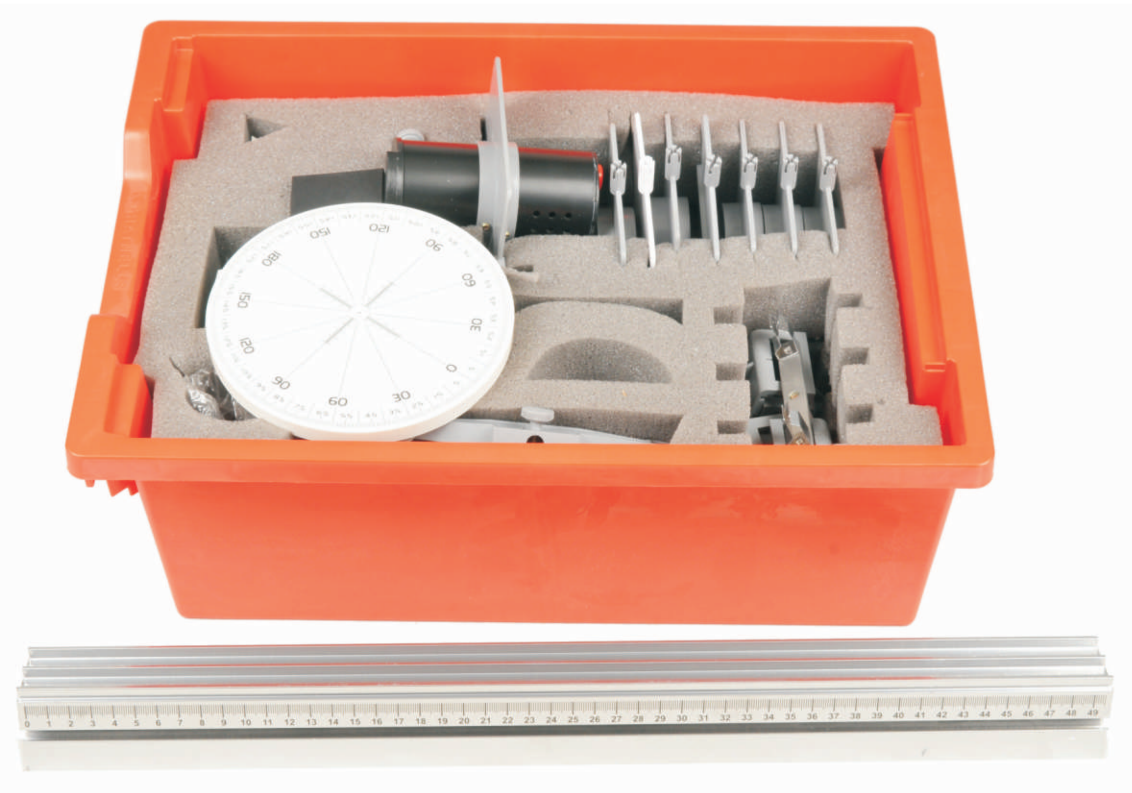
OPTICS KIT

CAT NO. PH 0653



Experiment Guide

ACTIVITIES INCLUDED:

- Diffraction
- Angle of Reflection Using a Plane Mirror
- Refraction of Different Shaped Prisms
- Refraction (Snell's Law)
- Index of Refraction
- Dispersion of Light (Rainbows)
- Dispersion of Infrared Light
- Mixing Colors
- Blocking Colors in a Prism Using Filters
- Study of Concave Mirrors
- Study of Convex Mirrors
- Study of Convex Lenses (Ray Diagrams)
- Study of Concave Lenses (Ray Diagrams)
- Finding the Focal Point of an Unknown Lens
- Magnifying Glasses
- How the Eye Works
- How Glasses Work in Farsighted Vision
- How Glasses Work in Nearsighted Vision
- How a Movie Projector Works
- Projecting Fire

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench	1
Adjustable optic bench feet	2
Sliding optics component holders	5
Slides (red, green and blue filters, a pin hole, a larger pin hole and a picture of a city, an arrow)	1 each
Lamp stand with lamp and adjustable lens	1
Connecting leads 500mm	2
9cm square plane mirror	1
9cm square clear plastic plate	1
Circular table with built in protractor (optics table)	1
Plastic refracting blocks (rectangle, semicircle, right triangle, concave and convex lens)	1 each
Equilateral Prism (25 x 25 mm)	1
Black square stand	1
Voltive candle	1

Small wooden post	1
Plastic cup	1
Plane holder (metal with 2 clips)	1
Slide with single slit	1
Slide with 5 slits	1
Adjustable concave and convex mirror in metal holder	1
Semi-circular dish	1
Slide holders	2
White Screen (10x11 cm)	1
Mounted convex lenses	4
Mounted concave lens	1
Flat condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
Power supply (12V)	1
Matches or lighter	2
Ruler/straight edge	1
Invisible tape	1 roll
Protractor	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
Cheap camera that has no infrared filter	1
Brightly colored paper	1 sheet
Crayons with no paper on them	1
Invisible tape	3 pieces
Computer paper	6 sheets
Sticky tack or clay	½” ball
Protractor	1
Corn oil	¼ cup
Glycerol	¼ cup
Ethyl alcohol	¼ cup
Water	¼ cup
Red pencil	1
Blue pencil	1

SAFE HANDLING OF APPARATUS:

Whenever working with an open flame, make sure all flammable and/or dangling objects are removed from the area and that all hair or ties, etc. are securely fastened and out of the way.

WARNING:

The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

The convex and concave mirrors have very sharp edges. Gloves that are resistant to being cut through should be used to switch between concave and convex mirrors.

Breakable Warning:

Many pieces of this optics bench are fragile, including the bench itself. Do not place this kit under heavy objects, expose to extreme heat or drop or strike the bench in any way.

The lenses and slides in this kit should be handled with care. Do not touch or scratch the surface of these lenses.

When not in use place lenses in the appropriate holders or containers. Do not leave them on the lab table or place other objects on top of them. Handle only the plastic edges of the lenses and slides.

MAINTENANCE REQUIRED:

Lenses may need to be cleaned from time to time to remove dust and finger prints. Clean only with warm soapy water. Use mild soap, or better yet lens cleaner. Rub dry in a single direction with a lint/dirt free cloth. A cloth used to clean glasses is ideal.

DIAGRAM LABELING ALL PARTS:

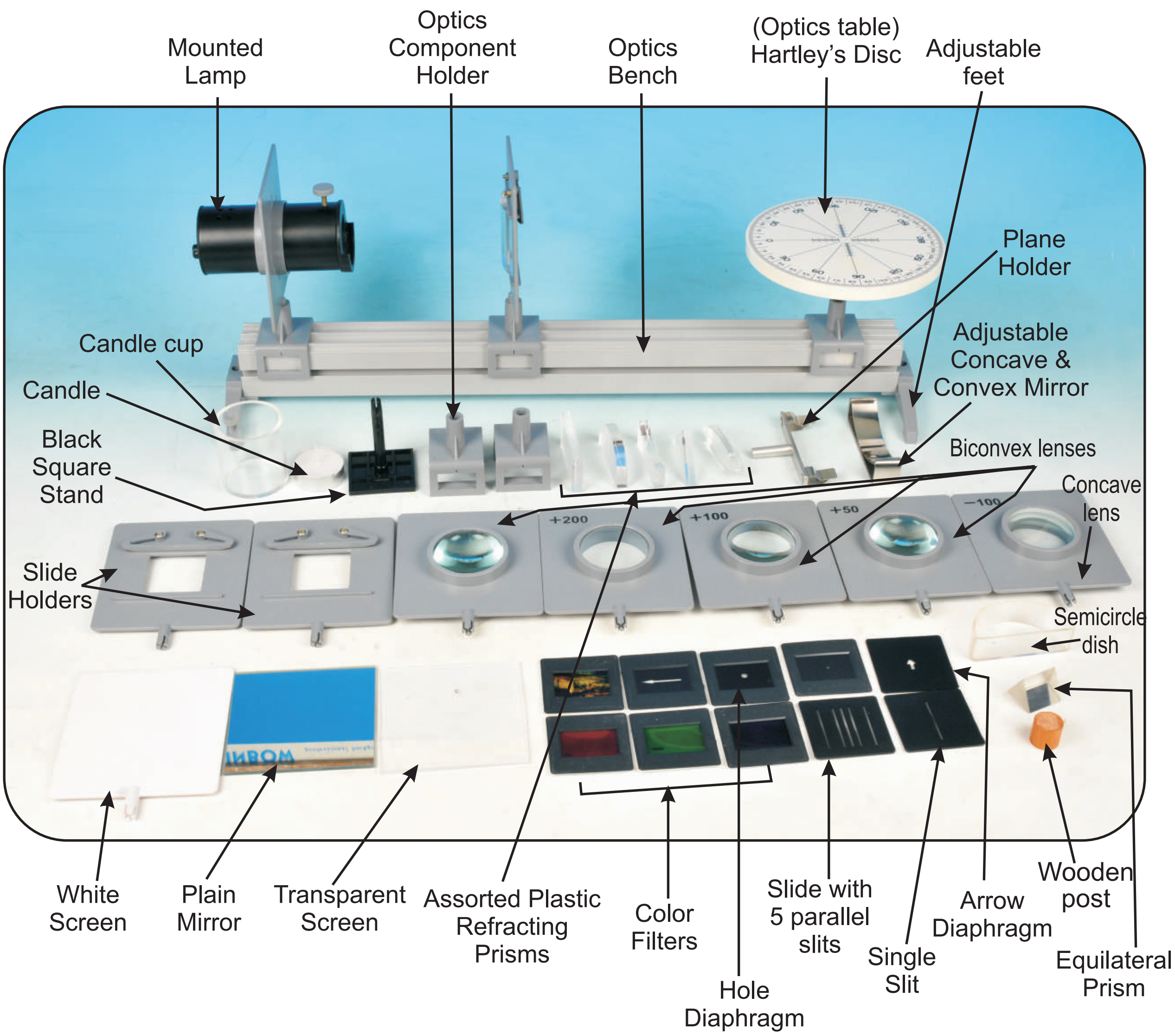


Diagram 1

DIFFRACTION

Diffraction is a wave property where a wave moves around a barrier and spreads out. Diffraction can be seen with sound waves, water (physical) waves, and it also occurs with light.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
White screen	1
Slide with one slit	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Power supply	1
Ruler	1

To demonstrate diffraction set up the optics bench as shown in diagram 2. Place the single slit as close as possible to the lamp.

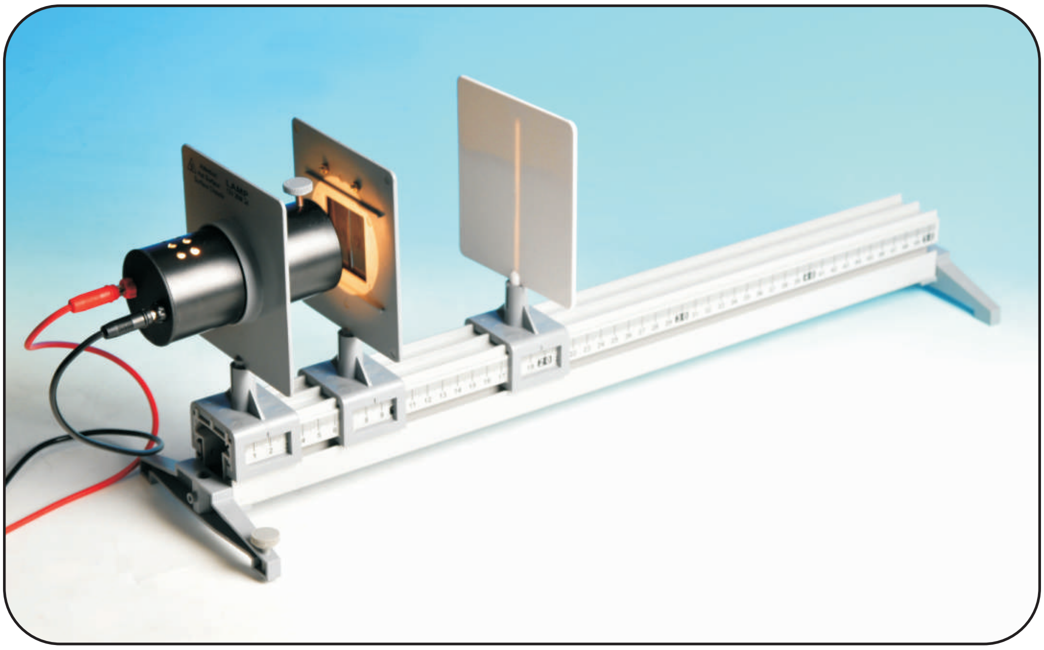


Diagram 2

QUESTIONS FOR STUDENTS:

If a single thin slit is placed in front of the lamp in order to let a thin beam of light through, what would this beam of light look like as it comes out of the slit. Draw a bird's eye view picture of what this would look like in the space provided below.

(Students may draw a wide beam or one single straight line. Some may actually show a beam that gets wider as it comes out of the slit. Any answer is acceptable here. You may want to ask students to share some of their thoughts/ideas)

What happens to the diameter of the beam as it moves farther away from the slit?
(any answer is acceptable here.)

Set up the apparatus as shown in diagram 2.

Have students measure the width of the beam at 10 cm from the slit and again at 40 cm from the slit. *(The students should see that the beam gets wider the further from the slit it is.)*

Will adding another slit or making the slit smaller or bigger make the beam of light parallel instead of getting wider as it goes away from the light source?
(No, doing these things will make no difference.)

The name we give for waves bending around a barrier is called *diffraction* .

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

DIFFRACTION

Diffraction is a wave property where a wave moves around a barrier and spreads out. Diffraction can be seen with sound waves, water (physical) waves, and it also occurs with light.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PREVIEW QUESTIONS:

1. If a single thin slit is placed in front of the lamp in order to let a thin beam of light through, what would beam of light look like as it comes out of the slit. Draw a bird's eye view picture of what this would look like in the space provided below.

2. What happens to the diameter of the beam as it moves farther away from the slit?

PROCEDURE:

1. To demonstrate diffraction set up the optics bench as shown in diagram 2. Place the single slit as close as possible to the lamp.

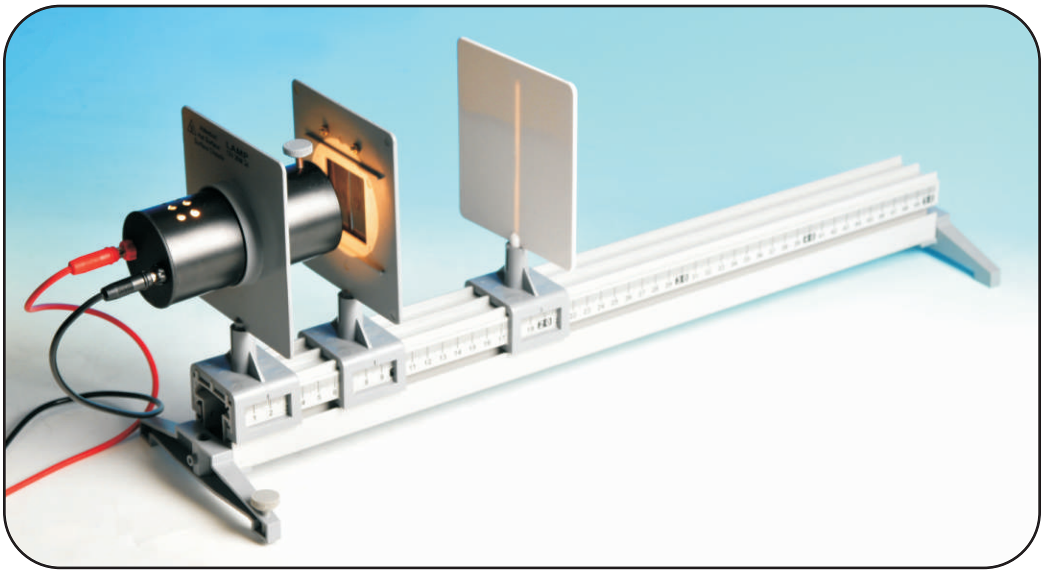


Diagram 2

1. Measure the width of the beam on the white screen at 10 cm from the slit and again at 40 cm from the slit. Record your findings and observations in the space provided below.

2. Will adding another slit or making the slit smaller or bigger make the beam of light parallel instead of getting wider as it goes away from the light source?

3. The name we give for waves bending around a barrier is called _______________.

ANGLE OF REFLECTION USING A PLANE MIRROR

The angle of incidence is the angle that the a beam of light going toward a reflecting surface or medium makes with the normal line on the surface of that medium. The angle of reflection is the angle that the beam reflecting off of that surface makes with the normal line. A normal line is a line perpendicular to the surface of the mirror or medium. For students it would seem natural to measure the angle between the surface of the plane mirror and the incident ray. However, when the surface of reflection is curved, it is not possible to do this. The normal to a curved surface as well as a flat surface can easily be found and therefore we measure our angles to the normal line.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	***Quantity***
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
Optics Table	1
Slide with single slit	1
Plane mirror	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
Power supply	1
Clay	½" ball

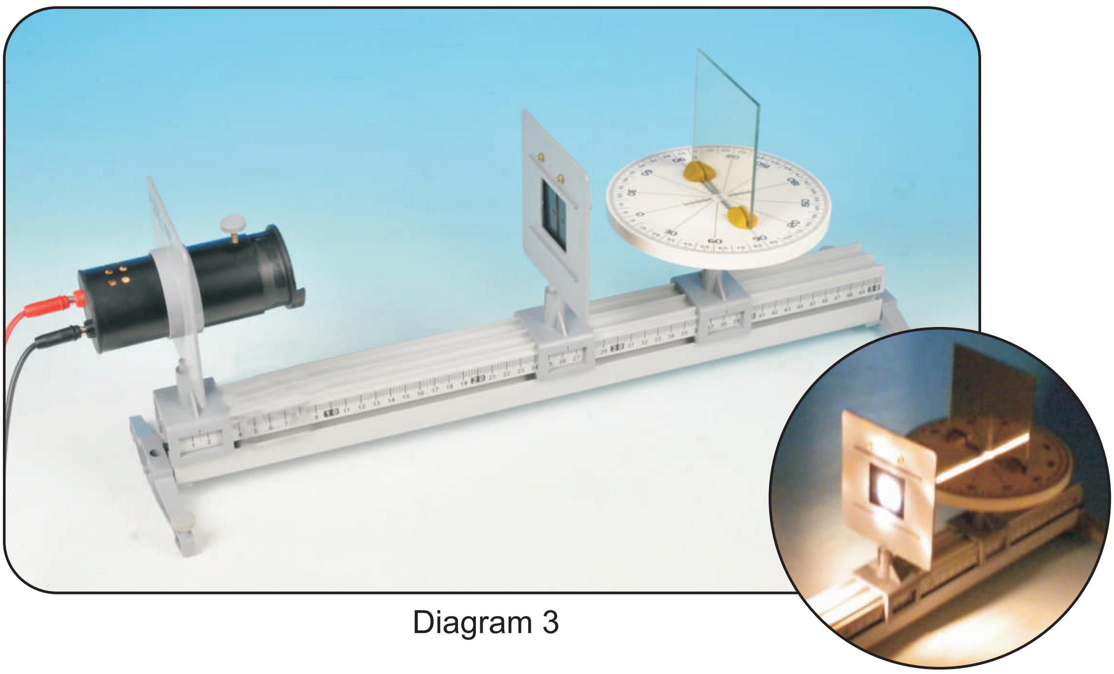


Diagram 3

1. Set up apparatus as shown in diagram 3. Be sure to remove the lens from the lamp. In order to have the incident ray shine directly on the 0 degree mark, the single slit slide may need to be slid either left or right to get proper alignment.

2. Line the mirror up so that the surface of the mirror is perfectly lined up with the 90 degree mark on the optics table. Use two pieces of clay on the edge of the mirror to hold the mirror in place.

3. Tip the mirror slightly forward so that the reflected ray is clearly illuminated on the board.

4. In the data table record your angle of incidence and angle of reflection. The zero degree line will always be 90° from the surface of your plane mirror as you rotate your mirror. This imaginary line 90° from the surface of your plane mirror is called the *normal line*.

5. Rotate the table so that the angle of incidence is 10°, then measure and record your angle of reflection.

6. Continue increasing the angle of incidence by 10° increments until you reach 80°, and continue to record both your angle of incidence and reflection.

