Optics and Lenses

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INTRODUCTION, HISTORY, AND DEMOGRAPHICS

James Madison Junior-Senior High opened its doors on September 8, 1965. The enrollment started with 2,003 students, of which 793 were senior high school students. By the end of 1967, the enrollment had increased and almost reached 2,700 students. Now the Madison High School for Meteorology and Space Science has a total enrollment of approximately 2,600 students in which African-Americans are the highest percentage, 51 percent. Hispanics rank second with 41 percent. According to the Texas Education Agency, Madison High School has an "acceptable" rating. Madison High School was considered in the recognized status from the years of 2002 to 2004. Madison is one of the many high schools in the Houston Independent School District to have a magnet program.

Madison High School is a magnet school for meteorology and space science in which it is associated with NASA. Students have the privilege of studying the dynamics of weather, space exploration, environmental science, geology, oceanography, broadcast, meteorology, manned space flight, and astronomy. Madison has an on-site station that it is being used to analyze real-time and historical weather data, access the Internet, and, most importantly, maintain personal contact with professionals in the fields of meteorology and space sciences. Also, weather is being reported from school on a local television station.

I teach the magnet and the regular students: three Pre-Calculus classes, each comprised of 40 students, and three Algebra Two classes, each comprised of 30 students. One of my pre-calculus and one of my algebra classes is comprised of Advanced Program students (Magnet Program). My students deserve an exciting and challenging curriculum, and the seminar "Physics, How Things Work," seemed like a wonderful opportunity for them to relate mathematics to math science integration and promote and motivate students toward science and technology. I can best describe my students as challenging and eager to learn new things, and this seminar helped me in bridging the gap between the mathematics and science curricula.

RATIONALE

I intend to teach optics, the field of optics and the lens formula, and do lessons and activities with my students, thus connecting science with mathematics.

Initially I will talk with my students about the general topics in optics like focus, focal length, experiment of images, objects, real images, virtual images, the lens formula, *etc*. The purpose of teaching this unit is to combine mathematics with science and further my own understanding in teaching math-science integration units.

This topic will help the students learn optics. They will learn in detail about the propagation of electromagnetic radiation most easily observed as visible light. They will learn about the characteristics of lenses and focal length. It will give them a broad vision about focus and focal length. "The *focal length* of a lens is the distance between the lens and the real image it forms of a very distant object" (*Physics* 521).

In this unit, students will further learn about the relationship between the object distance, image distance, and the focal length, thus learning and exploring the well-known lens equation. They will learn the everyday phenomena that the further you place the object, the closer the image is formed near the lens, and we will be learning about the lens equation, "one divided by the focal length of a lens is equal to the sum of one divided by the object distance and one divided by the image distance."

Students will also learn to explore the **real** and **virtual images** during the experiments. They can figure out the difference between the object, real image, and virtual image. Later students will learn about the **refractive index**.

OBJECTIVES

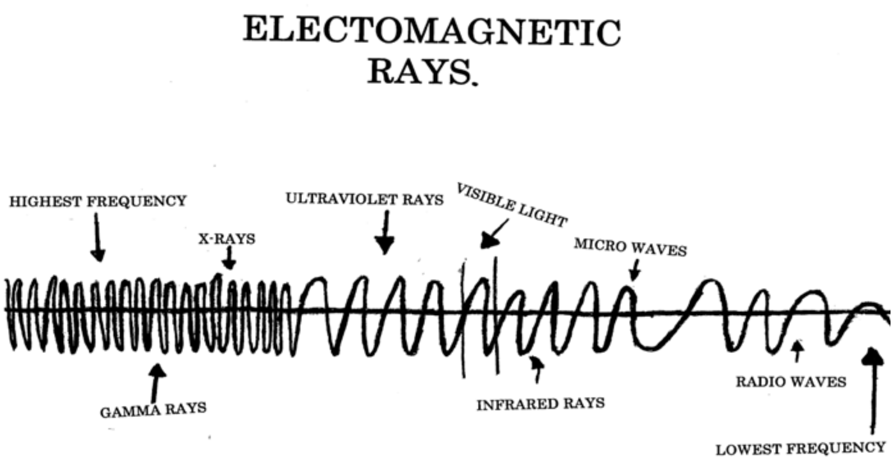
HISD Learning Focus 6.1

TEKS Physics.8C

Learning and process skills play a critical role in helping students develop scientific ideas. This unit provides numerous opportunities for students to learn about optics and lenses. Students will be assigned groups to research one of the topics on optics and lenses and do some experiments on them.

