogen atom makes a transition from the 5th excited state to the 1st excited state.

$\Delta E = 3.022$
eV
$\lambda = 411$ nm

2. When an electron is removed from an atom, the atom is said to be "ionized." The energy of the electron is then considered to be zero. How much energy would be required to ionize an electron from the 3rd excited state in a hydrogen atom? What frequency of light (if all of its energy was absorbed by the electron) would be required to ionize an electron in the ground state of a hydrogen atom?

$E_4 = 0.85$ eV
$f_1 = 3.29 \cdot 10^1$

3. What is the energy of a photon that will raise an electron from the ground state to the 2nd excited state? What color photons would be released if the electron jumped from the 2nd excited state to the 1st excited state, and then returned to the ground state?

$E_{1 \to 3} = 12.09$ eV
$\lambda_{3 \to 2} = 658$ nm
(Red)

4. What is the maximum wavelength of light that will ionize an electron in the ground state of a hydrogen atom?

$\lambda_{max} = 91$

5. A photon of wavelength 103 nm is emitted from a hydrogen atom. What two states must an electron have jumped between to create this photon?

$\Delta E = 12.06$
eV
So jump was from

6. Suppose titanium atoms, which have a work function of approx 4.33 eV, behave a lot like hydrogen atoms ($E \approx 1/n^2$). What color of light would be emitted by an electron in a single-electron titanium atom that dropped from the 3rd orbital to the ground state?

$\Delta E = 0.88$ eV
$\lambda = 1395$ nm
not a color ->

Appendix D.2 The Bohr Atom Practice Worksheet

THE BOHR ATOM

1. Determine the wavelength and frequency of light emitted when an electron in a hydrogen atom makes a transition from the 5^{th} excited state to the 1^{st} excited state.

$\frac{13.6}{25} = 0.544$ eV $\Delta E = 13.056$ $13.056 = 4.14\times10^{-15} f$ $3\times10^8 = 3.154\times10^{15}\lambda$

$f = 3.154\times10^{15}$ Hz $\lambda = 0.000000095$ m

2. When an electron is removed from an atom, the atom is said to be "ionized." The energy of the electron is then considered to be zero. How much energy would be required to ionize an electron from the 3^{rd} excited state in a hydrogen atom? What frequency of light (if all of its energy was absorbed by the electron) would be required to ionize an electron in the ground state of a hydrogen atom?

$E = \frac{13.6}{9} = 1.51$ eV

$13.6 = 4.14\times10^{-15} f$ $f = 3.29\times10^{15}$ Hz

3. What is the energy of a photon that will raise an electron from the ground state to the 2^{nd} excited state? What color photons would be released if the electron jumped from the 2^{nd} excited state to the 1^{st} excited state, and then returned to the ground state?

$\Delta E = 13.6 - \frac{13.6}{9} = 12.09$ eV

$\Delta E = \frac{13.6}{4} - \frac{13.6}{9} = 1.89$ eV → $f = 4.563\times10^{14}$ Hz → $\lambda = 657.53$ nm → Red

$\Delta E = 13.6 - \frac{13.6}{4} = 10.2$ eV → $f = 2.464\times10^{15}$ Hz → $\lambda = 121.8$ nm → U.V ray

4. What is the maximum wavelength of light that will ionize an electron in the ground state of a hydrogen atom?

$3\times10^8 = 3.29\times10^{15}\lambda$ $\lambda = 91.324$ nm

5. A photon of wavelength 103 nm is emitted from a hydrogen atom. What two states must an electron have jumped between to create this photon?

$3\times10^8 = (103\times10^{-9}) f$ $E = (4.14\times10^{-15})(2.913\times10^{15})$

$f = 2.913\times10^{15}$ Hz $E = 12.06$ eV → between 1 and 3

6. Suppose titanium atoms, which have a work function of approx 4.33 eV, behave a lot like hydrogen atoms ($E\approx1/n^2$). What color of light would be emitted by an electron in a single-electron titanium atom that dropped from the 3^{rd} orbital to the ground state?

$E = \frac{1}{9} = 0.11$ eV

$0.11 = 4.14\times10^{-15} f$ → $f = 2.684\times10^{13}$ Hz

$3\times10^8 = 2.684\times10^{13}\lambda$ → $\lambda = 11178$ nm → Infrared ?

Appendix E.1 Bohr Model Simulation Lab

Nothing is "Bohr"ing about FIZX

Objectives:

- Determine how well different models of the atom agree with observations
- Explain spectral lines for hydrogen gas in terms of the wavelength emitted
- Calculate the relationship between wavelength and energy of a photon

Prelab Questions:

1. Sketch the electromagnetic spectrum. Label X-rays, UV, Visible, Infrared, Radio. Label which ones have the wavelengths smallest vs the largest. Do the same for frequencies and energies in your diagram below.

2. What are the components of white light? How do we know?

3. What speed do light waves travel at through a vacuum of space (c)? ____________________

Use $c = f \lambda$ and calculate:

Frequency of green light with 545 nm (1 nm = 10^{-9} m)

Wavelength of the carrier wave of your favorite radio station (B96, Hot 103.5, etc.)

Frequency = ________ MHz (if FM) = _______________ x 10^6 Hz

4. Sketch your own model of an atom to include: Positive nucleus, 3 "orbits" of negative electrons.

-Are electrons attracted or repelled from the nucleus?

-Which level are they most likely to exist? Why?

Appendix E.1 Bohr Model Simulation Lab

Procedure:

Access the website: http://phet.colorado.edu
Click on **Play with Sims**
From the left hand menu pick **Physics** and then **Quantum Phenomena**
Choose **Models of the Hydrogen Atom** from the choices to the right.
Check the **Show Spectrometer** box and turn on the "**White light gun**"
Have upper left lever knob turned to "**Experiment (what really happens)**"

Part I: What can we observe going into and out of this experiment ?

1. The "White light gun" is shining white light onto the sample of Hydrogen Gas molecules in the box. Watch awhile (~45-60 sec) and see if anything happens to the different colored "light particles" (photons) going in or coming out of the box. Record your observations.

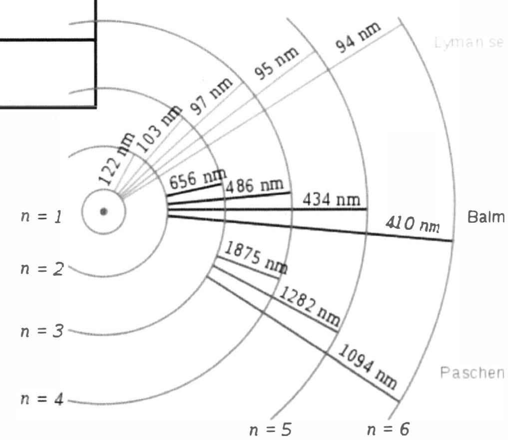
2. What does the box represent? Why do the photons (particles) of white light have different colors?

3. The spectrometer (bottom right) shows which colored photons are emitted (released by) the atom represented in the box. After the simulation has been running for at least 5 minutes, list the 4 wavelengths of the colors that have come from the atom and the amounts of each.

4. Calculate the energy (in Joules) corresponding to a "photon" for each wavelength you see. Use $E = hc/\lambda$ below where $h = 6.63 \times 10^{-34}$J-sec. Show work for one energy calculation please.

Wavelength (nm)	Energy (J)

5. Are photons of all colors being emitted by the atom in the box? If not, which colors aren't? Why? Use the diagram below (or your reference sheet) to help formulate your answer.



Appendix E.1 Bohr Model Simulation Lab

Part II: How well do predictions explain the observations?

The Bohr Model of the Hydrogen atom was specifically developed to explain the emission spectroscopy associated with pure elements as you have seen.

1. Switch from **Experiment** to **Prediction** in the upper left hand corner of the simulation. Switch to the **Bohr** model. Watch to see what happens in the simulation, the electron energy level diagram and the spectrometer. Do results agree with our original simulation on the previous page? Explain all correlations.

2. What do the n=1, 2, etc refer to? Which one is the "ground state" of the hydrogen atom. Why do electrons often end up there?

3. Describe what happens when a photon is absorbed by an electron:

4. Describe the process by which hydrogen gives off photons of light:

5. Which "jumps" seem to take place most often? Are there any colors of light that hydrogen can't give off?

6. Change the light gun to monochromatic. Test different colors of light and try to find any that work better than white light. Explain your results.

Appendix E.1 Bohr Model Simulation Lab

7. Click on the box on the top right corner that says "Show electron energy level diagram." Draw this diagram below and show how an electron could make a jump to release cyan light. Be sure to label the energy levels on your diagram below.

8. Does this lab simulation demonstrate that hydrogen's energy level are continuous or quantized? Use evidence from this lab and class to explain your answer.

9. Give some everyday examples of quantized levels or numbers. Use Google to help you to research if necessary.

Appendix E.2 Sample Student Bohr Model Simulation Lab

Nothing is "Bohr"ing about FIZX

Objectives:
- Determine how well different models of the atom agree with observations
- Explain spectral lines for hydrogen gas in terms of the wavelength emitted
- Calculate the relationship between wavelength and energy of a photon

Prelab Questions:

1. Sketch the electromagnetic spectrum. Label X-rays, UV, Visible, Infrared, Radio. Label which ones have the wavelengths smallest vs the largest. Do the same for frequencies and energies in your diagram below.

2. What are the components of white light? How do we know?

3. What speed do light waves travel at through a vacuum of space (c)? ____________________________

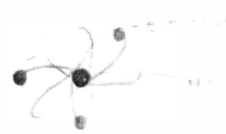
   Use c = f λ and calculate:

   Frequency of green light with 545 nm (1 nm = 10^{-9} m)

   Wavelength of the carrier wave of your favorite radio station (B96, Hot 103.5, Q101..etc):

   Frequency = ________ MHz (if FM) = _______________ x 10^6 Hz

4. Sketch your own model of an atom to include: Positive nucleus, 3 "orbits" of negative electrons.



-Are electrons attracted or repelled from the nucleus?

-Which level are they most likely to exist? Why?

Appendix E.2 Sample Student Bohr Model Simulation Lab

Procedure:
Access the website: http://phet.colorado.edu
Click on **Play with Sims**
From the left hand menu pick **Physics** and then **Quantum Phenomena**
Choose **Models of the Hydrogen Atom** from the choices to the right.
Check the **Show Spectrometer** box and turn on the "**White light gun**"
Have upper left lever knob turned to "**Experiment (what really happens)**"

Part I: What can we observe going into and out of this experiment ?

1. The "White light gun" is shining white light onto the sample of Hydrogen Gas molecules in the box. Watch awhile (~45-60 sec) and see if anything happens to the different colored "light particles" (photons) going in or coming out of the box. Record your observations.

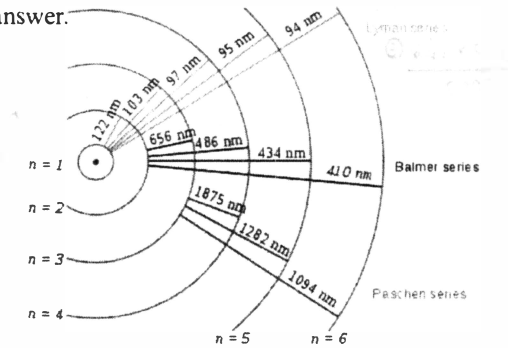
2. What does the box represent? Why do the photons (particles) of white light have different colors?

3. The spectrometer (bottom right) shows which colored photons are emitted (released by) the atom represented in the box. After the simulation has been running for at least 5 minutes, list the 4 wavelengths of the colors that have come from the atom and the amounts of each.

4. Calculate the energy (in Joules) corresponding to a "photon" for each wavelength you see. Use $E = hc/\lambda$ below where $h = 6.63 \times 10^{-34}$ J-sec. Show work for one energy calculation please.

Wavelength (nm)	Energy (J)

5. Are photons of all colors being emitted by the atom in the box? If not, which colors aren't? Why? Use the diagram below (or your reference sheet) to help formulate your answer.



Appendix E.2 Sample Student Bohr Model Simulation Lab

Name______________________________ Pd________

Part II: How well do predictions explain the observations?

The Bohr Model of the Hydrogen atom was specifically developed to explain the emission spectroscopy associated with pure elements as you have seen.

1. Switch from **Experiment** to **Prediction** in the upper left hand corner of the simulation. Switch to the **Bohr** model. Watch to see what happens in the simulation, the electron energy level diagram and the spectrometer. Do results agree with our original simulation on the previous page? Explain all correlations.

5. What do the n=1, 2, etc refer to? Which one is the "ground state" of the hydrogen atom. Why do electrons often end up there?

6. Describe what happens when a photon is absorbed by an electron:

7. Describe the process by which hydrogen gives off photons of light:

8. Which "jumps" seem to take place most often? Are there any colors of light that hydrogen can't give off?

9. Change the light gun to monochromatic. Test different colors of light and try to find any that work better than white light. Explain your results.

10. Click on the box on the top right corner that says "Show electron energy level diagram." Draw this diagram below and show how an electron could make a jump to release cyan light. Be sure to label the energy levels on your diagram below.

Appendix E.2 Sample Student Bohr Model Simulation Lab

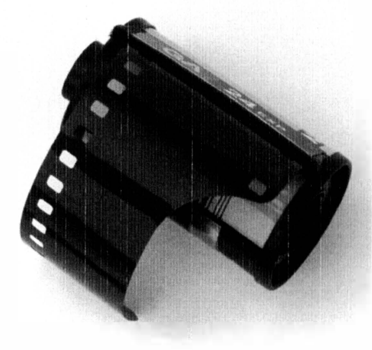
11. Does this lab simulation demonstrate that hydrogen's energy level are continuous or quantized? Use evidence from this lab and class to explain your answer. [illegible]

12. Give some everyday examples of quantized levels or numbers. Use Google to help you to research if necessary.

[illegible]

Appendix F.1 - Photography Webquest Lab

How Does Photography Work?



As we push into our discussion about holograms, we need to know how photosensitive films permanently store images upon their surfaces. Before digital photographs stored megapixel images in a computer file (like your cell phone making a SnapChat™), camera film was more than a hundred year old technological process to collect and store historical images. Some photography enthusiasts still use film for it's classic 'look' that it provides. In today's lesson we are going to use the knowledge gained during the Bohr's model of the atom lesson of this unit (specifically quantum energy jumps of electrons), to describe how photosensitive films in cameras work. Read up about the science by finding the information at the following website(s).

Locate the following website and read through it to find the answers to the following questions:
http://electronics.howstuffworks.com/camera.htm

1) What is the type of camera that the article mentions as it describes this process? Does this camera use electricity to produce the images?

2) What is the optical component of the camera and what's it's purpose in the camera? What kind of images does this component make?

3) What is the benefit that many cameras have if their lens is actually a zoom lens? In your explanation, please identify focal length.

Next navigate to the following website… http://electronics.howstuffworks.com/film.htm

4) What are the particles of light called? How is their energy related to the frequency of light versus the wavelength of light?

5) In the area below define **photochemistry**. How does certain plastics or your skin respond to the phenomenon of photochemistry?

6) Photographic film uses photosensitive materials to collect their images. For normal 35-mm cartridge film, what are the contents of the **base** of the film? What is its purpose in film development?

Appendix F.1 Photography Webquest Lab

7) On the other side of the base is the layer that where the photochemistry occurs. What is that layer called and what type of chemical grains are present upon it?

8) What do **spectral sensitizers** provide to the silver halide crystals' sensitivities?

9) Define **film speed** below. Also discuss the pros and cons to having a fast film speed versus a slow film speed.

10) What does **limited exposure latitude** mean for your picture and how would it appear as a result? Explain.

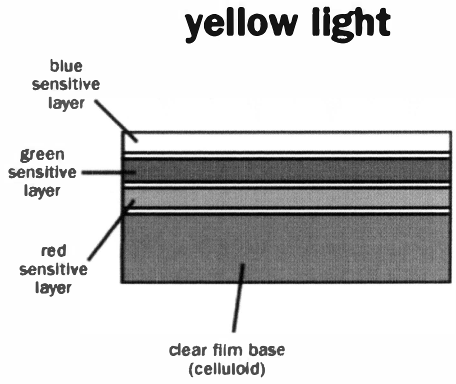
11) A **latent image** is formed by doing what with the camera?

12) What probably happens to the silver halide crystals present on the gelatin when light hits that layer? Explain below using your knowledge of quantum effects on electrons on the **conduction band.**

13) How is color film collect its photons in comparison to black and white film?