DATA TABLE:

Angle of Incidence (degrees)	*Angle of Reflection (degrees)*
0	0
10	10
20	21
30	30
40	40
50	48
60	60
70	68
80	82

Make a rule that describes how the angle of incidence affects the angle of reflection:
(The angle of incidence is always equal to the angle of reflection)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

ANGLE OF REFLECTION USING A PLANE MIRROR

BACKGROUND:

The angle of incidence is the angle that the a beam of light going toward a reflecting surface or medium makes with the normal line on the surface of that medium. The angle of reflection is the angle that the beam reflecting off of that surface makes with the normal line. A normal line is a line perpendicular to the surface of the mirror or medium.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	***Quantity***
Optics Bench with attached feet	1
Sliding Optics Bench Components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
Optics Table	1
Plane mirror	1
Single Slit Slide	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
Power supply 12V	1
Clay	½" ball

1. Set up apparatus as shown in diagram 3. Be sure to remove the lens from the

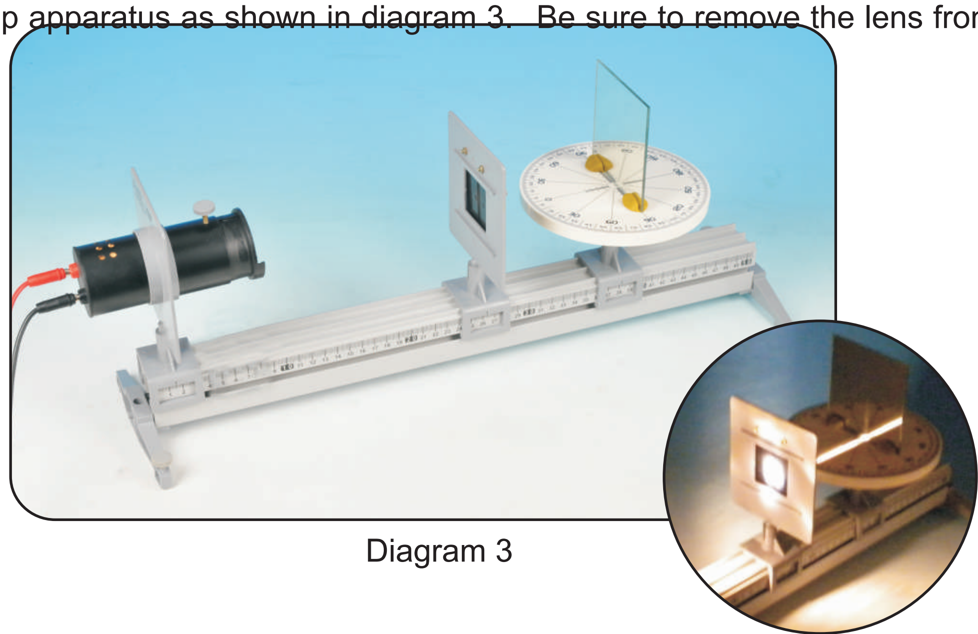


Diagram 3

lamp. In order to have the incident ray shine directly on the 0 degree mark, the single slit slide may need to be slid either left or right to get proper alignment.

2. Line the mirror up so that the surface of the mirror is perfectly lined up with the 90 degree mark on the optics table. Use two pieces of clay on the edge of the mirror to hold the mirror in place.

3. Tip the mirror slightly forward so that the reflected ray is clearly illuminated on the board.

4. In the data table record your angle of incidence and angle of reflection. The zero degree line will always be 90° from the surface of your plane mirror as you rotate your mirror. This imaginary line 90° from the surface of your plane mirror is called the ____________________.

5. Rotate the table so that the angle of incidence is 10°, then measure and record your angle of reflection.

6. Continue increasing the angle of incidence by 10° increments until you reach 80°, and continue to record both your angle of incidence and reflection.

DATA TABLE:

Angle of Incidence (degrees)	*Angle of Reflection (degrees)*

Make a rule that describes how the angle of incidence affects the angle of reflection:

REFRACTION OF DIFFERENT SHAPED PRISMS

BACKGROUND:

What happens to light beam when it travels through a medium instead of around it or being reflected off of it? As a beam of light travels from one medium to another it speeds up or slows down. As this happens, the direction the wave is traveling also changes. This bending of the wave and speed change is called refraction.

Trace each of the five prisms on blank piece of paper for your students. Then use the parallel slit slide to trace five beams of light going towards the slide at any angle you think will be interesting for the students. Make sure to put the flat side of the slide down so a pencil or pen can reach the paper on the other side of the slit. Photocopy this sheet with enough for each student plus a few extra in case some students want to redo their diagrams.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
Optics Table	1
Slide with five slits	1
Different shaped prisms	5
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
White paper	1
Red pencil	1
Blue pencil	1
Straight edge	1
12 V power supply	1

Have students predict what a beam of parallel rays will look like as they travel through the prisms by drawing their predicted rays with a blue pencil and ruler. Then have the students set up the optics bench as shown in diagram 4 and record the position of the actual rays by placing a dot where each of the five rays leave the prism and another dot about 1" away from the prisms' surface along the refracted rays. .

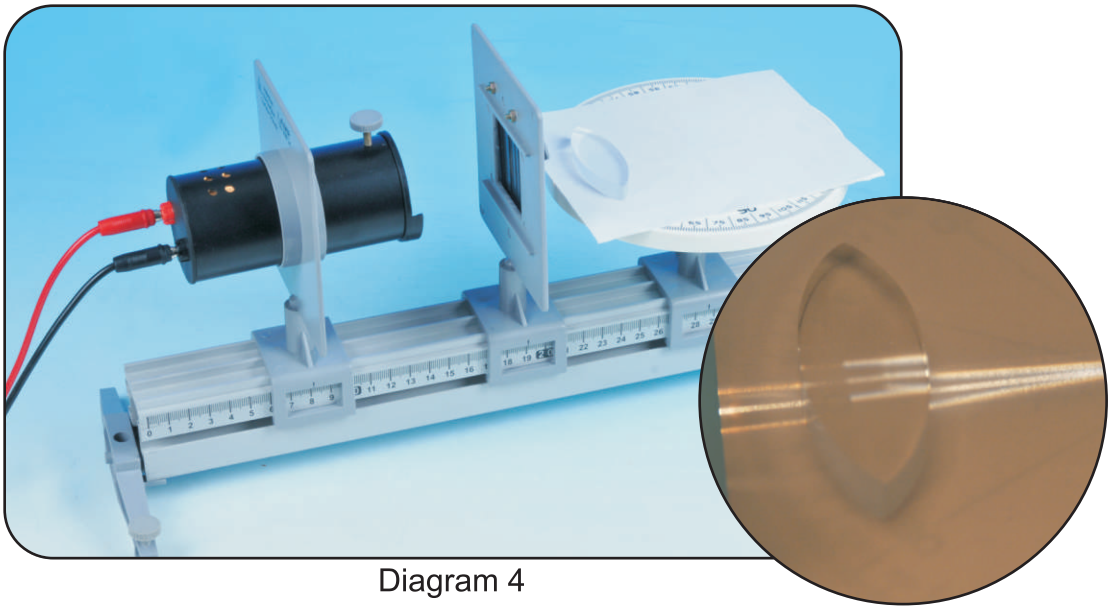


Diagram 4

Diagram 5

Students can then use a straight edge and their pencil to reconstruct where the rays were both inside the prism and the direction they took as they left the prism. As shown with the triangular prism in diagram 5.

FOLLOW UP QUESTIONS:

1. What happened to the beams as they traveled from air into the prism?
   (the beams changed direction)
2. Does rotating the prism change how much the light bends?
   (It changes the direction of the final beam, but not the angle it bends.)
3. Does the light bend only when entering the prism, only when exiting or both?
   (both)
4. Does the light bend towards or away from the normal when entering the prism?
   (Towards)
5. Does the light bend towards or away from the normal when exiting the prism?
   (Away)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

REFRACTION OF DIFFERENT SHAPED PRISMS

BACKGROUND:

What happens to light beam when it travels through a medium instead of around it or being reflected off of it? As a beam of light travels from one medium to another it speeds up or slows down. As this happens, the direction the wave is traveling also changes. This bending of the wave and speed change is called refraction.

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PROCEDURE:

1. On the sheet provided by your teacher is the outline of five different prisms. There are five parallel beams of light incident on your prisms are represented by the five rays traveling towards each outline. With a blue colored pencil and straight edge, predict the path each light beam will take as it passes through a prism of that shape. Draw the rays on your paper.
2. Set up your optics bench as shown in diagram 5. Put the five parallel beams slide as close to the optics table as possible.

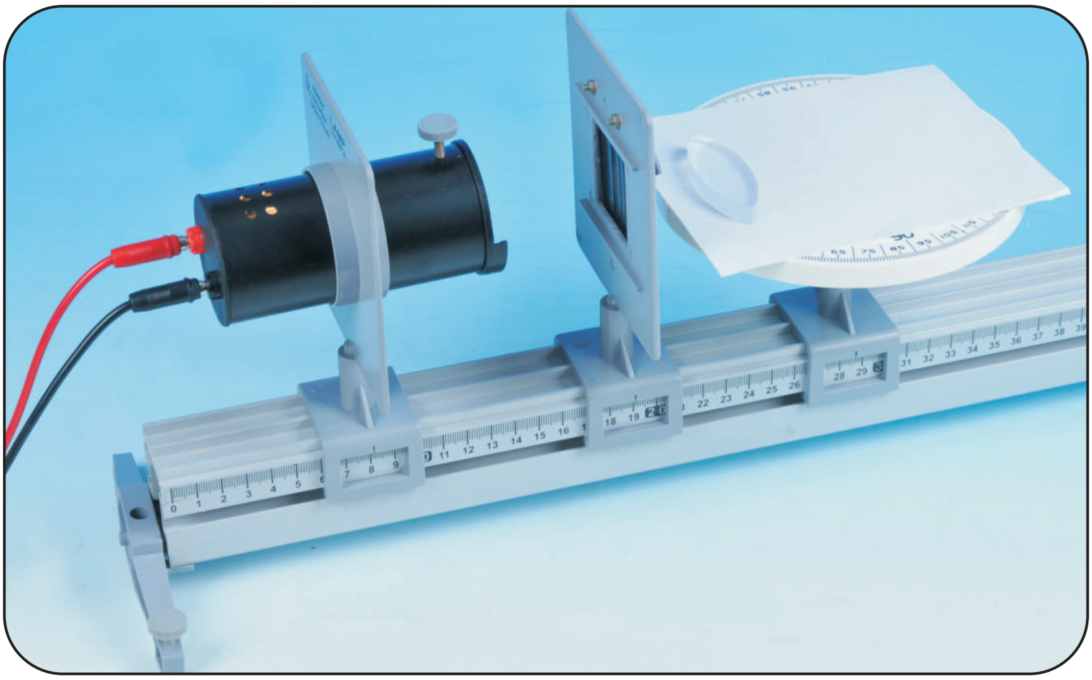

Diagram 4

3. Place the correct shaped prism exactly over the outline of paper with your rays on it.
4. Line the incident rays from the parallel slits up with the incident rays drawn by your teacher on the paper so that the actual incident rays are directly on top of the drawn incident rays.
5. With a red pencil place a dot on each of the five points where the rays leave the prism.
6. Place a second dot on top of each refracted ray about 1” from where the ray left the prism. Do this for each refracted ray.
7. Then use a straight edge and pencil to reconstruct where the rays were both inside the prism and the direction they took as they left the prism. Draw a straight line from the point where the ray enters the prism to the point where the ray leaves the prism for each ray. Next draw a straight line from where the ray leaves the prism to the dot you made about an inch away from where the ray left. Do this for each ray.

FOLLOW UP QUESTIONS:

1. What happened to the beams as they traveled from air into the prism?

2. Does rotating the prism change how much the light bends?

3. Does the light bend only when entering the prism, only when exiting or both?

4. Does the light bend towards or away from the normal when entering the prism?

5. Does the light bend towards or away from the normal when exiting the prism?

REFRACTION (SNELL'S LAW)

BACKGROUND:

Traveling through different medium causes a light ray to bend to different angles. Each transparent medium will speed up or slow down a light wave a different amount. Snell's Law states that the index of refraction of the first medium (n_1) times the sine of the incident angle ($_1$) is equal to the index of refraction of the second medium (n_2) times the sine of the refracted angle ($_2$):

Snell's Law:

$$n_1 \sin {}_1 = n_2 \sin {}_2$$

Absolute Indices of Refraction for a frequency = 5.09 × 1014 Hz)

Air 1.00	Corn oil 1.47	Diamond 2.42
Ethyl alcohol 1.36	Glass, crown 1.52	Glass, flint 1.66
Glycerol 1.47	Lucite 1.50	Quartz, fused 1.46
Sodium chloride 1.54	Water 1.33	Zircon 1.92

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
Optics Table	1
Slide with single slit	1
Rectangular prism	1
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
White paper	1
Straight edge	1
12 V power supply	1
Protractor	1

1. Use the rectangular shaped block and set up the optics bench as shown in Diagram 6.

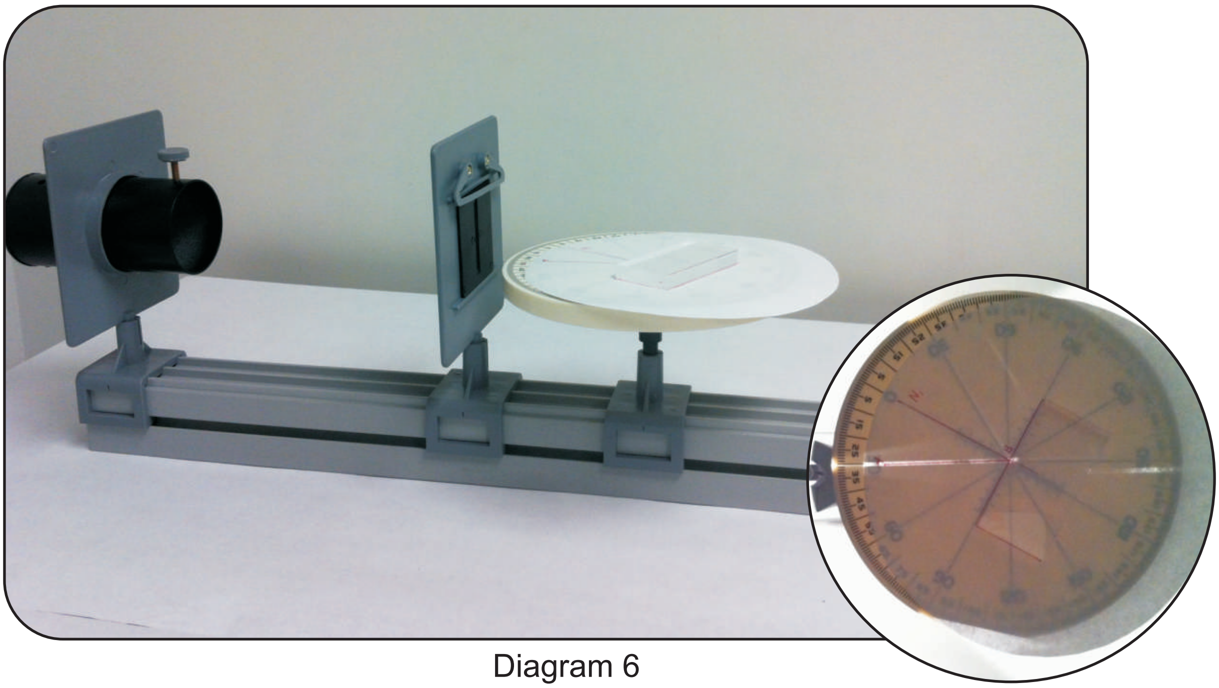

Diagram 6

2. Place the rectangular prism in the center of the paper and trace along all four sides.

3. Remove the block and draw a normal line to one of the long sides of the rectangular prism and label this line N1. Label the point where the block and the normal line intersect B.

4. Draw a line at a 30 degree angle from N1 to point B and label this starting point A.

5. Place the paper on the optics bench and place the rectangular prism on the paper exactly where it was traced.

6. Line the side of the prism up with the 90 degree line on the optics bench.

7. Rotate the paper and prism until the light shines directly on top of the line AB.

8. Place one dot where the light ray leaves the block on the other side and a second dot somewhere on top of the ray about 1” from where the ray leaves the prism on the other side.

9. Remove your prism and paper from the optics bench and label the point where the light ray immerged from the prism as point C and label the second point where the light ray was 1” from where it emerged at point D.

10. At point C draw a second normal line to the surface of the prism and label this N2.

11. With a straight edge connect dots B and C.

12. Your final picture should look like diagram 7.

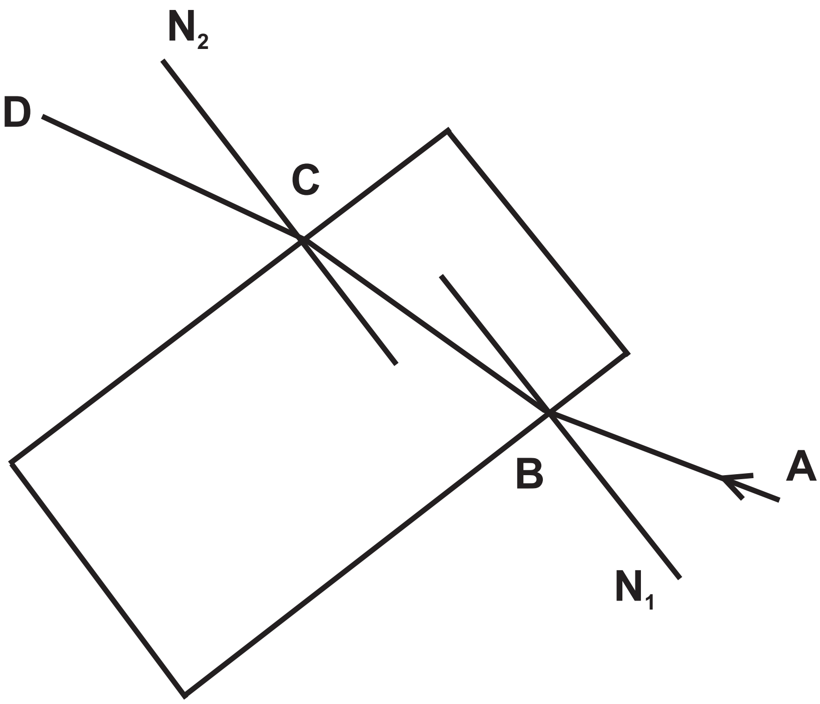

Diagram 7

13. Measure the angles ABN_1, CBN_1, BCN_2, and DCN_2 and write those values on the space provided below.

ABN1___30°____ CBN1___16°_____ BCN2__16°______ DCN2__30°______

14. Use Snell's Law to calculate the index of refraction of the prism.

$n_1 \sin {}_1 = n_2 \sin {}_2$

$(1.00)(\sin 30^{\circ}) = n_2 \sin(16^{\circ})$

$n_2 = 1.8$ (this is a typical student response, answers may vary $\pm$ .2 depending on how students measure)

FOLLOW UP QUESTIONS:

1. What was the index of refraction of your prism? *(1.8)*

2. How did the measured angle ABN1 compare to the angle DCN2? Why do you think you got this result? *(The angles have the same measure because the index of refraction of air is the same on both sides of the prism)*

3. When traveling from air into plastic, did the ray bend toward or away from the normal? *(towards)*

4. When traveling from plastic into air, did the ray bend towards or away from the normal? *(away)*

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

REFRACTION (SNELL'S LAW)

BACKGROUND:

Traveling through different medium causes a light ray to bend to different angles. Each transparent medium will speed up or slow down a light wave a different amount. Snell's Law states that the index of refraction of the first medium (n_1) times the sine of the incident angle ($_1$) is equal to the index of refraction of the second medium (n_2) times the sine of the refracted angle ($_2$):

Snell's Law:

$$n_1 \sin \ _1 = n_2 \sin \ _2$$

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1. Use the rectangular shaped block and set up the optics bench as shown in the diagram 6.

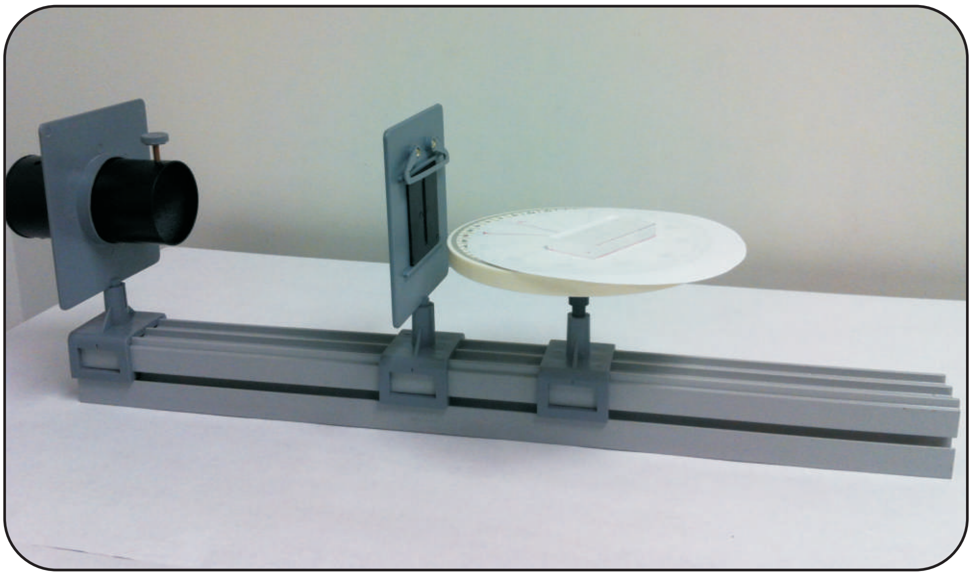


Diagram 6

2. Place the rectangular prism in the center of the paper and trace along all four sides.
3. Remove the block and draw a normal line to one of the long sides of the rectangular prism and label this line N1. Label the point where the block and the normal line intersect B.
4. Draw a line at a 30 degree angle from N1 to point B and label this starting point A.
5. Place the paper on the optics bench and place the rectangular prism on the paper exactly where it was traced.