UNIT BACKGROUND

First the students will learn about optics. Optics is the science that deals with electromagnetic rays. We see objects because of reflected light. Light is reflected off their surface to our eyes. We can see the objects because they are luminescent. Electromagnetic rays consist of gamma rays, x-rays, ultraviolet rays, visible light, infrared rays, micro waves and radio waves. Gamma rays are the deepest penetrating rays and have the highest frequency, while the radio waves have the lowest frequency. Gamma rays are utilized in treatment of different types of cancer. X-rays are used in medical examination of bones, teeth, and other human body organs. Ultraviolet rays are used for sterilization of medical instruments. Similar applications of infrared light include physical therapy, while microwaves and radio waves are used for AM/FM radio and television.



(Adapted from http://streaming.discoveryeducation.com)

Students later in this unit will further learn about the advantage and utility of optics in our everyday life.

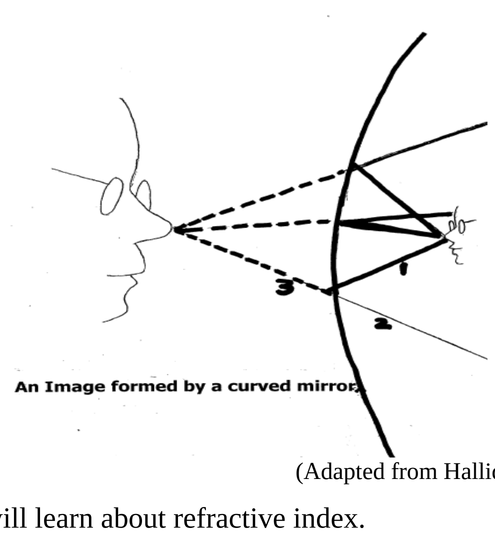
“Optics is part of everyday life” (*Physics* 521). Rainbows and mirages are just a couple of examples we see everyday. “Rainbows are optical and meteorological phenomena that cause a spectrum of light to appear in the sky when the Sun shines onto droplets of moisture in the Earth’s atmosphere” (*Physics* 521). A mirage is a “naturally-occurring phenomenon in which light rays are bent to produce a displaced image of distant objects or the sky” (*Physics* 521). “Fake” water on a hot road is the most common example of an everyday mirage we see.

Eyeglasses or contact lenses are another use of everyday optics from which many people benefit. Eyeglasses are normally used for vision correction, eye protection, or protection from ultraviolet rays. Lenses are now made from various plastics including polycarbonate but were originally made from glass. Some plastics have advantages over glass. Plastics have better transmission of visible light, greater absorption of ultraviolet light, and a greater index of refraction. Plastic has an index of refraction up to 1.66, which is higher than glass, with an index of refraction of 1.52. Glass is scratch resistant and provides the clearest possible vision. Plastics are lightweight, more impact resistant, and are easily scratched. Glasses are heavier than plastics. They are breakable, absorb ultraviolet light, and cause the least amount of distortion.

Optics is also used in cameras. A camera is used to capture images, either as a photograph or as a video. “Cameras may work with the light of the visible spectrum or with other portions of the electromagnetic spectrum” (*Physics* 521). A camera generally consists of an enclosed hollow with an opening at one end for light to enter, and has a recording or viewing surface called an aperture for capturing the light at the other end. The lens on most cameras is positioned in front of the camera’s opening to gather the incoming light and focus all or part of the image on the recording surface when taking a picture or recording a video. Some cameras have a fixed-size aperture and some have the aperture controlled by a diaphragm mechanism.

Real images and virtual images

With this unit the students will be able to learn about **objects, real images,** and **virtual images.** There are two types of images that can be formed: real images and virtual images. Real images are those from which light rays actually diverge. A real image is one that can be focused onto a screen. Virtual images are those from which light only appears to diverge. An example is your image behind a mirror. Light does not come from behind the mirror.



