Optics Workshop at Chaya Someswara

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Contents

1 Workshop Objectives

- Understand laws of reflection (normal, incident ray, reflected ray, angle of incidence, angle of reflection)
- Understand laws of refraction (normal, angle of incidence, angle of refraction, Snell's law)
- Real and apparanet depth, refractive index, parallex
- Identification of convex lens, concave lens, convex mirror, and concave mirror
- Understand the meaning of pole, focal point, focal length, object, image, object distance, image distance, sign convention, lens formula, mirror formula, image properties (real/virtual, magnified/diminished, erect/inverted)
- Understand construction of eye, lens, retina, defects, and corrections
- Perception of depth with two eyes.
- Prism, ray tracing in prism, angles of interest and their relations, deviation by prism, angle of minimum deviation

See workshop home page

2 Experiments on Reflection

2.1 Laws of Reflection

2.1.1 Equipments

Plane mirror, thermocole sheet, paper, thumb pins, pins, protractor, scale, pencil

2.1.2 Introduction

The laws of reflection are,

1. The incident ray, reflected ray, and normal lies in the same plane.
2. The angle of incidence (i) is equal to the angle of reflection (r)

2.1.3 Procedure

1. Use thumb pins to fix the white paper on the thermocol sheet.
2. Place the mirror near to one edge of the paper and mark its position.
3. Draw normal to the plane mirror.
4. Place two pins vertically on one side of the normal so that line joining two pins make an angle of approximately 30 degree with the normal.

5. See image of two pins from other side of the normal and place a pin vertically so that it is in line with images of other two pins. Similarly, place one more pin at some distance from the first pin.
6. Extend the lines. Measure angle of incidence and angle of reflection.
7. Repeat for one more incident angle, say 45 degree.
8. Now, see the head of the pins in step (4). Raise one of the pin and press another pin. Now repeat step (5) such that images of the pin-head are aligned. Visualise the plane containing incident ray, reflected ray and normal. You may place a paper on this plane. Raise another pin and visualize again.

2.2 Game of Funny Cap

This game requires two plane mirrors (joined together) and a cap. Sit in front of the two mirrors. How many images do you see? How does number of images changes when the angle between two mirrors is changed. Set the angle so that you see two images. Wear the cap and see into the mirrors. There are two objects (colors) on the left and the right side of the cap. Quickly touch the object stated by a volunteer. Do you see anything strange? Why does this happen? Try to explain this with your knowledge of reflection by plane mirror. See that an image by the first mirror can act as an object of the second mirror and so on.

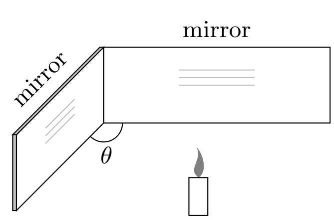
2.3 Beautiful Scene with Plane Mirrors

2.3.1 Equipments

Two plane mirrors, protractor to measure angle, a vertical object (like candle).

2.3.2 Introduction

The number of images formed by two adjacent plane mirrors depends on the angle between the mirrors. If x (in degrees) is the angle between the plane mirrors then number of images formed by them is given by n=360/x -1



2.3.3 Procedure

1. Place both the mirrors vertically with 180 degree angle between them.
2. Place an object in the space between the two mirrors.
3. You will see single image of the object in mirror. Reduce the angle between mirrors and observe multiple images which makes a very beautiful scene.

4. Now, measure the maximum angle between two mirrors when you get 1, 3, 5, and 7 images. Verify that these angles corresponds to the above formula.

5. Draw the ray diagram when angle between two mirrors is 90 degree.

3 Experiments on Refraction

3.1 Snell's law using glass slab

3.1.1 Equipment

Rectangular glass slab, thermocole sheet, white paper, protractor, pencil, scale, pins, thumb pins.

3.1.2 Introduction

The Snell's laws of refraction are,

1. The incident ray, refracted ray, and normal lies in the same plane.

2. The angle of incidence (i), angle of refraction (r) and the refractive index of the medium (n) are related by $\sin(i)/\sin(r)=n$

3.1.3 Procedure

1. Use thumb pins to fix a paper on the thermocole sheet.

2. Place the glass slab in the middle of the paper. Draw its boundary.

3. Find centre of the longer straight face and draw normal to it.

4. Draw a line starting from the centre of straight face making an angle of 30 degree from the normal.

5. Fix two pins vertically, separated by a distance of 10 cm or more, on this line.

6. See image of two pins from other side of the slab and place a pin vertically so that it is in line with the images of other two pins.

