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TECHNOLOGY IN THE CLASSROOM:
STUDENT UNDERSTANDING OF IMAGE FORMATION BY
CONVERGING AND DIVERGING LENSES AND MIRRORS -
RAY TRACING V. COMPUTER SIMULATION

A RESEARCH PAPER SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
MASTER OF ARTS IN EDUCATION (PHYSICS)

BY

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Abstract

As technology has become a larger influence in education, governments and school administrators have increased their calls for utilization of computer technology in teaching. In physics, computer simulations for laboratory investigations are an attractive application of technology. This study examines the teaching and learning of image formation in converging and diverging mirrors and lenses using geometric optics. Data were collected using physics students from two similar high school sections enrolled in the same course with the same teacher. One section performed a traditional ray tracing image formation lab activity using paper, pencils, and rulers, and the other section performed a computer simulated image formation activity. The groups switched roles for the mirror and lens activities so that each student performed one computer simulation activity and one paper and pencil lab activity. Student performance was evaluated using pretests and posttests. The data showed a significant advantage in student performance associated with the more traditional paper and pencil activity. It is evident from this study that a computer-based or higher technology teaching strategy may not always be the most beneficial for students.

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Introduction

As different forms of technology become less expensive and more readily available for classroom use, the possibilities for influencing student understanding by using technology increase. In the case of Physics Education there are many on-line labs, simulations, and activities covering many physics concepts from which to choose. These resources offer readily available, inexpensive, and easy to use simulations and activities. A teacher with a computer and internet connection could access these simulations in the classroom. This might avoid the expense of specialized equipment, offer activities covering labs too dangerous to set up in a school environment, and avoid the time and labor associated with classroom lab setup and cleanup. The question, though, is whether technology is always the best alternative to enhance student understanding.

This study compares the learning outcomes of two similar groups of high school students studying geometric optics using ray tracing. Each group received the same preliminary classroom instruction and an identical pretest.

One group then was given a computer based simulation activity, while the other did a more traditional paper and pencil ray tracing activity. At the conclusion of the activity, each group was given an identical posttest. The procedure was used for a curved mirror activity, and then the groups were reversed for a thin lens activity. This way, each student gained experience with both computer simulations and traditional paper and pencil ray tracing. Each student also received instruction in curved mirrors and thin lenses.

The results indicated that the students who participated in the paper and pencil ray tracing activity performed substantially better on the posttest than did their peers in the computer simulation group. This was true in both the mirror and thin lens activities. The hands-on activity appears to produce a greater gain in student understanding than the computer simulation in this case.

Additional research is indicated using true random samples. The groups in this study were simply two sections of the same course taught by the same teacher. The concept of image formation seems to be weak as well with some students providing correct rays, but not drawing an image, or drawing it incorrectly. Similarly, some students were able to construct one correct ray, but could not correctly draw another in order to form an image.

Literature Review

The question of the efficacy of computer simulations has been taken up by a number of researchers. Redish, Risley, and Margolis (1988) pointed out

that computers are being used, and the issue is how to use this tool effectively. Zacharia (2003) points out that the reach of computers in education is pervasive and difficult to ignore. Bayrak (2008) indicates that computers are reliable, do not forget, do not get tired or emotional, and do not have ethnic or cultural bias. Yeung (2004), quoting Youngblut (1998), reinforces the belief that computers "...are capable of enhancing student-centered (or self-organized) learning because of various unique features and educational values as embedded in using 3D and VR media for learning" (p. 1). He found fault with 2D projections in a learning environment noting that "those self-learning resources can help students develop their ability to visualize, understand, and mentally construct the details of complex scientific data and models which will otherwise be lost, distorted or easily misinterpreted in planar 2D projection" (p. 1). Yeung (2004) also identifies the impetus of much of the attention on computer based education and simulations as the emphasis on technology advocated by many governmental bodies, both local and national.

An emphasis on technology has led researchers to look into its impact. Zacharia (2003) noted the success of computer simulations in concept development in science, yet in later research he notes that "Despite all the research efforts into educational potential of simulations, numerous issues still remain" (Zacharia, 2005, p. 1741). He looked into how learners' understanding develops using interactive simulations. He cites studies by Cummings, Marx,

Thornton, & Kuhl (1999); de Jong & van Joolingen (1998); and Steinberg (2000) showing that “learning gains of simulations are ambiguous, especially in respect to their connection to the development of a coherent framework of conceptual understanding” (p.1743), finally suggesting that “...university physics professors should be encouraged to use simulations along with the application of the POE model in their own teaching and classroom” (p. 1763). The term POE here refers to Predict-Observe-Explain as a teaching strategy. Here, then, is research indicating that simulations might be more effective as a supplement to other teaching strategies. This sentiment was repeated in an exchange with James Carruthers, a professor of Chemical Engineering at Purdue University who stated that simulations can be an effective supplement (personal communication, July 14, 2011).

In looking at simulations, Kelly, Bradley & Gratch (2008) note, “Historically, physics simulations were presented as procedural or sequential in nature” (p. 3), and that “in recent years computer-based simulations have morphed into an interactive interface for student exploration” (p. 3). They further note that research has shown mixed results with respect to gains in student achievement and understanding. In their discussion they assert: “there is very little difference in learning that takes place in real (equipment) laboratory environment and learning that occurs in the laboratory simulation setting” (p.15). Again, they reinforce that “simulations should be viewed as a

viable alternative or supplement to the equipment lab, but not necessarily a replacement” (p. 15), and cite Hasson & Bug (1995); as well as Doerr (1997) when they do so. Bryan and Slough (2009) add research into the design of the simulation itself as a significant factor. Zacharia and Anderson (2003) also write that the simulation should provide a framework to support further student inquiry.

The difficulty is in finding simulations which will engage the students and allow students to explore their own questions (Drayton, Falk, Stroud, Hobbs, & Hammerman, 2010). Kelly et al. (2008, p. 19) suggest further study to “compare and contrast student ability to transfer information gleaned from laboratory activity during simulation or traditional labs.” Drayton et al. (2010) found that simply using technology does not necessarily improve student engagement or even improve the classroom experience.

This study attempts to compare student achievement using traditional lab methods with student achievement using computer simulation.

Method

Participants

The participants in this study consisted of 37 high school physics students. They were enrolled in two sections of the same Honors Physics course at an urban Catholic high school. The sections consisted of 20 students in one and 17 students in the other. They were predominantly juniors (11th grade).

In the group of 17 students (Group 1) there were 9 girls and 8 boys. Only one of the students, a girl, was a senior (12th grade). The other 16 students were juniors. The demographics of the group were 1 Asian (5.9%), 2 African-American (11.8%), 4 Hispanic (23.5%) and 10 Caucasian (58.8%). This is approximately the same as for the school overall with less than 1% American Indian, 4.7% Asian, 9.9% African-American, 11.5% Hispanic, 65.9% Caucasian, and 7.4% multiracial.