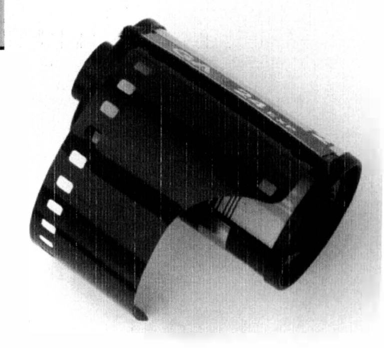
14) What is a **negative** image and what is its purpose in the processing of images? Explain the steps of processing.

15) What do **couplers** provide to the image making process? What color mixing system does film use in comparison to your television?



Appendix F.2 Photography Webquest Lab Key

How Does Photography Work? (***ANSWER KEY***)



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Locate the following website and read through it to find the answers to the following questions:
http://electronics.howstuffworks.com/camera.htm

1) What is the type of camera that the article mentions as it describes this process? Does this camera use electricity to produce the images?

IT'S A MANUAL SINGLE LENS REFLEX (SLR) CAMERA AND IT DOES NOT REQUIRE ELECTRICITY TO PRODUCE ITS IMAGES.

2) What is the optical component of the camera and what's it's purpose in the camera? What kind of images does this component make?

THE OPTICAL COMPONENT IN THE CAMERA IS THE LENS AND IT FORMS REAL IMAGES UPON THE EXPOSED FILM.

3) What is the benefit that many cameras have if their lens is actually a zoom lens? In your explanation, please identify focal length.

A ZOOM LENS HAS THE ABILITY TO CHANGE THE FOCAL LENGTH OF THE LENS AS A WHOLE. THE FOCAL LENGTH IS THE DISTANCE WHICH THE LENS FOCUSES PARALLEL LIGHT BEAMS ON THE PRINCIPLE AXIS.

Next navigate to the following website… http://electronics.howstuffworks.com/film.htm

4) What are the particles of light called? How is their energy related to the frequency of light versus the wavelength of light?

THEY ARE CALLED PHOTONS. THE HIGHER THEIR ENERGY, THE HIGHER THEIR ASSOCIATED FREQUENCY, BUT THEY HAVE SHORTER WAVELENGTHS.

5) In the area below define **photochemistry**. How does certain plastics or your skin respond to the phenomenon of photochemistry?

THE PROCESS BY WHICH ELECTROMAGNETIC RADIATION CAUSES CHANGES TO MATTER. PLASTICS CAN HARDEN (CURE) UNDER UV EXPOSURE, WHILE THE SAME RADIATION CAN CAUSE HUMAN SKIN TO BURN OR TAN.

6) Photographic film uses photosensitive materials to collect their images. For normal 35-mm cartridge film, what are the contents of the **base** of the film? What is its purpose in film development?

THE BASE CONTAINS A CELLULOID WHICH FILTERS THE LIGHT AND WILL CONTROL CHEMICAL REACTIONS UPON THE FILM.

Appendix F.2 Photography Webquest Lab

7) On the other side of the base is the layer that where the photochemistry occurs. What is that layer called and what type of chemical grains are present upon it?

THAT LAYER IS THE GELATIN AND IT CONTAINS SILVER HALIDE CRYSTALS WHICH ARE PHOTOSENSITIVE.

8) What do **spectral sensitizers** provide to the silver halide crystals' sensitivities?

THEY ALLOW THE CRYSTALS TO BE MORE SENSITIVE TO THE WAVELENGTHS OF RED, GREEN, BLUE COLORED LIGHT. THOSE THREE ARE THE PRIMARY COLORS OF LIGHT.

9) Define **film speed** below. Also discuss the pros and cons to having a fast film speed versus a slow film speed.

FILM SPEED IS THE SENSITIVITY OF THE FILM. FASTER FILM IS MORE HELPFUL FOR OBJECTS THAT MAY BE IN MOTION, WHEREAS SLOWER FILM IS MORE USEFUL FOR PORTRAIT PHOTOGRAPHY. IN THAT CASE THE OBJECT IS LIKELY MOTIONLESS. FASTER FILM MIGHT NOT ALLOW AS MUCH DETAIL IN ITS RESOLUTION.

10) What does **limited exposure latitude** mean for your picture and how would it appear as a result? Explain.

IF FILM IS UNDEREXPOSED, ALL THE LIGHT FROM A SCENE LIKELY WASN'T ABSORBED AND BE DARKER THAN NORMAL. ALTERNATIVELY IF IT IS OVEREXPOSED, TOO MUCH LIGHT WAS ABSORBED AND THE IMAGE WOULD BE WASHED OUT.

11) A **latent image** is formed by doing what with the camera?

OPENING THE CAMERA'S SHUTTER FOR MERELY A FRACTION OF A SECOND.

12) What probably happens to the silver halide crystals present on the gelatin when light hits that layer? Explain below using your knowledge of quantum effects on electrons on the **conduction band.**

AN ELECTRON PRESENT IN THAT GRAIN IS EXCITED AND RAISED INTO THE CONDUCTION BAND FORMING A SINGLE SILVER ATOM. EVENTUALLY ENOUGH SILVER FORMS TO MAKE A STABLE IMAGE SITE.

13) How is color film collect its photons in comparison to black and white film?

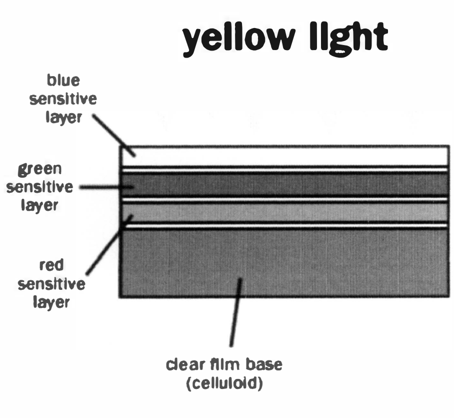
IT GATHERS THE COMPONENTS OF THE LIGHT (RED, GREEN, BLUE) SEPARATELY IN SPECIFIC SENSITIVE LAYERS ON THE FILM.

14) What is a **negative** image and what is its purpose in the processing of images? Explain the steps of processing.

A NEGATIVE IMAGE IS THE REVERSE IMAGE OF THE PRODUCED IMAGE. IN AREAS WHERE THE FILM HAD HIGH EXPOSURE THE NEGATIVE IS DARK. WHERE THE FILM HAD LITTLE EXPOSURE, THE NEGATIVE IS LIKELY LIGHT IN COLOR. IT IS POSSIBLE TO DEVELOP THE NEGATIVE INTO A COPIED PHOTOGRAPH.

15) What do **couplers** provide to the image making process? What color mixing system does film use in comparison to your television?

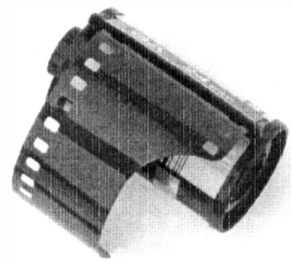
COUPLERS AID THE OXIDATION PROCESS DURING PROCESSING. COLOR FILM USES SUBTRACTIVE COLOR MIXING WHEREAS TELEVISIONS USE ADDITIVE COLOR MIXING.



Appendix F.3 Sample Student Photography Webquest Lab

Name ______ Pd ____

How Does Photography Work?



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Locate the following website and read through it to find the answers to the following questions: http://electronics.howstuffworks.com/camera.htm

1) What is the type of camera that the article mentions as it describes this process? Does this camera use electricity to produce the images?

Is a manual single lens review (SLR) camera. no it does not

2) What is the optical component of the camera and what's it's purpose in the camera? What kind of images does this component make?

the lens, ~~it~~ takes the beams of light bouncing off an object and redirects them to form a real image.

3) What is the benefit that many cameras have if their lens is actually a zoom lens? In your explanation, please identify focal length.

You are able to move different lens elements. Therefore, you can ~~ad~~ adjust magnification power (focal length) of the lens

Next navigate to the following website... http://electronics.howstuffworks.com/film.htm

4) What are the particles of light called? How is their energy related to the frequency of light versus the wavelength of light?

They are photons; the energy of each photon is ~~d~~ inversely related to wavelength and directly related to frequency

5) In the area below define **photochemistry**. How does certain plastics or your skin respond to the phenomenon of photochemistry?

It is the process by which electromagnetic energy causes chemical changes to matter. they cause pigments to darken

6) Photographic film uses photosensitive materials to collect their images. For normal 35-mm cartridge film, what are the contents of the **base** of the film? What is its purpose in film development?

It contains a transparent plastic material (celluloid) and coatings. They ~~HR~~ filter light and control chemical reactions

Appendix F.3 Sample Student Photography Webquest Lab

7) On the other side of the base is the layer that where the photochemistry occurs. What is that layer called and what type of chemical grains are present upon it?

The chemical grains are silver-halide crystals on the back side

8) What do **spectral sensitizers** provide to the silver halide crystals' sensitivities?

They make them more sensitive to blue, green, and red light

9) Define **film speed** below. Also discuss the pros and cons to having a fast film speed versus a slow film speed.

Film speed is the relative speed rating of the film. If it is faster, it has greater light sensitivity-easier to take pictures of fast-moving objects or in low light.

10) What does **limited exposure latitude** mean for your picture and how would it appear as a result? Explain.

If it is underexposed, it lacks detail and is dark. If it is overexposed, it is super washed out.

11) Forming a **latent image** is formed by doing what with the camera?

It is formed by opening the shutter for a fraction of a second

12) What probably happens to the silver halide crystals present on the gelatin when light hits that layer? Explain below using your knowledge of quantum effects on electrons on the **conduction band**.

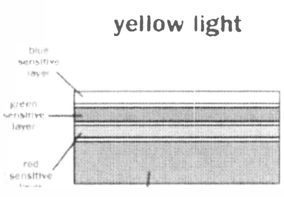
The photons are absorbed by electrons which transfer to the conduction band, then to different parts to form silver atoms.

13) How is color film collect its photons in comparison to black and white film?

In color film, there is seperate layers for blue, red, and green colors.

14) What is a **negative** image and what is its purpose in the processing of images? Explain the steps of processing.

~~The darkest~~ It is inverted colors. It is printed onto photographic paper. You put it in the developer, rinse it, put it in the fixing bath, and wash it.



15) What do **couplers** provide to the image making process? What color mixing system does film use in comparison to your television?

They react with the oxidized developer to form colors. They use subtractive, tv's use additive.

Appendix G.1 Photography Resolution Lab

Determining Optimal Lighting by Resolution

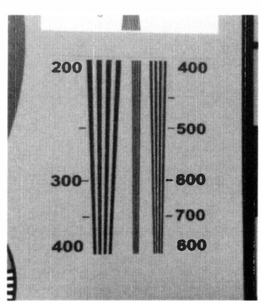
Cameras of yesteryear did not commonly include a convenient LCD screen and a memory storage device to preview and save your quickly snapped photographs - nor were they built in your everyday smart phone. Back in your parents' time, bulkier cameras similar to today's more professional SLR style cameras pictured at right, had to be preloaded with photosensitive film. Pressing on the camera's shutter release would quickly expose the film to whatever the lens happened to be focused upon. That image was permanently documented upon the film but you could not necessarily view the image immediately. You either needed to develop the film yourself if you had access to your own dark room, or process the film at a local photo shop to see the resulting image.

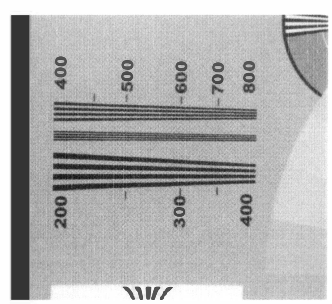
Conveniently the Polaroid™ company developed a series of cameras and film technology (pictured at left) which eliminated the need to process the film. As soon as the user snapped his or her picture, the camera would eject the film all the while chemically treating the film with emulsifier. Within five minutes of ejection the new picture would be visible. These Polaroid models are no longer available and thus we will be using the Fuji Instax™ Mini 8.

In today's experiment we would like to use this instant film technology to answer a few questions:
1) What is the ideal lighting illumination which provides the best picture resolution for the camera?
2) Does a maximum illumination exist such that any more illumination on a target no longer improves the resolution?

At the laboratory setups you are provided with a camera, lab stand, four reading lamps with 40W bulbs in them and a resolution placard template by Digital Image Flow. You are to shoot a single shot at the placard per each description that is described below and then determine the appropriate resolution be looking at the vertical and horizontal scales as pictured below. The placard should be 60 cm from the camera at all times and each bulb should be 50 cm from the placard. The resolutions will be determined after inspection of your photo underneath a microscope centrally located in the room.

Setup Description	Vertical Scale	Horizontal Scale	Color Distinction
1 40W Bulb			
2 40W Bulb			
3 40W Bulb			
4 40W Bulb			
4 40W Bulb + Flash			
No Bulbs + Flash			





Appendix G.1 Photography Resolution Lab

On this section of your packet have someone from your group tape, paste and label your six pictures to this sheet.

Appendix G.1 Photography Resolution Lab

Conclusion and Extension Questions:

1) What happened to the rated resolution as you increased the amount of illumination upon the placard template?

2) Where would you determine the most optimum resolution occurred for your six setups?

3) At what illumination did it seem that you finally observed the true colors of the placard?

4) Is there a difference between the values of the vertical and horizontal scales from your observations? Explain why they did or why did not.

5) Did you find a maximum amount of resolution regardless if you increased the illumination past a certain point? If so, what was that maximum resolution and illumination?

6) What may cause those limits if they existed? Think about yesterday's webquest to formulate your answer.

Appendix G.1 Sample Student Photography Resolution Lab

Determining Optimal Lighting by Resolution

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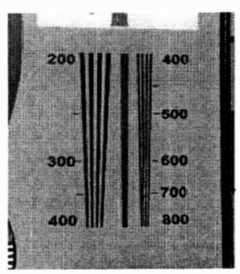
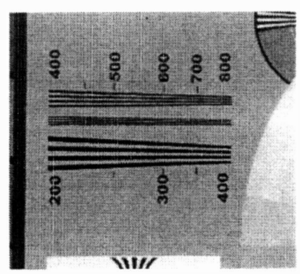
Setup Description	Vertical Scale	Horizontal Scale	Color Distinction
1 40W Bulb	[illegible]	225	No
2 40W Bulb	[illegible]	[illegible]	No
3 40W Bulb	300	300	(Red - purple) A little bit
4 40W Bulb	400	325	(Blue - green) A little bit
4 40W Bulb + Flash	425	400	Yes
No Bulbs + Flash	425	350	No





Appendix G.2 Sample Student Photography Resolution

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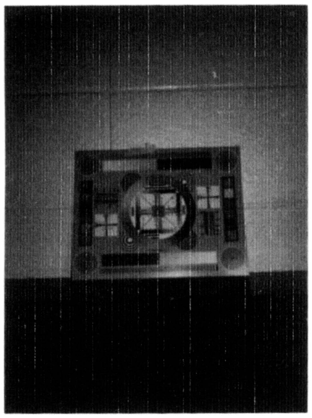
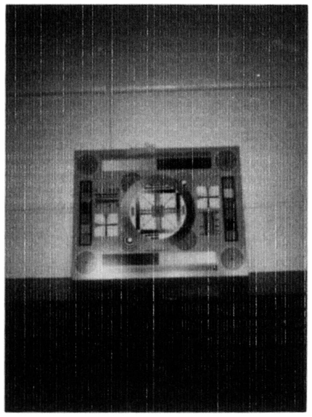
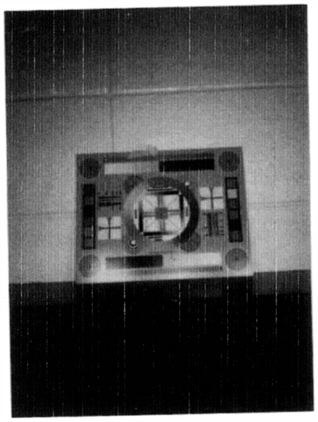
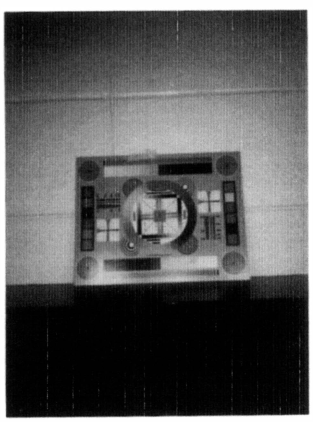
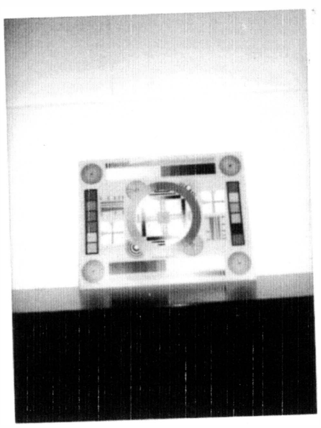
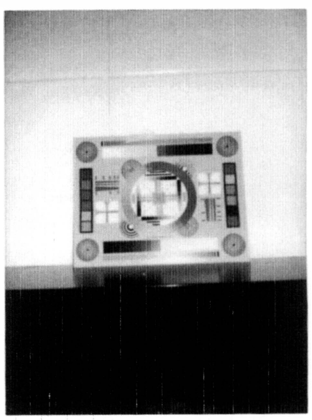












Appendix G.2 Sample Student Photography Resolution Lab

Conclusion and Extension Questions:

1) What happened to the rated resolution as you increased the amount of illumination upon the placard template?