(Adapted from Halliday, Rensick, and Walker, Chapter 35.)

In the end we will learn about refractive index.

Refractive index

“The **refractive index** (or **index of refraction**) of a medium is a measure for how much the speed of light is reduced inside the medium” (*Physics* 521).

Definition of **refractive index**: “The refractive index n of a medium is defined as the ratio of the phase velocity c of a wave phenomenon of light in a vacuum to the phase velocity v_p in the medium” (*Physics* 521). For example, typical glass has a refractive index of 1.5, which means that light travels at 1 / 1.5 = 0.67 times the speed in air or vacuum. Two common properties of glass and other transparent materials are directly related to their refractive index. First, light rays change direction when they cross the interface from air to the material, an effect that is used in lenses and glasses. Second, light reflects partially from surfaces that have a refractive index different from that of their surroundings.

Learning and understanding about lenses and images produced

A **lens** is any transparent object having two nonparallel curved surfaces or one plane surface and one curved surface. Lenses are usually made of glass but can be made of other transparent materials.

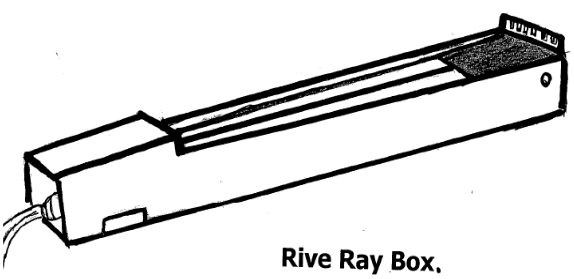
With all converging lenses, paraxial rays are parallel to the principal axis and focus to a point on the lens axis, called the **focal point.** The distance from this point to the lens is called the **focal length**. **Focal plane** is defined as the plane on which light from infinity forms an image for small incident angles. The real image is produced on the opposite side from the object while the virtual images are always on the same side as the object.

EXPERIMENTS

Experiment One: Find the focal length of a lens using lens equation

Materials needed: Concave lens, Convex lens, Rive Ray Box

Rive Ray Box is a light source that projects clean rays of light across any horizontal surface.



Rive Ray Box.

(Adapted from http://basicsciencesupplies.com)

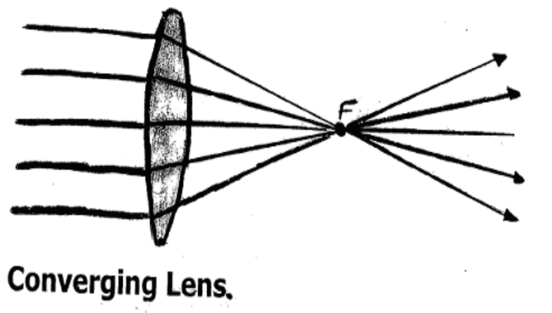
Instructional strategies and directions

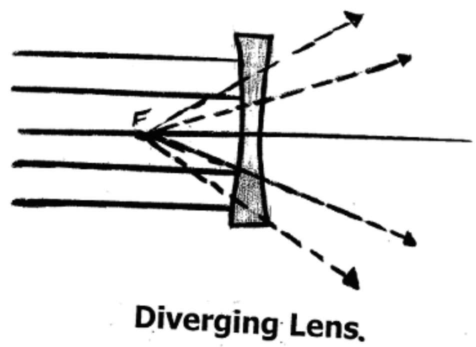
A lens is a transparent object with two refracting surfaces in which the central axis coincides. We will learn about two types of lenses: Concave lenses and Convex Lenses.

A lens that makes initially parallel light rays to converge is called a converging lens or convex lens. A lens that makes initially parallel light rays to diverge is called a diverging lens or concave lens.

Object distance is the distance from the converging point of rays to the convex lens. Image distance is the distance from the convex lens to the image.

The first column should be the one you control i.e. the object distance. The second column is the one you measure the image distance. Finally we calculate the focal length. We also write the error bars for each measurement.