The group of 20 students (Group 2) was made up of 9 girls and 11 boys. In this group there were 4 seniors, all of them boys. The remaining 16 students were juniors. The demographics were 2 Asian (10%), 2 Hispanic (10%), and 16 Caucasian (80%).

The school administration will shift students among sections of the same course at the semester. Therefore, these students had not been together in these particular groups for an entire semester when the study was undertaken.

To be eligible for the Honors Physics course, a student must have passed Chemistry 1 with a B or better, must have passed Geometry with a B or better, and must have completed or be concurrently enrolled in Algebra II. The physics grade averages of the two sections were not substantially different. Just prior to the study Group 1 had an 86.7% average while Group 2 had an 87.1% average grade.

While the sample was not randomly selected, the two groups were very

similar. These are generally high-achieving students late in their junior year of high school. They are of mixed ethnicity, and have only been together as a physics class for a few months.

Curved Mirrors

The groups were given instruction in the basics of light as an electromagnetic wave to introduce the subject. See Appendix A for the instructional plan. They were then given instruction in ray tracing for curved mirrors.(Appendix B). Following the initial instruction, a pretest (Appendix C) was administered. Group 1 was then taken to a computer lab and asked to complete the activity (Appendix D) using the simulation to form images when given specific placements of an object. The simulation was chosen, in part, because of its use of multiple rays. This was expected to address the misconception of ray tracing requiring “special” rays (Eylon, 1996; p. 93). Prior to this activity, these same students had completed physics activities in the computer lab, so should have had a reasonable level of comfort with using the equipment.

The particular computer lab available to the physics class did not have Microsoft Word installed. The word processing software available to these students was Open Office. It turned out that they were not particularly conversant with the differences between the Open Office word processor and the more familiar Microsoft Word. The differences in the copy and paste

functions caused problems for many of the students. Whereas Microsoft Word will allow a user to paste a large image or passage into a small space by just enlarging the space to fit, Open Office seems to require a space large enough to accommodate the image before it is pasted in. This may seem like a minor inconvenience, but it took what seemed to be an inordinate amount of effort on the part of both the teacher and the students to make the accommodations necessary. It is of concern here as it was a distraction from the goals of the activity. Students may have been so concerned with the mechanics of the activity that they missed the point of learning about ray tracing and the image formation of curved mirrors.

There were sufficient computers in the lab for each student to work independently, however not all of the computers were able to access the simulation. As a result, a few students were allowed to work in pairs so that all were able to experience the simulation without requiring make-up sessions.

The other group (Group 2) was asked to draw ray tracing diagrams of the several cases of curved mirrors and object placement (Appendix E). They were given large (approximately 40" x 36") sheets of butcher paper, meter sticks, compasses, and colored markers. The instructions simply asked for ray tracing drawings illustrating the cases of object more than two focal lengths from the converging mirror; object exactly two focal lengths from the converging mirror; object exactly at the focal length of the converging mirror; object less than one

focal length from the converging mirror. They were also asked to draw similar cases for diverging mirrors. As the activity went on, this was modified to be at least two cases for diverging mirrors in the interest of time.

At the conclusion of these activities the students were given a posttest that was identical to the pretest given following the initial instruction. The butcher paper drawings and the computer activity printouts were assigned participation grades, but were not included in the study data.

Lenses

A similar approach was taken in the instruction on image formation in thin lenses. First, all students were given classroom instruction on image formation in thin lenses. See Appendix F for the instructional plan. It generally followed traditional instruction with a review of refraction, introduction of the index of refraction as a ratio of velocities, and then demonstration of ray tracing through converging and diverging lenses. Lateral magnification was introduced and manipulation of the thin lens equation to show image size and placement was demonstrated.

Following the classroom instruction, the two groups were asked to complete their activity. This time Group 2 went to the computer lab, and Group 1 was provided butcher paper, meter sticks, compasses, and colored markers to complete their activity.

Again, the student's unfamiliarity with the installed word processing

software was something of a distraction. Again, a few students were required to work in pairs as not all of the computers were able to access the simulation.

The simulation activity (Appendix G) asked students to place objects at specific points and observe the placement and characteristics of the resulting image for both converging and diverging lenses. They were asked if the image was real or virtual, upright or inverted, and larger or smaller than the object for each case. The cases were: object more than two focal lengths from a converging lens; object exactly two focal lengths from a converging lens; object between one and two focal lengths from a converging lens; object exactly one focal length from a converging lens; object less than one focal length from a converging lens. There were similar cases for diverging lenses. Again, the students doing the simulation activity were asked to cut and paste images of the various cases into a document to be printed and turned in.

Students doing the paper and marker ray tracing were asked to draw similar cases (Appendix H). As with the mirror activity the cases involving image formation of diverging lenses were reduced as a practical matter to any two cases for diverging lenses. It took relatively less time for the students in the simulation group to complete their activity than those in the manual group. In order to administer the posttest to each section on the same day and minimize unauthorized communication among the students, the groups were kept to a similar schedule.

Following the activities, a posttest (Appendix I) identical to the lenses pretest and the same for both groups was administered. Data collected included a numeric grade determined by a rubric, a notation as to whether or not a student spontaneously used ray tracing to answer multiple choice questions, and observations from the drawings on the tests.

Results

Curved Mirrors

The pretest results for the mirror activities showed little understanding of the ray tracing concept. The pretest and posttest were both scored using the same point allocation. Two points were awarded for each correct multiple choice response, and five points for each drawing. In the drawings one point was awarded for correctly drawing appropriate rays up to two points. One point was awarded for correctly locating the image and one point each for labeling the image as real or virtual; and larger, smaller, or the same size as the object. Group 1 scored an average of 8.82 out of a possible 26 points. The standard deviation of this score was 6.06 indicating a large variance, or a wide flat distribution. Group 2 pretest average score was 5.85 out of 26 possible points with a standard deviation of 4.23. Applying a T-test to these data yields a value of 1.51, less than necessary to indicate statistical significance. So, as one might expect, both groups performed at the same statistical level on the pretest.

The identical posttest, though, showed Group1 (the computer simulation group) scoring an average of 9.94 again from a possible 26 points, with a standard deviation of 5.73. Group 2 (the paper and pencil group) scored an average of 16.75 on the same posttest with a standard deviation of 7.33. A T-test applied to the posttest data yields a value of 3.17 indicating statistical significance of the difference between the groups. Briefly, the two groups started out at about the same level, but the paper and pencil activity group outperformed the computer simulation group in a statistically significant way. Pretest and posttest averages for the curved mirror activities are presented in Figure 1.