6. Line the side of the prism up with the 90 degree line on the optics bench.
7. Rotate the paper and prism until the light shines directly on top of the line AB.
8. Place one dot where the light ray leaves the block on the other side and a second dot somewhere on top of the ray about 1” from where the ray leaves the prism on the other side.
9. Remove your prism and paper from the optics bench and label the point where the light ray immerged from the prism as point C and label the second point where the light ray was 1” from where it emerged at point D.
10. At point C draw a second normal line to the surface of the prism and label this N2.
11. With a straight edge connect dots B and C.
12. Measure the angles ABN1, CBN1, BCN2, and DCN2 and write those values on the space provided below.

    ABN1______ CBN1_______ BCN2_______ DCN2_______

13. Use Snell's Law to calculate the index of refraction of the prism. Show all work in the space provided below including formula and substitution with units.

FOLLOW UP QUESTIONS:

1. What was the index of refraction of your prism?
2. How did the measured angle ABN1 compare to the angle DCN2? Why do you think you got this result?
3. When traveling from air into plastic, did the ray bend toward or away from the normal?
4. When traveling from plastic into air, did the ray bend towards or away from the normal?

INDEX OF REFRACTION

BACKGROUND:

As a light ray travels from one medium to another it speeds up or slows down. As the light speeds up or slows down it changes direction (bends). How far the light bends is a property of the medium in which it travels, and the ratio of the speed of the object in that medium to the speed of light in a vacuum is called the index of refraction, or the refractive index. This number is has no units and is commonly represented by “n” in formulas and equations. In this experiment students can study the index of refraction of certain liquids. As an extension, a teacher can also give the index of refraction of certain medium and have the students identify the medium using a reference table. The following fluids work well for this experiment:

Water – 1.33, corn oil – 1.47, and ethyl alcohol – 1.36, Glycerol- 1.47

A teacher may disguise the color of the liquids without changing the index of refraction too much by adding food coloring to the liquids. If using ethyl alcohol, glycerol or other chemicals, make sure that all proper safety procedures are followed such as wearing safety goggles and working in a well-ventilated area.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Slide holder	1
Optics Table	1
Slide with single slit	1
Semicircular Dish	1
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Corn Oil	Enough to fill the dish
12 V power supply	1
Glycerol	Enough to fill the dish
Water	Enough to fill the dish
Ethyl Alcohol	Enough to fill the dish

Have students make a prediction: Before you are three liquids, as light passes through these liquids, the light will bend based on the index of refraction. In the space provided below, make a hypothesis and list the liquids in order from highest index of refraction to lowest index of refraction. Justify your reasoning.

HYPOTHESIS:

(Anything is acceptable here. Allow students to pour some of the liquids out, the glycerol is very thick, while the ethyl alcohol is thin and runny. You may want to do several different liquids and give each group of students a different liquid to report back to the class on or you may want to have each group test three different liquids on their own.)

PROCEDURE:

1. Set up your apparatus as shown in diagram 8. Place your semicircular dish so the flat edge is exactly lined up and centered on the 90° line as shown in the diagram.

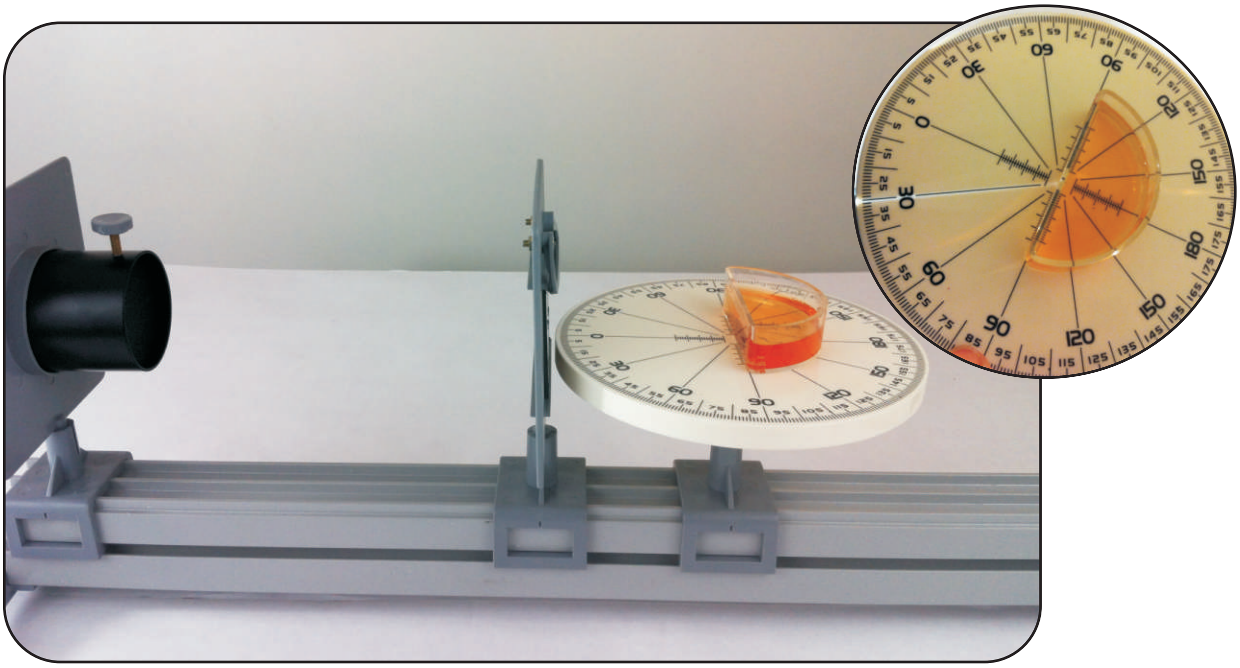


Diagram 8

2. Add your given liquid to the semi-circle dish and record its name on the data table. Fill to about 1/4" from the top of the dish.
3. Start with the beam of light lined up exactly on the 0° line. You may need to move your single slit either left or right in order to get the beam of light to travel exactly on top of the 0° line.
4. Record your angle of incidence (in this case 0°) and your angle of refraction (also 0°) in the data table provided.
5. Rotate the optics table 10° and record the value of the refracted ray. Continue to increase the angle of incidence until you have at least 6 good data points spaced out between 0° and 60°. Two refracted rays may appear. This is because the top

of the dish does not contain liquid, you can get rid of the second ray by taking a sheet of paper or your hand and slowly covering the top of the slit until one of the rays disappears.

DATA TABLE:

Liquid: _Corn oil_

Angle of incidence (degrees)	*Angle of refraction (degrees)*
0	0
5	3.5
15	10
25	17
30	20
40	27
50	31

DATA ANALYSIS:

1. Use Snell's Law to find the index of refraction for corn oil for each of your angles. Show one sample calculation below showing all work including formula and substitution with units.

$$n_1\sin\ _1 = n_2\sin\ _2$$

$$(1.00)(\sin 30^\circ) = n_2\sin(20^\circ)$$

n_2=1.46 (this is a typical student response, answers may vary $\pm$.5 depending on how students measure)

2. What is your average index of refraction?

Angle of incidence (°)	*Angle of refraction (°)*	*Sin (angle of incidence)*	*Sin (angle of refraction)*	*Incident in radians*	*Refracted in radians*	*n2=Sin I/ Sin R*
0	0	0	0	0	0	#DIV/0!
5	3.5	0.08715574	0.0610485	0.087266	0.061087	1.427647
15	10	0.25881905	0.1736482	0.261799	0.174533	1.490479
25	17	0.42261826	0.2923717	0.436332	0.296706	1.445483
30	20	0.5	0.3420201	0.523599	0.349066	1.461902
40	27	0.64278761	0.4539905	0.698132	0.471239	1.415861
50	31	0.76604444	0.5150381	0.872665	0.541052	1.487355

Average: 1.454788

3. What are the values of the index of refraction for the other substances that were tested? Use these values to put the substances in order from highest index of refraction to lowest.

(Teachers may want students to answer this question using their own data and the data of their classmates before the accepted values are given to the students. A typical response for this question would be … Glycerol and corn oil were too close to be determined which was higher since one group found glycerol to be 1.45, and one found glycerol to be 1.50, another group found corn oil to be 1.40 and 1.52, however water had a lower index of refraction at 1.28.)

4. What is the given value for the index of refraction for your substance? What is your percent error?

The given value for the index of refraction of corn oil is 1.47, and the percent error is 1.4%

5. In the previous "Snell's Law" experiment, the rectangular prism refracts light as the light beam enters the prism and again the light is refracted when it leaves the prism. Why is the light not refracted when it leaves the semicircular dish?

(The light is refracted, the light speeds up at is leaves the dish, however, since the outside of the dish is a semi-circle, the light always leaves the semi-circle at an angle of 0^o *to the normal, so the light ray does not bend.)*

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

INDEX OF REFRACTION

BACKGROUND:

As a light ray travels from one medium to another it speeds up or slows down. As the light speeds up or slows down it changes direction (bends). How far the light bends is a property of the medium in which it travels, and the ratio of the speed of the object in that medium to the speed of light in a vacuum is called the index of refraction, or the refractive index. This number is has no units and is commonly represented by "n" in formulas and equations. In this experiment students can study the index of refraction of certain liquids. As an extension, a teacher can also give the index of refraction of certain medium and have the students identify the medium using a reference table. The following fluids work well for this experiment:

Water – 1.33, corn oil – 1.47, and ethyl alcohol – 1.36, Glycerol- 1.47

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

HYPOTHESIS:

Before you are three liquids, as light passes through these liquids, the light will bend based on the index of refraction. In the space provided below, make a hypothesis and list the liquids in order from highest index of refraction to lowest index of refraction. Justify your reasoning.

PROCEDURE:

1. Set up your apparatus as shown in diagram 8. Place your semicircular dish so the flat edge is exactly lined up and centered on the 90° line as shown in the diagram.

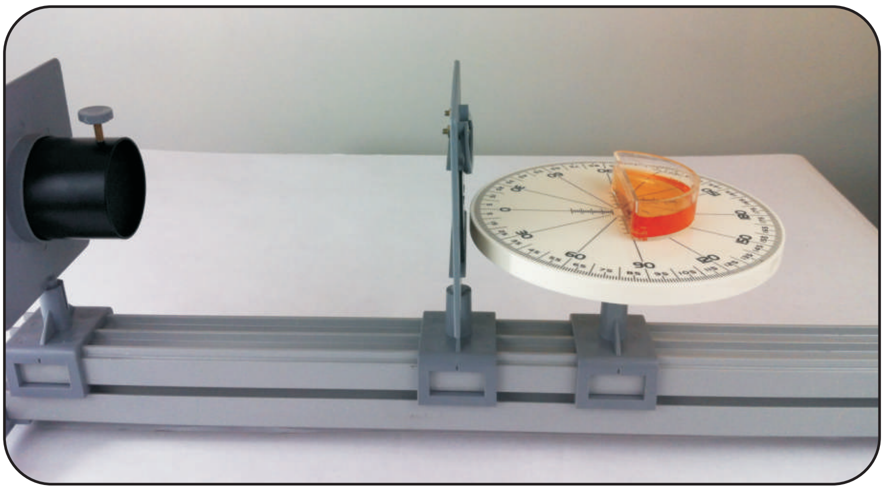


Diagram 8

2. Add your given liquid to the semi-circle dish and record its name on the data table. Fill to about 1/4" from the top of the dish.
3. Start with the beam of light lined up exactly on the 0° line. You may need to move your single slit either left or right in order to get the beam of light to travel exactly on top of the 0° line.
4. Record your angle of incidence (in this case 0°) and your angle of refraction (also 0°) in the data table provided.
5. Rotate the optics table 10° and record the value of the refracted ray. Continue to increase the angle of incidence until you have at least 6 good data points spaced out between 0° and 60°. Two refracted rays may appear. This is because the top of the dish does not contain liquid, you can get rid of the second ray by taking a sheet of paper or your hand and slowly covering the top of the slit until one of the rays disappears.

DATA TABLE:

Liquid: ________________________

Angle of incidence (degrees)	*Angle of refraction (degrees)*

DATA ANALYSIS:

1. Use Snell's Law to find the index of refraction for corn oil for each of your angles. Show one sample calculation below showing all work including formula and substitution with units.

2. What is your average index of refraction?

3. What are the values of the index of refraction for the other substances that were tested? Use these values to put the substances in order from highest index of refraction to lowest.

4. What is the given value for the index of refraction for your substance? What is your percent error?

5. In the previous "Snell's Law" experiment, the rectangular prism refracts light as the light beam enters the prism and again the light is refracted when it leaves the prism. Why is the light not refracted when it leaves the semicircular dish?

DISPERSION OF LIGHT (RAINBOWS)

The separation of visible light into its component colors by means of a prism, usually a triangular prism, is called dispersion. Visible light, also known as white light, is really a mix of many different colors. Each color has a slightly different index of refraction which means that some colors bend or change direction more than others when traveling from one medium to another. Light with a red wavelength (electromagnetic waves that have a wavelength of about 700nm) do not bend as much as light with a violet wavelength (electromagnetic waves that have a wavelength of about 400 nm). White light separated by a prism always separates the colors in the following order from least bent to most bent: red, orange, yellow, green, blue, and violet.

EQUIPMENT NEEDED:

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	4
Lamp mounted with red and black leads and lens removed	1
Black square stand	1
Equilateral triangular prism	1
Slide with single slit	1
Slide holder	1
White screen	1
Flat Condenser	1

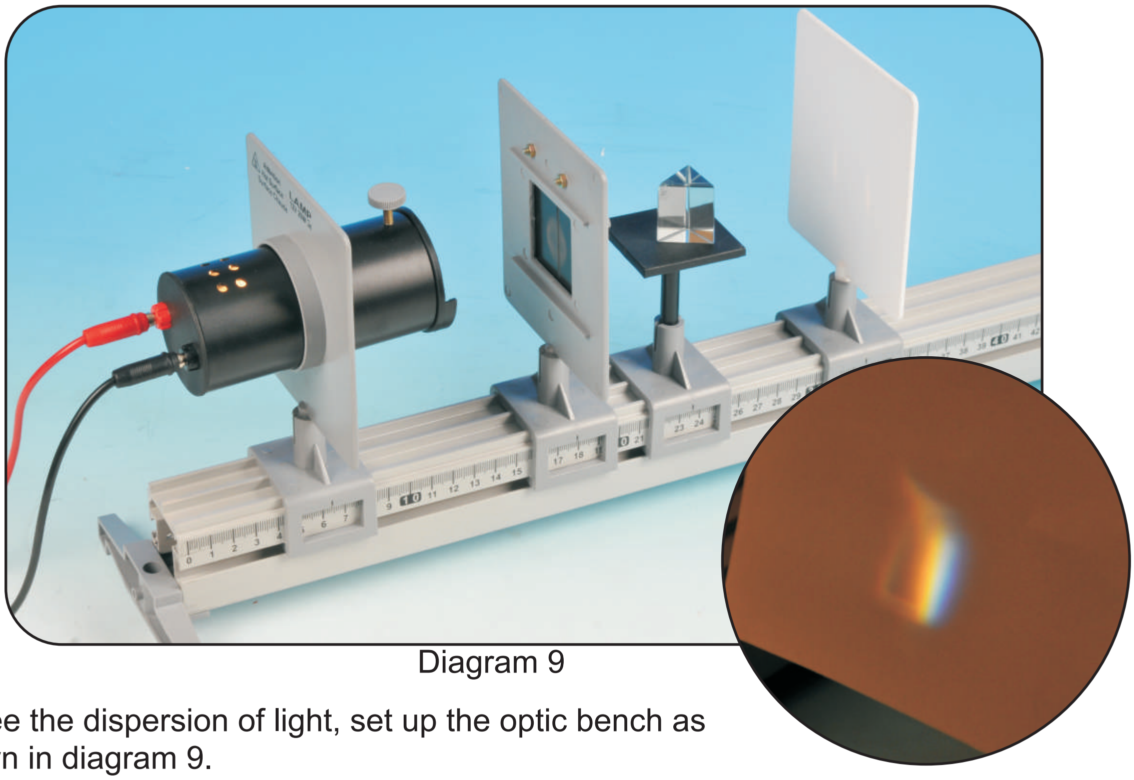


Diagram 9

To see the dispersion of light, set up the optic bench as shown in diagram 9.

The rainbow may be off to one side or another past the white screen. The screen can either be removed from the optics bench to see the rainbow, or the screen can be enlarged by folding a sheet of white paper over the top of the screen.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	4
Lamp mounted with red and black leads and lens removed	1
Small square stand	1
Equilateral triangular prism	1
Slide with single slit	1
Slide holder	1
White screen	1
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
White, stiff piece of paper	1
Power supply	1
Invisible tape	2 pieces
Camera with no infrared filter	1

Set up your apparatus as shown in diagram 8 and add a sheet of paper over the screen that can be drawn on. Rotate the prism so the rainbow is as wide as possible and mark with a pencil the exact spot where you can no longer see the red of the rainbow with your eyes. Then look at the rainbow though a camera that has no infrared filter on it. Most cheap cameras, including cell phones do not have a filter. As you look through the camera look at the line that shows the edge of the red color. You will notice that the camera picks up some red color past this mark. The camera picks up some infrared radiation, which is also refracted by the prism and converts it to visible light for the camera screen.

MIXING COLORS

When using paint, the primary colors of paint are yellow, magenta and cyan. Primary colors are used to make every possible color of paint. However when mixing light, the primary colors used are red, green and blue light. Mixing all three together will make white light. Students typically have experience mixing paint, but not mixing light. It is often surprising to them how the colors combine.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	2 (or 3)
Sliding optics bench components holders	5 (or 7)
Lamp mounted with red and black leads and lens removed	2 (or 3)
Red color slide	1
Blue color slide	1
Green color slide	1
Slide holder	2 (or 3)
White screen	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	2 (or 3)

Set up the apparatus as shown in diagram 10. Have students predict which colors will appear by mixing the two colors of light, and then have students record their actual observations. You will need three separate light sources, one source for red, one for green and one for blue. To mix the colors, shine both colors on the white screen at the same time.

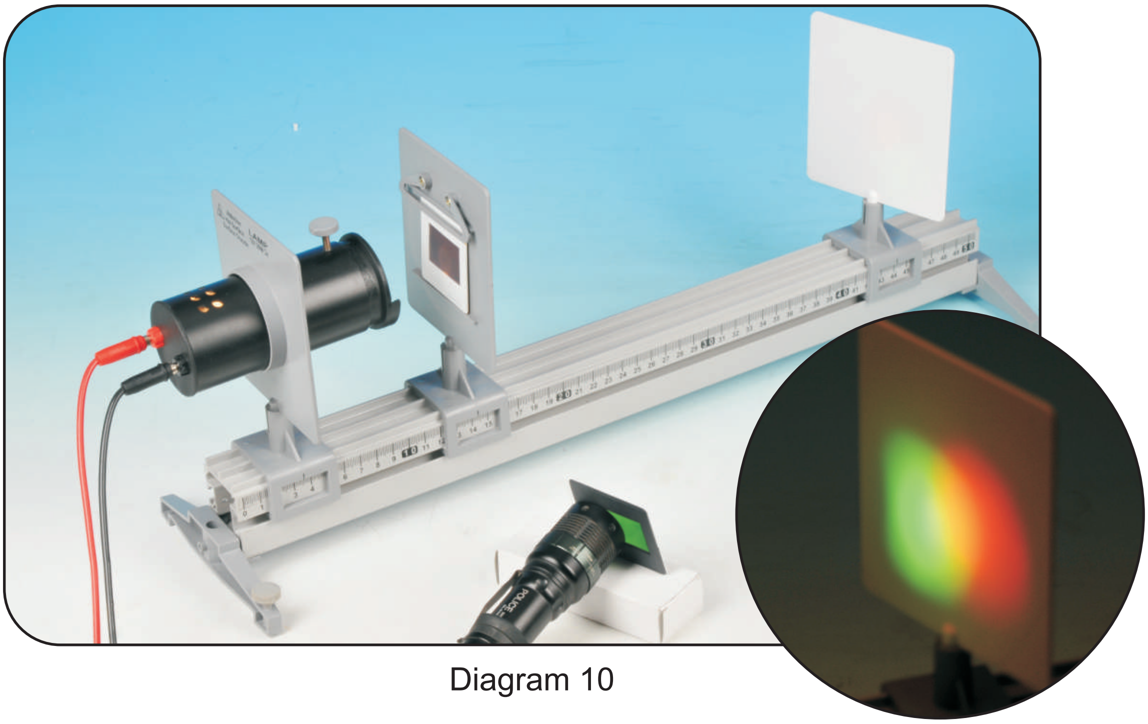


Diagram 10

Colors mixed	*Predicted Color*	*Color Made*
Red and Blue	Purple (typical response)	magenta
Red and Green	Brown (typical response)	yellow
Green and Blue	Cyan (typical response)	cyan
Red Green & Blue	Black (typical response)	white

BLOCKING COLORS IN A PRISM USING FILTERS

BACKGROUND:

When light hits a surface, three things can happen: the light can be reflected, absorbed, or transmitted. A combination of reflection and absorption happen on most opaque surfaces. When a piece of paper looks “red” to our eyes, is it creating red light? No, it's absorbing everything but the red color. The red color that is reflected is what our eyes detect and see, therefore the paper looks red. The paper only looks red when light containing the color red is shining on it. If very little light is shining, the paper looks black, or you may not even see the paper depending on how little light there is.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	4
Lamp mounted with red and black leads and lens removed	1
Red color slide	1
Blue color slide	1
Green color slide	1
Slide holder	1
Small black table	1
White screen	1
Equilateral prism	1
Slide with single slit	1
Slide holder	1
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	1
Brightly colored paper or index cards	1
Crayons or Markers of different colors	1

Students can observe how colors cannot easily be seen in low light situations by using some brightly colored index cards or pieces of paper and some crayons with the labels taken off. First turn off the lights in the room so the room is very dark. Then hand the students a piece of paper and a crayon. Have the students write which color they think their paper is with the crayon, and then write the color they think the crayon is on their paper. After the students are done, turn the lights on and they will be surprised at how little they can discern color in low light situations.