[illegible]

2) Where would you determine the most optimum resolution occurred for your six setups?

[illegible]

3) At what illumination did it seem that you finally observed the true colors of the placard?

[illegible]

4) Is there a difference between the values of the vertical and horizontal scales from your observations? Explain why they did or why did not.

[illegible]

5) Did you find a maximum amount of resolution regardless if you increased the illumination past a certain point? If so, what was that maximum resolution and illumination? [illegible]

What may cause those limits if they existed? Think about yesterday's webquest.

[illegible]

Appendix H.1 Light Topics Handout

Group Presentation Topics: *LIGHT*

Your group of up to three students will choose one of the following topics on which to present a 7-10 minute presentation. As we have studied the physics behind light and optics during class, we have brought up many real-world applications that we are interested in knowing the "why" behind! Here is your chance to pick one of those topics that is of particular interest to you and research it to find out more information. You will then share your findings with the class in a brief presentation.

Holographic "Virtual" Music Concerts

Polaroid 'instant' cameras - We used these in class, but how do they exactly work?

The development and history of the Hubble space telescope

Vision - nearsighted and farsighted eyes and how the vision is corrected

The eye -- how we see, interpret images, etc.

Optical illusions in nature and/or conceived

Television screens and color

Why is the sky blue? Why are sunsets red?

3-D movie technology

During a clear night sky why do stars twinkle, while planets do not?

The history and usage of fiber optic cables in communication

Summertime mirages

Polarizers -- How are they made? How do polaroid sunglasses work?

LCD screens -- another use of polarizers

Gamma rays... their various applications, and the controversy of their use

Digital Micromirror Device (DMD) and its possible use for projecting movies in theaters

Insects/Animals and their use of eyesight/color (pick a specific animal/insect)

Two-way mirrors (i.e. police interrogation mirrors)

Military night vision systems

"Heads-up display" used in military aircraft and in some commercial automobiles

Military use of Infrared technology in crowd control

Endoscopes and their use in the medical fields to examine the interior of the body

Corrective eye surgery

Black holes and light!

History and contemporary usage of the Laser Beam

Color blindness or other eye abnormalities

AMOLED technology usage including personal devices

Something Else Your Group Wants to Explore Dealing with Light: Have an idea for a presentation dealing with sound that your group wants to pursue? Check with Mr. H for approval before proceeding. He'll probably OK it, but just wants to check and make sure there's 7-10 minutes worth of material for you to present.

Appendix H.2 Light Topics Sample Rubric

Light Project Rubric

The following rubric will be used for the group presentations.

Some students may also receive less than 4 pts in the Coverage category, based on his or her work in class due to the motivation ratings from their project partners.

Name	Score (out of 45)

	EXEMPLARY	GOOD	FAIR	POOR	MISSING
Coverage— Did you adequately cover and explain the topic that was assigned?	**10**—encyclopedic, understandable coverage and explanation of the topic	**9**—coverage of the topic is good, but I'm uncertain if group knows some terms used	**7**—coverage of the topic is fair. A little hard to understand information at times	**6**—topic coverage is random, some major points and concepts missing in coverage	**4**—some coverage of the basics; time allotted in class to work obviously not used well
Organization of Presentation	**6**—Information presented as an interesting story sequence	**5**—Information presented logically and easy to follow	**4**—Most information seems to be presented in correct sequence	**2**—Hard to follow; sequence of information is jumpy	**0**—lacking any structure whatsoever
Contribution of Topic— How does your topic show significance to the advancement of science	**6**—scientific significance explained in full detail and extremely well	**5**—scientific significance mentioned and explained to audience.	**4**—scientific significance was mentioned but not explained	**2**—scientific significance was only hinted upon during presentation	**0**—significance of topic not addressed.
Visuals/Builds— Did you have visuals? Did they add to the presentation, or were they just "flair"?	**6**—visuals/builds actively helped audience understand topic	**5**—visuals/builds help understanding a little, one or two for flair	**4**—visuals good, but most seem like they're flair	**2**—visuals shown have no purpose being in presentation	**0**—lacking any visuals whatsoever
Coherence— Did your group work as a whole, or was the presentation choppy?	**6**—presentation seems well-rehearsed and practiced beforehand	**5**—some planning is evident in presentation	**4**—a few times occurred when group members interrupted/contradicted others	**2**—some lack of structure to talk; interruptions/contradictions frequent	**0**—complete lack of structure to the presentation
Timing— Did your presentation last in the 7-10 minute range?	**6**—time in the 7-10 minute range	**5**—time in the 5-6 or 10-11 minute ranges	**4**—time in the 4-5 or 11-11:30 range	**2**—time just less than 4 minutes or just over 11:30 minutes	**0**—timing is far off the mark
Works Cited— Did you include a works cited slide on your presentation that had at least 4 different sources	**5**—4 sources listed, one of which is from Mr H's recommended sites	**4**—Only 3 sources included and/or not one is from Mr H's recommended sites	**3**—Only 2 sources included	**2**—Only 1 source included	**0**—lacking any works cited sources whatsoever
Mr H's Grade					

NOTES:

Appendix H.3 Annotated Bibliography Guidelines

Works Cited / References guidelines "Light Presentation"

How You'll Be Graded:

- Research sources:
  - one source <u>**MUST**</u> be either a **print source** or an **online database**
  - the other sources may be a website or another online database/print source
- Write an Annotated Bibliography using the format:
  - **citation** of source
  - 3-5 sentence **summary** of the information found in the source
  - a **rating** of the source at the end of the paragraph (excellent, fair, poor, etc.) and a reason for the rating.

NOTE: The annotated bibliography should have your NAME, a TITLE, and correct citations (MLA style). Please use italics for the paragraph to set it apart from the citation.

Ima Student
Mr Hogan
Light and Optics Mini Project
13 December 2015

Polarized Sunglasses: An Annotated Bibliography

Thompson, Brian J. "Polarized Light." <u>World Book Online Reference Center</u>. 2006. Oak Forest High School Library, Oak Forest, IL. 19 Nov. 2006. <http://www.worldbookonline.com/wb/Article?id=ar436860>.

This article discussed how light is polarized. It talked about how light is a transverse wave that vibrates in many directions and that when light is passed through a polarizing filter, only one direction of light passes through. It also brought up different polarizing materials that are used as well as the applications of those materials. The article mentioned that sunglasses are one application of a polarized material that can be used to help block out the light that is naturally polarized horizontally from reflections off of pavement and water. For this reason, the sunglasses are polarized using a vertical transmission axis so that much of the light is filtered out. This source was rated two bulbs out of three because it contained a lot of scientific information, but not very much information about actual sunglasses.

Appendix I.1 Scratch Holography Lab

Scratch 'Abrasion' Holograms

If you ever have seen bright blurry three dimensional splotches on a dark color car hood on a bright day, what you are truly are observing is a hologram!

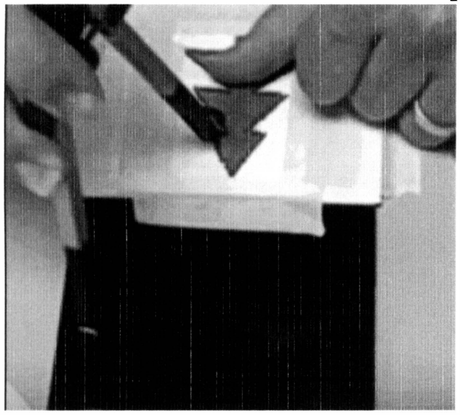
This phenomenon is actually a special type of hologram called an abrasion hologram. In order to see the reflected image you need to cause an abrasion pattern (scratches) upon a ductile surface such as plastic. The surface that we will be using in today's lesson activity is acrylic sheeting that is 1/8th - inch thick.

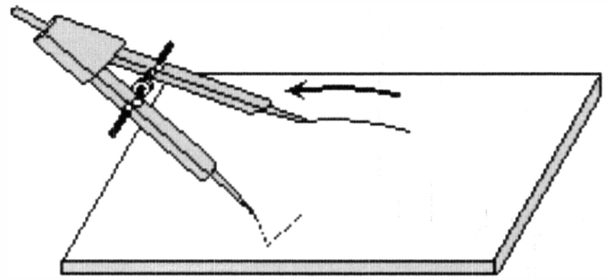
To formulate the abrasions upon the surface we will be using compass tools that you have seen previously in your mathematics courses. When you use your compass, make sure that you maintain an equal radius on the arch of your abrasions and each side has a needle in it (i.e. it's double needled and has no lead preloaded).

First thing you will need to do is to determine the design of your scratch hologram. Your instructor's acrylic plate samples are limited to a size 3" by 5.5" and you can use the template below which is exactly at those dimensions. Whatever the design of your choice. It only needs to fit within that frame in order to see it in full detail.

Next you can start finding the locations of your chosen pattern that will be translated for the image. You want to make the dots as numerous as possible for the most clear image, but the more you do the possibility of error increases. I would recommend making dots about every half a centimeter around the perimeter of your design. Observed as pictured below.

Appendix I.1 Scratch Holography Lab





Tape the dotted pattern and your plastic sheet solidly to your working surface.

At each location where you have identified your pattern to be transposed to the acrylic sheet, you will place one end of your compass needle. Then in a sweeping motion fully across the surface you will gently scratch the plastic in an arch-like pattern. Repeat for all locations of your chosen pattern and observe in the picture above. When you complete the scratch it should be light enough that the surface is not flaking.

When your abrasion is complete on the surface of your acrylic sheet, it should be ready! Take it outside in the bright sun to see if you can see your created scratch hologram!

Now let us contemplate what today's activity has taught us about light ray optics, reflection and the hologram produced.

Summary Questions:

1. What is the point source that is illuminating the acrylic sheet? Where is it located in reference to you as you hold the sheet?

2. Considering the distance the point source is from the acrylic surface, how would the incident beams of light be oriented to each other in reference to the sheet?

3. As light hits the arched scratches and reflects off, is the light reflected in a specular behavior or is the light scattered? Explain your answer.

4. Depending on your answer above, holograms are formed from interference patterns as we have discussed previously. Explain below how reflected light upon the scratched arches can provide interference with other light beams incident upon the surface.

5. Lastly holograms are supposed to be able to be broken down into smaller pieces of their original forms and it still works. If you sliced your holographic sheet in half – by breaking it – see if you can take it outside and still see your image. Try it, report your findings below and explain why it does or does not work.

Appendix I.2 Sample Student Scratch Holography Lab

Name________________ Pd______

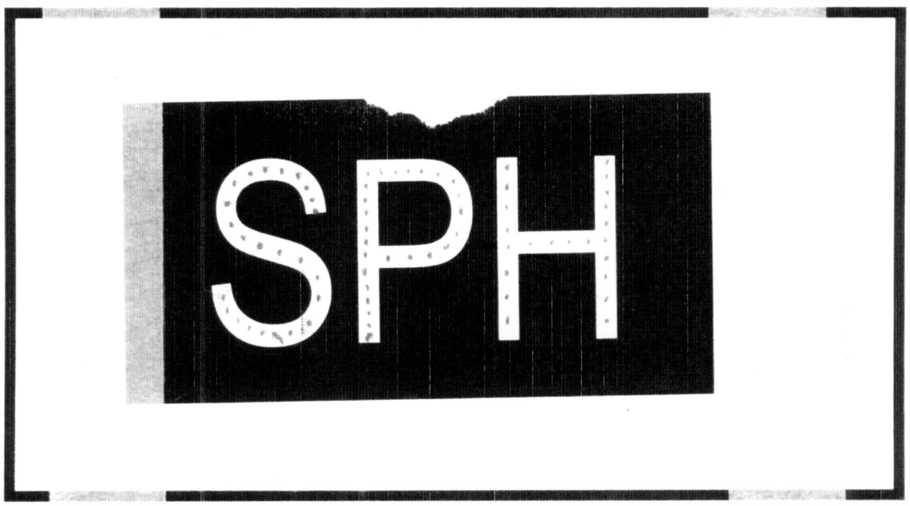
Scratch 'Abrasion' Holograms

If you ever have seen bright blurry three dimensional splotches on a dark color car hood on a bright day, what you are truly are observing is a hologram!

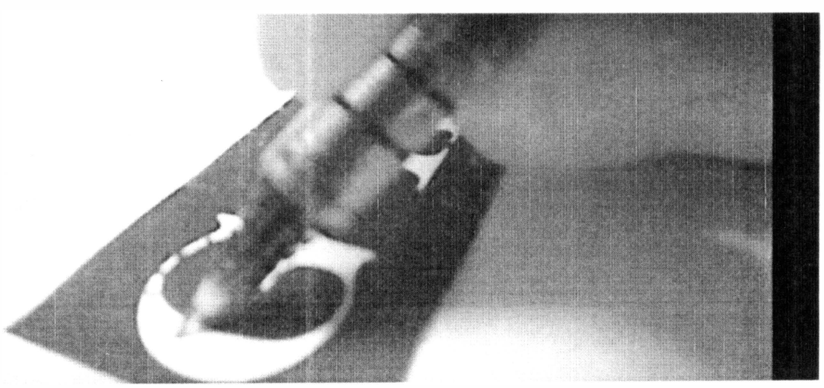
This phenomenon is actually a special type of hologram called an abrasion hologram. In order to see the reflected image you need to cause an abrasion pattern (scratches) upon a ductile surface such as plastic. The surface that we will be using in today's lesson activity is acrylic sheeting that is 1/8th - inch thick.

To formulate the abrasions upon the surface we will be using compass tools that you have seen previously in your mathematics courses. When you use your compass, make sure that you maintain an equal radius on the arch of your abrasions and each side has a needle in it (i.e. it's double needled and has no lead preloaded).

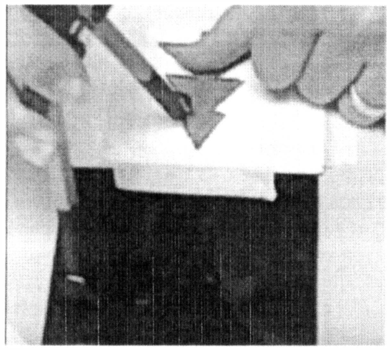
First thing you will need to do is to determine the design of your scratch hologram. Your instructor's acrylic plate samples are limited to a size 3" by 5.5" and you can use the template below which is exactly at those dimensions. Wh... ever the design of your choice. It on... needs t... fit within that frame in order to see it in full detail.

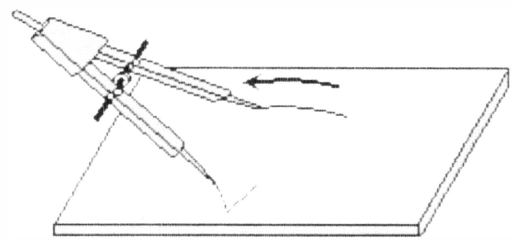


Next you can start finding the locations of your chosen pattern that will be translated for the imag... ...ou want to make the dots as numerous as possible for the most clear image, but the more you do the possibility of error increases. I would recommend making dots abo... every half a centimeter around the perimeter of your design. Observed as pictured below.



Appendix I.2 Sample Student Scratch Holography Lab





Tape the dotted pattern and your plastic sheet solidly to your working surface.

At each location where you have identified your pattern to be transposed to the acrylic sheet, you will place one end of your compass needle. Then in a sweeping motion fully across the surface you will gently scratch the plastic in an arch-like pattern. Repeat for all locations of your chosen pattern and observe in the picture above. When you complete the scratch it should be light enough that the surface is not flaking.

When your abrasion is complete on the surface of your acrylic sheet, it should be ready! Take it outside in the bright sun to see if you can see your created scratch hologram!