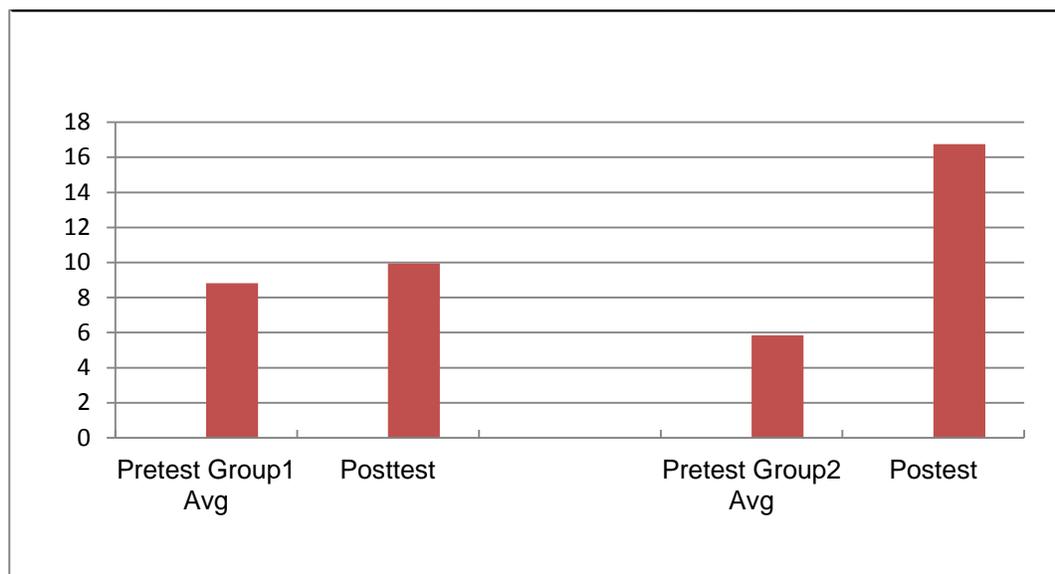


Figure 1: Mirrors Pretest/Posttest Averages

Lenses

The pretest (Appendix I) results for the thin lens activities also showed

little understanding of the ray tracing concept. Again the pretest and posttest were both scored using the same point allocation. Two points were awarded for each correct multiple choice response, and five points for each drawing. In the drawings one point was awarded for correctly drawing appropriate rays up to two points. One point was awarded for correctly locating the image and one point each for labeling the image as real or virtual; and larger, smaller, or the same size as the object. Group 1 scored an average of 7.27 out of a possible 26 points. The standard deviation of this score was 6.39, again indicating a large variance, or a wide flat distribution. Group 2 pretest average score was 9.05 out of 26 possible points with a standard deviation of 6.07. Applying a T-test to these data yields a value of 0.53, less than necessary to indicate statistical significance. Once again, both groups performed at the same statistical level on the pretest.

The identical posttest, though, showed Group1 (paper and pencil group) scoring an average of 16.82 again from a possible 26 points, with a standard deviation of 6.42. Group 2 (computer simulation group) scored an average of 10.06 on the same posttest with a standard deviation of 6.49. A T-test applied to the posttest data yields a value of 3.18 indicating statistical significance of the difference between the groups. Briefly, the two groups started out at about the same level, but the paper and pencil activity group outperformed the computer simulation group in a statistically significant way. Pretest and posttest averages for the lenses activities are presented in Figure 2.

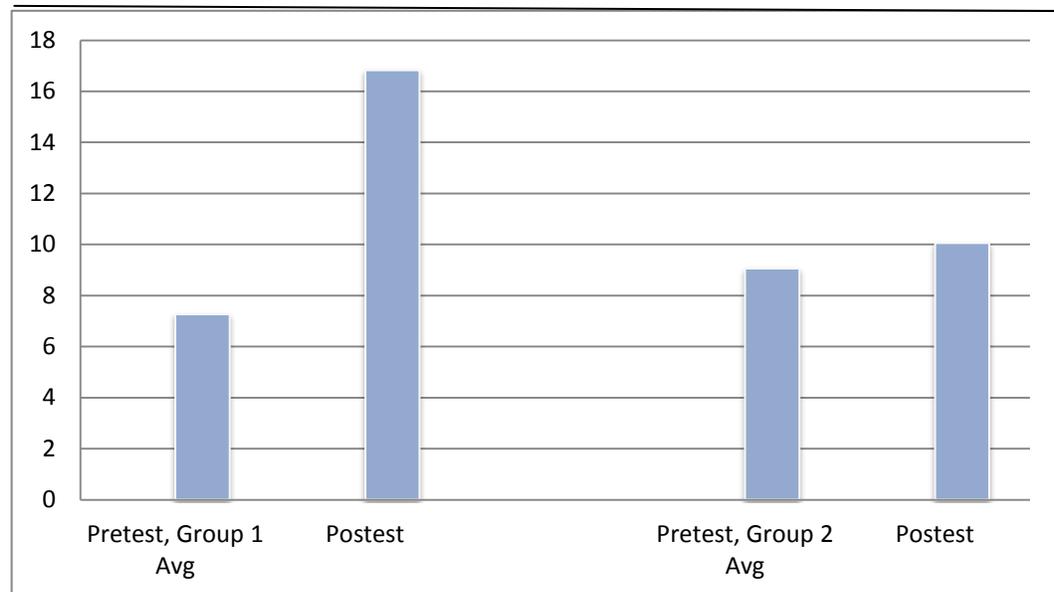


Figure 2: Lenses Pretest/Posttest Averages

In each case, mirrors and lenses, the paper and pencil activity group significantly outperformed the computer simulation activity group. It is interesting to note that the spontaneous use of ray tracing to answer multiple choice questions was more prevalent in the mirrors unit than in the later thin lenses unit. Group 1 had six students draw rays in the margins of the mirrors pretest, and four in the posttest, only two of whom had drawn rays on the pretest. Group 2 had six draw rays on the pretest and eight draw rays on the mirror posttest. Four of the students drew rays on both pretest and posttest. With such a small sample it would be impractical to infer significance. Anecdotally, however, those who drew rays generally did better on the assessment. It is not

clear whether the higher achievement is a function of drawing rays, or that higher achieving students are more likely to draw rays to clarify their thoughts.

In the thin lens unit, fewer students used drawings on the multiple choice portion of the assessments. In looking at the questions on the tests, more multiple choice questions lend themselves to ray tracing on the mirror test than on the thin lens test. Still, Group 1 had three draw rays on the thin lens pretest and only two on the posttest. Neither of the two on the posttest had drawn rays on the pretest. Group 2 had three draw rays on the thin lens pretest and only two on the posttest as well. In this case, there was one student who consistently drew rays on his assessments. His scores were slightly above the mean on the pretests, but well above the mean on the posttests. This individual scored above the average, but well within one standard deviation on both pretests. On the posttests though, he scored more than one standard deviation above the mean on the mirrors unit and very near to one standard deviation above the mean on the thin lenses unit. Perhaps additional research is warranted to help determine the contribution of spontaneous use of ray tracing to understanding geometric optics.