A white surface reflects all colors. Use the white screen in the kit and the equilateral prism to create a rainbow on the white screen. Set up the apparatus as shown in diagram 10. Introduce the appropriate slides between the single slit and the prism. The slides have a wide band of plastic around the top and a thin band around the sides. Hold the slides so the thin band is in the middle of the rainbow. That way the top half of the rainbow shows the filtered light and directly below the band, the entire rainbow appears. This is shown in diagram 11 as well.

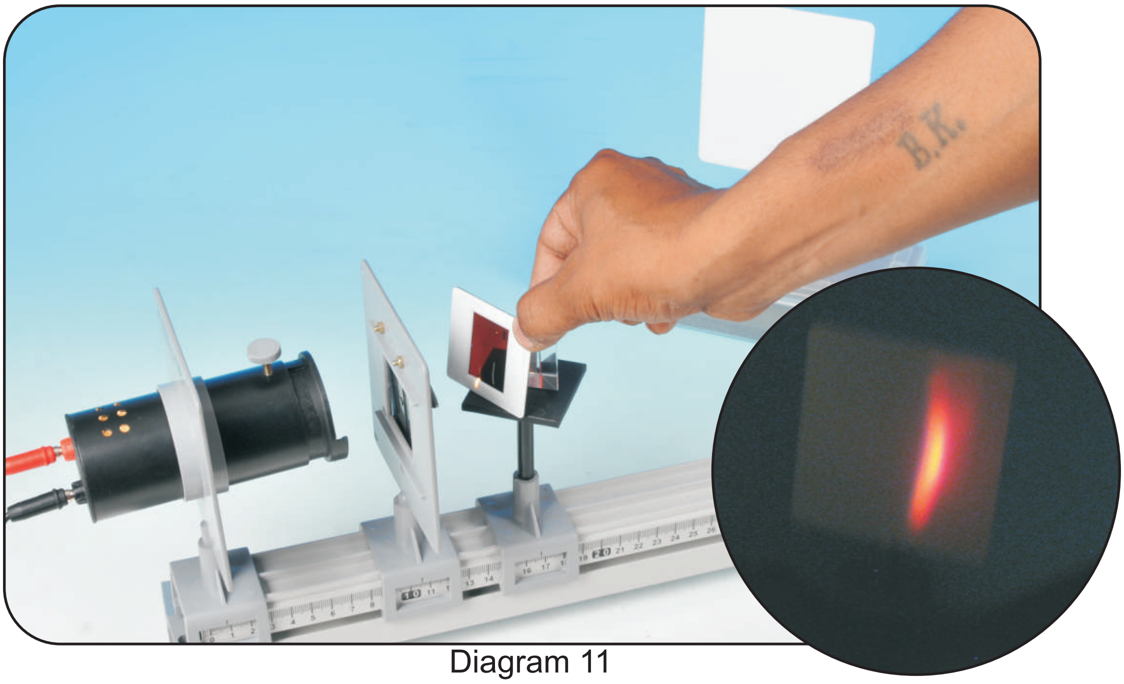


Diagram 11

Have students predict what will happen to the rainbow if a filter is used to allow only a certain frequency of color though.

1. If a red filter is used to allow only red light into the prism, what will the rainbow look like? *(Students may think that the whole rainbow will turn red, or that the red part of the rainbow will disappear. Have students write down their thoughts and then share them with the class.)*

   Observations with red filter:

   (The red, orange and yellow part of the rainbow will stay but the colors will look to have different intensities of red.)

2. If a blue filter is used to allow only blue light into the prism, what will the rainbow look like? *(Again have students write down their thoughts and discuss.)*

   Observations with the blue filter:

   (Approximately the yellow through violet portion of the rainbow appears, although the yellow now appears blue. Since only blue light is allowed through, only colors that have some blue light in them will appear on the spectrum.)

3. If a green filter is used to allow only green light into the prism, what will the rainbow look like? *(Again have students write down their thoughts and discuss.)*

Observations with the green filter:

(Approximately the orange through blue portion of the rainbow appears, although the green is most prominent. Since only green light is allowed through, only colors that have some green light in them will appear on the spectrum.)

4. If all three filters are used to allow light into the prism, what will the rainbow look like? *(Again have students write down their thoughts and discuss.)*

Observations with all three filters:

(No light is shown through since all of the colors of white light are filtered out.)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

BLOCKING COLORS IN A PRISM USING FILTERS

BACKGROUND:

When light hits a surface, three things can happen: the light can be reflected, absorbed or transmitted. A combination of reflection and absorption happen on most opaque surfaces. When a piece of paper looks “red” to our eyes, is it creating red light? No, it's absorbing everything but the red color. The red color that is reflected is what our eyes detect and see, therefore the paper looks red. The paper only looks red when light containing the color red is shining on it. If very little light is shining, the paper looks black, or you may not even see the paper depending on how little light there is.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

A white surface reflects all colors. Use the white screen in the kit and the equilateral prism to create a rainbow on the white screen.

1. Set up the apparatus as shown in diagram 11.
2. Introduce the appropriate slides between the single slit and the prism. The slides have a wide band of plastic around the top and a thin band around the sides. Hold the slides so the thin band is in the middle of the rainbow. That way the top half of the rainbow shows the filtered light and directly below the band, the entire rainbow appears. This is shown in diagram 11 as well.

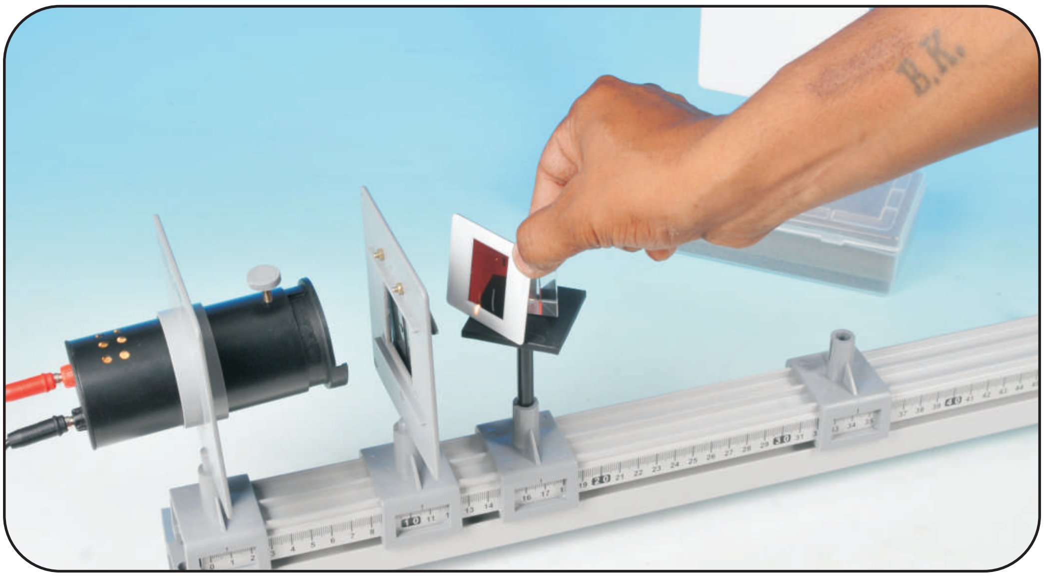


Diagram 11

3. Predict what will happen to the rainbow if a filter is used to allow only a certain frequency of color though.

a. If a red filter is used to allow only red light into the prism, what will the rainbow look like?

Observations with red filter:

b. If a blue filter is used to allow only blue light into the prism, what will the rainbow look like?

Observations with the blue filter:

c. If a green filter is used to allow only green light into the prism, what will the rainbow look like?

Observations with the green filter:

d. If all three filters are used to allow light into the prism, what will the rainbow look like?

Observations with all three filters:

STUDY OF CONCAVE MIRRORS

BACKGROUND:

A concave mirror is shaped a little like a cave in that the middle of the mirror is farther away from the light source than the outside of the mirror. A concave mirror has a smooth reflective surface that bows inwards in an arc shape. It focuses parallel beams of light into one specific and unique point known as the focal point. Since the beams of light do indeed cross at this middle point, a real image is formed. Real images are always inverted, or upside down from the object that originally made the image. Concave mirrors can also form a virtual image.

To begin the study of concave mirrors, take the flexible mirror and set it up as shown in diagram 12a. The inner flexible part of the mirror can be removed by carefully sliding the reflective surface from the top or bottom of the mirror, bending it the appropriate direction and reinserting it.

WARNING: Use caution and some work gloves that are resistant to being cut through when reversing the mirror. The edges are extremely sharp and can easily cut you.

Diagram 12a

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Optics table	1
Concave/convex mirror	1
Slide with single slit	1
Slide with five slits	1
Slide holder	1
Flat Condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	2
Invisible Tape	1

PROCEDURE:

1. Set up the apparatus as shown in diagram 12b. The closer the five slit slide is to the optics table, the more parallel the beams will appear.

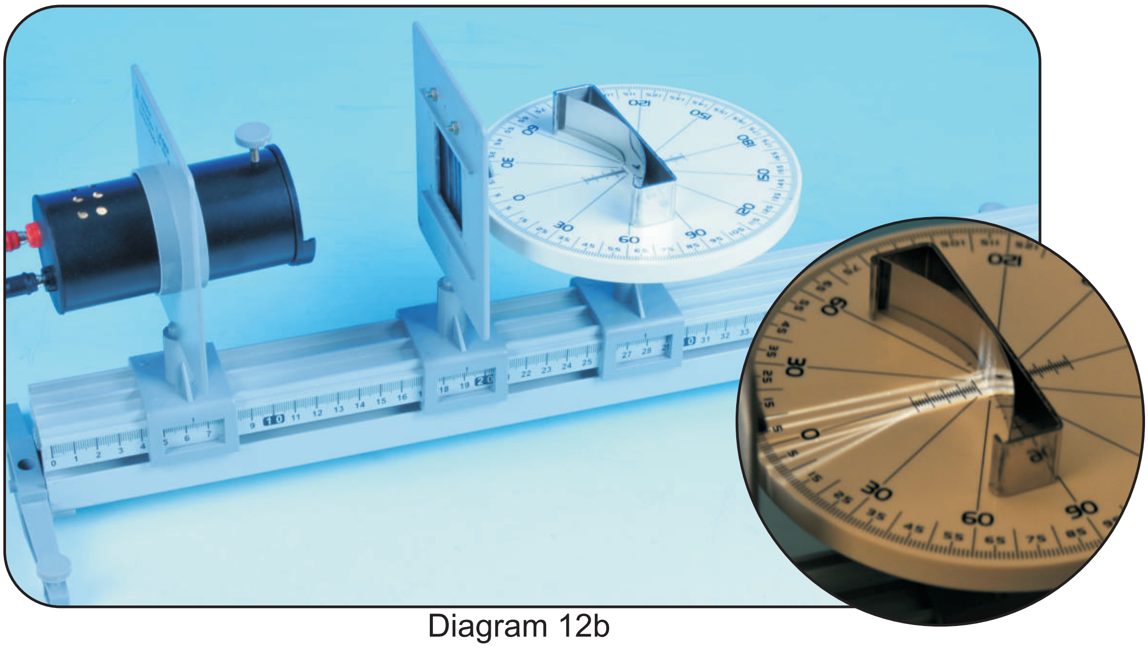


Diagram 12b

2. Notice that all the parallel beams are reflected through the same point. This point is called the *focal point*. It is a given distance from your mirror. This distance from the mirror to the spot where all the beams cross is called the *focal length*. Make a marker to mark the place where the focal point is by putting a dot on a piece of invisible tape and then folding one edge over to create a handle so that the tape can easily be removed and repositioned. See diagram 13.

Diagram 13

3. The focal length is _______________ for this mirror.

4. Write a rule for predicting where a beam of light parallel to the normal will reflect for a concave mirror and write this rule below:

   (A parallel beam of light will be reflected through the focal point of a concave mirror.)

5. Next replace the parallel beams of light with a single beam by using the single slit slide. Shift the slide left or right until the incident beam hits exactly on the normal of the concave mirror. The spot where the normal line touches crosses the surface of the mirror is called the *vertex*. This means at 0° the beam will be reflected directly back on top of itself.

6. Rotate the optics table so that the incident ray hits the vertex at every possible angle.

7. Write a rule that describes how the incident ray and the reflected ray behave in terms of angle of incidence and angle of reflection.

   (The angle of incidence is always equal to the angle of reflection for any incidence ray that hits the mirror at the vertex.)

8. Twice the focal length is called the *center of curvature*. The mirror is shaped like an arc, which is a segment of a circle. The center of curvature is the place that is equidistance from every point on the surface of the mirror. Double the focal length to find the center of curvature and place a dot made with invisible tape on your center of curvature.

9. Slide your single slit to any point on the left or right of center and then rotate your optics table so that the incident ray travels through the center of curvature and hits the mirror. You can move your single slit to several different positions to check your results.

10. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels through the center of curvature on its way to the mirror.

    (The reflected ray is reflected back through the center of curvature)

11. Now rotate your optics table so that the incident ray passes through the focal point on its way to the mirror. You can move your single slit to several different positions to check your results.

12. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels through the focal point on its way to the mirror.

    (The reflected ray travels parallel to the normal line if it passes through the focal point on its way to the mirror.)

Students can use this knowledge to draw optics diagrams that predict the size, orientation, location and type of image an object will produce.

A sample of ray diagrams of the concave mirrors is shown below:

Concave Mirrors

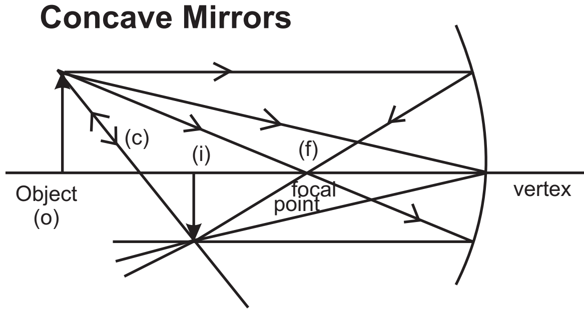


image : real, inverted, smaller, on the same of the mirror

(f) focal point, (c) center of curvature

(o) object, (i) image

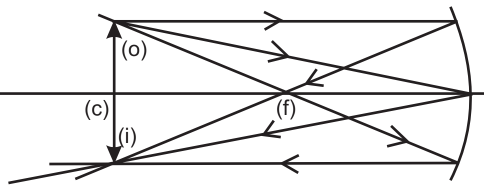


image : real, inverted, the same size on the same side of the mirror

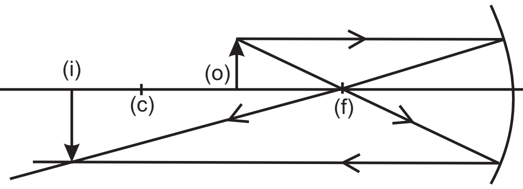


image : real, inverted, larger size the same size on the same side of the mirror

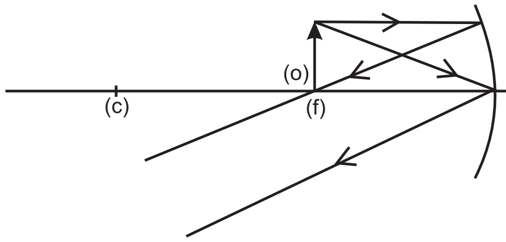


image : none, all reflected rays are parallel

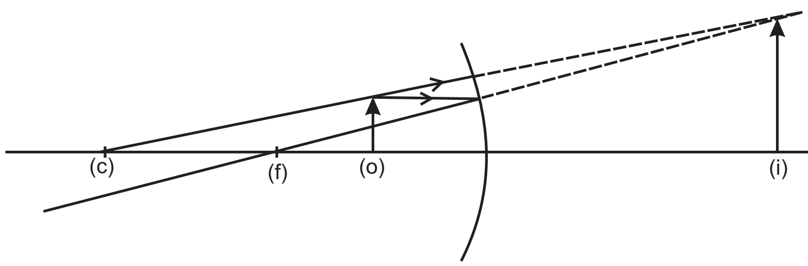


image : virtual, upright, larger, on the opposite side of the mirror

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

STUDY OF CONCAVE MIRRORS

BACKGROUND:

A concave mirror is shaped a little like a cave in that the middle of the mirror is farther away from the light source than the outside of the mirror. A concave mirror has a smooth reflective surface that bows inwards in an arc shape. It focuses parallel beams of light into one specific and unique point known as the focal point. Since the beams of light do indeed cross at this middle point, a real image is formed. Real images are always inverted, or upside down from the object that originally made the image. Concave mirrors can also form a virtual image.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

1. Set up the apparatus as shown in diagram 12b. The closer the five slit slide is to the optics table, the more parallel the beams will appear. The center of the reflective surface should be in the cross hairs on the optics table and the back of the mirror should be parallel to the 90° line on the optics table.

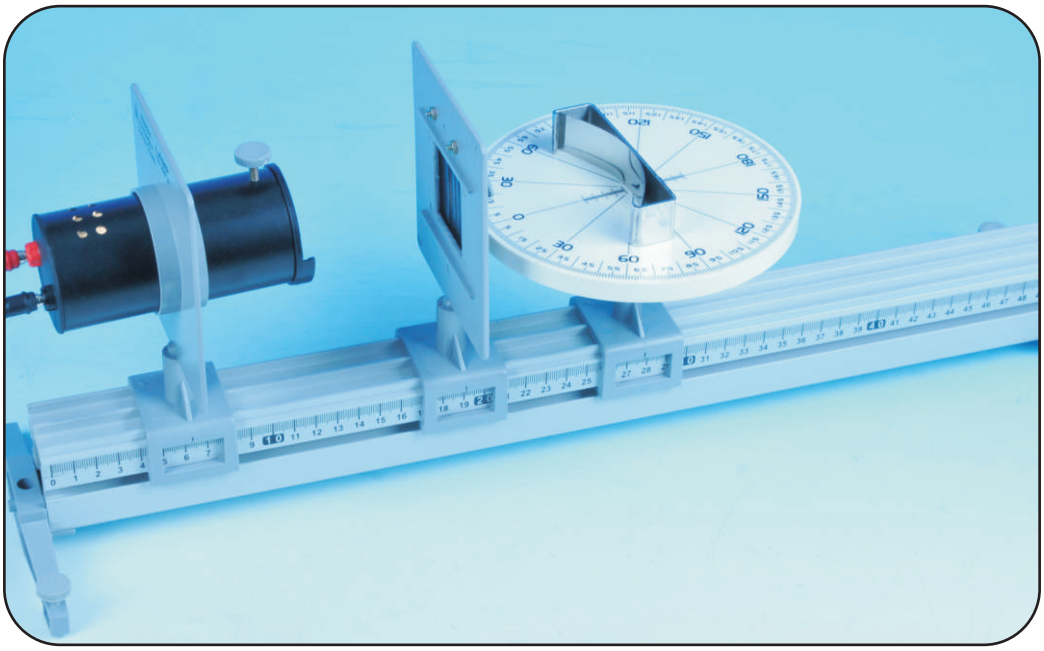


Diagram 12b

2. Notice that all the parallel beams are reflected through the same point. This point is called the ________________. It is a given distance from your mirror. This distance from the mirror to the spot where all the beams cross is called the ____. Make a marker to mark the place where the focal point is by putting a dot on a piece of invisible tape and then folding one edge over to create a handle so that the tape can easily be removed and repositioned. See diagram 13

Diagram 13

3. The focal length is ________________ for this mirror.

4. Write a rule for predicting where a beam of light parallel to the normal will reflect for a concave mirror and write this rule below:

5. Next replace the parallel beams of light with a single beam by using the single slit slide. Shift the slide left or right until the incident beam hits exactly on the normal of the concave mirror. The spot where the normal line touches crosses the surface of the mirror is called the ________________. This means at 0° the beam will be reflected directly back on top of itself.

6. Rotate the optics table so that the incident ray hits the vertex at every possible angle.

7. Write a rule that describes how the incident ray and the reflected ray behave in terms of angle of incidence and angle of reflection.

8. Twice the focal length is called the ______________________. The mirror is shaped like an arc, which is a small segment of a circle. The center of curvature is the place that is equidistance from every point on the surface of the mirror. Double the focal length to find the center of curvature and place a dot made with invisible tape on your center of curvature.