7. Similarly, place one more pin at some distance from this pin. Extend the lines.

8. Measure angle of incidence and angle of refraction at the first face. Notice that ray bends towards the normal. Calculate the refractive index of the material using the formula given above.

9. Similarly, measure the angle of incidence and angle of refraction for the refraction that takes place at the second face. Note that ray bends away from the normal. Calculate the refractive index of the glass using formula given above.

10. Why angle of refraction at the first face is equal to the angle of incidence at the second face?

11. Repeat above step with angle of incidence at first face equal to 45 degree.

3.2 Play with the Cards

3.2.1 Equipment

Rectangular glass slab, playing cards, scale

3.2.2 Introduction

1. Parallax If two objects A and B are separated from each other and we see from a position C along line AB, it appears to us that two are touching each other and we are not able to see them as separate objects. However, if we shift our eyes towards left, the two will look separated. If we do not have depth perception, object A will look towards left and B towards right. Similarly, if we shift the eye towards right, the object appears separated, A towards right and B towards left. If the two objects A and B are actually at same place then they always appear in contact wherever you move your eyes.

2. Apparent Depth The apparent depth h and real depth H are related to refractive index of the medium by n=H/h

3.2.3 Procedure

1. Draw a line on a sheet of paper. Place it on a table and put a transparent glass slab over it. The longer side of the slab should be vertical.

2. Mark similar line on another paper sheet. Put some blank cards (sheets) on the table adjacent to the slab and on the top of this stack put the marked sheet. Looking from the above, the two lines should be in the same line.

3. Insert or remove sheets from the stack to adjust the height so that no PARALLAX remains between the two lines, one as seen through the slab and other on top of the stack. In this situation, the depth of the stack is same as the image of the line formed by the slab.

4. Measure the apparent depth (h) and real depth (H) of the line. Calculate the refractive index of the glass by using the formula given above.

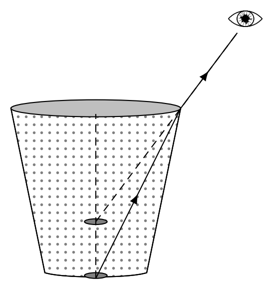
3.3 Rising of the Coin

3.3.1 Equipments

A bowl, coin, water

3.3.2 Introduction

When light travels from one medium to another medium, it bends at the interface between two media according to Snell's Law. This demo is an interesting way to demonstrate refraction of light.



3.3.3 Procedure

1. Put a coin in an opaque vessel placed on a table. Looking at the coin, move back your head till the coin just disappear from the view. Then ask someone to pour water into the vessel gently, without displacing the coin. As the vessel fills with water, the coin will rise into view.

2. Why does this happen? Initially, the rays emerging from the coin do not fall on the eye. However, when water is poured into the glass, the rays bend at the surface of the water and reach the eye. As the rays from the coin comes to water surface, it bends away from the normal. Thus light which was earlier going from above the eye now reaches the eye after refraction. This makes the coin visible.

3. Draw the ray diagram.

4 Spherical Mirror Formula

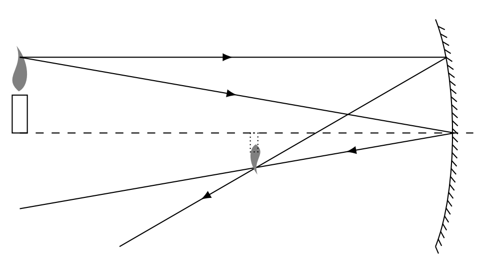
4.1 Have Fun with Concave Mirror

4.1.1 Equipments

A concave mirror, V-stand, Screen, candle, matchbox, meter scale.

4.1.2 Introduction

The object distance u, the image distance v, and the focal length of the mirror f are related by the mirror formula, $1/v + 1/u = 1/f$.



4.1.3 Procedure

1. Pick the concave mirror.

2. Find the approximate focal length of the concave mirror. Make a sharp circular image of a distant object (like sun). The mirror, the sun, and its image should be in the same straight line. Measure distance between the mirror and the image. It is the approximate focal length (f). Draw the ray diagram.