Now let us contemplate what today's activity has taught us about light ray optics, reflection and the hologram produced.

Summary Questions:

1. What is the point source that is illuminating the acrylic sheet? Where is it located in reference to you as you hold the sheet?

The light located by my hand

2. Considering the distance the point source is from the acrylic surface, how would the incident beams of light be oriented to each other in reference to the sheet?

Parallel

3. As light hits the arched scratches and reflects off, is the light reflected in a specular behavior or is the light scattered? Explain your answer.

The light scatters since the scratches make the surface uneven

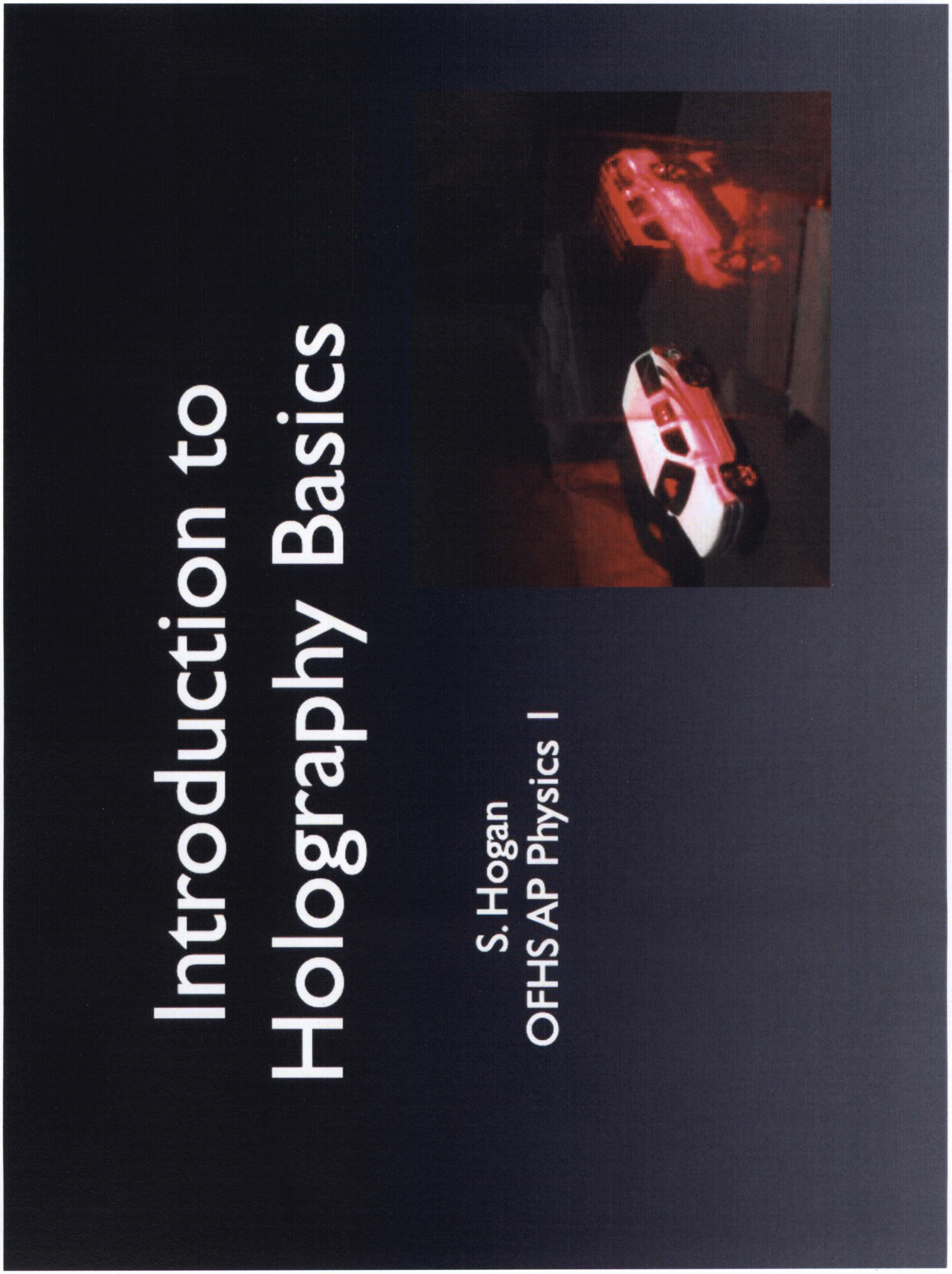
4. Depending on your answer above, holograms are formed from interference patterns as we have discussed previously. Explain below how reflected light upon the scratched arches can provide interference with other light beams incident upon the surface.

When it bounces off, it interferes with the other light in the room

5. Lastly holograms are supposed to be able to be broken down into smaller pieces of their original forms and it still works. If you sliced your holographic sheet in half – by breaking it – see if you can take it outside and still see your image. Try it, report your findings below and explain why it does or does not work.

It still works because the light is still able to scatter across the scratches on the half of the glass, which would still produce the image

Appendix J.1 Introduction to Holography Keynote



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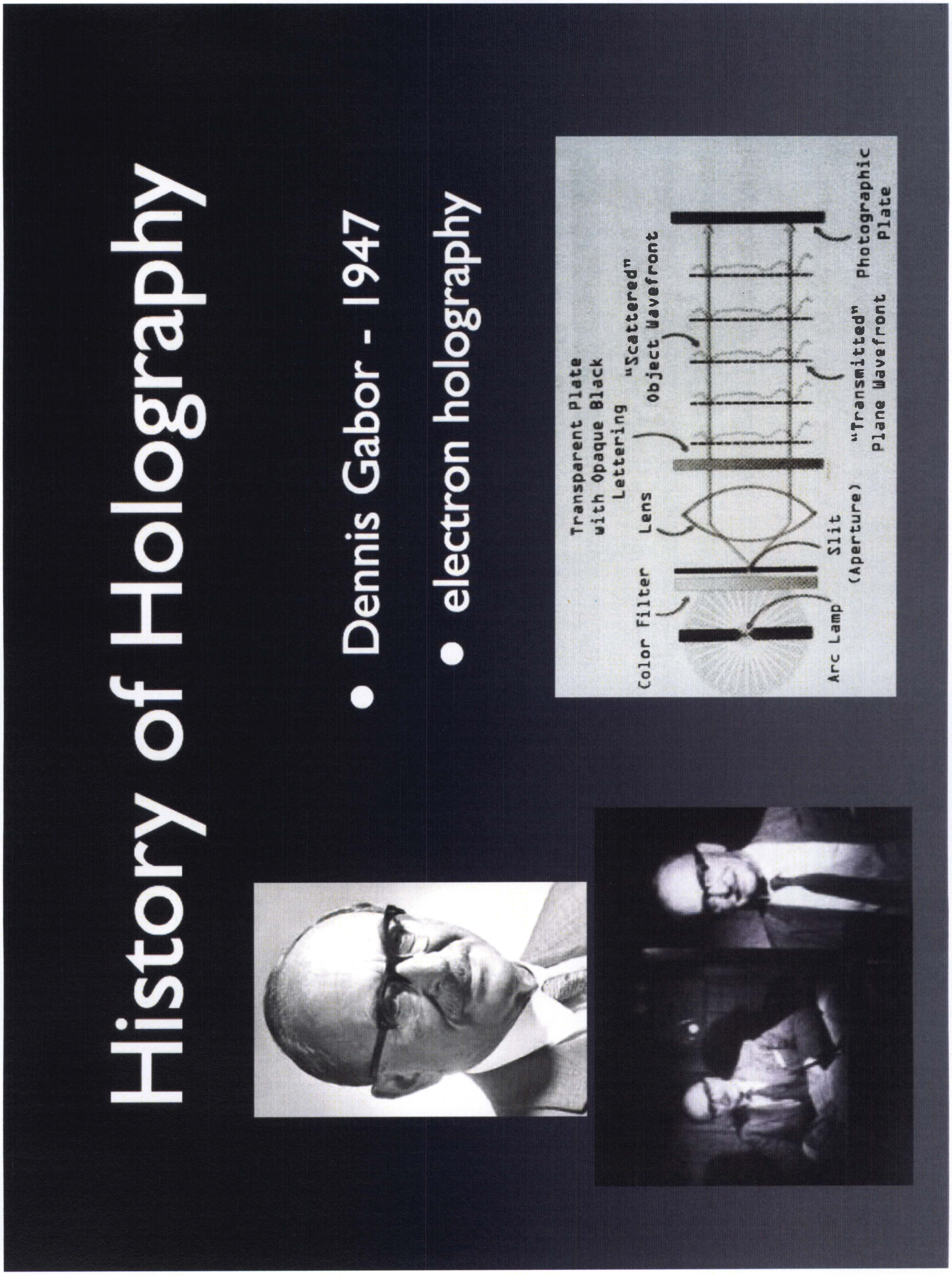

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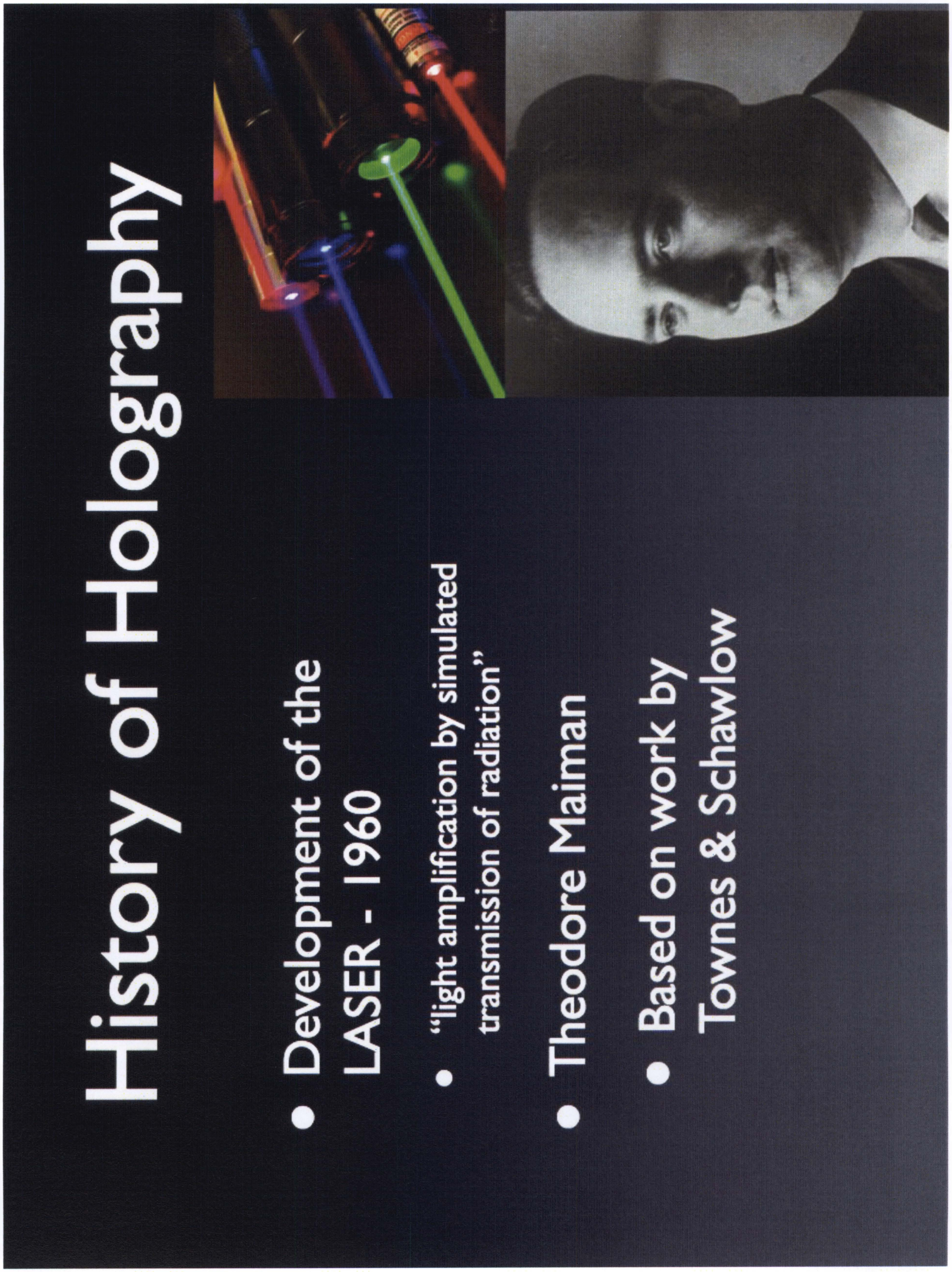

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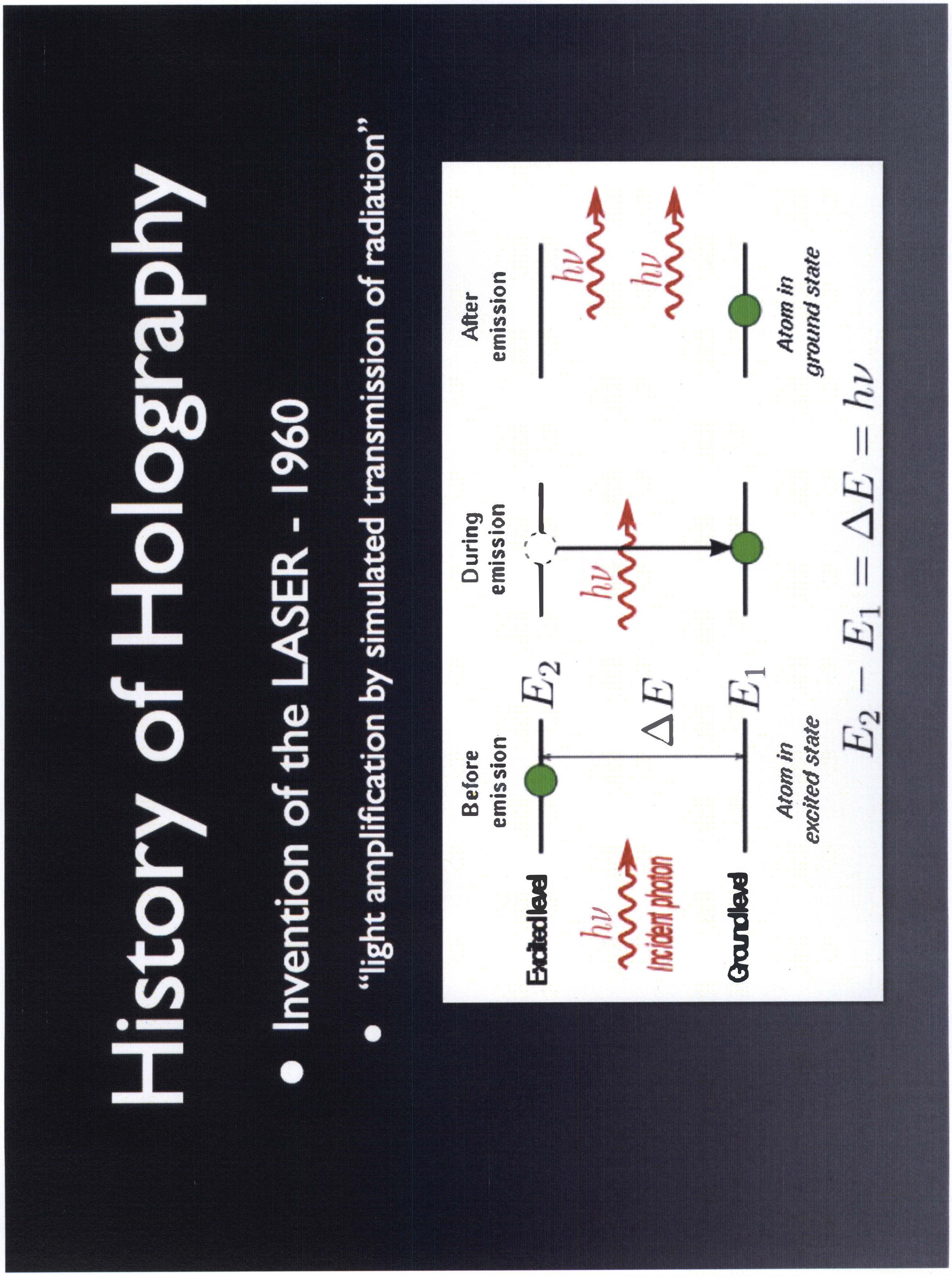