9. Slide your single slit to any point on the left or right of center and then rotate your optics table so that the incident ray travels through the center of curvature and hits the mirror. You can move your single slit to several different positions to check your results.

10. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels through the center of curvature on its way to the mirror.

11. Now rotate your optics table so that the incident ray passes through the focal point on its way to the mirror. You can move your single slit to several different positions to check your results.

12. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels through the focal point on its way to the mirror.

STUDY OF CONVEX MIRRORS

BACKGROUND:

A convex mirror is shaped so that the center of the mirror is closer to the object that is being reflected than the outside edges of the mirror, which are further away. These mirrors are often used at convenience stores to see down aisles or used as a passenger side mirror in automobiles because they can take larger area and reflect it to appear in a smaller space. Convex mirrors also have a focal point and a center of curvature but these points reside behind the mirror. Since the beams never cross but get radiated away from the surface of the mirror, this mirror can only form virtual (imaginary) images. Virtual images are always right side up (erect) and are smaller than the object. The images appear on the opposite side (or in) the mirror. Unlike concave mirrors, a convex mirror's image does not depend on the position from the focal point to the surface of the mirror that the object is placed.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Optics Table	1
Concave/convex mirror	1
Slide with single slit	1
Slide with five parallel slits	1
Slide holder	1
Flat condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	2
Invisible tape	2 pieces
White computer paper	1

PROCEDURE:

To begin the study of convex mirrors, take the flexible mirror and set it up as shown in diagram 14. The inner flexible part of the mirror can be removed by carefully sliding the reflective surface from the top or bottom of the mirror, bending it the way you want and reinserting it.

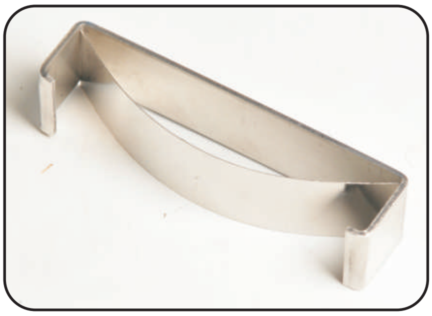
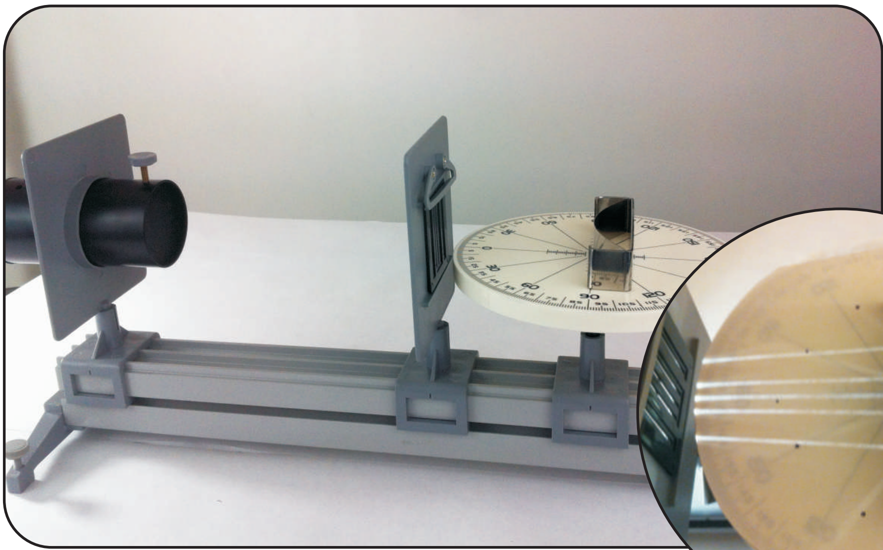


Diagram 14

WARNING: Use caution and some work gloves that are resistant to being cut through when reversing the mirror. The edges are extremely sharp and can easily cut you.

1. Set up the apparatus as shown in diagram 15. The closer the five slit slide is to the optics table, the more parallel the beams will appear.



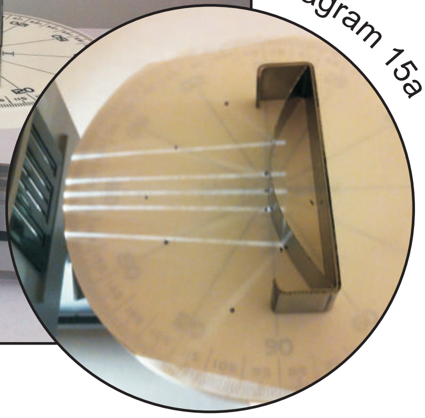


Diagram 15a

Diagram 15

2. Notice that all the parallel beams are dispersed. Put a piece of white paper under the mirror and trace the surface of the mirror. Then place one dot where each of beam is incident on the mirror and a second dot on each reflected ray one inch from the mirror, as shown in diagram 15a.

3. Remove the paper and place on a flat surface to draw the incident rays and reflected rays by connecting the dots with a straight edge.

4. Then use your straight edge to trace the reflected rays back through the surface of the mirror to where they would appear to come from. The lines should all cross at one point. This point is called the <u>focal point</u>. It is a given distance from your mirror. This distance from the mirror to the spot where all the beams cross is called the <u>focal length</u>. Use an invisible tape marker to mark the focal point on your optics table. (See Concave Mirrors Study for instructions on how to make the marker.)

5. The focal length is ________________ for this mirror.

6. Write a rule for predicting where a beam of light parallel to the normal will reflect for a convex mirror and write this rule below:

   <u>*(A parallel beam of light will be reflected as though it appears to come from the focal point of a convex mirror.)*</u>

7. Next replace the parallel beams of light with a single beam by using the single slit slide. Shift the slide left or right until the incident beam hits exactly on the normal of the concave mirror. The spot where the normal line touches crosses the surface of the mirror is called the <u>vertex</u>. This means at 0° the beam will be reflected directly back on top of itself.

8. Rotate the optics table so that the incident ray hits the vertex at every possible angle.

9. Write a rule that describes how the incident ray and the reflected ray behave in terms of angle of incidence and angle of reflection.

   (The angle of incidence is always equal to the angle of reflection for any incidence ray that hits the mirror at the vertex. Drawing a straight line behind the mirror in the opposite direction as the reflected ray will show where the ray appears to have come from.)

10. Twice the focal length is called the center of curvature. The center of curvature is the place that is equidistance from every point on the surface of the mirror. Double the focal length to find the center of curvature and place a tape marker there.

11. Slide your single slit to any point on the left or right of center and then rotate your optics table so that the incident ray is aimed directly towards the center of curvature and hits the mirror. You can move your single slit to several different positions to check your results.

12. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels towards the center of curvature on its way to the mirror.

    (The reflected ray is reflected back through the same path it originated from. The reflected ray will appear to come from behind the mirror as though it traveled straight through the mirror from the center of curvature.)

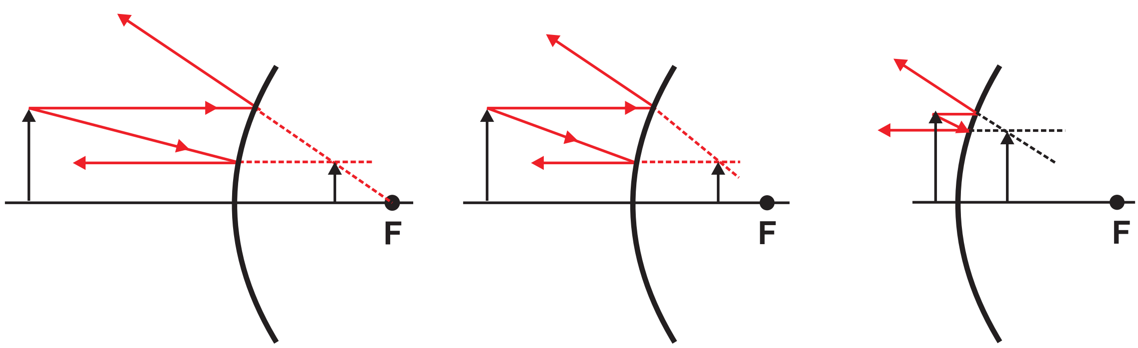
13. Now rotate your optics table so that the incident ray is aimed directly at the focal point on its way to the mirror. You can move your single slit to several different positions to check your results.

14. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels directly towards the focal point on its way to the mirror.

    (The reflected ray always travels parallel to the normal line and looks as though it came from behind the mirror, parallel to the normal line.)

Students can use this knowledge to draw optics diagrams that predict the size, orientation, location and type of image an object will produce.

A sample of ray diagrams of the concave mirrors is shown below:



ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

STUDY OF CONVEX MIRRORS

BACKGROUND:

A convex mirror is shaped so that the center of the mirror is closer to the object that is being reflected than the outside edges of the mirror, which are further away. These mirrors are often used at convenience stores to see down aisles or used as a passenger side mirror in automobiles because they can take larger area and reflect it to appear in a smaller space. Convex mirrors also have a focal point and a center of curvature but these points reside behind the mirror. Since the beams never cross but get radiated away from the surface of the mirror, this mirror can only form virtual (imaginary) images. Virtual images are always right side up (erect) and are smaller than the object. The images appear on the opposite side (or in) the mirror. Unlike concave mirrors, a convex mirror's image does not depend on the position from the focal point to the surface of the mirror that the object is placed.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

1. Set up the apparatus as shown in diagram 15. The closer the five slit slide is to the optics table, the more parallel the beams will appear.

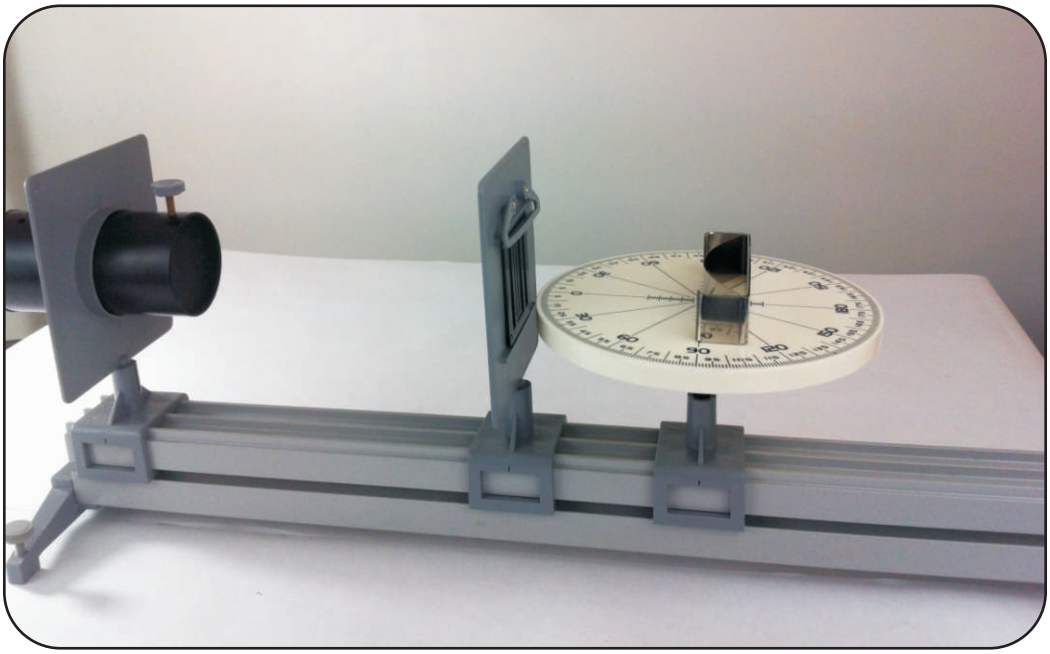


Diagram 15

2. Notice that all the parallel beams are dispersed. Put a piece of white paper under the mirror and trace the surface of the mirror. Then place one dot where each of beam is incident on the mirror and a second dot on each reflected ray one inch from the mirror.

3. Remove the paper and place on a flat surface to draw the incident rays and reflected rays by connecting the dots with a straight edge.

4. Then use your straight edge to trace the reflected rays back through the surface of the mirror to where they would appear to come from. The lines should all cross at one point. This point is called the ________________. It is a given distance from your mirror. This distance from the mirror to the spot where all the beams cross is called the ________________. Use an invisible tape marker to mark the focal point on your optics table. (See Concave Mirrors Study for instructions on how to make the marker.)

5. The focal length is ________________ for this mirror.

6. Write a rule for predicting where a beam of light parallel to the normal will reflect for a convex mirror and write this rule below:

7. Next replace the parallel beams of light with a single beam by using the single slit slide. Shift the slide left or right until the incident beam hits exactly on the normal of the concave mirror. The spot where the normal line touches crosses the surface of the mirror is called the _______________ This means at 0° the beam will be reflected directly back on top of itself. This is shown in diagram 16.

Diagram 16

8. Rotate the optics table so that the incident ray hits the vertex at every possible angle.

9. Write a rule that describes how the incident ray and the reflected ray behave in terms of angle of incidence and angle of reflection.

10. Twice the focal length is called the ____________________. The center of curvature is the place that is equidistance from every point on the surface of the mirror. Double the focal length to find the center of curvature and place a tape marker there.
11. Slide your single slit to any point on the left or right of center and then rotate your optics table so that the incident ray is aimed directly towards the center of curvature and hits the mirror. You can move your single slit to several different positions to check your results.
12. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels towards the center of curvature on its way to the mirror.

13. Now rotate your optics table so that the incident ray is aimed directly at the focal point on its way to the mirror. You can move your single slit to several different positions to check your results.
14. Write a rule in the space below that describes how the reflected ray behaves when the incident ray travels directly towards the focal point on its way to the mirror.

STUDY OF CONVEX LENSES (RAY DIAGRAMS)

BACKGROUND

A convex lens has one or two spherical surfaces on it. The middle of the lens is the thickest point and the edges of the lens are the thinnest point of the lens. Convex lenses focus parallel beams of light into one specific and unique point known as the focal point. Since the beams of light do indeed cross at this focal point, a real image is formed. Real images are always inverted, or upside down from the object that originally made the image. Convex lenses can also form a virtual image.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Optics table	1
Convex lens	1
Slide with single slit	1
Slide with five slits	1
Slide holder	1
Flat condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	2
Invisible tape	2 pieces
White computer paper	1

PROCEDURE:

To begin the study of convex lenses it is easier to study the lenses in two dimensions before studying three dimensions.

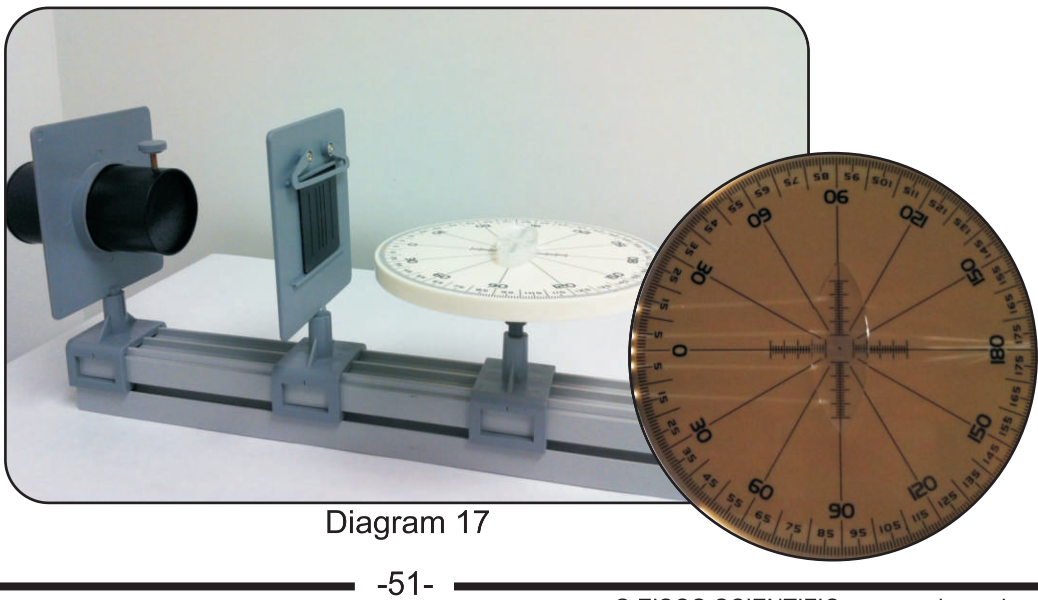


Diagram 17

1. Set up the apparatus as shown in diagram 17. The closer the five slit slide is to the optics table, the more parallel the beams will appear.

2. Notice that all the parallel beams are refracted through the same point. This point is called the focal point. It is a given distance from the center of your two-dimensional lens. This distance from the mirror to the spot where all the beams cross is called the focal length. Make a marker using a piece of invisible tape (as shown in "Study of Concave Mirrors") and mark the focal point.

3. Then measure this same distance on the opposite side of the lens and mark the focal point on that side of the lens.

4. The focal length is ________________ for this lens.

5. Write a rule for predicting where a beam of light parallel to the normal will refract to for a concave mirror and write this rule below:

   (A parallel beam of light will be reflected through the focal point on the opposite side of the incident rays of a convex lens.)

6. Now rotate your optics table so that the incident ray passes through the focal point on its way to the lens as shown in diagram 18. You can move your single slit to several different positions to check your results.

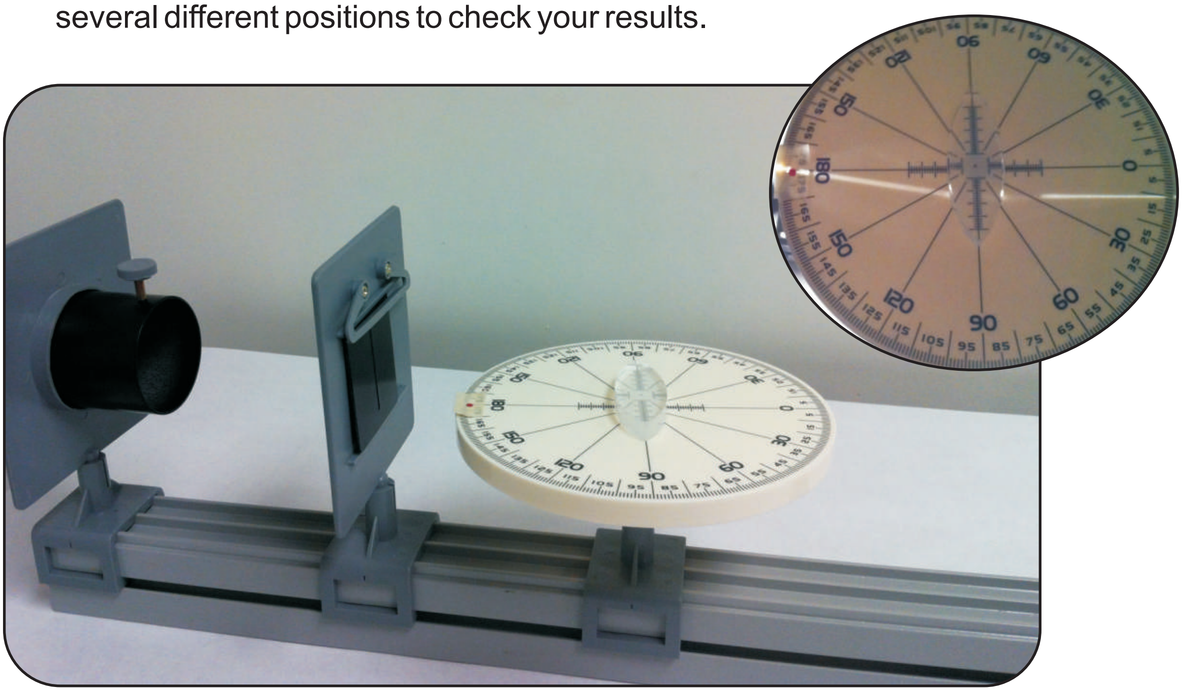


Diagram 18

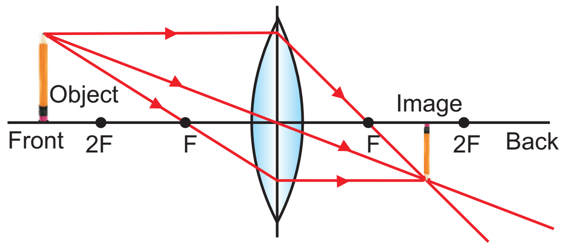
7. Write a rule in the space below that describes how the refracted ray behaves when the incident ray travels through the focal point on its way to the lens.

   (The refracted ray travels parallel to the normal line on the opposite side of the lens if it passes through the focal point on its way to the lens.)

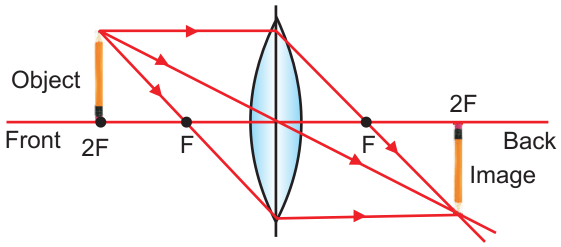
Students can use this knowledge to draw optics diagrams that predict the size, orientation, location and type of image an object will produce.