(Adapted from Bloomfield, Chapter 15)

Using the Lens Equation

1/focal length = 1 / object distance + 1 / image distance

Focal length	Object Distance	Image Distance
6.25	11+- 0.01	14.5
6.46	14.5 + - 0.01	12
6.31	11.5 + - 0.01	14

Finding the focal length by calculations

1/f = 1 / O. D + 1 / I. D or

O. D = Object distance

I.D = image Distance

1/ f = ID + OD / OD. ID or

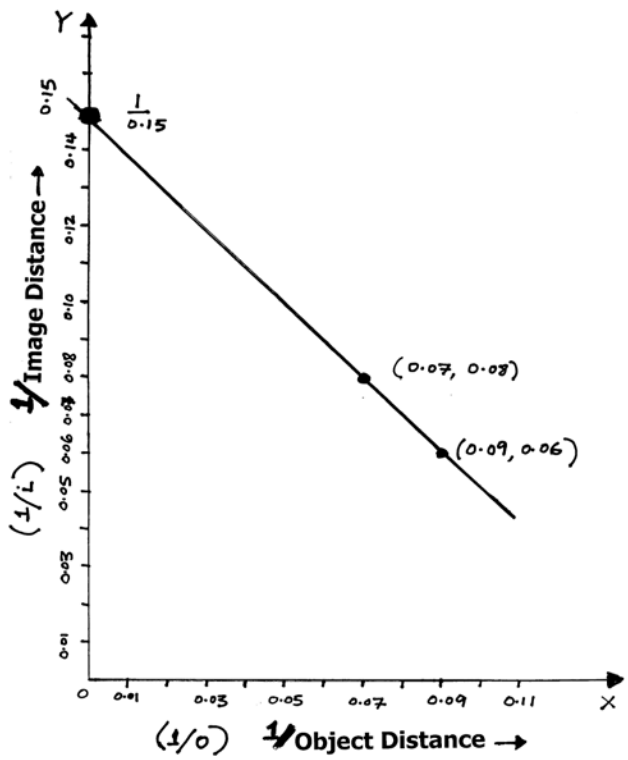
Therefore

f (ID + OD) = OD. ID or

f = OD. ID / (ID + OD)

f = OD.ID / (ID + OD)	**OD. ID**	**OD + ID**
159.5/25.5 = 6.25 cm	11.14.5 = 159.5	11 + 14.5 = 25.5
168/26 = 6.46 cm	14.12 = 168	14 + 12 = 26
161/25.5 = 6.31 cm	11.5.14 = 161	11.5 + 14 = 25.5

OD	**1 / O.D**	**ID**	**1/ ID**
11 cm	.09	14.5 cm	.068
14 cm	.07	12 cm	.08
11.5 cm	.086	14 cm	.07



(Based on data collected from doing experiments on lenses by Ali Jafry)

Reciprocal of Object Distance versus Reciprocal of image Distance

Where X axis = 1/object distance

Y axis = 1/ image distance

Experiment Two: Finding the refraction of light using prism and determining the incident and the refracted angles.

Instructional strategies and directions

Students will explore refraction of light using a triangular prism.

1. First set the prism in front of a rive ray box.
2. Use the rive ray box to flash light through the lens.
3. See how the light rays are changed when you slide rive ray box back and forth. The rays of light can be made parallel by sliding the rive ray box.
4. Measure the incident angle with the help of protractor.
5. Measure the refracted angle with the help of protractor.

Let find the ratio of Sin (incident angle) / Sin (refracted angle) by using a triangular prism.

The following table shows that the ratio of the

Sin (incident angle) / Sin (refracted angle) is constant.