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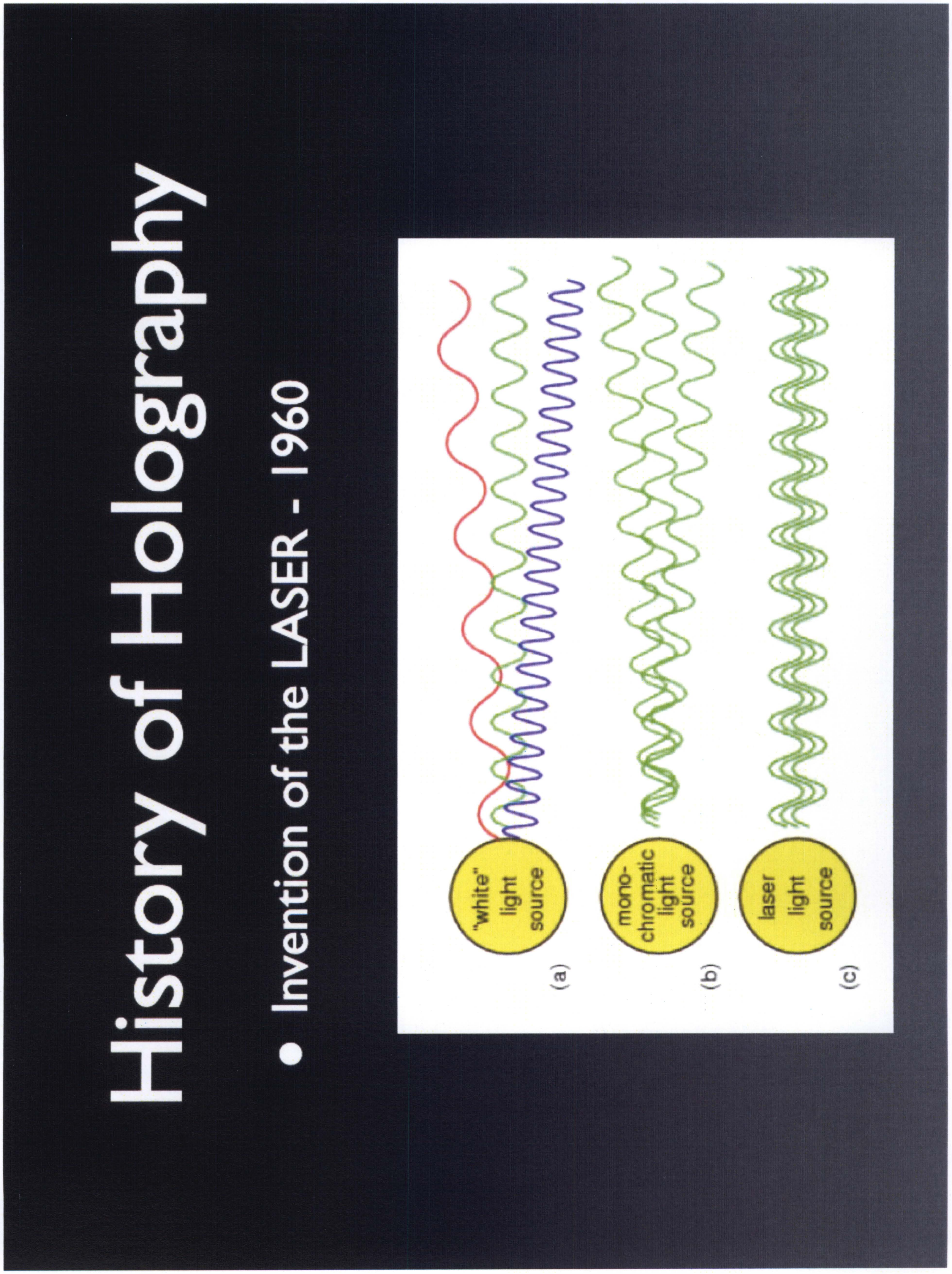

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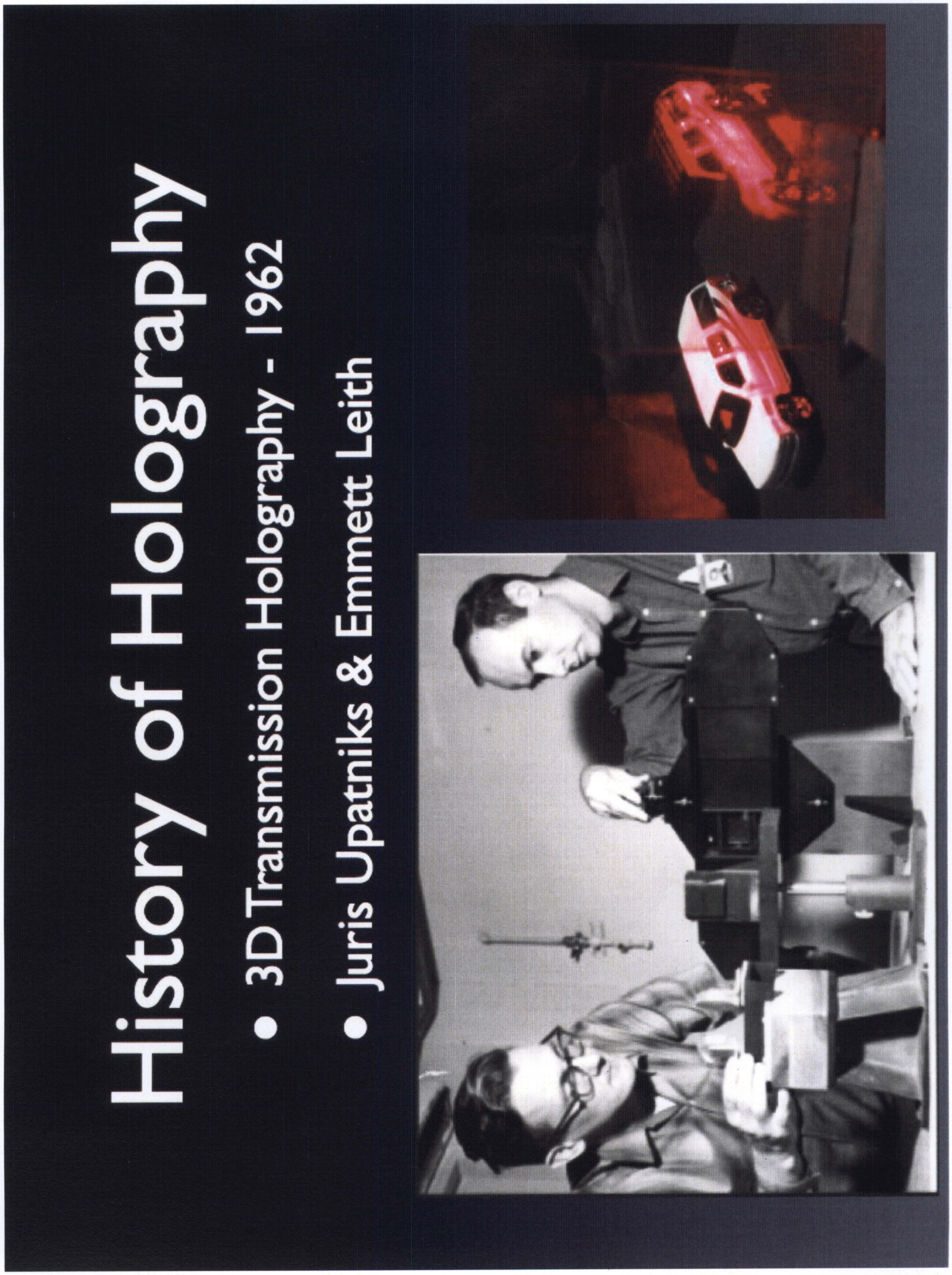

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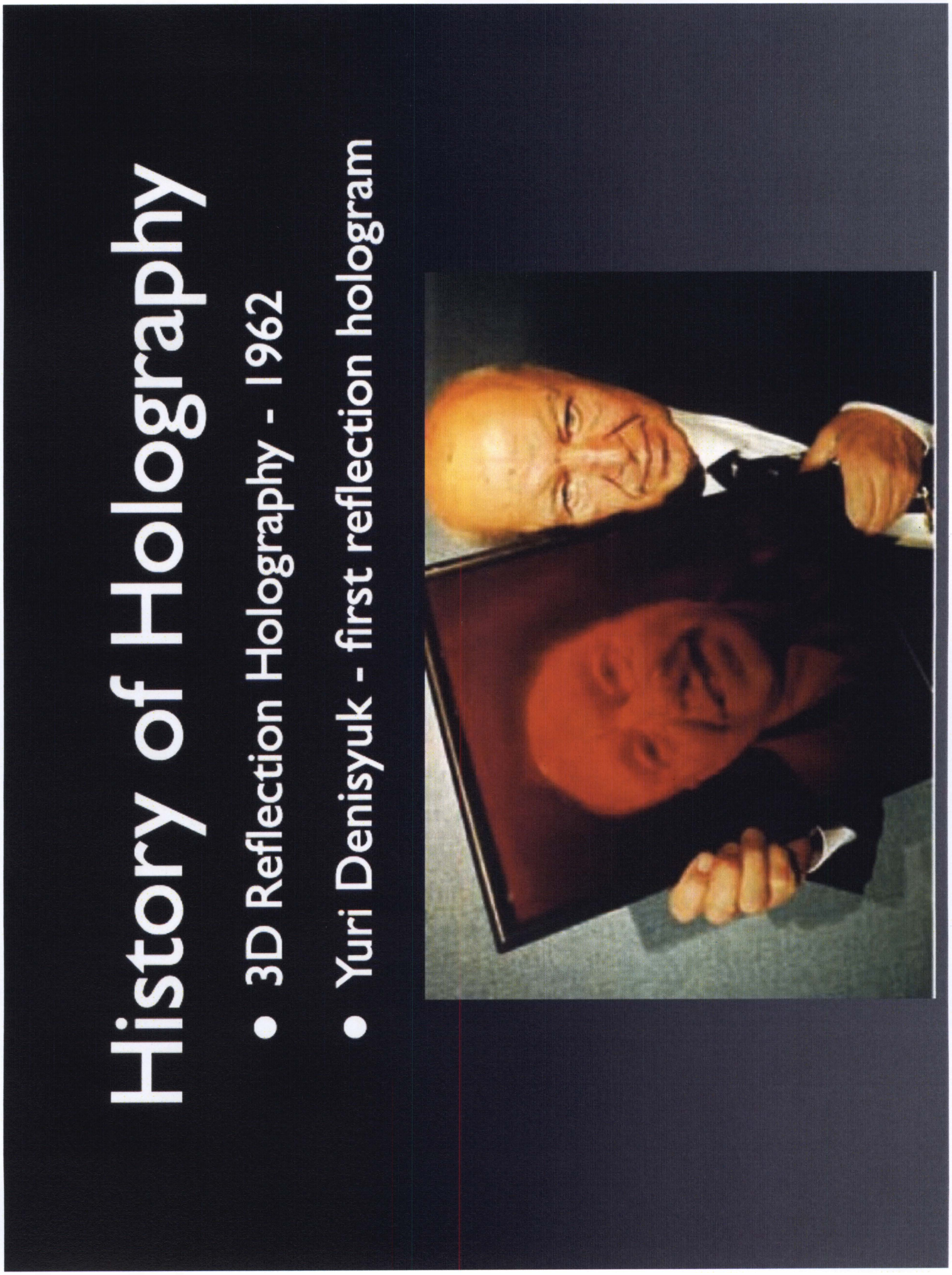

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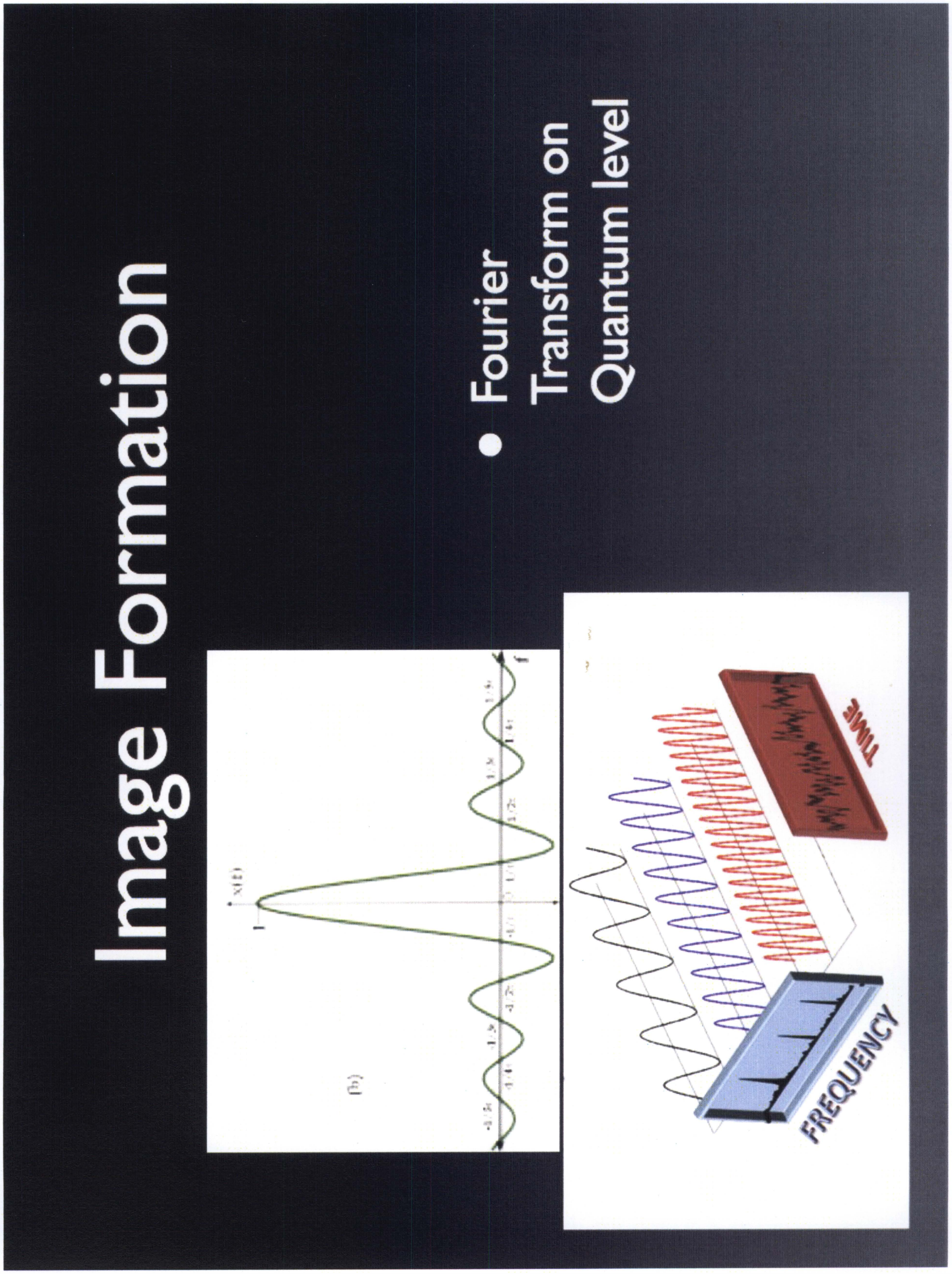