3. Fix the mirror vertically on a V stand. Draw a long straight line and place the mirror on one end. The pole of the mirror should be exactly above the line.

4. Light a candle (object) and place it at the middle of the line. Make sure that flame of the candle is at the same height as the pole of the mirror. Confirm it through measurement with a scale.

5. Place the mirror approximately 2f distance from the candle. Find a point where candle and its image are at the same distance from the mirror. This point is located at 2f from the mirror. Measure distance of this point from the mirror and find f. The screen should not block the path from the candle to the mirror. Draw the ray diagram?

6. Move the candle so that distance between the mirror and the candle is more than 2f. Move the screen such that there is a sharp image of the candle formed on the screen. The image is (a) real/virtual (b) smaller/ bigger (c) erect/ inverted. Measure u and v. Is u negative or positive? Is v negative or positive? Calculate f by using the mirror formula given above. Draw the ray diagram.

7. Move the candle so that distance between the mirror and the candle is less than 2f. Move the screen such that there is a sharp image of the candle formed on the screen. You need to shift the screen slightly so that it does not block the ray from the candle to reach the mirror. The image is (a) real/ virtual (b) smaller/ bigger (c) erect/ inverted. Measure the value of u and v. Calculate f by substituting in formula given above. Draw the ray diagram.

8. Move the candle so that the distance between the mirror and the candle is less than or equal to f. What do you observe? What are properties of the image? Draw the ray diagram.

4.2 Why we have Two Eyes?

Keep a glass in front of you. Ask your friends to sit about 5 m from the table. Hold a coin in your hand and move it slowly near the glass. One by one your friends should cover one eye and say when the coin is just above the glass. When they say so, drop the coin. You will find that in most cases your friends judge the position of the coin wrongly, and the coin falls outside the glass. But if they look through both the eyes, they will be able to judge the position of the coin correctly most of the time, and the coin will drop into the glass. This happens because we are unable to judge depth, or the relative distance between objects, with one eye, especially when the objects are at some distance from the eye. Two eyes are required to perceive depth. Also, we can see a wider area with two eyes than with one eye.

5 Spherical Lens Formula

5.1 Have Fun with Convex Lens

5.1.1 Equipments

A convex lens, V-stand, Screen, candle, matchbox, meter scale.

5.1.2 Introduction

The object distance u, the image distance v, and the focal length of the lens f are related by the lens formula, 1/v - 1/u =1/f. Note that u is the distance of the object from the lens and v is the distance of the image from the lens.

5.1.3 Procedure

1. Take a convex lens.

2. Find the approximate focal length of the convex lens. Make a sharp image of a distant object (like sun). Measure distance between the lens and the image. It is the approximate focal length (f). Note that a convex lens converges parallel rays at its focus. Draw the ray diagram showing rays from the sun, lens, focus, and focal length.

3. Fix the lens vertically on a V stand. Draw a long straight line and place the lens in the middle of the line. The pole of the lens should be exactly above the line.

4. Light a candle (object) and place it at one end of the line. The flame of the candle should be at about the same height as the pole of the lens. Confirm this by using a scale.

5. Place the screen on other side of the lens.

6. Move the lens so that distance between the lens and the candle is more than 2f. Move the screen so that sharp image of the candle is formed on the screen. Tick the correct options: The image is (a) real/ virtual (b) smaller/ bigger (c) erect/ inverted. Measure the value of u and v. The object distance u is negative or positive? The image distance v is negative or positive? Calculate f by substituting u and v in the lens formula given above. Draw the ray diagram.

7. Move the lens so that distance between the lens the candle is equal to 2f. Now, adjust the lens and the screen such that image distance is equal to the object distance. Can you find the focal length by measuring image distance? This is a quick way to find focal length of a convex lens. You can try this method to find focal length of other convex lens given to you. Tick the correct options: The image is (a) real/virtual (b) smaller/ bigger (c) erect/ inverted. Draw the ray diagram.

8. Move the lens so that distance between the lens and the candle is less than 2f. Move the screen so that sharp image of the candle is formed on the screen. Tick the correct options: The image is (a) real/virtual (b) smaller/ bigger (c) erect/ inverted. Measure the value of u and v. Calculate f by substituting in formula given above. Draw the ray diagram.