Sin(incident angle)	Sin (refracted angle)	Sin (incident angle) / Sin (refracted angle)
Sin (65^0)	Sin (85^0)	Sin (65^0) / Sin (85^0)= .90
Sin (60^0)	Sin (75^0)	Sin (60^0) / Sin (75^0)=.896
Sin (63^0)	Sin (88^0)	Sin (63^0)/ Sin (88^0) =. 90

Experiment Three: To understand the process of refraction using a beaker with water

Materials: Water beaker, pencil

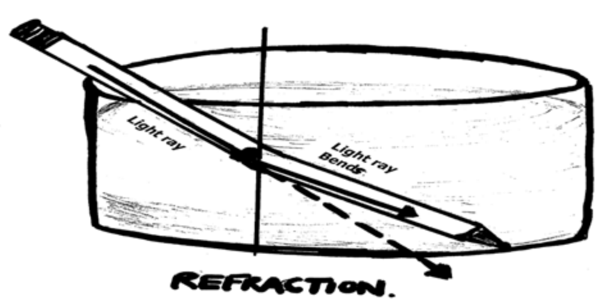
Strategies and Directions

Refraction is the bending of light at the boundary between two mediums of different densities. As light passes from one medium to the next, the light waves bend.

Experiment: Pencil appears to be broken at the water line in a beaker. This is due to refraction. Rays of light bend when they pass through water. Refraction involves a change in medium. When light meets the boundary of the new medium at an angle the light wave is bent before it continues as a straight line and it creates the distorted image.

Student Assessment

1. Why does light travels at different speed in different mediums?
2. Why does the pencil appear to be broken at the water line in a beaker?
3. What makes light waves travel faster in air that in water?
4. What have you learned about reflection and refraction?
5. What have you learned from this experiment?



(Adapted from Halliday, Rensick, and Walker, Chapter 34)

LESSON PLANS

Lesson Plan One

Objective

Student will be learning about and exploring, converging and diverging images using concave and convex lens.

Introduction

A lens is any transparent object having two nonparallel curved surfaces or one plane surface and one curved surface.

Concept Development

With all converging lenses, incident rays parallel to the principal axis focus at a point on the lens axis. The point is called the focal point. The distance from this point to the lens is called the focal length. The students will measure the object distance and image distance to find the focal length by using the lens formula.

Student Practice

Students will explore different types of lenses and images formed by them. Set the lens in front of a rive ray box. Use the rive ray box to flash light through the lens. See how the light rays are changed when you slide rive ray box back and forth. The rays of light become parallel when you move it away. Similarly the rays of light converge and diverge by sliding the rive ray box back and forth.

Assessment

Assessment will be graded on a class presentation made by students on lenses. Students will be assessed on the analysis and experiment on lens.

Closure

This lesson will help the students learn about the properties of lenses. This will help them in understanding the concept of divergent and convergent rays.

Resources

How Things Work, Third Edition, Louis A. Bloomfield
Fundamentals of Physics, Fifth Edition, David Halliday, Robert Rensick
Physics, Holt, Rinehart and Winston (2002)
Modern Physics, John E. Williams, Frederick E. Trinklein, H. Clark, Metcalfe

Lesson Plan Two

Objective
Students will learn and explore incidence, reflection and refraction.

Introduction

A narrow beam of light angles downward from the left and traveling through air encounters a plane glass surface. Part of the light is reflected by the surface. The angle of incidence is angle 1. The angle of reflection is angle 2 and the angle of refraction is angle 3. All angles are measured from the normal. The plane containing the incident ray and the normal is the plane of incidence.

Concept Development

Light traveling through a uniform medium always travels in a straight line. When the light passes through a different medium its path will change. This change in direction of light is called reflection. Smoothness of surface determines the manner in which light is reflected. A rough, textured surface reflects light in many different directions while smooth, shiny surfaces reflect light in one direction only. Refraction is the bending of light as it travels from one medium to another. It occurs when light velocity changes. The ray is bent toward the normal when light moves from a medium in which its speed is higher as compared to the medium in which its speed is lower. The ray is bent away from the normal when light moves from a medium in which its speed is lower as compared to the medium in which its speed is higher.

Student Practice

Students will explore and learn reflection and refraction of light by doing experiments.

1. Set up the glass surface.
2. Shine the flashlight using rive ray box at an angle through the glass surface.
3. Look for the angle of incidence, reflection, and refraction.
4. Repeat the experiment.

Assessment

Assessment will be made on their presentation on incidence, reflection and refraction.

How they can figure out the incident ray?
How they can figure out the reflected ray?
How much of the light was refracted?

Closure

This lesson will help the students learn about incidence, reflection and refraction.