The multiple choice questions themselves indicated some understanding of the paths of rays in mirrors and thin lenses, but difficulty with some other related concepts. On the mirror posttest student responses were poor on the second and third question which asked about the formation of real or virtual

images. Fourteen of the 39 students answered Question 3 incorrectly and 8 answered Question 2 incorrectly. They did well on Question 1 covering the path of a particular ray, with only 4 answering incorrectly. On the lens posttest, 18 answered Question 1 incorrectly – indicating some difficulty with the concept and definition of index of refraction. Further evidence of that is in the response to Question 2 as 22 answered incorrectly, many confusing the effect of refraction with the Law of Reflection. As in the mirror posttest, more students correctly answered the question about the path of a particular ray, with only 9 incorrect responses to Question 3.

In the drawings that the students produced in answer to the pretest and posttest questions, there were several interesting issues. Many students seemed not to grasp the idea that more than one ray is required to locate an image. A common error on both the pretests and the posttests was to simply draw one ray. A typical example of this is depicted in Figure 3.

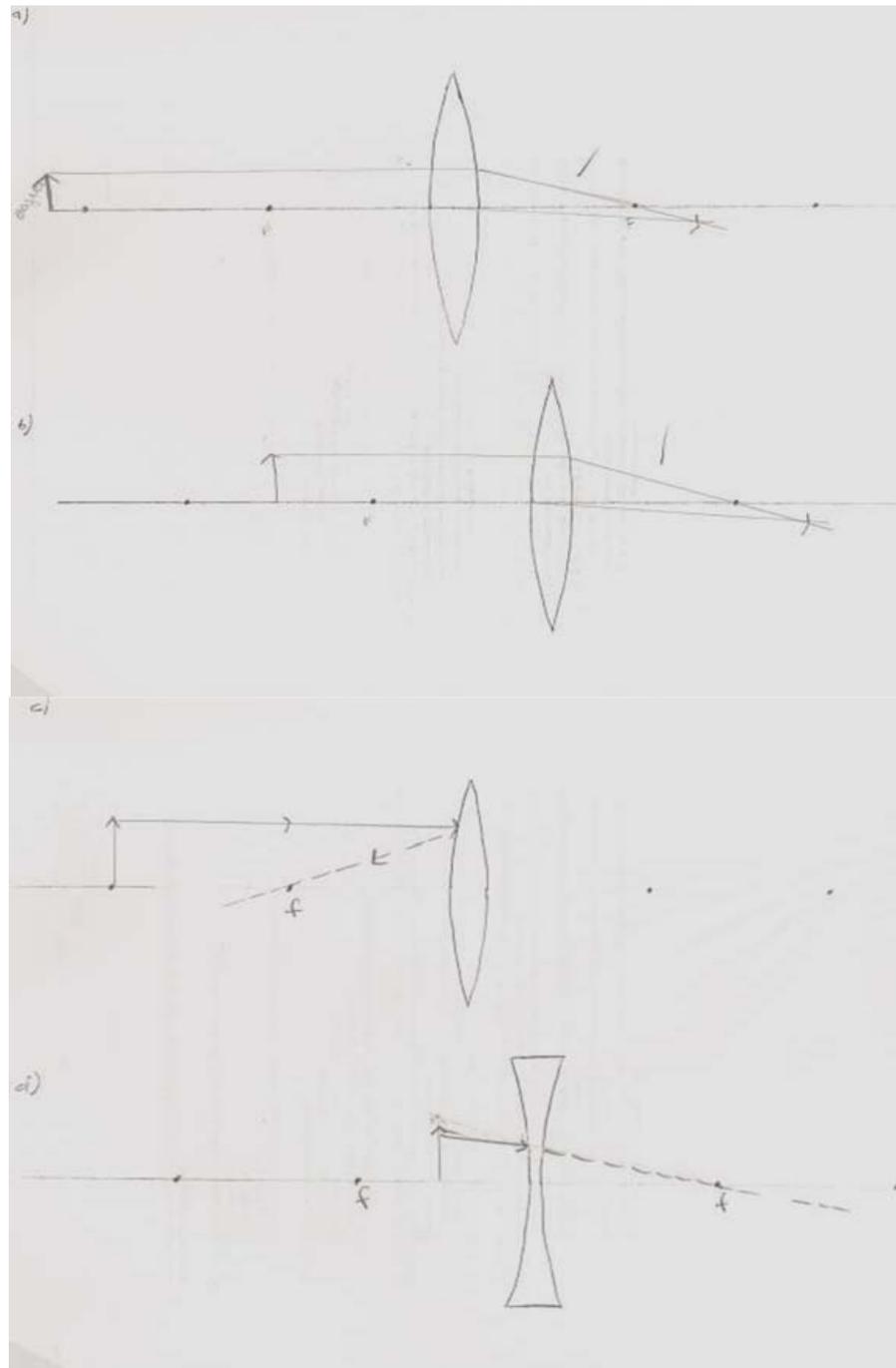


Figure 3: Examples of student work depicting only one ray

Some students were able to correctly describe the image (for example, real, inverted, larger than the object) but had drawn only one ray. This may indicate memorization on the student's part, rather than an understanding of the optical concepts. Often the student drawing would correctly represent a ray parallel to the principle axis being reflected or refracted properly through the focal point. Other rays on the same drawing would not follow any consistent rules and would not lead to correct location and formation of the image. This seemed less prevalent in the students who had done the paper and pencil activity.

Another difficulty was confusion about the definitions of real and virtual images. Compounding the definitional issues was some confusion that caused some students to show reflected rays in a lens situation forming a virtual image. This occurred often enough on their posttest drawings to note, but was not analyzed as part of the study. It appears that these sorts of errors were less prevalent among the students who did the paper and pencil activity.

Discussion

In this study, student achievement following a laboratory lesson based on a computer simulation was compared to student achievement following a similar laboratory lesson based on a paper and pencil manipulative activity. The data show a statistically significant increase in student achievement when the paper and pencil manipulative laboratory activity is used as compared to when

the computer simulation is used. This result reinforces the notion that computer simulations may not in many cases be the best alternative to a hands-on laboratory experience. Indeed, in this case there was no significant change in student achievement from the pretest to the posttest when the computer simulation activity was used. The hands-on activity produced a significant increase in student achievement as measured by the pretest and posttest.

Certainly, this study should not be construed to condemn computer simulations as tools in a physics classroom. Computer simulations are convenient, generally accessible, can be used when specialized equipment is too expensive or too dangerous to be practical, and consume few if any lab resources aside from having the computers available. Rather, this study should show that computer simulations' value may not be in replacing hands-on activities, but perhaps in supplementing them. In this case, the simulation used multiple rays and should have dispelled the idea that the rays used in ray tracing are somehow special. The simulation allowed the use of multiple objects, allowing a student to place an object off of the principle axis and observe the location of the image. It also allowed the student to observe rays from an object as reflected light rather than the object being a light source. Further, the simulation allowed exploration of field of view concepts not normally addressed in high school ray tracing lessons. In other words, the computer simulation can be a rich addition to a lesson on ray tracing, but it should not be a replacement for a hands-on laboratory experience.