9. Move the lens so that distance between the lens and the candle is equal to f or less than f. Do you face any problem this time? What can you say about the properties of image i.e., (a) real/ virtual (b) smaller/ bigger (c) erect/inverted. Draw the ray diagram.

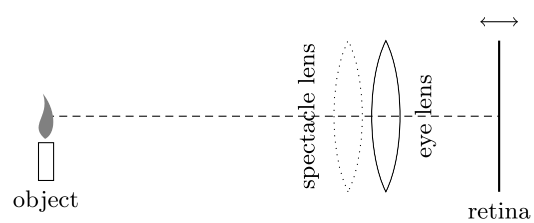
5.2 Become an Eye Doctor

5.2.1 Equipments

A V stand, a screen, candle, matchbox, convex lens, set of convex and concave lenses of different focal lengths.

5.2.2 Introduction

Let us understand how spectacles help in seeing. Human eye has various transparent parts which may be thought of a convex lens of some focal length which can be changed little bit while seeing objects at different distances. For clear viewing the image should form on the retina. Most common defects of vision, myopia and hypermetropia, occurs because the distance of the retina from the eye lens is less than or greater than what is required. Spectacles make the incoming light beam more divergent or less divergent to help the image to form on retina.



5.2.3 Procedure

1. Take the lens of small focal length. What is its approximate focal length?

2. Fix this lens in a stand to represent the eye lens.

3. Keep the candle at some distance (say 15 cm) from the lens.

4. Keep the screen on the other side of the lens to get sharp image of the candle. The screen represents the retina.

5. Now displace the screen slightly away from the lens. This represents a myopic eye where the eye ball is elongated or due to some other reasons the image forms before the retina. You see the image gets blurred.

6. Put an additional lens from the given stock in front of the eye lens and see the image. This is your spectacles glass to correct the myopia.

7. Now remove the additional lens, focus the image on retina by adjusting its position. Now shift the retina little bit towards the eye lens. This represents presbyopic eye where due to contraction of eyeball or otherwise, the image forms behind the retina.

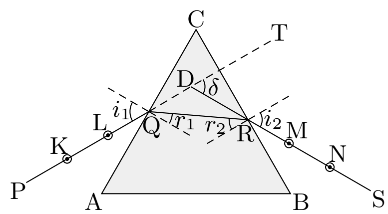
8. Put proper lens in front of the eye lens so that the image forms on the retina.

6 Prism

6.1 Let us Trace a Ray of Light Through a Prism

6.1.1 Equipments

Glass prism, thermocole sheet, paper, scale, pencil, protractor, pins, thumb pins



6.1.2 Procedure

1. Use thumb pins to fix a sheet of white paper on a thermocole sheet.
2. Place the prism in the middle and draw its outline. Remove the prism and mark three corners as A, B and C. Measure the prism angle A that is angle between lines AC and AB.
3. Let Q be the middle point of AC. Draw normal to AC at the point Q.
4. Draw a line starting from Q and makes an angle of 60 degree with the normal. Let this line be QP.
5. Put the prism on ABC. On the line QP, fix a pin K about 3-4 cm from Q and another pin L such that gap between two pins is about 10 cm.
6. Now look at the image of the pins from the side BC of the prism.
7. Fix a pin M such that it appears to be in a straight line, the other pins will disappear behind M. Fix another pin N (at least 10 cm from M) such that all four pins appear to be in a straight line.
8. Remove the prism and the pins. Join by a straight line the points where the pins M and N were inserted. This line, SR, meet BC at R. Join Q and R by a straight line. The lines PQ, QR and RS represent the directions of the incident ray, the ray within prism and the emergent ray respectively.
9. Draw perpendiculars to AC and BC at Q and R respectively. Measure the angles i1, r1, i2 and r2. Also, measure the angle of deviation d, i.e., the angle between PQ and RS.
10. Verify that A=r1+r2 and d=(i1+i2)-(r1+r2)
11. Now, reduce the angle of incidence in steps of 10 degrees and measure the angle of deviation. Take 4 readings. Plot angle of incidence versus angle of deviation. Do you observe something interesting? Record your observations in the following table

i1	i2	r1	r2	d
60				
50				
40				
30				

6.2 Dispersion

Make a slit such that sun light passes through it. Make the sun rays to fall on the prism and see the dispersion of white light into multiple colors. Why does it happen?