Resources

How Things Work, Third Edition, Louis A. Bloomfield.
Fundamental of Physics, Fifth Edition, David Halliday, Robert Rensick.
Physics, Holt, Rinehart and Winston (2002).

Lesson Plan Three

Objective

Student will learn and explore total internal reflection.

Introduction

Total internal reflection of light from a point source S in glass occurs for all angles of incidence greater than the critical angle. At the critical angle the refracted ray points along the air-glass interface. For angle of incidence greater than this angle, there is no refracted ray and all the light is reflected, this process is called total internal reflection.

Concept Development

Total internal reflection shows the rays of monochromatic light from a point source S in glass incident on the interface between glass and air. This is shown in the figure on the next page where ray a, which is perpendicular to the interface, partially reflects at the interface and the remainder of light travel through the glass with no change in direction. Total internal reflection occurs when light moves along a path from a medium with a higher index of refraction to the medium with a lower index of refraction. At a particular angle of incidence called the critical angle, the refracted ray moves parallel to the boundary, making the angle of refraction equal to 90 degrees.

Student Practice

Students will learn about total internal reflection by doing class presentations.

Students will write a paragraph supported with pictures about total internal reflection.

Assessment

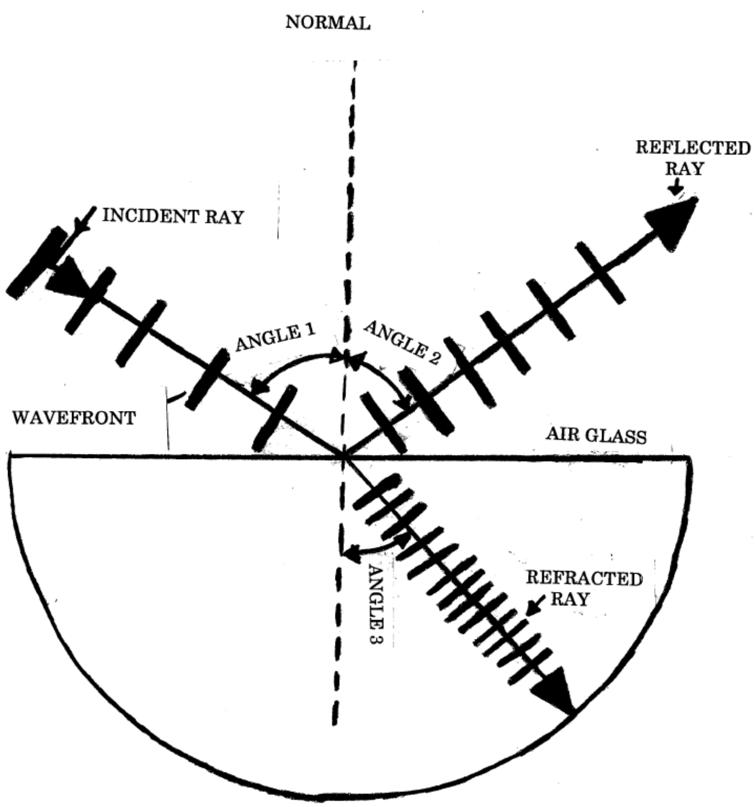
Assessment will be made on class participation and questioning by students.
Why was the light reflected?
What do you think causes internal reflection?