A sample of ray diagrams of the concave mirrors is shown below:

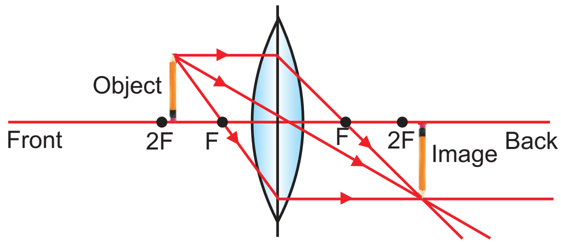
Ray Diagrams



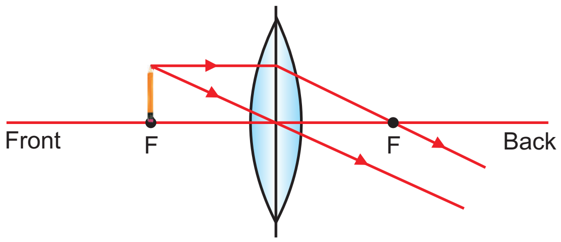
Configuration : object outside 2F, real smaller image between F and 2F



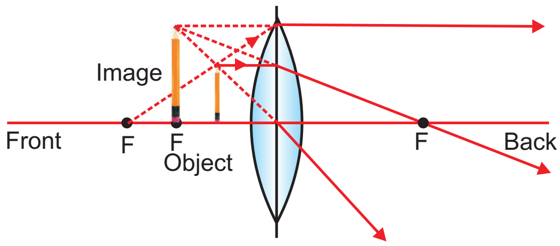
Configuration : object at 2F, real image at 2F same size object



Configuration : object between F and 2F, magnified real image outside 2F



Configuration : object at F, image at infinity



Configuration : object inside F, magnified virtual Image on the same side of the lens as the object

Diagram 19

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

STUDY OF CONVEX LENSES (RAY DIAGRAMS)

BACKGROUND:

A convex lens has one or two spherical surfaces on it. The middle of the lens is the thickest point and the edges of the lens are the thinnest point of the lens. Convex lenses focus parallel beams of light into one specific and unique point known as the focal point. Since the beams of light do indeed cross at this focal point, a real image is formed. Real images are always inverted, or upside down from the object that originally made the image. Convex lenses can also form a virtual image.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

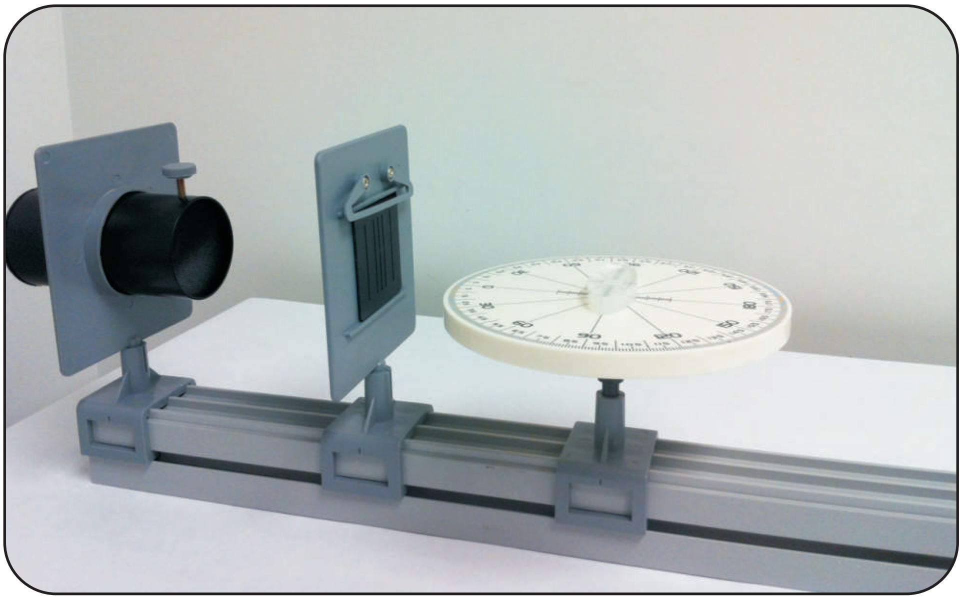


Diagram 17

1. Set up the apparatus as shown in diagram 17. The closer the parallel slits are to the optics table, the more parallel the beams will appear.

2. Notice that all the parallel beams are refracted through the same point. This point is called the __________________. It is a given distance from the center of your two-dimensional lens. This distance from the mirror to the spot where all the beams cross is called the ________________. Make a marker using a piece of invisible tape (as shown in "Study of Concave Mirrors") and mark the focal point.

3. Then measure this same distance on the opposite side of the lens and mark the focal point on that side of the lens.

4. The focal length is ________________ for this lens.

5. Write a rule for predicting where a beam of light parallel to the normal will refract to for a concave mirror and write this rule below:

6. Now rotate your optics table so that the incident ray passes through the focal point on its way to the lens as shown in diagram 18. You can move your single slit to several different positions to check your results.

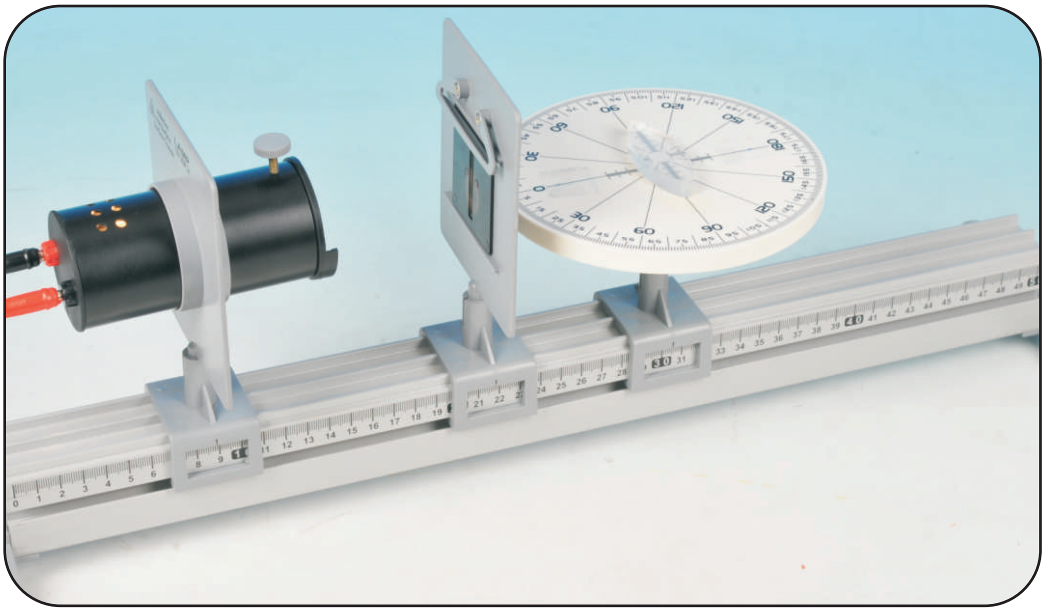


Diagram 18

7. Write a rule in the space below that describes how the refracted ray behaves when the incident ray travels through the focal point on its way to the lens.

STUDY OF CONCAVE LENSES (RAY DIAGRAMS)

BACKGROUND:

A concave lens is shaped so that the center of the lens is thinner than the outside edge of the lenses. Since the beams never cross but get refracted away from the surface of the lens, this lens can only form virtual (imaginary) images. Virtual images are always right side up (erect) and smaller than the object. The images appear on the opposite of the lens between the focal point and the lens. Unlike convex lenses, a concave lenses' image type does not depend on the position from the focal point to the surface of the mirror that the object is placed.

REQUIRED COMPONENTS (INCLUDED)

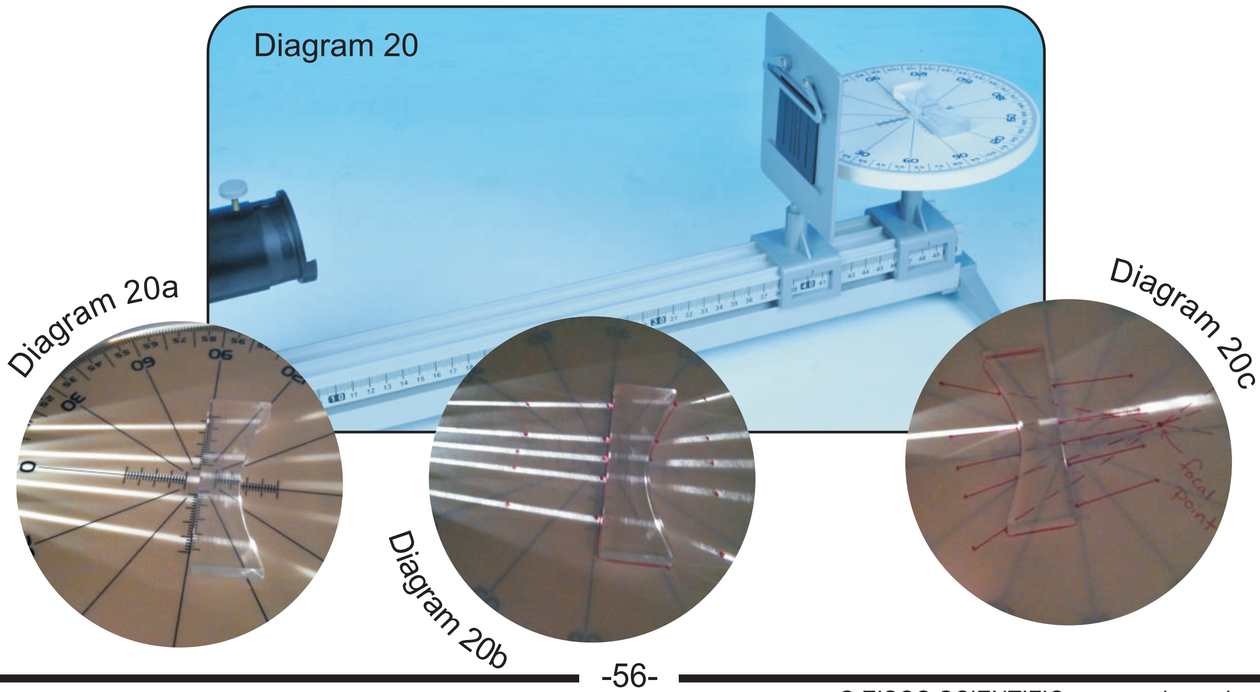
Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
Lamp mounted with red and black leads and lens removed	1
Optics table	1
Concave lens	1
Slide with one slit	1
Slide with five slits	1
Slide holder	1
Flat condenser	1

REQUIRED COMPONENTS (NOT INCLUDED)

Power supply	1
Invisible tape	2 pieces
White computer paper	1

PROCEDURE:

1. To begin the study of concave lenses, set up your optics bench as shown in diagram 20. The closer the parallel slits are to the optics table, the more parallel the beams will appear.



2. Notice that all the parallel beams are dispersed in diagram 20a. Put a piece of white paper under the lens and trace the surface of the lens. Then place one dot on each beam as it travels towards the mirror. Place a second dot where each beam is incident on the lens and a third dot on each refracted ray where it leaves the lens. Place a fourth dot on each ray one inch from where it left the lens. This is shown in diagram 20b.

3. Remove the paper and place on a flat surface to draw the incident rays and refracted rays by connecting the dots with a straight edge.

4. As shown in diagram 20c, use your straight edge to trace the refracted rays back through the surface of the lens to where they would appear to come from. The lines should all cross at one point. This point is called the *focal point.* It is a given distance from your lens. This distance from the lens to the spot where all the beams cross is called the *focal length*. Use an invisible tape marker to mark the focal point on your optics table. (See Concave Mirrors Study for instructions on how to make the marker.)

5. The focal length is _______________ for this lens.

6. Write a rule for predicting where a beam of light parallel to the normal will refract for a concave lens and write this rule below:

   (A parallel beam of light will be refracted as though it appears to come through the focal point on the same side of the concave lens that the original beams traveled through.)

7. Replace the five parallel slit slide with a single slit slide and move the single slit to the left or right so the ray of light is slightly off center.

8. Now rotate your optics table so that the incident ray is aimed directly towards the focal point on the other side of the lens. This is shown in diagram 20c. You can move your single slit to several different positions to check your results.

9. Write a rule in the space below that describes how the refracted ray behaves when the incident ray travels through the focal point on its way to the lens.

   (The refracted ray always travels parallel to the normal line and looks as though it came from behind the lens, parallel to the normal line.)

Students can use this knowledge to draw optics diagrams that predict the size, orientation, location and type of image an object will produce.

A sample of ray diagrams of the concave mirrors is shown below:

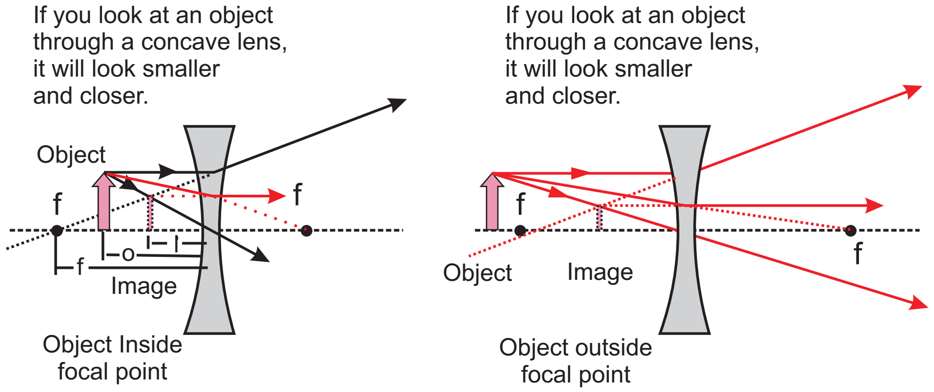


Diagram 21

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

STUDY OF CONCAVE LENSES (RAY DIAGRAMS)

BACKGROUND:

A concave lens is shaped so that the center of the lens is thinner than the outside end of the lenses. Since the beams never cross but get refracted away from the surface of the lens, this lens can only form virtual (imaginary) images. Virtual images are always right side up (erect) and smaller than the object. The images appear on the opposite of the lens between the focal point and the lens. Unlike convex lenses, a concave lenses' image does not depend on the position from the focal point to the surface of the mirror that the object is placed.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

1. To begin the study of concave lenses, set up your optics bench as shown in diagram 20. The closer the parallel slits are to the optics table, the more parallel the beams will appear.

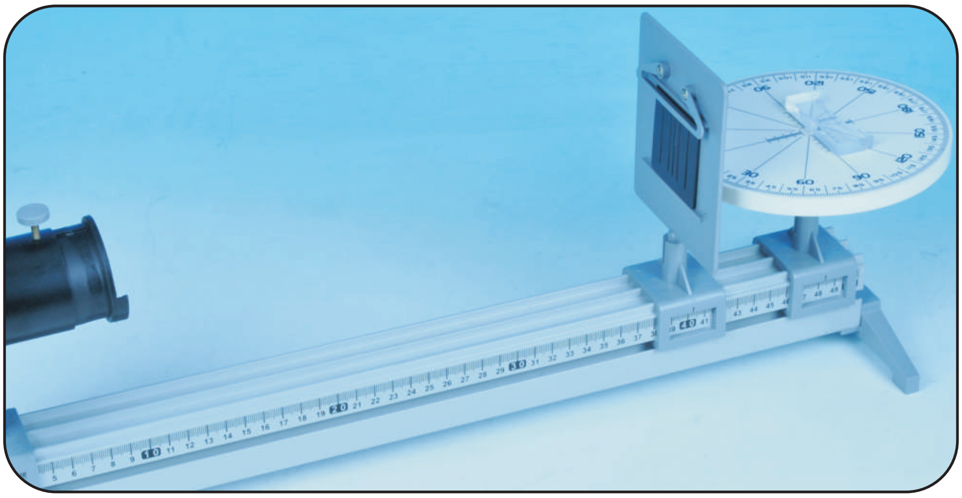


Diagram 20

2. Notice that all the parallel beams are dispersed. Put a piece of white paper under the lens and trace the surface of the lens. Then place one dot on each beam as it travels towards the mirror. Place a second dot where each beam is incident on the lens and a third dot on each refracted ray where it leaves the lens. Place a fourth dot on each ray one inch from where it left the lens.

3. Remove the paper and place on a flat surface to draw the incident rays and refracted rays by connecting the dots with a straight edge.

4. Then use your straight edge to trace the refracted rays back through the surface of the lens to where they would appear to come from. The lines should all cross at one point. This point is called the _________________. It is a given distance from your lens. This distance from the lens to the spot where all the beams cross is called the _______________. Use an invisible tape marker to mark the focal point on your optics table. (See Concave Mirrors Study for instructions on how to make the marker.)

5. The focal length is ________________ for this lens.

6. Write a rule for predicting where a beam of light parallel to the normal will refract for a concave lens and write this rule below:

6. Replace the five parallel slit slide with a single slit slide and move the single slit to the left or right so the ray of light is slightly off center.

7. Now rotate your optics table so that the incident ray is aimed directly towards the focal point on the other side of the lens. You can move your single slit to several different positions to check your results.

8. Write a rule in the space below that describes how the refracted ray behaves when the incident ray travels through the focal point on its way to the lens.

FINDING THE FOCAL POINT OF AN UNKNOWN LENS

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	2
White screen	1
+50 lens	1
+100 lens	1
+200 lens	1
-100 lens	1
Unknown lens	1

PROCEDURE:

1. The focal point of several lenses can be found by using an open window as a light source and the optics bench. Set up your apparatus as shown in diagram 21.

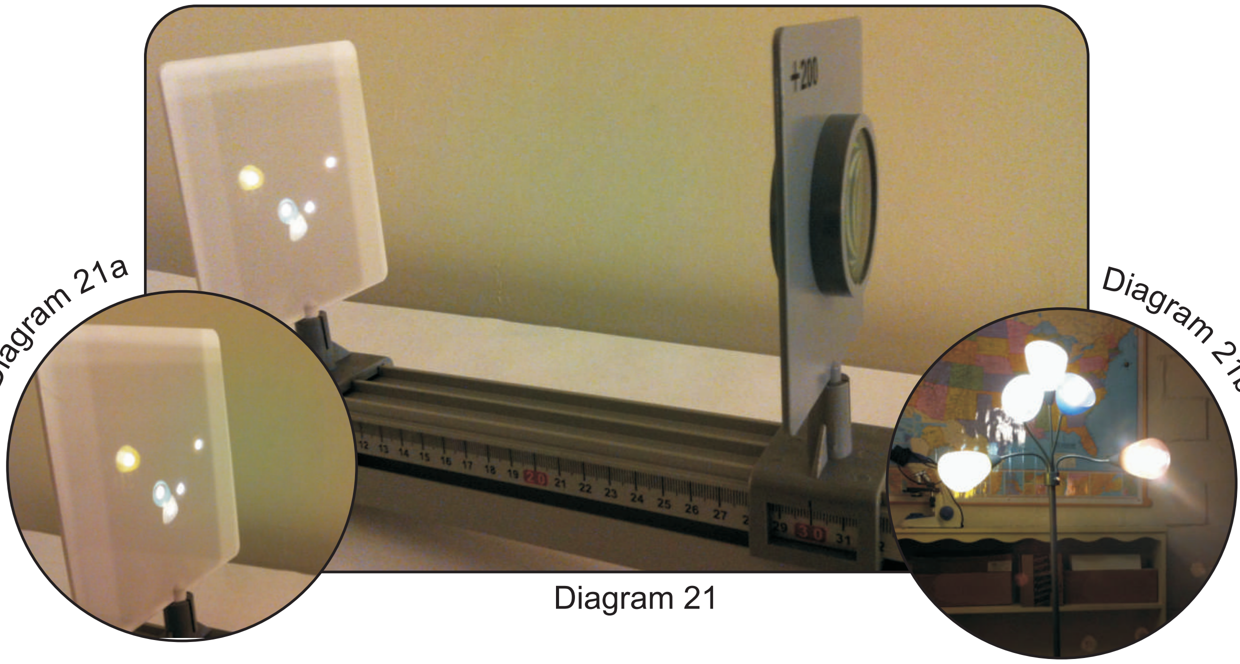


Diagram 21a

Diagram 21b

Diagram 21

2. Move the screen until a clear image is focused on the screen. See diagram 21a. The object is shown in diagram 21b.
3. Record the distance between the lens and the screen in the data chart.
4. Replace the lens with a different lens and repeat steps 2-4 for all five lenses.
5. Make a graph of number stated on the lens vs. focal length for your data.
6. Draw a best fit line.
7. Using your graph, estimate what the curvature of the unmarked lens would be.