Among the limitations of this study are the non-random sample, the technical difficulties in the use of the computer simulation, and the limited scope of the project. The samples were selected for convenience. As such, there is no assumption of randomness and therefore generalizability. A random sample of larger size would yield a more generalizable result. These results can only be stated with certainty for the students who participated in the project.

The technical difficulties encountered in the computer lab were reasonably typical of what might be expected. There will always be technical issues, and some of the computers will not work the way they are expected to work. This is a price of technology. That said, the student distraction caused by trying to effectively cut and paste may have contributed to the lack of achievement among the groups using computer simulations. This distraction likely had small if any effect on the student outcomes. It was not analyzed in this study. Another distracting influence might have been the need for some students to work in pairs in the computer lab. The physical setting of the computer lab is not conducive to pairs as the computers are closely spaced on a perimeter table. There is no space for additional people to fit comfortably without also requiring students on either side to shift a bit. This uncomfortable seating may have contributed to the lack of achievement by the simulation group. In the hands- on activity, students worked in their accustomed lab groups, so there was nothing out of the ordinary there.

Recommendations

The need for additional research is indicated in several areas. First, of course, would be to closely repeat the project using a larger random sample. As discussed previously, this would yield a generalizable result appropriate to inform teaching in other environments.

It would be interesting to explore the use of simulations as a tool for inquiry, rather than in a structured activity such as this. Allowing the student to discover the capabilities of the simulation while observing the interaction of the rays and mirrors or lenses to form images might be a more effective use of computer simulations. The students tended to focus on the activity rather than on the concepts. They seemed to simply want to finish the assignment and get on with whatever was next.

Research into the use of computer simulations as supplemental activities is indicated. Even if a computer simulated laboratory investigation is shown not to be as effective as its hands-on counterpart, perhaps greater value of the simulated activity would be realized in using it to supplement, rather than replace, the hands-on activity. In this case, following the hands-on activity, a simulation might appropriately be used to help eliminate the special ray misconception and the field of view concept could easily be added to the lesson.

A more ambitious inquiry might be made into discovering the design characteristics of the most effective simulation. The degree of interactivity and

the ease of adding rays or changing optical parameters could be explored. It may be that it is not computer simulations that are ineffective as stand-alone lab activities. It may be that the currently available computer simulations are ineffective as stand-alone lab activities.

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Appendix A

Unit Lesson Plan

Date: Spring 2011

Subject Matter: Light and Optics Course/Grade

Level: Honors Physics

Topic: Light as an Electromagnetic wave

Unit Plan: Light

Lesson #: 1

Period/Time: 4x45 Min

Goal: To introduce the properties and characteristics of light as an electromagnetic wave

Objectives:

1. SWBAT describe electromagnetic radiation as an interaction among electric and magnetic fields.
2. SWBAT explain that light as an electromagnetic wave occupies a small portion of the electromagnetic spectrum.
3. SWBAT explain that all waves reflect, refract, interfere and diffract.
4. SWBAT explain the wavelet model of light.
5. SWBAT explain the ray model of light.
6. SWBAT describe the benefits of each with respect to the behaviors in Objective 3.
7. SWBAT apply the Law of reflection to specular and diffuse reflection situations.
8. SWBAT determine the location of bright and dark fringes in single and double slit situations.
9. SWBAT explain the changes to the speed of light in various media.
10. SWBAT determine the index of refraction given the speed of light in a material.

Materials/Equipment/Technology:

1. Blackboard/chalk
2. laser pointer
3. plane mirror

4. Pretest
5. Light worksheet
6. single slit demo
7. posttest

Procedures:

Initiating Activity:

o Asses prior knowledge (KWL on Blackboard) Developmental Activities:

1. Intuitive discussion of radiation in everyday life.
2. Lecture presentation on electromagnetic radiation
3. Prior knowledge discussion of electromagnetic spectrum
4. Discussion of wave interactions reflection, refraction, diffraction, interference)
5. Lecture presentation of wavelet and ray models of light
6. Lecture presentation of Law of Reflection showing approaches with each model.
7. Demonstration of Law of Reflection using plane mirror
8. Demonstration of Diffraction, and interference
9. Lecture presentation of single and double slit calculations
10. Discussion of refraction as a wave speed phenomenon and index of refraction

Conclusion/Culminating Activities:

Worksheets

Homework assignments from text

Student Assessment Procedures:

Performance Measures:

Verbal and Visual assessment of participation

Worksheet

Homework

Posttest

Enrichment/Follow-Up Assignments:

Go over and correct Homework

Student Feedback: Visual and Verbal Assessment throughout lesson

Appendix B

Unit Lesson Plan

Date: Spring 2011

Subject Matter: Light and Optics

Course/Grade Level: Honors Physics

Topic: Geometric Optics Image Formation in Converging and Diverging Mirrors

Unit Plan: Light

Lesson #: 2

Period/Time: 1x45 Min

Goal: To introduce the Image Formation in Converging and Diverging Mirrors using Ray Tracing.

Objectives:

1. SWBAT describe real and virtual images
2. SWBAT show how real and virtual images form
3. SWBAT quantitatively relate image distance, object distance and focal length
4. SWBAT determine approximate image placement, size, and type (real or virtual) for any placement of object

Materials/Equipment/Technology:

1. Blackboard/chalk
2. diverging and converging mirrors for demo
3. Pretest
4. Ray tracing handout
5. posttest

Procedures:

Initiating Activity:

- Asses prior knowledge (KWL on Blackboard) Developmental Activities:
 1. Intuitive discussion of applications of curved mirrors in everyday life.
 2. Lecture presentation of finding the focal point of a curved mirror
 3. Lecture presentation of image formation by a converging mirror
 4. Lecture presentation of the sign conventions for mirror calculations
 5. Lecture presentation of image formation by a diverging mirror

Conclusion/Culminating Activities:

Lab (3x45)

Homework assignments from text

Student Assessment Procedures:

Performance Measures:

Verbal and Visual assessment of participation throughout lesson

Lab reports

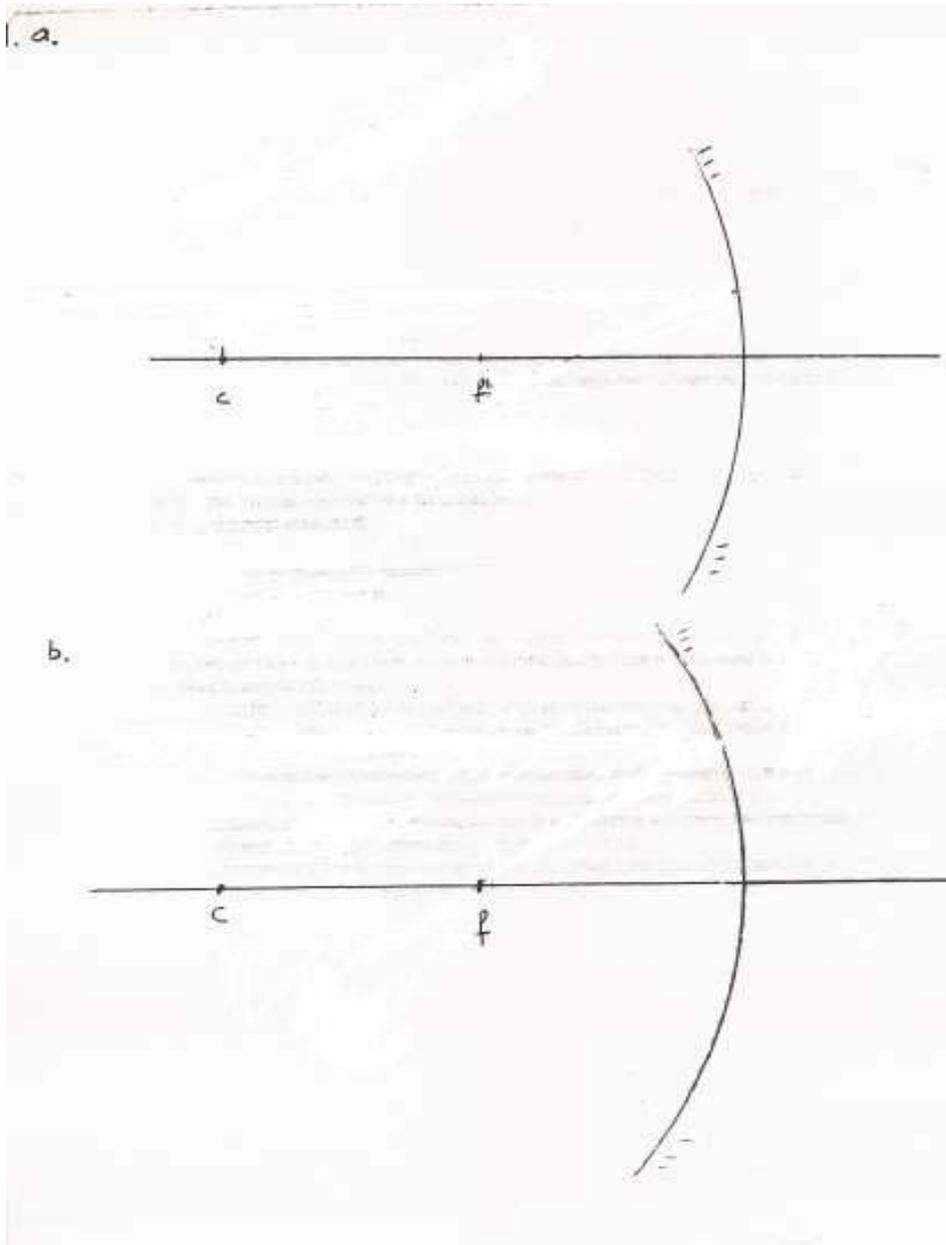
Homework

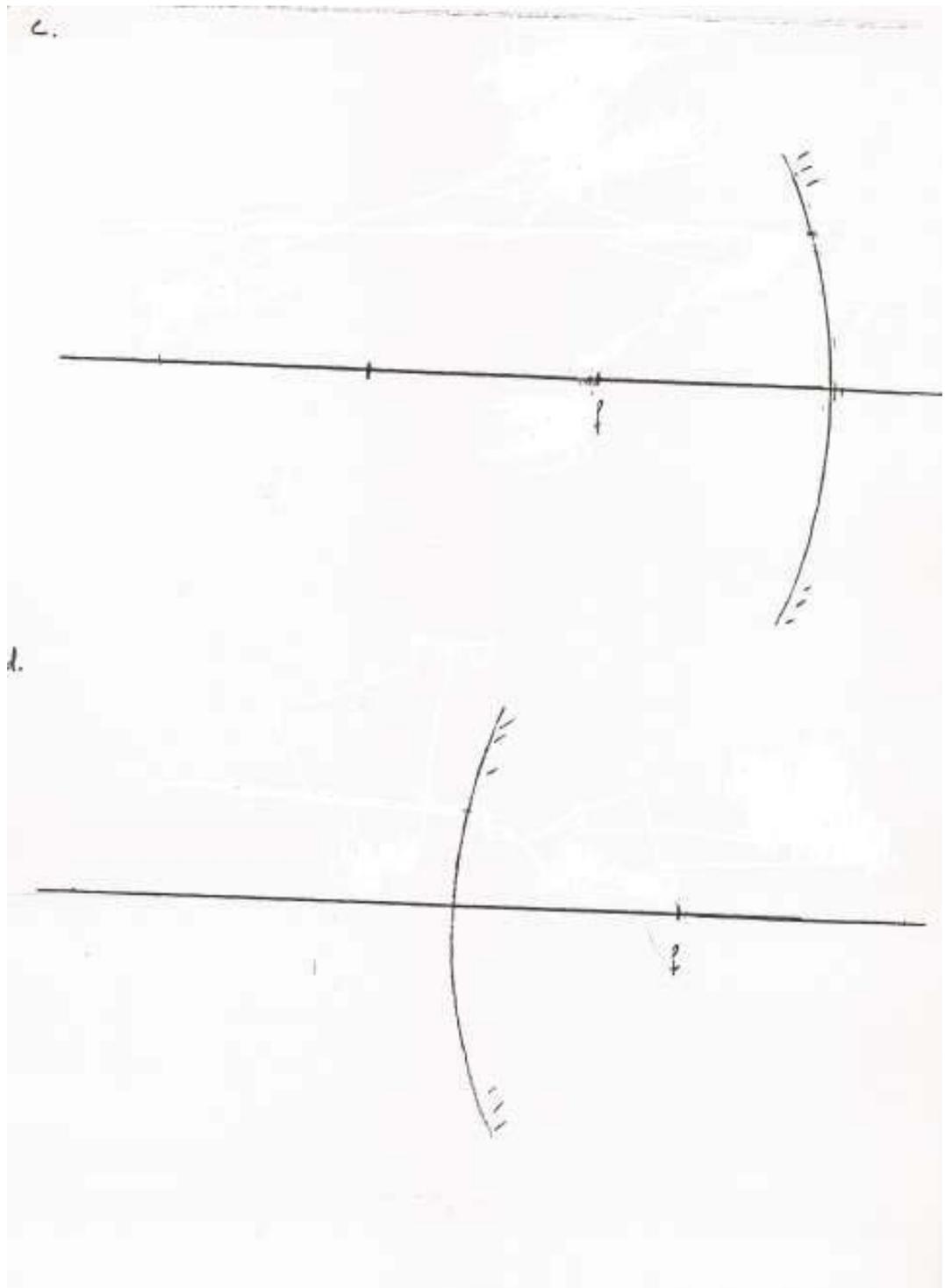
Posttest

Appendix C

Quiz

1. Light arriving at a concave (converging) mirror on a path parallel to the axis is reflected
 - a. back parallel to the axis
 - b. back on itself
 - c. through the focal point
 - d. through the center of curvature
2. An image formed when light rays pass through the image location, and could appear on paper or film placed at that location is referred to as a
 - a. real image
 - b. virtual image
3. An object is situated between a concave mirror's surface and its focal point. The image formed in this case is
 - a. real and inverted
 - b. real and erect (upright)
 - c. virtual and erect (upright)
 - d. virtual and inverted
4. Draw the appropriate rays on the templates included with the quiz for the following situations. Be careful to include labels as necessary, and indicate the directions of the rays.
 - a. Locate and label (real, virtual, upright, inverted, larger, smaller) the image when an object is exactly twice the focal length from a converging (concave) mirror.
 - b. Locate and label the image when an object is between the focal point and the surface of a converging (concave) mirror.
 - c. Locate and label the image when the object is more than two focal lengths from a converging (concave) mirror.
 - d. Locate and label the image when the object is less than one focal length from a diverging (convex) mirror.

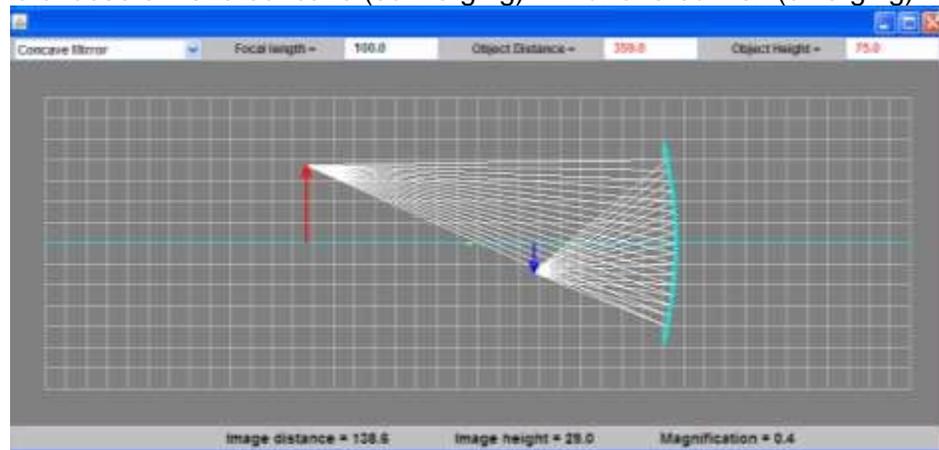




Appendix D

Images Formed by Converging and Diverging Mirrors

Go to the web site <http://www.schulphysik.de/suren/Applets.html>. From the “Applet Menu” pull-down menu, choose “Optics” and “Spherical Mirrors and Lenses.” After you click on the box, you will see a window open that allows you to choose either a concave (converging) mirror or a convex (diverging) mirror.



Part I – Images in a Converging Mirror

With the simulation set on “concave mirror,” move the object to various distances to the left of the mirror. Use a screen capture program to copy and paste diagrams like the one above showing rays forming the image and the location of the image when the **object distance** is:

- 1) more than twice the focal length away,
- 2) exactly twice the focal length away,
- 3) between one and two focal lengths away,
- 4) exactly one focal length away, and
- 5) less than one focal length away.

Below each captured image, state whether the image is:

- a) *real*, *virtual*, or *no image formed*, b) *upright* or *inverted*, and
- c) *reduced*, *enlarged*, or the *same size*.

Remember that real images are always inverted and on the same side of the mirror as the object. Virtual images are always upright and on the opposite side of the mirror.

Part I – Images in a Converging Mirror Results

paste screen shot here
1) Object is more than twice the focal length away The image is
paste screen shot here
2) Object is exactly twice the focal length away The image is