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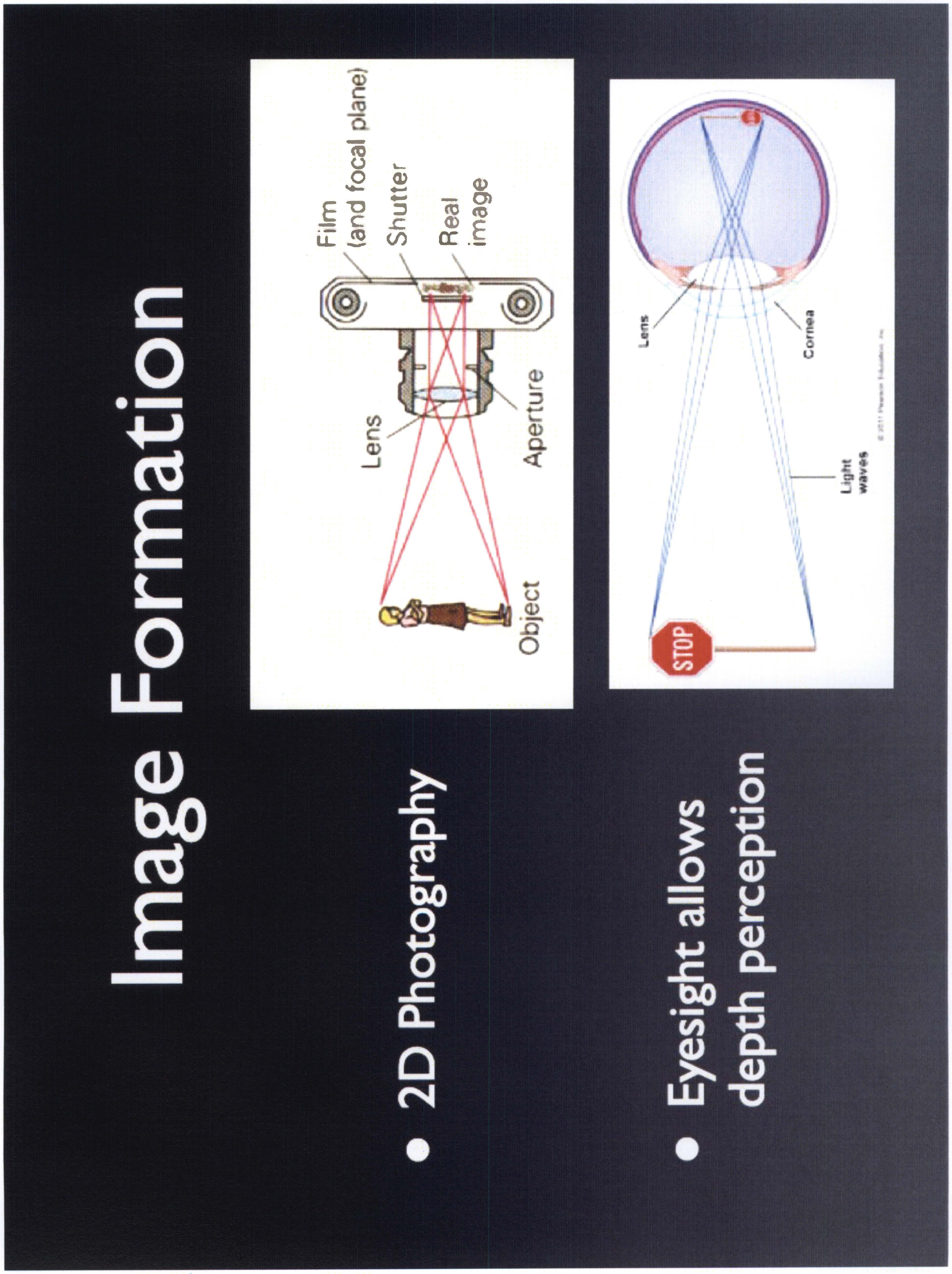

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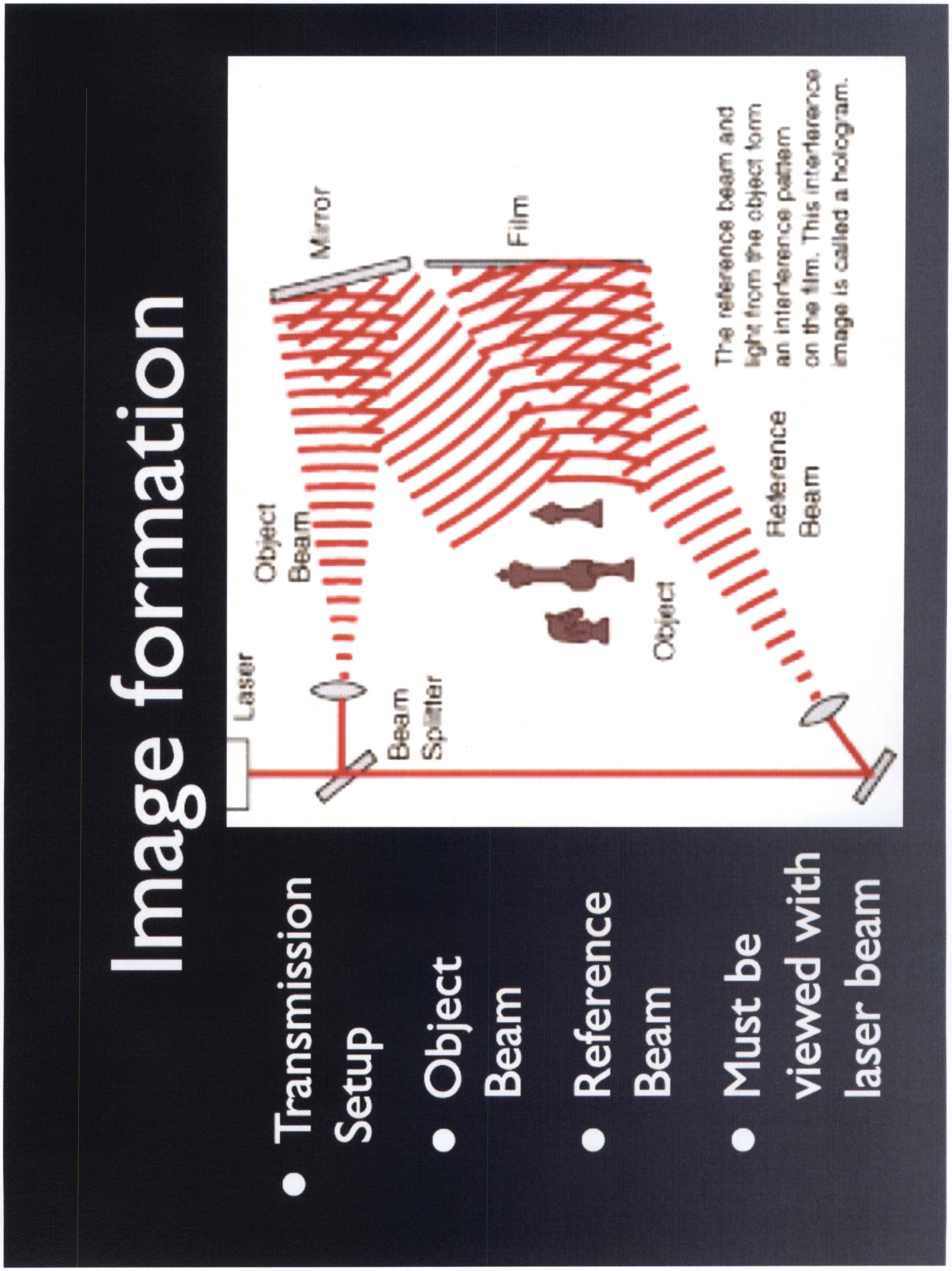

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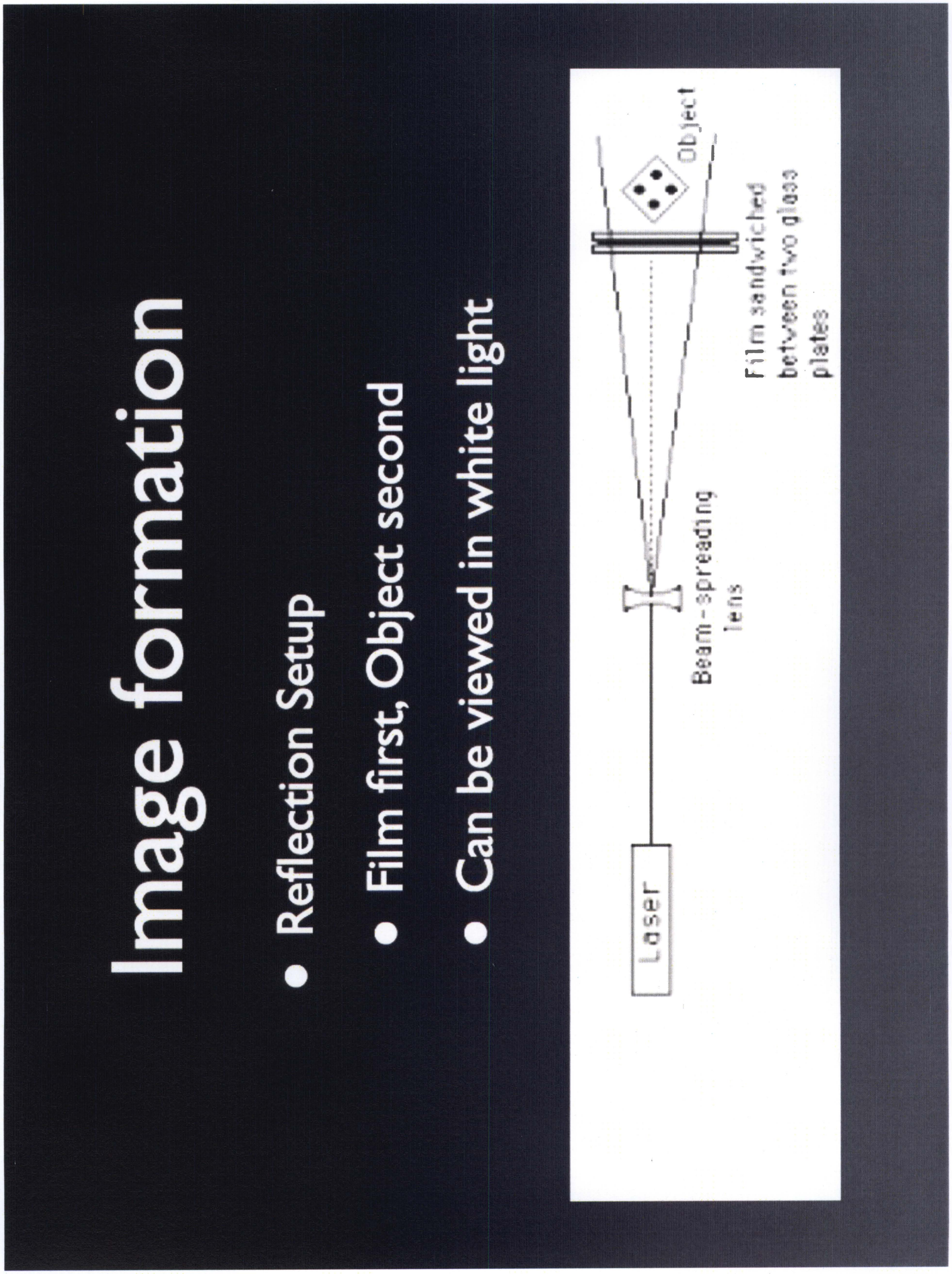

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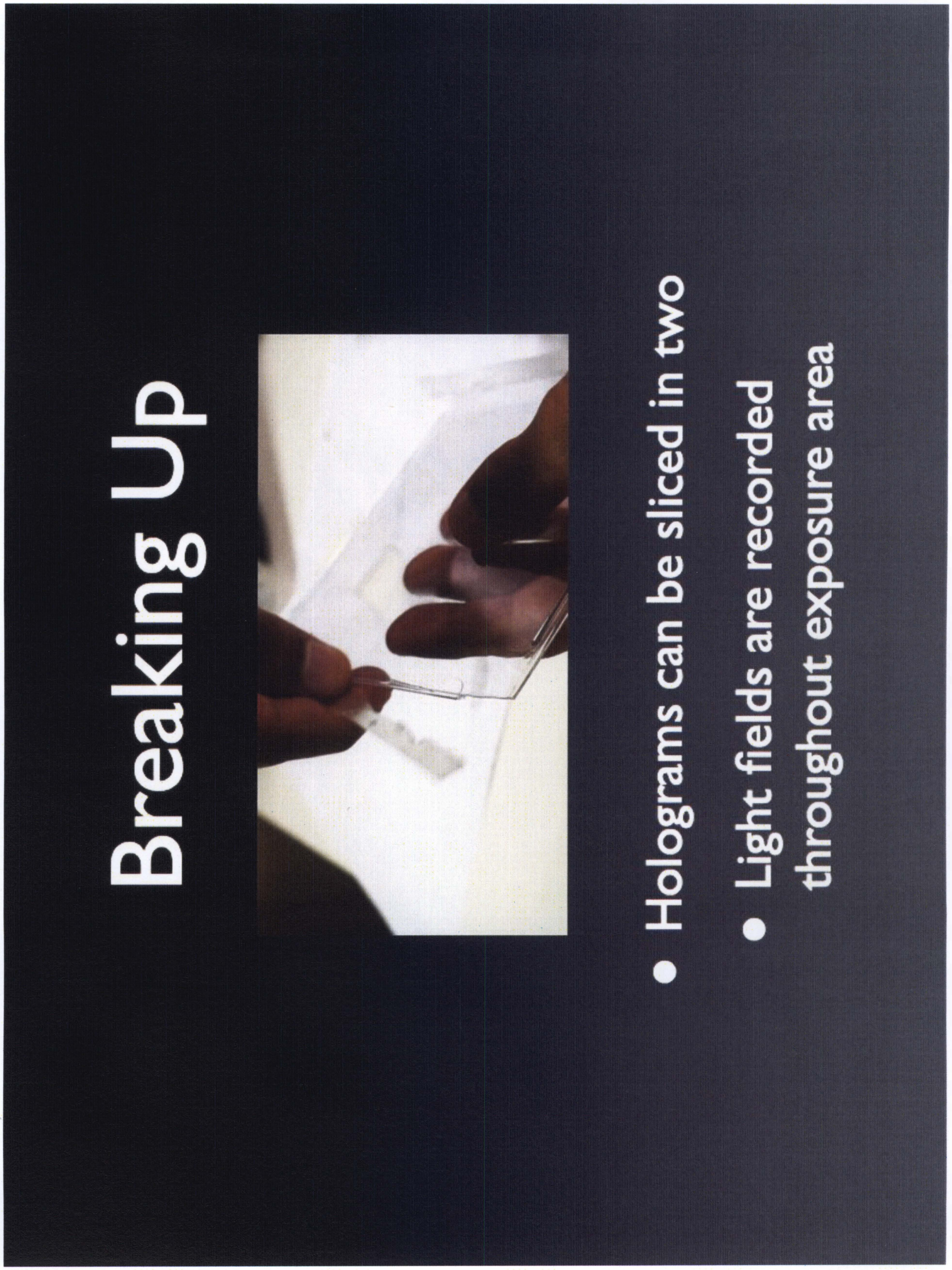

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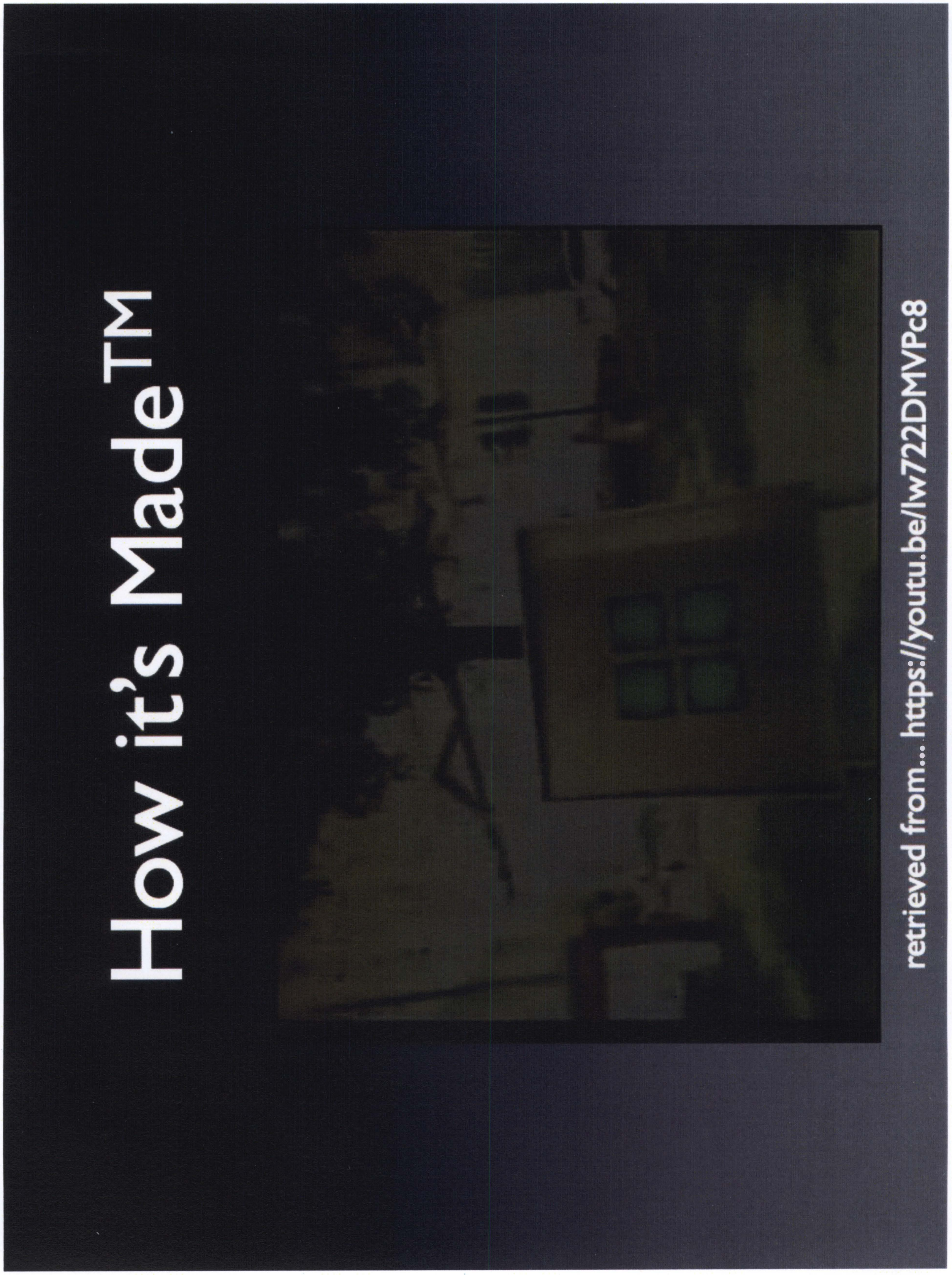


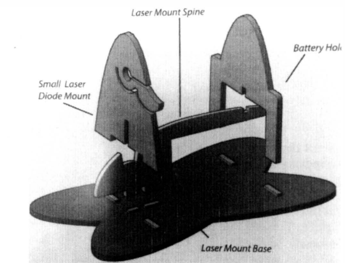
Appendix K.1 Holography Lab

Holography Lab

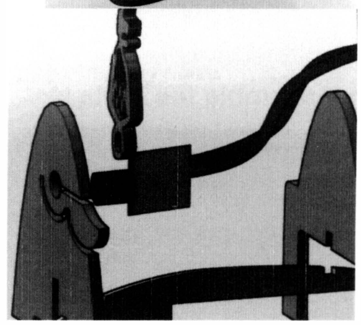
This is it, we are finally making our holograms today! You will be walking home with your own permanent 3D image of your own design. Let's capture those 3D interference patterns upon the plates! As you complete the procedure, answer the associated questions that pertain to each step after the laboratory is completed. Each step is important in completing the lab correctly, if you have any questions please ask Mr H for help!