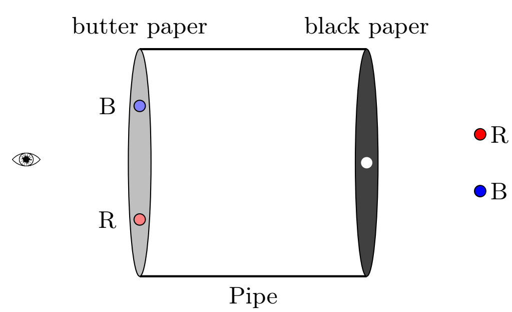
7 Miscellaneous

7.1 Total Internal Reflection

This can be demonstrated by using dettol bottle.

7.2 Lateral inversion by mirror

7.3 To know the working of Pin Hole Camera



7.3.1 Procedure

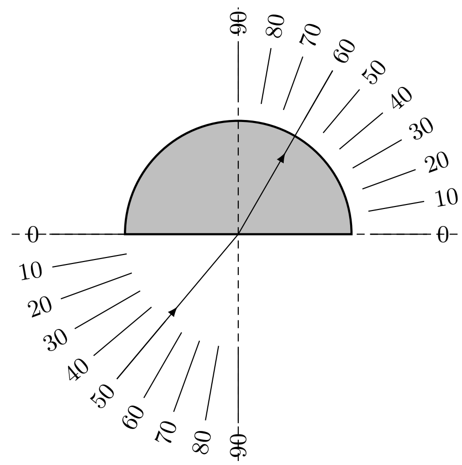
1. Observe the pin hole camera
2. Put up two LEDs, one blue and one red, side by side. Connect them to adapters and lit them.
3. Face your camera towards the LEDs, the hole towards the LEDs. Can you see the image?
4. Check, which of the image is on left and which is on right. Is it in the same order as the actual LEDs or it gets reversed in order?
5. Check if you can see the details of an LED in the image, its round body and so on.
6. Increase the distance of the camera from the LEDs. What happens to the image?
7. Face the camera towards other objects like a photo on your mobile screen. Are you able to see the image?

7.3.2 Discussion

An image is formed when at any point on the screen, you get light coming from a definite point of the object. In a lens, refraction ensures that. In pin hole the small size of the hole ensures that. The image is faint as only a small pencil of light from a given point of object reaches the screen.

7.4 Verification of the Snell's Law Using Semi-circular Disc

You need a semi-circular disc, paper, thermocole sheet, pins, protractor, laser light.



1. Place the semi-circular disc on the paper. Draw its boundary. Find centre of the face and draw normal to it.

2. Draw three lines making an angle of 30 degree, 45 degree, and 60 degree with the normal.

3. Place the laser such that incident ray is parallel to one of the line and it strike the semi-circular disc at centre of rectangular face. Observe the refracted light. Mark two points on the path of refracted line and join them. Measure angle of incidence, angle of refraction, and calculate n using formula given above.

4. Repeat above step for other two angles.

5. Why incident ray should strike at the centre of rectangular face of semi-circular disc?

7.5 Light Box

This is for demonstration. Need a power plug point and relatively dark place. The setup can be used to demonstrate:

1. The rays from a point source becomes parallel if it is placed at the focus of a convex lens. Open the light box and show the source (bulb) and the lens (inside the box). Now close it and switch on the power to light the bulb. Slide the tube till rays of light becomes parallel.

2. The convex lens converges parallel rays at its focus. Adjust the light source such that emergent rays are parallel. Now place a convex lens and observe where the raws converges. You can use this to measure focal length of the convex lens.

3. The concave lens diverges the rays of light.

7.6 Paper Microscope

7.6.1 Introduction

The apparent size of an object (as seen by the eye) increases as the object comes closer to the eye. But you cannot bring the object too close to the eye as the image does not form on the retina. This is because the eye cannot decrease the focal length of the eye lens beyond a limit. With a pin hole in a paper you can overcome this difficulty.

7.6.2 Procedure

1. Take the sheet of paper (approx 3 inch by 3 inch) and punch a small hole using the tip of your pen.

2. Make the hole smooth if there are threads coming out at periphery. This is your paper microscope.

3. Now take a printed page very close to your eye, say at 3-4 cm. You are not able to read what is written on the page.

4. Keeping the printed page in the same position, bring the paper microscope in between the eye and the page. Are you able to see the letters clearly?