paste screen shot here
3) Object is between one and two focal lengths away The image is
paste screen shot here
4) Object is exactly one focal length away The image is
paste screen shot here
5) Object is less than one focal length away The image is

Part II – Images in a Diverging Mirror

With the simulation set on “convex mirror,” move the object to various distances to the left of the mirror. Use a screen capture program to copy and paste diagrams showing rays forming the image and the location of the image when the **object distance** is:

- 1) more than twice the focal length away,
- 2) exactly twice the focal length away,
- 3) between one and two focal lengths away,
- 4) exactly one focal length away, and
- 5) less than one focal length away.

Below each captured image, state whether the image is:

- a) *real*, *virtual*, or *no image formed*, b) *upright* or *inverted*, and
- c) *reduced*, *enlarged*, or the *same size*.

Remember that real images are always inverted and on the same side of the mirror as the object. Virtual images are always upright and on the opposite side of the mirror.

Part II – Images in a Diverging Mirror Results

paste screen shot here
5) Object is more than twice the focal length away The image is
paste screen shot here
2) Object is exactly twice the focal length away The image is
paste screen shot here
3) Object is between one and two focal lengths away The image is
paste screen shot here
4) Object is exactly one focal length away The image is
paste screen shot here
5) Object is less than one focal length away The image is

Appendix E

Optics Lab

Converging and Diverging Mirrors

Ray Tracing

In this Lab your group will draw out representations of converging and diverging mirrors and trace rays to locate images.

1. Using a compass draw a converging mirror of radius 15 cm on the butcher paper. Be sure to allow at least 20 cm on either side of the mirror.

2. Locate the focal point, center of curvature, and principal axis.

3. Draw an object 5 cm tall with one side on the principal axis and located more than twice the focal length away. Indicate on the paper whether the image is

- a) real, virtual, or no image formed
- b) upright or inverted
- c) reduced, enlarged, or the same size

4. Repeat the procedure for objects

- a) exactly twice the focal length away
 - b) between one and two focal lengths away
 - c) Exactly one focal length away and less than one focal length away.
- Note that real images are always inverted and on the same side of the mirror as the object. Virtual images are always upright and on the opposite side of the mirror.

5. Repeat the entire procedure for diverging mirrors

Appendix F

Unit Lesson Plan

Date: Spring 2011

Subject Matter: Light and Optics

Course/Grade Level: Honors Physics

Topic: Geometric Optics Image Formation in Converging and Diverging Lenses

Unit Plan: Light

Lesson #: 3

Period/Time: 1x45 Min

Goal: To introduce the Image Formation in Converging and Diverging Lenses using Ray Tracing.