DATA TABLE:

Number on the Lens	*Focal Length of the lens (cm)*
+50	6.1
+100	10.6
+200	22.2
-100	Cannot make an image
Unknown	4.5

DATA ANALYSIS:

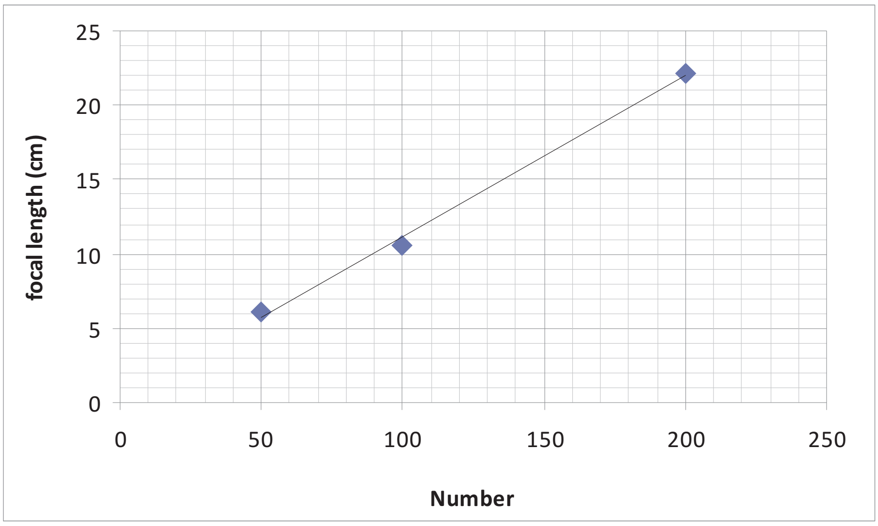


Diagram 22

FOLLOW UP QUESTIONS:

1. There was one lens that was unable to make an image on the screen, which lens was this? Explain why the lens could not make an image.

   (The concave lens was unable to make an image on the screen because only real images can be projected on the screen and the concave lens can only make virtual images.)

2. Describe the relationship between the focal length of the lens and the thickness of the lens.

   (As the focal length increases the thickness of the lens decreases.)

3. What was your estimated curvature of the unmarked lens?

   (+40)

4. What is the relationship between the number on the lens and the focal length?

   (The number on the lens is the focal length written in mm)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

FINDING THE FOCAL POINT OF AN UNKNOWN LENS

PROCEDURE:

1. The focal point of several lenses can be found by using an open window as a light source and the optics bench. Set up your apparatus as shown in diagram 21.

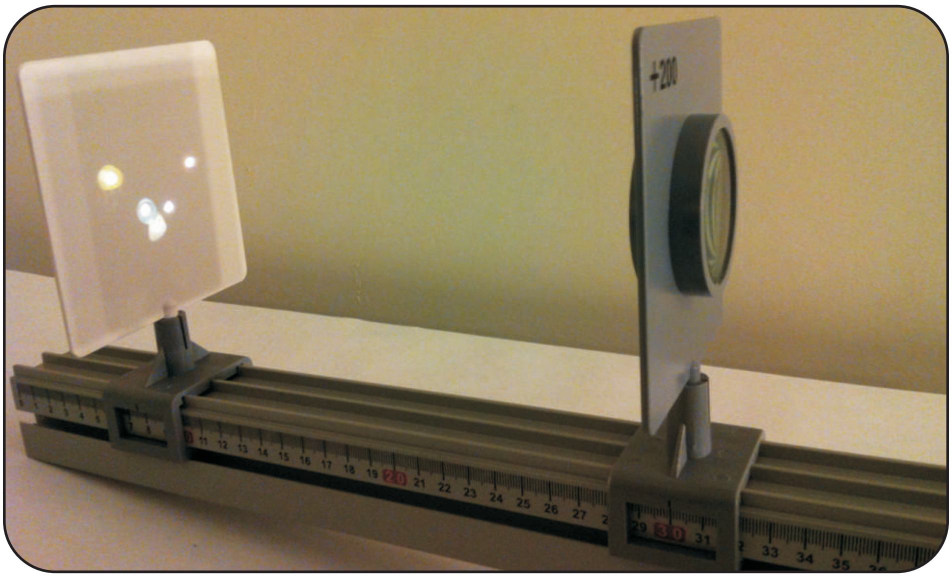


Diagram 21

2. Move the screen until a clear image is focused on the screen.
3. Record the distance between the lens and the screen in the data chart.
4. Replace the lens with a different lens and repeat steps 2-4 for all five lenses.
5. Make a graph of number stated on the lens vs. focal length for your data.
6. Draw a best fit line.
7. Using your graph, estimate what the curvature of the unmarked lens would be.

DATA TABLE:

Number on the Lens	*Focal Length of the lens (cm)*
+50	
+100	
+200	
-100	
Unknown	

FOLLOW UP QUESTIONS:

1. There was one lens that was unable to make an image on the screen, which lens was this? Explain why the lens could not make an image.

2. Describe the relationship between the focal length of the lens and the thickness of the lens.

3. What was your estimated curvature of the unmarked lens?

4. What is the relationship between the number on the lens and the focal length?

MAGNIFYING GLASS

1. Look at the optics table using the f=+200, f=+100, and f=+50 lens. Move the lens closer to the table so that table is between the lens and the focal length of the lens and record your observations in the space provided below.

   (The image appears larger, upright and on the other side of the glass. Because the image is upright (erect) I know that the image is virtual.)

   This is a magnifying lens. Is it possible to use the f =-100 as a magnifying lens?
   (It is not possible, only convex lenses can produce a larger image.)

HOW THE EYE WORKS

BACKGROUND:

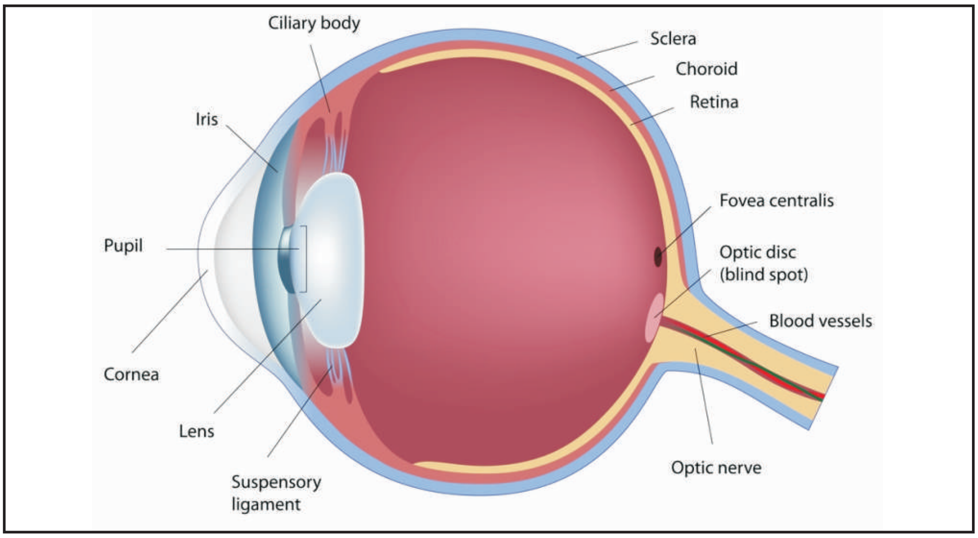


Diagram 23

1. Label the retina, iris, cornea, lens in the eye diagram above. The iris is the colored part of your eye. It controls how much light is let into the eye. The retina is a screen in the back of your eye that collects the image the eye sees. The lens and cornea work together to focus the light to make an image and the cornea protects the eye.

2. Is the lens of your eye a convex or concave lens? *(My lens is a convex lens. In order to produce an image that can be projected on a screen or on the retina, the image must be real and only convex lenses can produce real images.)*

REQUIRED COMPONENTS (INCLUDED)

Name of Part	***Quantity***
Optics bench with attached feet	1
Sliding optics bench components holders	2
White screen	1
+100 lens	1

PROCEDURE:

1. Face one end of your optics bench towards some bright light source. An open window works well. On the opposite end of your optics bench, set up the screen (your retina) and the f= +100mm lens (your lens) and see if you can focus the scene outside on the back of your retina.

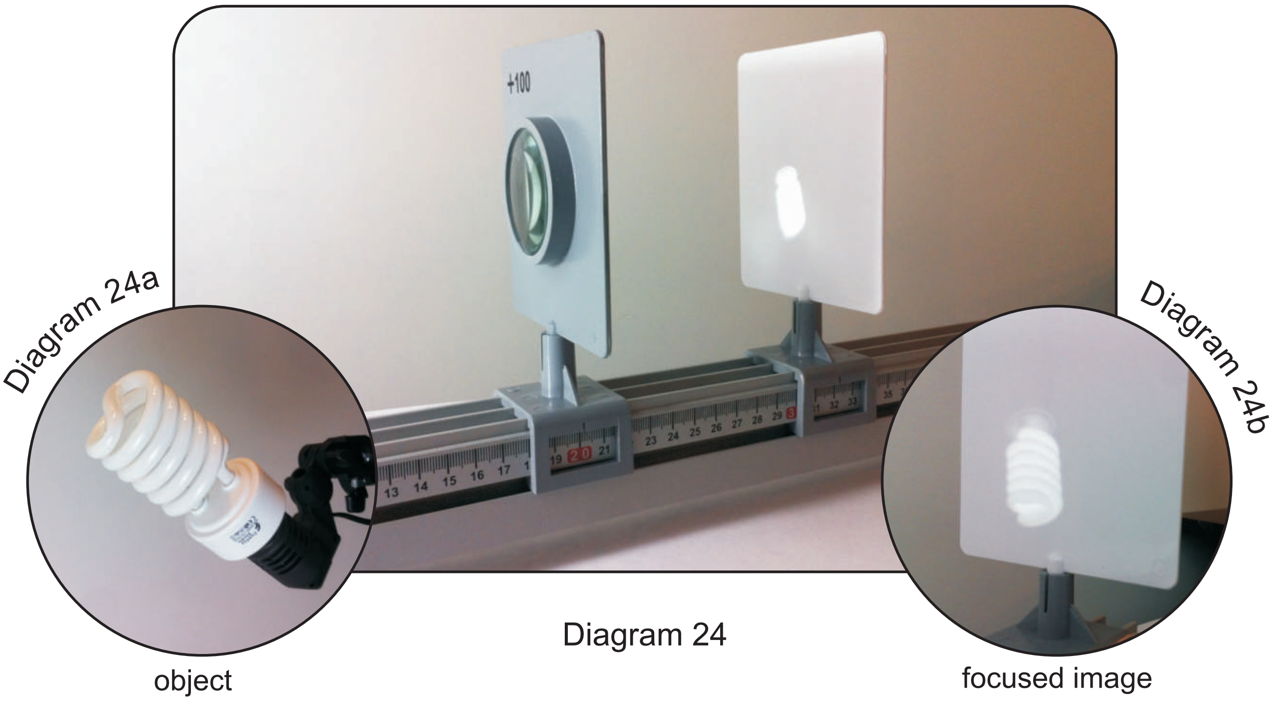


Diagram 24

2. Record the distance that the lens is from the screen when the image is focused.
   *11 cm using the +100 lens*___*cm*

3. The rays of the outside light come into your eye pretty much parallel to each other. How do parallel rays behave when they travel through your lens? Write the rule below.
   (Parallel beams of light will be refracted through the focal point, so the image is in focus when the screen is on the focal point.)

4. Is your image erect or inverted?
   (Inverted. As a baby your brain sees everything upside down. Our brain learns over time to flip the image in our brain so things are right side up.)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

HOW THE EYE WORKS

BACKGROUND:

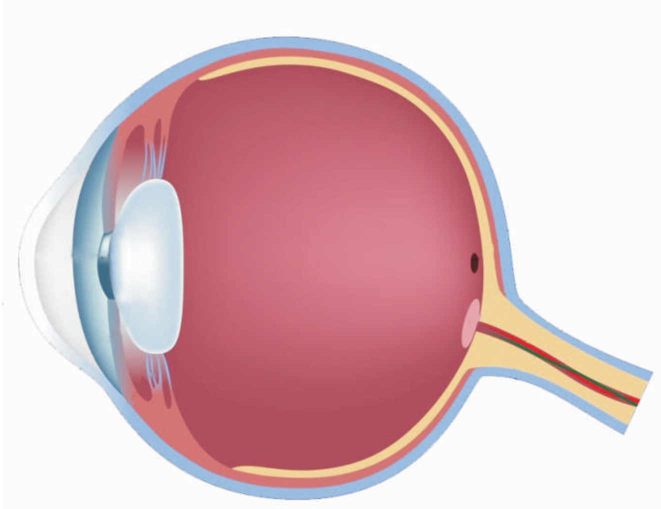


Diagram 23

1. Label the retina, iris, cornea, lens in the eye diagram above. The iris is the colored part of your eye. It controls how much light is let into the eye. The retina is a screen in the back of your eye that collects the image the eye sees. The lens and cornea work together to focus the light to make an image and the cornea protects the eye.

2. Is the lens of your eye a convex or concave lens?

PROCEDURE:

1. Face one end of your optics bench towards some bright light source. An open window works well. On the opposite end of your optics bench, set up the screen (your retina) and the f= +100mm lens (your lens) and see if you can focus the scene outside on the back of your retina.

Diagram 24

2. Record the distance that the lens is from the screen when the image is focused.

3. The rays of the outside light come into your eye pretty much parallel to each other. How do parallel rays behave when they travel through your lens? Write the rule below.

4. Is your image erect or inverted?

HOW GLASSES WORK IN FARSIGHTED VISION

BACKGROUND:

If we say, person has farsighted vision (also called hyperopia), this means that the light is focused behind the retina instead of on the retina. This can be caused by an eyeball that is too short, a cornea that is not curved enough or a lens that sits too far back in the eye. People with hyperopia can usually see far distances, but up close their vision is blurry and they will need glasses for reading. A convex lens can be used to correct farsighted vision.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
White screen	1
+100 lens	1
+200 lens	1

PROCEDURE:

1. Start with the +100 lens and the screen aligned so there is a clear image on the screen

2. Move the retina (screen) closer to the lens and record what happens to the vision of the person. This is a person whose eyeball is too short. Record your observations. *(The closer the screen and image get to one another the more blurry the image and the person's vision become.)*

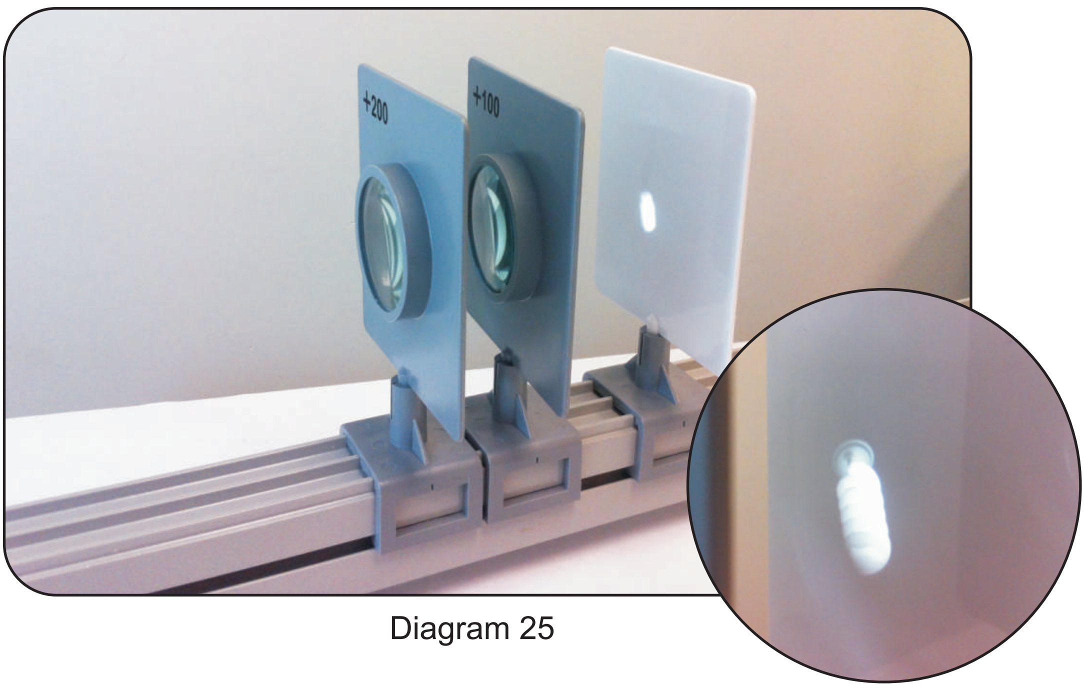


Diagram 25

3. Use the +200 convex lens to add some glasses (another lens) to the other side of the optics bench as shown in diagram 25 and then bring the lenses together so that they are touching. Adjust the screen (retina) until the image is clear again and then record the distance between the retina (screen) and the lens (the lens closer to the screen)

   7cm

4. For a person with farsighted vision because their eyeball is too short, was the distance between the lens and the retina less than, greater than or equal to the distance in a person with normal vision?

   (The person with normal vision had a distance of 11 cm between their lens and their retina, the person with the farsighted vision had a smaller distance.)

5. What type of lenses would be in the glasses for a person with farsighted vision?

   (Convex lenses)

6. A person cannot change the distance between their retina and their lens, in order to be able to see clearly, what can an optometrist change?

   (An optometrist can change the focal point of the glasses, so that the lenses of the glasses work with the lenses of the eye in order to produce a clear image on the retina. The optometrist can also adjust where the glasses sit on a person's face to correct vision.)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

HOW GLASSES WORK IN FARSIGHTED VISION

BACKGROUND:

If we say, a person has farsighted vision, also called hyperopia, this means that the light is focused behind the retina instead of on the retina. This can be caused by an eyeball that is too short, a cornea that is not curved enough, or a lens that sits too far back in the eye. People with hyperopia can usually see far distances, but up close their vision is blurry and they will need glasses for reading. A convex lens can be used to correct farsighted vision.

PROCEDURE:

1. Start with the +100 lens and the screen aligned so there is a clear image on the screen

2. Move the retina (screen) closer to the lens and record what happens to the vision of the person. This is a person whose eyeball is too short. Record your observations. (The closer the screen and image get to one another the more blurry the image and the person's vision become.)

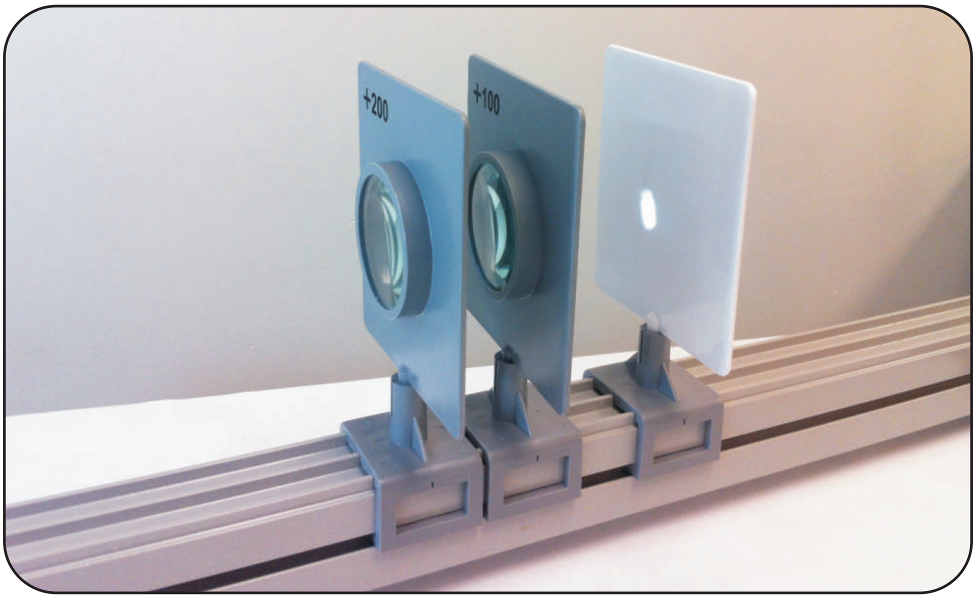


Diagram 25

3. Use the +200 convex lens to add some glasses (another lens) to the other side of the optics bench as shown in diagram 25 and then bring the lenses together so that they are touching. Adjust the screen (retina) until the image is clear again and then record the distance between the retina (screen) and the lens (the lens closer to the screen)

____

4. For a person with farsighted vision because their eyeball is too short, was the distance between the lens and the retina less than, greater than or equal to the distance in a person with normal vision?

5. What type of lenses would be in the glasses for a person with farsighted vision?

6. A person cannot change the distance between their retina and their lens, in order to be able to see clearly, what can an optometrist change?

HOW GLASSES WORK IN NEARSIGHTED VISION

BACKGROUND:

If we say a person has nearsighted vision, also called myopia, this means that image is focused in front of the retina. This can be caused by the distance between their lens and their retina being too large or the cornea being too rounded. People with myopia can usually see close (near) distances, but far away their vision is blurry and they will need glasses for driving.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
White screen	1
+100 lens	1
-100 lens	1

PROCEDURE:

1. Start with the +100 lens and the screen aligned so there is a clear image on the screen.

2. Move the retina (screen) farther from the lens and record what happens to the vision of the person. Record your observations. (The further the screen and image get to one another the more blurry the image and the person's vision become.)