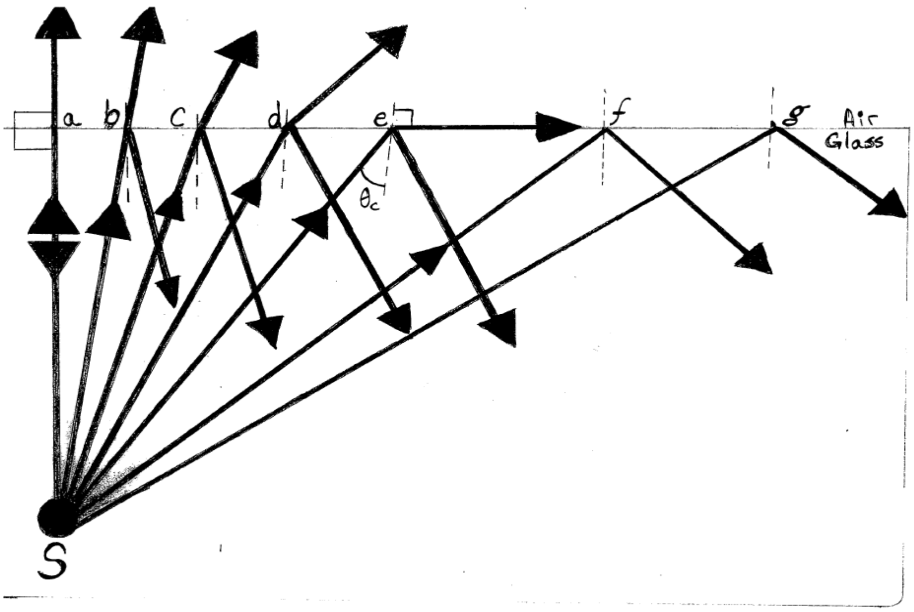
Closure

Learning and summarizing total internal reflection.

Resources

Modern Physics, John E. Williams, Frederick E. Trinklein, H. Clark, Metcalfe
Fundamentals of Physics, Fifth Edition, David Halliday, Robert Rensick
Physics, Holt, Rinehart and Winston (2002).





Total Internal Reflection.

(Adapted from Halliday, Rensick, and Walker, Chapter 34)

Lesson Plan Four

Objectives

Student will learn about and explore the following:

- Real image and virtual image
- Taking picture from a digital camera

Introduction

There are two types of images that can be formed.

Real Images: Real images are those from which light rays actually diverge. A real image can be focused onto a screen.

Virtual Images: Virtual images are those from which light only appears to diverge. An example is your image behind a mirror. Light does not come from behind the mirror.

Student Practice

Students will explore real and virtual image by doing experiments with lenses.

To test a real image, you will need a video camera or any type of digital camera. Take a picture or record the subject. You can put the image on a screen and still have it when the subject isn't present because the light rays actually diverge.

To test a virtual image, you will need a mirror. Stand in front of the mirror and you will see that your image is present. Move away and your image will disappear because the light rays only appear to diverge.

Assessment

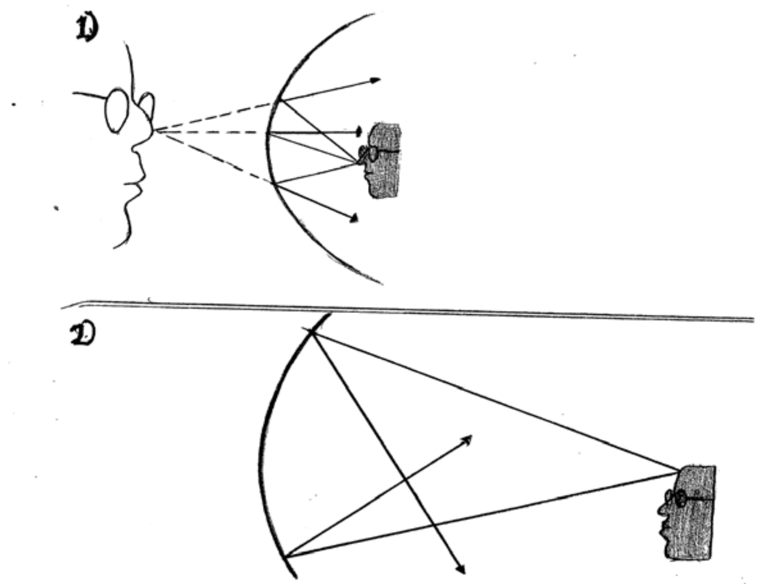
Assessment will be made on the students' participation and presentation on real and virtual images. Students will write a paragraph supported with pictures about real image and virtual image. How is virtual image different from a real image?

Closure

Learning and summarizing real and virtual images.

Resources

Modern Physics, John E. Williams, Frederick E. Trinklein, H. Clark, Metcalfe
Fundamentals of Physics, Fifth Edition, David Halliday, Robert Rensick
Physics, Holt, Rinehart and Winston (2002).



A Virtual and Real image.

(Adapted from Halliday, Rensick, and Walker, Chapter 35)

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