Objectives:

1. SWBAT describe refraction in lenses
2. SWBAT show how real and virtual images are formed by lenses
3. SWBAT quantitatively relate image distance, object distance and focal length
4. SWBAT determine approximate image placement, size, and type (real or virtual) for any placement of object

Materials/Equipment/Technology:

1. Blackboard/chalk
2. diverging and converging lenses for demo
3. Pretest
4. Ray tracing handout
5. posttest

Procedures:

Initiating Activity:

Asses prior knowledge (KWL on Blackboard) Developmental Activities:

1. Intuitive discussion of applications of lenses in everyday life.
2. Lecture presentation of finding the focal point of a lens
3. Lecture presentation of image formation by a converging lens
4. Lecture presentation of the sign conventions for lens calculations
5. Lecture presentation of image formation by a diverging lens

Conclusion/Culminating Activities:

Lab (3x45)

Homework assignments from text

Student Assessment Procedures:

Performance Measures:

Verbal and Visual assessment of participation

Lab reports

Homework

Posttest

Enrichment/Follow-Up Assignments:

Go over and correct Homework

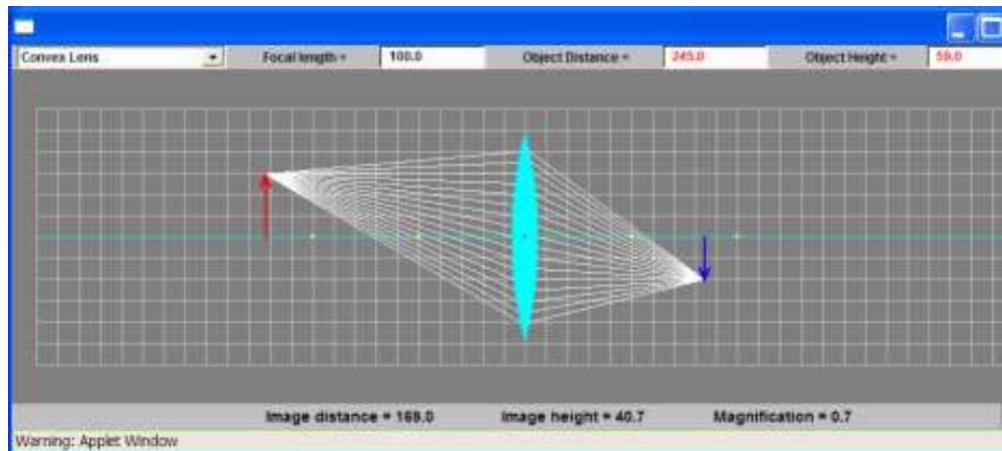
Student Feedback:

Visual and Verbal Assessment throughout lesson

Appendix G

Images Formed by Converging and Diverging Lenses

Go to the web site <http://www.schulphysik.de/suren/Applets.html>. From the “Applet Menu” pull- down menu, choose “Optics” and “Spherical Mirrors and Lenses.” After you click on the box, you will see a window open that allows you to choose either a convex (converging) lens or a concave (diverging) lens.



Part I - Images in a Converging Lens

With the simulation set on “convex lens,” move the object to various distances to the left of the lens. Use a screen capture program to copy and paste diagrams like the one above showing rays forming the image and the location of the image when the **object distance** is:

- 1) more than twice the focal length away,
- 2) exactly twice the focal length away,
- 3) between one and two focal lengths away,
- 4) exactly one focal length away, and
- 5) less than one focal length away.

Below each captured image, state whether the image is:

- a) *real*, *virtual*, or *no image formed*, b) *upright* or *inverted*, and
- c) *reduced*, *enlarged*, or the *same size*.

Remember that real images are always inverted and on the opposite side of the lens from the object. Virtual images are always upright and on the same side as the object.

Part I - Images in a Converging Lens Results

paste screen shot here
1) Object is more than twice the focal length away The image is
paste screen shot here
2) Object is exactly twice the focal length away The image is
paste screen shot here
3) Object is between one and two focal lengths away The image is
paste screen shot here
4) Object is exactly one focal length away The image is
paste screen shot here
5) Object is less than one focal length away The image is

Part II - Images in a Diverging Lens

With the simulation set on “concave lens,” move the object to various distances to the left of the lens. Use a screen capture program to copy and paste diagrams showing rays forming the image and the location of the image when the **object distance** is:

- 1) more than twice the focal length away,
- 2) exactly twice the focal length away,
- 3) between one and two focal lengths away,
- 4) exactly one focal length away, and
- 5) less than one focal length away.

Below each captured image, state whether the image is:

- a) *real*, *virtual*, or *no image formed*, b) *upright* or *inverted*, and
- c) *reduced*, *enlarged*, or the *same size*.

Remember that real images are always inverted and on the opposite side of the lens from the object. Virtual images are always upright and on the same side as the object.

Part II - Images in a Diverging Lens Results

paste screen shot here
1) Object is more than twice the focal length away The image is
paste screen shot here
2) Object is exactly twice the focal length away The image is
paste screen shot here
3) Object is between one and two focal lengths away The image is
paste screen shot here
4) Object is exactly one focal length away The image is
paste screen shot here
5) Object is less than one focal length away The image is

Appendix H

Optics Lab

Converging and Diverging Lenses

Ray Tracing

In this Lab your group will draw out representations of converging and diverging lenses and trace rays to locate images.

1. Draw a thin converging (convex) lens with a focal length of 8 cm on the butcher paper. Be sure to allow at least 20 cm on either side of the lens.
2. Locate the focal points, 2 focal lengths, and principal axis.
3. Draw an object 5 cm tall with one side on the principal axis and located more than twice the focal length away. Indicate on the paper whether the image is
 - a) real, virtual, or no image formed
 - b) upright or inverted
 - c) reduced, enlarged, or the same size
4. Repeat the procedure for objects
 - a) Exactly twice the focal length away
 - b) Between one and two focal lengths away
 - c) Exactly one focal length away
 - d) Less than one focal length away.Note that real images are always inverted and on the opposite side of the lens as the object. Virtual images are always upright and on the same side of the lens.
5. Repeat the entire procedure for diverging (concave) lenses.

Appendix I
Quiz

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

- 1) For all transparent material substances, the index of refraction
 - a) is less than 1.
 - b) is equal to 1.
 - c) is greater than 1.
 - d) could be any of the given answers; it all depends on optical density.

- 2) In a lens, the angle of incidence
 - a) must equal the angle of refraction.
 - b) is always less than the angle of refraction.
 - c) is always greater than the angle of refraction.
 - d) may be greater than, less than, or equal to the angle of refraction.

- 3) A light ray, traveling parallel to the axis of a convex thin lens, strikes the lens near its midpoint. After traveling through the lens, this ray emerges traveling obliquely to the axis of the lens
 - a) passing through its focal point.
 - b) crossing the axis at a point equal to twice the focal length.
 - c) passing between the lens and its focal point.
 - d) such that it never crosses the axis.

- 4) Draw appropriate rays on the templates included with the quiz for the following situations. Be sure to include labels as necessary, and indicate the direction of the rays.
 - a) Locate and label the image when an object is located more than twice the focal length from a thin converging lens.
 - b) Locate and label the image when an object is located between the focal point and the surface of a thin converging lens.
 - c) Locate and label the image when an object is exactly twice the focal length from the surface of a thin converging lens.
 - d) Locate and label the image when an object is located less than one focal length from the surface of a thin diverging lens.