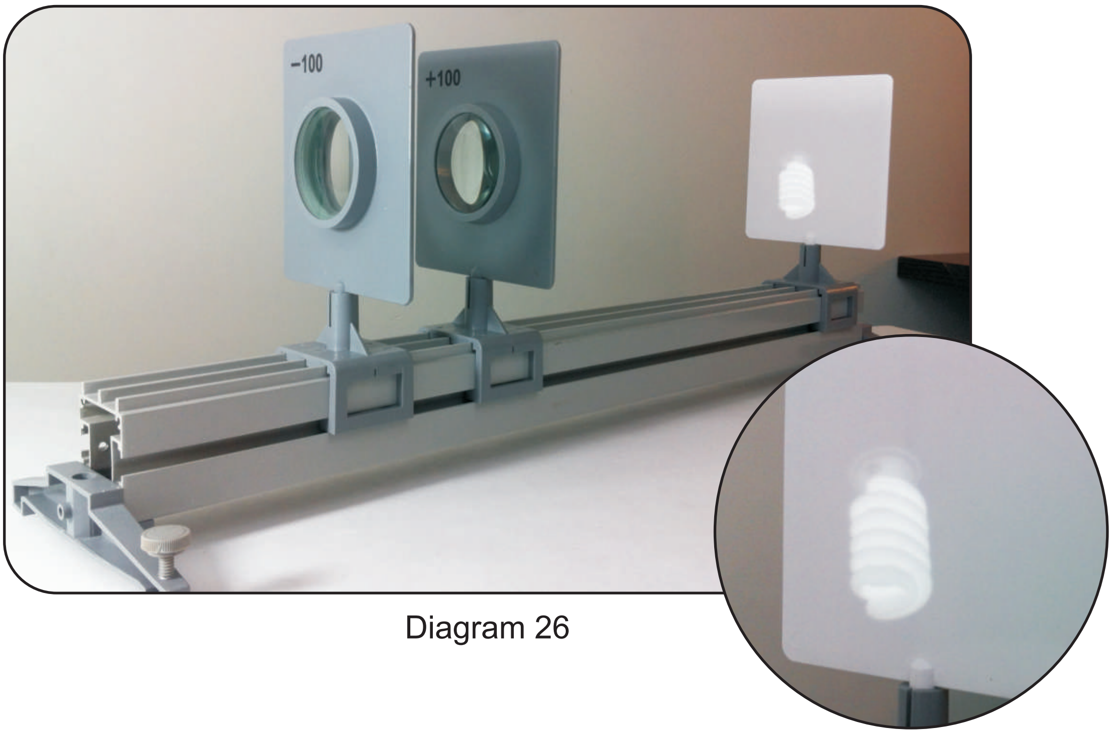


Diagram 26

3. Use the -100 concave lens to add some glasses (another lens) to the other side of the optics bench as shown in diagram 26 and then bring the lenses together so that they are touching. Adjust the screen (retina) until the image is clear again and then record the distance between the retina (screen) and the lens (the lens closer to the screen)

   33cm

4. For a person with nearsighted vision, was the distance between the lens and the retina less than, greater than or equal to the distance in a person with normal vision?

   (The person with normal vision had a distance of 11 cm between their lens and their retina, the person with the farsighted vision had a larger distance.)

5. What type of lenses would be in the glasses for a person with nearsighted vision?

   (Concave lenses)

6. A person cannot change the distance between their retina and their lens, in order to be able to see clearly, however some people have lasik eye surgery. This is where the cornea of the eye is reshaped using a laser. Would a nearsighted person want their cornea flattened or more round?

   (A person with nearsighted vision would want the shape of the cornea to be flatter, this would increase the focal point of their cornea allowing the image to be produced further away from their lens and focus on the back of their retina.)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

HOW GLASSES WORK IN NEARSIGHTED VISION

BACKGROUND:

A person who has nearsighted vision (also called myopia) means that image is focused in front of the retina. This can be caused by the distance between their lens and their retina being too large or the cornea being too rounded. People with myopia can usually see close (near) distances, but far away their vision is blurry and they will need glasses for driving.

PROCEDURE:

1. Start with the +100 lens and the screen aligned so there is a clear image on the screen.

2. Move the retina (screen) farther from the lens and record what happens to the vision of the person. Record your observations. (The further the screen and image get to one another the more blurry the image and the person's vision become.)

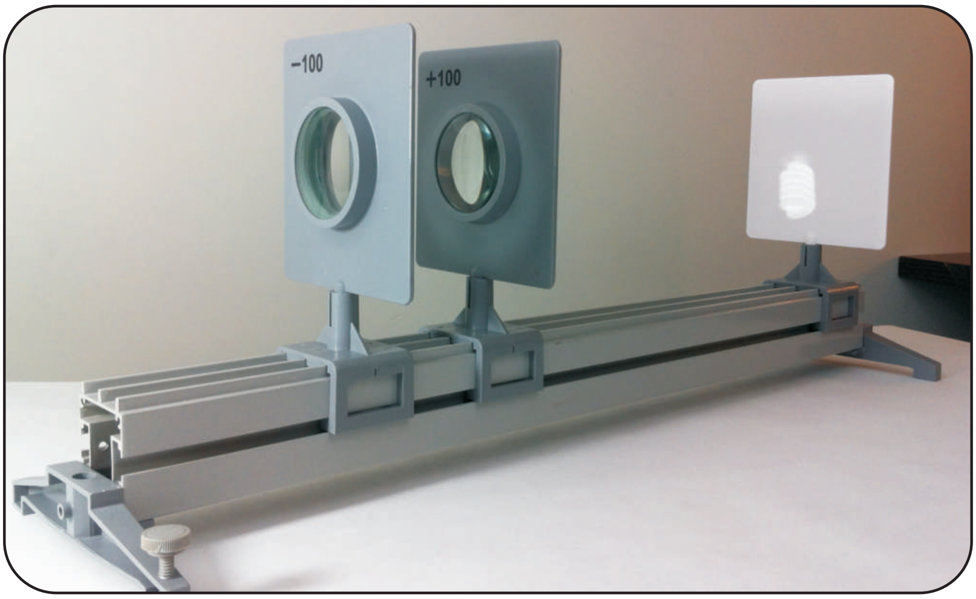


Diagram 26

3. Use the -100 concave lens to add some glasses (another lens) to the other side of the optics bench as shown in diagram 26 and then bring the lenses together so that they are touching. Adjust the screen (retina) until the image is clear again and then record the distance between the retina (screen) and the lens (the lens closer to the screen)

____

4. For a person with nearsighted vision, was the distance between the lens and the retina less than, greater than or equal to the distance in a person with normal vision?

5. What type of lenses would be in the glasses for a person with nearsighted vision?

6. A person cannot change the distance between their retina and their lens, in order to be able to see clearly, however some people have lasik eye surgery. This is where the cornea of the eye is reshaped using a laser. Would a nearsighted person want their cornea flattened or more round?

HOW A MOVIE PROJECTOR WORKS

BACKGROUND:

Many simple and useful devices are made from lenses. Inventions such as the astronomical telescope, the terrestrial telescope, and the microscope can all be modeled with this optics bench.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	4
White screen	1
+50 lens	1
Slide holder	1
Slide of arrow	1
Slide of city scene	1
Lamp	1
Red and black leads for lamp	2

REQUIRED COMPONENTS (NOT INCLUDED)

Power Supply	1

PROCEDURE:

Here we will set up our bench to model a slide projector.

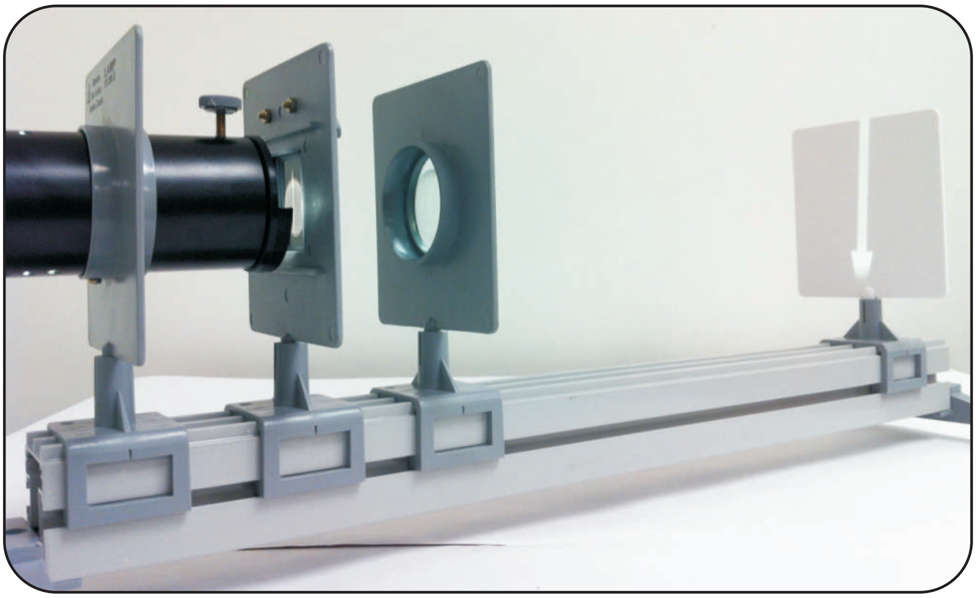


Diagram 27

1. Setup the optics bench to look like diagram 27. Notice that the lens is in place on the lamp for this experiment and the slide is very close to the lamp.

2. Place the arrow in the slide holder and use the f =+50mm lens to focus an image on the transparent screen.

3. Replace the arrow slide with the slide of the village.
   Record your observations below:
   (The image is real and magnified and inverted. The image can be moved in and out of focus by moving the slide to the left or right.)

ACTIVITY SHEET FOR STUDENTS USE

Name:____ Date:____________

HOW A MOVIE PROJECTOR WORKS

BACKGROUND:

Many simple and useful devices are made from lenses. Inventions such as the astronomical telescope, the terrestrial telescope, and the microscope can all be modeled with this optics bench.

WARNING: The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.

PROCEDURE:

Here we will set up our bench to model a slide projector.

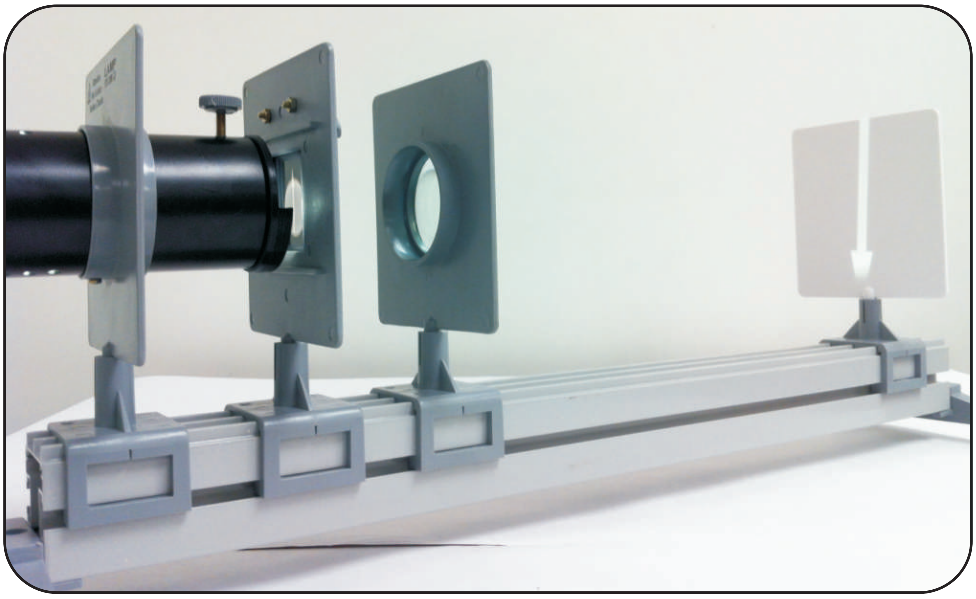


Diagram 27

1. Setup the optics bench to look like diagram 27. Notice that the lens is in place on the lamp for this experiment and the slide is very close to the lamp.

2. Place the arrow in the slide holder and use the f =+50mm lens to focus an image on the transparent screen.

3. Replace the arrow slide with the slide of the village.
   Record your observations below:

4. Research the optical set up of some other simple devices as listed in the background section and set up your optics bench to model these devices.

PROJECTING FIRE

WARNING: Before beginning this experiment, make sure to tie all hair back, remove all dangling or loose articles of clothing, and remove all flammable materials from the area. Take all safety precautions necessary when working with an open flame.

Use sticky tack or some other material to prevent the candle from sliding around on the apparatus. Take care not to move the candle too quickly or melting wax could drip and cause burns.

Students have a theoretical understanding of how lenses work after completing the ray diagrams. This activity puts all the lens concepts together. Students will see the images formed by a convex lens. They should be able to accurately predict what will happen.

Preview Questions: During this experiment, we will see actual images produced by a candle flame and be able to apply our knowledge of lenses to a real life situation. Using your knowledge of lenses, answer these questions to the best of your ability. After completing your experiment, you may revisit these questions before turning in your final answers.

1. Does a convex lens converge or diverge light rays?
   (Converge unless the object is between the focal point and the lens, in this case the rays diverge. If the object is at the focal point the image does neither)
2. Does a concave lens converge or diverge light rays?
   (Diverge only)
3. What happens to the image formed by a convex lens as an object moves closer to the lens?
   (The image gets larger as the object moves closer to the lens, at the focal point the image disappears and after the focal point the image turns from inverted to erect.)
4. An image cannot be formed by a convex lens when the object is located where?
   (At the focal point)
5. Can a convex lens can form real images, virtual images or both?
   (Both)
6. Can a concave lens can form real images, virtual images or both?
   (Virtual images)

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Optics bench with attached feet	1
Sliding optics bench components holders	3
White screen	1
+100 lens	1
Black square stand	1
Candle	1
-100 lens	1

REQUIRED COMPONENTS (NOT INCLUDED)

Matches or lighter	1
Clay or sticky tack	½" ball

PROCEDURE:

1. Set up your apparatus as shown in diagram 28. The lens should be at the 25cm mark. Use the f=+100 mm lens. Notice that the candle is stuck to the stand with clay or sticky tape so it does not slide off the stand while being moved along the optics bench.

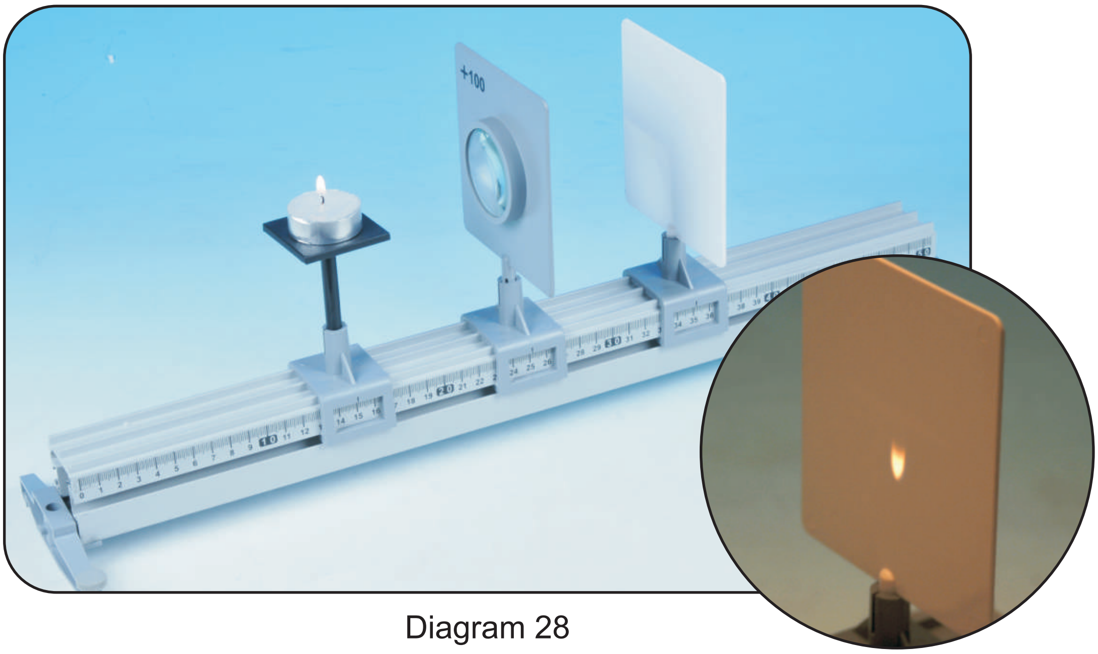


Diagram 28

2. Move the candle and paper at equal distance but opposite directions from the lens until you see a focused image of the candle on the paper. The candle and the paper should be the same distance from the lens within 0.5cm.

   (Using the f=+100mm lens a typical result might be at 45.4mm and 4.2mm)

3. This distance is called the center of curvature, which happens to be twice the focal length (also called 2F)

The center of curvature is at <u>*20.6*</u> cm from the lens

The focal point is at <u>*10.3*</u> cm from the lens

4. Place the object (the candle) at each of the locations listed on your data table. Determine the position of the image by moving the screen until a clear image is seen.

Position of Object	***Distance of image from lens (cm)***	***Type of Image (Real or none)***	***Erect or inverted image?***	***Size of image compared to object***
Beyond 2F	*23.4*	*Real*	*Inverted*	*Smaller*
At 2F	*20.6*	*Real*	*Inverted*	*Same size*
Between F and 2F	*16.4*	*Real*	*Inverted*	*Larger*
At F	*None*	*None*	*None*	*None*

5. Position the candle between the focal point and the lens and look through the lens at the candle. Describe the image you see.
(The image is virtual, right side up and larger than the object.)

6. Replace the convex lens with the concave lens (f=-100mm) and look at the candle through the concave lens. Describe the image you see.
(The image is virtual, right side up and smaller than the object.)

ACTIVITY SHEET FOR STUDENTS USE

Name:_______________________________________ Date:____________

PROJECTING FIRE

WARNING: Before beginning this experiment, make sure to tie all hair back, remove all dangling or loose articles of clothing, and remove all flammable materials from the area. Take all safety precautions necessary when working with an open flame.

Preview Questions: During this experiment, we will see actual images produced by a candle flame and be able to apply our knowledge of lenses to a real life situation. Using your knowledge of lenses, answer these questions to the best of your ability. After completing your experiment, you may revisit these questions before turning in your final answers.

1. Does a convex lens converge or diverge light rays?

2. Does a concave lens converge or diverge light rays?

3. What happens to the image formed by a convex lens as an object moves closer to the lens?

4. An image cannot be formed by a convex lens when the object is located where?

5. Can a convex lens can form real images, virtual images or both?

6. Can a concave lens can form real images, virtual images or both?

PROCEDURE:

1. Set up your apparatus as shown in diagram 28. The lens should be at the 25cm mark. Use the f=+100 mm lens. Notice that the candle is stuck to the stand with clay or sticky tape so it does not slide off the stand while being moved along the optics bench.

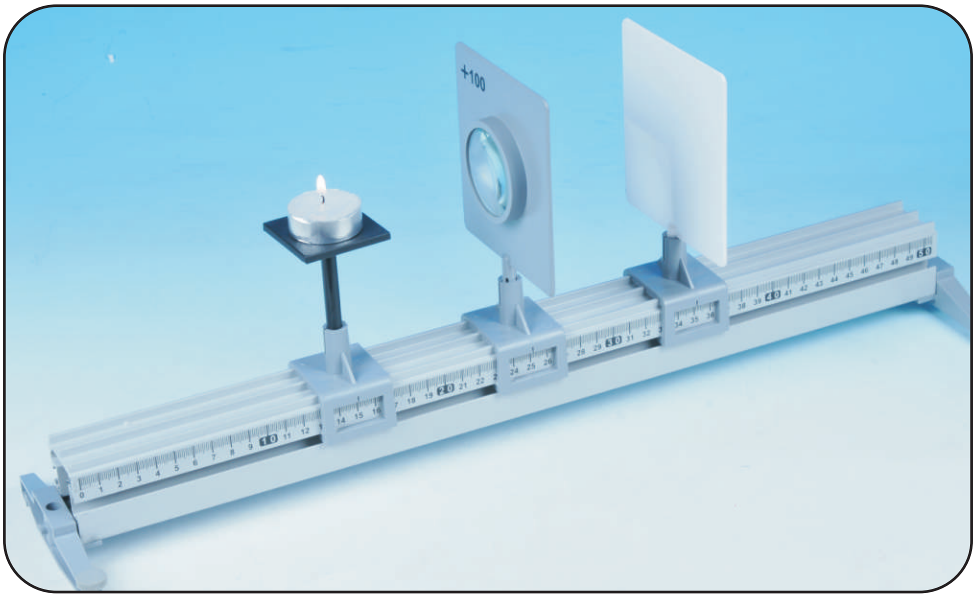


Diagram 28

2. Move the candle and paper at equal distance but opposite directions from the lens until you see a focused image of the candle on the paper. The candle and the paper should be the same distance from the lens within 0.5cm.

3. This distance is called the center of curvature, which happens to be twice the focal length (also called 2F)

The center of curvature is at ___________ cm from the lens

The focal point is at ___________________ cm from the lens

4. Place the object (the candle) at each of the locations listed on your data table. Determine the position of the image by moving the screen until a clear image is seen.

Position of Object	***Distance of image from lens (cm)***	***Type of Image (Real or none)***	***Erect or inverted image?***	***Size of image compared to object***
Beyond 2F				
At 2F				
Between F and 2F				
At F				

5. Position the candle between the focal point and the lens and look through the lens at the candle. Describe the image you see.

6. Replace the convex lens with the concave lens (f=-100mm) and look at the candle through the concave lens. Describe the image you see.

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