Working with a 20–mW red laser in today's setup is relatively harmful. But at any time it should NOT be shone into anyone's eyes!

Procedure:



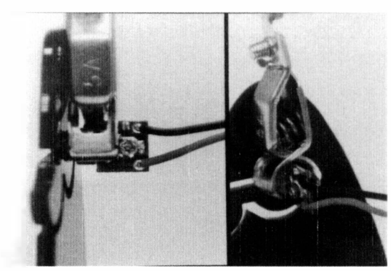
1) Assemble your group's laser mount with the following pieces:
- Laser Mount Base
- Laser Diode Mount - Small
- Laser Mount Battery Holder
- Laser Mount Spine



2) Unscrew the front barrel from the main body of the laser diode and set aside the front barrel, lens and spring. Insert the threaded part of the laser diode into the small laser diode mount with the circuit board oriented vertically.

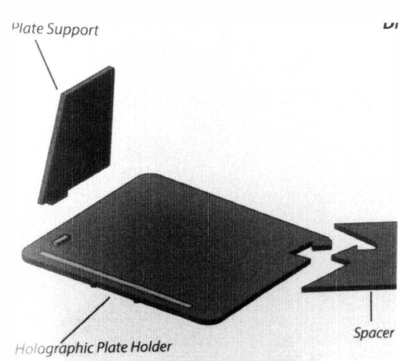
Question: Why must the circuit board be oriented vertically? Explain.

3) Load two AA batteries (not included) into the battery pack and slide the battery pack under neath the laser mount battery holder with the wires facing toward the back. The battery pack itself should remain turned off. Use the alligator connectors to connect the red and black wires on the battery pack to the red and black wires on the laser diode.



4) Attach the special clip vertically to the barrel of the laser diode, just in front of the circuit board. The special clip will only grab a small portion of the barrel and will hang overt part of the circuit board, but should NOT touch any part of the circuit board.

Question: What is the purpose of this clip on the laser? Explain knowing what is important to make quality holograms.



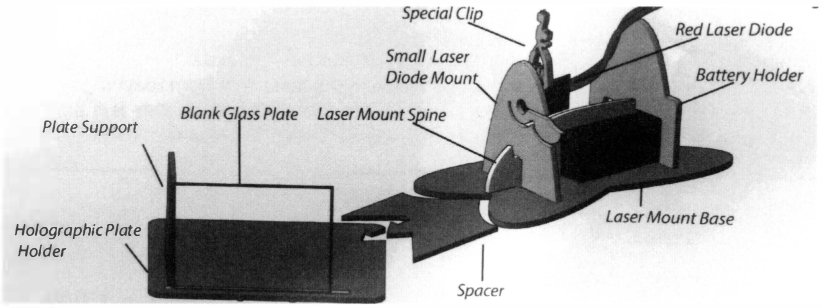
5) Assemble the plate holder. Fit together the following plate holder pieces:
- Holographic plate holder
- Plate support
- Spacer

Appendix K.1

6) Preparing to make your hologram. Turn on the batter pack of your laser so that it is now operating. Allow the laser diode to warm up for 5 minutes.

Question: Why must the laser diode warm up for this time? Explain.

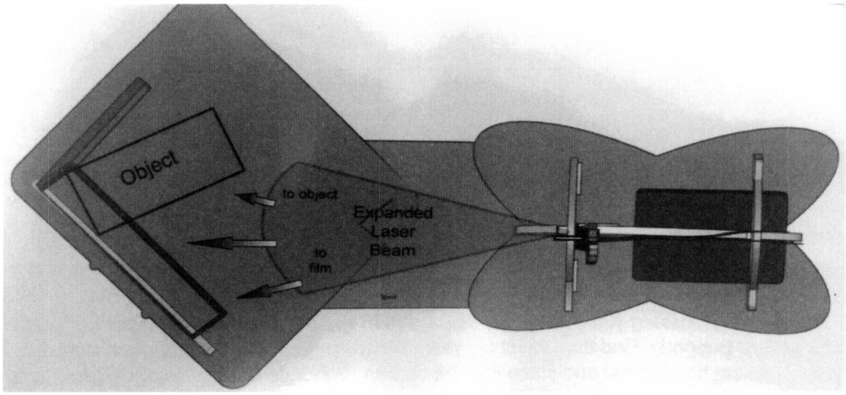
7) While waiting for the laser diode to warm up, take the blank glass plate out and place it in the long slot of the holographic plate holder so that one edge leans against the plate support. **BTW: It is very important that when we do the experiment that the film plate rests securely in the same fashion against the slant of the plate support.**



Find the object for your hologram (which can be the matchbox car that is supplied with the kit) and place it in the etched rectangle on the holographic plate.

Question: What is the purpose of the glass film plate to rest against the plate support? Explain knowing what is important to make quality holograms.

8) By placing the white card from your kit on the blank glass plate, you should see that the beam is spreading toward the object and the blank glass plate. Gently adjust the laser so that the laser is illuminating both the object and film area simultaneously if necessary. Make sure that the object is not blocking the laser light from reaching the film or you will not get a hologram produced whatsoever.



9) When you are finished and the laser looks as though it would illuminate the object and the glass plate simultaneously, you can remove the blank glass plate and white card. Be careful not to nudge or slightly change the orientation of the laser upon the setup.

Appendix K.1 Holography Lab

10) Locate your folded black card and open it about halfway so that it will stand on its edge. Place the card in front of the illuminated laser diode, so no laser light reaches your object or film area.

Question: Why is this step necessary? Explain.

Question: The black card is like a shutter to the experiment? Explain why it is and why we use a black color.

11) Make sure that you laser has been continuously on for at least five minutes to this point. If it was not warmed up properly, you will not get a good hologram.

12) Making your hologram, FINALLY! When all groups in the classroom are also at this step, turn on your blue LED light. Mr H will be turning off all other lights in the room.

Question: Why are we using a blue LED light as a flashlight during this time? Explain.

13) With the room darkened, open the Litiholo 2.0 "Instant Hologram" Film box. CAREFULLY remove one film plate and close the box immediately afterwards. Place the film plate in the plate holder. REMEMBER that the film plate should rest in the bottom of the long slot on the plate holder with one edge of the film plate leaning securely against the angled plate support (just like the blank glass plate in step #7).

14) At this point wait a full minute for any possible vibrations to die down (count in your head one Mississippi, two Mississippi). Because even the smallest vibrations are enemy of holograms. REMAIN STILL, DO NOT TALK, AND DO NOT TOUCH the surface on which your setup lies.

Question: Why are vibrations one of the worst ambient problems in producing holograms? Explain.

15) GENTLY lift up your black card so that it no longer blocks the red laser beam and the laser is exposed. We will expose the hologram for twelve (12) minutes. Again, SILENCE is necessary during this time. You may sit underneath the back lab tables if you want to go someplace safe for the waiting time.

16) After exposure time is completed, replace the black card so that it blocks the laser beam again.

17) Viewing your hologram. Bring your hologram to Mr H in the front of the room. He will view your hologram exposure with his red laser. Hopefully you'll impress him with your awesome work habits!

Congratulations! You've just made your first hologram! Take it home with you!

Question: What type of hologram is this? Transmission or Reflection? Explain how you know the answer.

Appendix K.1 Holography Lab

18) The setup to your hologram can absorb only a minute amount of vibrations. What would be the maximum amplitude of that vibration according to your laser beam? [Hint: Think about the possible phase changes of your interference patterns].

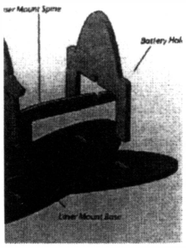
19) It is possible to make the other type of hologram during this lab. And let's try it! Research the other type of hologram and detail your procedure below of how you'll be able to make that type of hologram… then try it for yourself! If you do it successfully and show to Mr H, he might be tempted to provide EC :)

Appendix K.2 Sample Student Holography Lab

Holography Lab

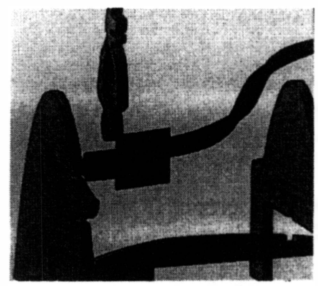
This is it, we are finally making our holograms today! You will be walking home with your own permanent 3D image of your own design. Let's capture those 3D interference patterns upon the plates! As you complete the procedure, answer the associated questions that pertain to each step after the laboratory is completed. Each step is important in completing the lab correctly, if you have any questions please ask Mr H for help!

Working with a 20–mW red laser in today's setup is relatively harmful. But at any time it should NOT be shone into anyone's eyes!



Procedure:

1) Assemble your group's laser mount with the following pieces:
- Laser Mount Base
- Laser Diode Mount - Small
- Laser Mount Battery Holder
- Laser Mount Spine

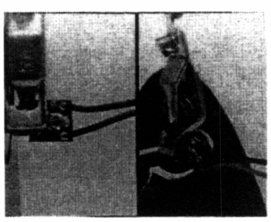


2) Unscrew the front barrel from the main body of the laser diode and set aside the front barrel, lens and spring. Insert the threaded part of the laser diode into the small laser diode mount with the circuit board oriented vertically.

Question: Why must the circuit board be oriented vertically? Explain.

so the circuit board can fit on the holder, and so the beam can shoot through the hole which is vertically across

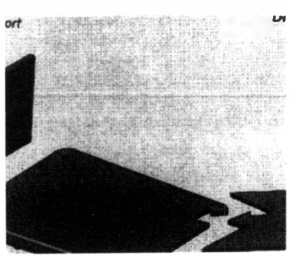
3) Load two AA batteries (not included) into the battery pack and slide the battery pack under neath the laser mount battery holder with the wires facing toward the back. The battery pack itself should remain turned off. Use the alligator connectors to connect the red and black wires on the battery pack to the red and black wires on the laser diode.



4) Attach the special clip vertically to the barrel of the laser diode, just in front of the circuit board. The special clip will only grab a small portion of the barrel and will hang overt part of the circuit board, but should NOT touch any part of the circuit board.

Question: What is the purpose of this clip on the laser? Explain knowing what is important to make quality holograms.

The purpose of the clip is to keep the laser in place, because stability is important in making quality holograms. The clip also increase the mass increasing its inertia.



5) Assemble the plate holder. Fit together the following plate holder pieces:
- Holographic plate holder
- Plate support
- Spacer

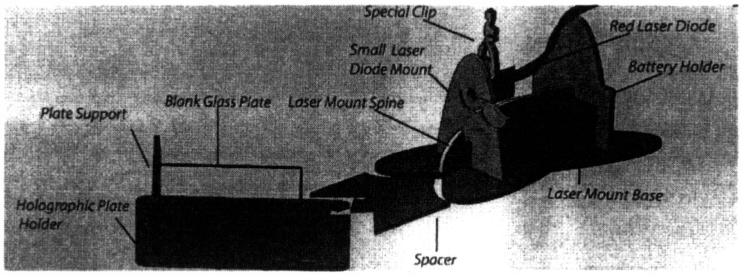
Appendix K.2 Sample Student Holography Lab

6) Preparing to make your hologram. Turn on the batter pack of your laser so that it is now operating. Allow the laser diode to warm up for 5 minutes.

Question: Why must the laser diode warm up for this time? Explain.

So the light can reach the full capacity of a beam.

7) While waiting for the laser diode to warm up, take the blank glass plate out and place it in the long slot of the holographic plate holder so that one edge leans against the plate support. **BTW: It is very important that when we do the experiment that the film plate rests securely in the same fashion against the slant of the plate support.**

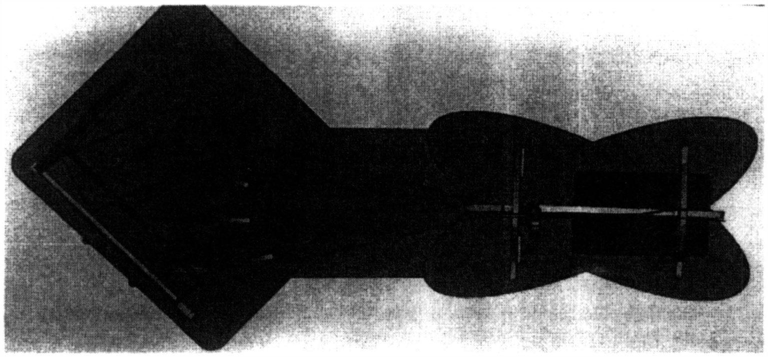


Find the object for your hologram (which can be the matchbox car that is supplied with the kit) and place it in the etched rectangle on the holographic plate.

Question: What is the purpose of the glass film plate to rest against the plate support? Explain knowing what is important to make quality holograms.

That way the glass is stable during the process.

8) By placing the white card from your kit on the blank glass plate, you should see that the beam is spreading toward the object and the blank glass plate. Gently adjust the laser so that the laser is illuminating both the object and film area simultaneously if necessary. Make sure that the object is not blocking the laser light from reaching the film or you will not get a hologram produced whatsoever.



9) When you are finished and the laser looks as though it would illuminate the object and the glass plate simultaneously, you can remove the blank glass plate and white card. Be careful not to nudge or slightly change the orientation of the laser upon the setup.

Appendix K.2 Sample Student Holography Lab

10) Locate your folded black card and open it about halfway so that it will stand on its edge. Place the card in front of the illuminated laser diode, so no laser light reaches your object or film area.

Question: Why is this step necessary? Explain.

It allows the light to reach its widest wavelength, and basically allows the laser to warm up even more in one concentrated area.

Question: The black card is like a shutter to the experiment? Explain why it is and why we use a black color.

The black card acts as a shutter because it's blocking the light from passing through to our object. Also we use the color black because black absorbs light, which is what we need for this step.

11) Make sure that you laser has been continuously on for at least five minutes to this point. If it was not warmed up properly, you will not get a good hologram.

12) Making your hologram, FINALLY! When all groups in the classroom are also at this step, turn on your blue LED light. Mr H will be turning off all other lights in the room.

Question: Why are we using a blue LED light as a flashlight during this time? Explain.

Because the white light will interfere with the red laser light emitted, and we don't want this happening. It's for this reason that a blue LED light is used to prevent as much interference.

13) With the room darkened, open the Litiholo 2.0 "Instant Hologram" Film box. CAREFULLY remove one film plate and close the box immediately afterwards. Place the film plate in the plate holder. REMEMBER that the film plate should rest in the bottom of the long slot on the plate holder with one edge of the film plate leaning securely against the angled plate support (just like the blank glass plate in step #7).

14) At this point wait a full minute for any possible vibrations to die down (count in your head one Mississippi, two Mississippi). Because even the smallest vibrations are enemy of holograms. REMAIN STILL, DO NOT TALK, AND DO NOT TOUCH the surface on which your setup lies.

Question: Why are vibrations one of the worst ambient problems in producing holograms? Explain.

Even with the smallest vibrations, interference can occur. We want the best possible hologram to come out, so everything must be still and steady.

15) GENTLY lift up your black card so that it no longer blocks the red laser beam and the laser is exposed. We will expose the hologram for twelve (12) minutes. Again, SILENCE is necessary during this time. You may sit underneath the back lab tables if you want to go someplace safe for the waiting time.

16) After exposure time is completed, replace the black card so that it blocks the laser beam again.

17) Viewing your hologram. Bring your hologram to Mr H in the front of the room. He will view your hologram exposure with his red laser. Hopefully you'll impress him with your awesome work habits!

Congratulations! You've just made your first hologram! Take it home with you!

Question: What type of hologram is this? Transmission or Reflection? Explain how you know the answer.

I know this is a transmission hologram because we are using a flash of a laser, that illuminates the object, to transmit the picture of the object onto a recording medium.

Appendix L.1 Student Sample Presentation Grade Report

Project Rubric

The following rubric will be used for the group presentations.

Some students may also receive less than 4 pts in the Coverage category, based on his or her work in class due to the motivation ratings from their project partners.

Name	Score (out of 45)
[redacted]	45

	EXEMPLARY	GOOD	FAIR	POOR	MISSING
Coverage—Did you adequately cover and explain the topic that was assigned?	10—encyclopedic, understandable coverage and explanation of the topic	9—coverage of the topic is good, but I'm uncertain if group knows some terms used	7—coverage of the topic is fair. A little hard to understand information at times	6—topic coverage is random, some major points and concepts missing in coverage	4—some coverage of the basics; time allotted in class to work obviously not used well
Organization of Presentation	6—Information presented as an interesting story sequence	5—Information presented logically and easy to follow	4—Most information seems to be presented in correct sequence	2—Hard to follow, sequence of information is jumpy	0—lacking any structure whatsoever
Contribution of Topic—How does your topic show significance to the advancement of science	6—scientific significance explained in full detail and extremely well	5—scientific significance mentioned and explained to audience	4—scientific significance was mentioned but not explained	2—scientific significance was only hinted upon during presentation	0—significance of topic not addressed
Visuals/Builds—Did you have visuals? Did they add to the presentation or were they just "flair"?	6—visuals/builds actively helped audience understand topic	5—visuals/builds help understanding a little, one or two for flair	4—visuals good, but most seem like they're flair	2—visuals shown have no purpose being in presentation	0—lacking any visuals whatsoever
Coherence—Did your group work as a whole or was the presentation choppy?	6—presentation seems well-rehearsed and practiced beforehand	5—some planning is evident in presentation	4—a few times occurred when group members interrupted/contradicted others	2—some lack of structure to talk interruptions/contradictions frequent	0—complete lack of structure to the presentation
Timing—Did your presentation last in the 7-10 minute range?	6—time in the 7-10 minute range	5—time in the 5-6 or 10-11 minute ranges	4—time in the 4-5 or 11-11:30 range	2—time just less than 4 minutes or just over 11:30 minutes	0—timing is far off the mark
Works Cited—Did you include a works cited slide on your presentation that had at least 4 different sources	5—4 sources listed, one of which is from Mr H's recommended sites	4—Only 3 sources included and/or not one is from Mr H's recommended sites	3—Only 2 sources included	2—Only 1 source included	0—lacking any works cited sources whatsoever
Mr H's Grade NOTES:					

+ Good Explanation of material!
+ Excellent material coverage!
+ Quite honestly one of the best presentations I've seen in my career. Great Job!!

Appendix L.2 Student Sample Annotated Bibliography

Mr. Hogan
Light and Optics mini project
May 19, 2016

Color Blindness Bibliography

"What Is Color-Blindness." *What Is Color-Blindness*. J.L. Morton, n.d. Web. 19 May 2016. http://www.colormatters.com/color-and-vision/what-is-color-blindness

This article discusses the general topic of color blindness. It tells us that color blindness is the inability to see color properly, and that it comes from the missing color-sensitive pigment cells in the retina. It goes on to explain that the retina is the layer of nerves at the back of the eye. In addition, it give the statistics of how many women and men each have color blindness. It also provides information on the Ishihara 38 plates test for color blindness. This source is rated fair because it gives good information, but it is very general.

Stephenson, Craig. "The Physics of Color Vision and Color Blindness - Color Blindness." *The Physics of Color Vision and Color Blindness - Color Blindness*. N.p., n.d. Web. 19 May 2016. http://ffden-2.phys.uaf.edu/212_spring2005.web.dir/Craig_Stephenson/colorblindness.html

This article discusses some common misconceptions that people have about color blindness and a few of the different types of color blindness. It also talks about the reasons why color blindness happens and the causes of it. How the different types of color blindness are categorized are also discussed. There are also charts included as to how the colors are seen. This source is rated excellent because it provides accurate information and is very detailed.

"Types of Colour Blindness." *Colour Blind Awareness*. Colour Blind Awareness, n.d. Web. 19 May 2016. <http://www.colourblindawareness.org/colour-blindness/types-of-colour-blindness/

This article goes into detail about the lesser common types of color blindness. It talks about the causes of each and how they present in different people. It also talks about the reasons for these anomalies, caused by the cones in the retina of the eyes. Additionally, the article details the colors that are mistaken with each type of the color blindness that it outlines and the everyday difficulties that may arise from each type. This source is rated excellent because it has everything that needs to be known about each of its topics and it is well written.

Appendix L.2 Student Sample Annotated Bibliography

"Deuteranopia – Red-Green Color Blindness | Colblindor." *Colblindor*. Colblindor, n.d. Web. 19 May 2016.
http://www.color-blindness.com/deuteranopia-red-green-color-blindness/

This article gives the details of deutan color blindness. These color blindnesses are known as deuteranopia and deuteranomaly. The article describes the differences between these two, such as missing medium-wavelength cones completely missing in deuteranopia, whereas they are present but weak in deuteranomaly. Additionally, it provides comparison pictures between normal vision and deutan colorblindness, as well as statistics about each. These statistics include percentage of males with each type of deutan color blindness and the percentage of women with the same color blindness. This source is rated fair as it has good information, but is not very clear at times.

"Tritanopia – Blue-Yellow Color Blindness | Colblindor." *Colblindor*. Colblindor, n.d. Web. 19 May 2016.
<http://www.color-blindness.com/tritanopia-blue-yellow-color-blindness/

This article outlines the colors involved with tritan color blindness, that blue is confused with green and yellow is confused with violet. The two tritan color blindnesses are called tritanopia and tritanomaly. In tritanopia, the short-wavelength cones are completely missing and it is more severe than tritanomaly which only involves a mutation in the short-wavelength cones. It also provides the information that the mutation is not located on the X chromosome, therefore, men and women are equally affected. In addition, the article tells that tritanopes generally have fewer problems in everyday situations than people with red-green color blindness. This article is rated fair because the information is good, but it is not written very well.

"Achromatopsia." *Genetics Home Reference*. U.S. National Library of Medicine, 17 May 2016. Web. 19 May 2016. <https://ghr.nlm.nih.gov/condition/achromatopsia

This article outlines the details and severity of achromatopsia. It describes achromatopsia as the inability to see any colors; only black, white, and various shades of gray can be seen. In addition, it provides the many other issues that come along with achromatopsia. These issues include increased sensitivity to light and glare, the involuntary movement of the eyes back and forth, and very dull vision. Farsightedness and nearsightedness can also occur in people with achromatopsia. Within the first few months of life, these problems will develop. The article also outlines the major difference between achromatopsia and other color blindnesses being a complete lack of color in achromatopsia, while other color blindnesses only

Appendix L.2 Student Sample Annotated Bibliography

result in problems distinguishing between certain color. This article was rated excellent because it was very detailed, but concise and easy to read.

Stephenson, Craig. "The Physics of Color Vision and Color Blindness - Color Blindness." *The Physics of Color Vision and Color Blindness - Color Blindness*. N.p., n.d. Web. 19 May 2016. http://ffden-2.phys.uaf.edu/212_spring2005.web.dir/Craig_Stephenson/colorblindness.html

This article discusses some common misconceptions that people have about color blindness and a few of the different types of color blindness. It also talks about the reasons why color blindness happens and the causes of it. How the different types of color blindness are categorized are also discussed. There are also charts included as to how the colors are seen. This source is rated excellent because it provides accurate information and is very detailed.

"Rod and Cone Cells." *Rod And Cone Cells Stock Images.* Dreamstime, n.d. Web. 20 May 2016. <http://www.dreamstime.com/stock-images-rod-cone-cells-illustration-human-eye-image 36873814

This article contains a detailed photo of the cones and rods that are present in the retina. Both the cone and rod have a separate outer segment connected to the inner segment by the connecting cilium. In the center of each, there is a cluster of mitochondria with a nucleus beneath; at the bottom, they both have synaptic endings that look like small tree branches. The only differences are that the outer segments are different and the cone is shorter than the rod. The outer segment of the rod is shaped like a ladder, whereas the outer segment of the cone is shaped like a comb. This source was rated excellent because the photo is simple but effective at showing the similarities between cones and rods.

"Color Blindness Tests | Colblindor."*Colblindor*. Colblindor, n.d. Web. 20 May 2016. <http://www.color-blindness.com/color-blindness-tests/>.

This article describes different color vision tests as well as give links for them online. The Ishihara 38 Plates CVD Test, Farnsworth-Munsell 100 Hue Color Vision Test, the Color Arrangement Test, and the RGB Anomaloscope are all different tests to see how your color vision is, and, if you have a color vision deficiency, how severe it is. The article gives backgrounds to all of these tests, such as the creators, how they

Appendix L.2 Student Sample Annotated Bibliography

thought of the tests, and where the tests were actually created. These tests also are used to diagnose various color vision deficiencies. The article also informs of how well each test works and which test may diagnose a certain deficiency the best. This article was rated excellent because it is very well organized and very detailed.

Stephens-Davidowitz, Noah. "Solipsist's Log." *Solipsists Log*. WordPress, 26 Mar. 2012. Web. 20 May 2016. <http://www.solipsistslog.com/color/>.

This article discusses the topic of light. It discusses how energy works with light and how light is made up of photons. It goes over the wavelength and frequency of light and simplifies the way light works. Additionally, it describes the dimensions that light works in and the planes on which it travels. This source was rated fair because it was very detailed, but quite lengthy.

Appendix M.1 Grant Application to the B228 Education Foundation

BREMEN HIGH SCHOOL DISTRICT 228
EDUCATION FOUNDATION
GRANT APPLICATION

Name: Stephen Hogan **Date Submitted:** 12/22/15

School: Oak Forest High School

Title of Project: Holography in the Secondary Science Setting

Starting Date of Project: 5/4/16 **Ending Date of Project:** 5/19/16

Purpose, goals, and objectives of project:

This proposed project would serve as a keystone unit study of three dimensional holography in an AP Science curriculum. The purpose of the unit is to incorporate holograms and the scientific concepts that they involve in the secondary science setting. Traditionally holograms were not experimented and studied at the secondary level, due to the vast financial (~$10K) and physical (blackroom) resources required in their study. Recent technological advancements have allowed holograms to be produced at about a tenth of the price as well as in more forgiving environments.

The goals and objectives of the project would for students to see the interdisciplinary connections between…

- Wave interference (Physics)
- Fourier Transforms (Physics & Math)

Appendix M.1 Grant Application to the B228 Education Foundation

- Reflection & Refraction of Light (Physics)
- Photochemistry (Chemistry)
- Photon spectra (Physics & Chem)

Describe the project's activities:

- Diffraction Lab - Study of waves through barrier openings
- 2D Wave Interference Tank Lab - Study of superposition of waves
- Young's Double Slit Experiment of Light - Study of fringe patterns on screen services
- Photon Wavelength Spectroscopy Lab - Study of the relationship between energy and wavelength of light
- Exploration of Film Technology - Study of photochemistry and resolution
- Modeling the Fourier Transform patterns in waves
- And finally -> Making Holograms!

What are the expected benefits for students who will be involved in the project, and how will these benefits be perpetuated for other students after the project has been concluded?

Students would be involved in scientific inquiry of activities not traditionally included in the secondary science levels. Not only that the laboratory project has a 'take home' feature where students can take the final product of their experiments (ie. their holograms) as a souvenir to keep for themselves and show to friends and family members. Potentially of a domino effect can happen where friends of these students could say "Hey that's cool! I want to sign up for AP Physics!".

Appendix M.1 Grant Application to the B228 Education Foundation

Describe the students targeted for the project, and how many will initially participate?

The project is piloted for students enrolled in AP Physics at OFHS during the 2015-16 school year. Currently sophomore through senior level students are enrolled in the two classes. Overall these students The experiments will occur after the AP exams in May and senior level students might not be able to complete the entire project, but at least they will be introduced to the topic.

During the first three years, how many students or how will the school benefit?

Approximately 20 students per year for a total of 60 students locally at OFHS. Potentially the equipment for which the requested grant funds would be purchasing, could also be utilized at the other district schools as well on a shared basis.

Evaluation Procedure:

Throughout the guided inquiry experiments into the unit, students would be expected to maintain a journal of their findings and observations of the concepts behind the science. In conclusion, students will be expected to present to the class their expertise in a seminar settings on the science behind holograms. Those presentations would be evaluated through a defined performance rubric.

Budget:

-Itemize budget for the grant requested. Be specific, if possible list vendors.

Item Description	Qty	Price
Fuji Instax Mini 8 Camera from Amazon.com ($79.90)	6	$479.40
Fujifilm Instax Mini Instant Film, 10 Sheets x 5 packs from Amazon.com ($38.49)	1	$38.49
Resolution Chart from Amazon.com ($13.95)	3	$41.94

Appendix M.1 Grant Application to the B228 Education Foundation

Item Description	Qty	Price
Bestlight Ultra 160 Flash Panel from Amazon.com ($23.50)	6	$141.00
Litiholo Student Hologram Kit ($99.95)	5	$499.75
Shipping costs from Litholo		$21.14

-Total cost of project: $1229.69 **Grant Requested: $1229.69**

-Other funding source and amount:

Collectively we did receive one free Litiholo kit and 1000x optical scope via a donation from Dr Steven W Daniels, physics department chair at Eastern Illinois University. Currently we have no other guaranteed funds promised for this project but we have also applied for crowdsourcing through professional educational channels.

X I understand that should I terminate my employment with Bremen High School District 228, any items received through the Educational Foundation Grant must be returned to my department supervisor before I leave.

Appendix N.1 Release Form

Parent/Guardian Notification and Release Form (Due May 3, 2016)

Attention AP Physics 1 Parents & Guardians,

This letter is to notify you that your student will be participating in an alternative final unit plan on holography in AP Physics 1. The alternative final unit is a personal thesis project that Mr. Hogan will be conducting with your enrolled student, based on effective methods of incorporating hologram instruction into the high school physics curriculum. This unit plan will replace the administration of a typical final exam at the conclusion of the school year, but it is still worth 20% of your student's overall grade. Also, Mr. Hogan will be keeping documentation of your student's progress in the unit plan to support his thesis claims. These documents may include pictures of students completing classroom activities and sample completed instructional worksheets. All names will be omitted on the sample instructional worksheets on the thesis publication. At random, Mr. Hogan will choose which documentation to be included in his final thesis project, which will be submitted during the Summer 2016 term at Eastern Illinois University.

If you wish for your student to not participate in this alternative unit plan, he or she will be provided with a study guide for a traditional final examination to be administered on May 19, 2016. Please indicate your choice below and if you have any questions at all, Mr. Hogan can be reached by email at shogan@bhsd228.com. Please check the box of your choice.

☐ I permit my student to complete the holography unit as described.

☐ I do not permit my student to complete the holography unit as described.

Student Printed Name: ____

Parent/Guardian Printed Name: ____________________________________

Parent/Guardian Email Address: ____________________________________

Parent/Guardian Signature: ____