University of Salahaddin-Erbil
College of Education
Department of Physics

Optics Lab.

First Semester:

Ray (Geometrical) Optics

Lecturer:
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Outline

Experiment No. (1)

Studying the Phenomenon of Reflection and Refraction of Light

Experiment No. (2)

Studying the Focal Length of a Convex Lens

Experiment No. (3)

Studying the Focal Length of a Concave Mirror

Experiment No. (4)

Studying the Chromatic Aberration of a Lens

Experiment No. (5)

Studying the Relation between Intensity of Light and the Distance from the Light Source (Inverse Square Law)

Experiment No. (6)

Studying the Relation between Intensity of Light and Angle of Reflection (Lambert's law)

Experiment No. (7)

Studying the Aberration of a Plano Convex Lens (Astigmatism)

Introduction

Q/ What is Optics?

Optics is the branch of physics that studies the behaviour and properties of light, including its interactions with matter and the construction of instruments that use or detect it.

Geometrical Optics, or Ray Optics:

It is a branch of optics where light is described by rays.

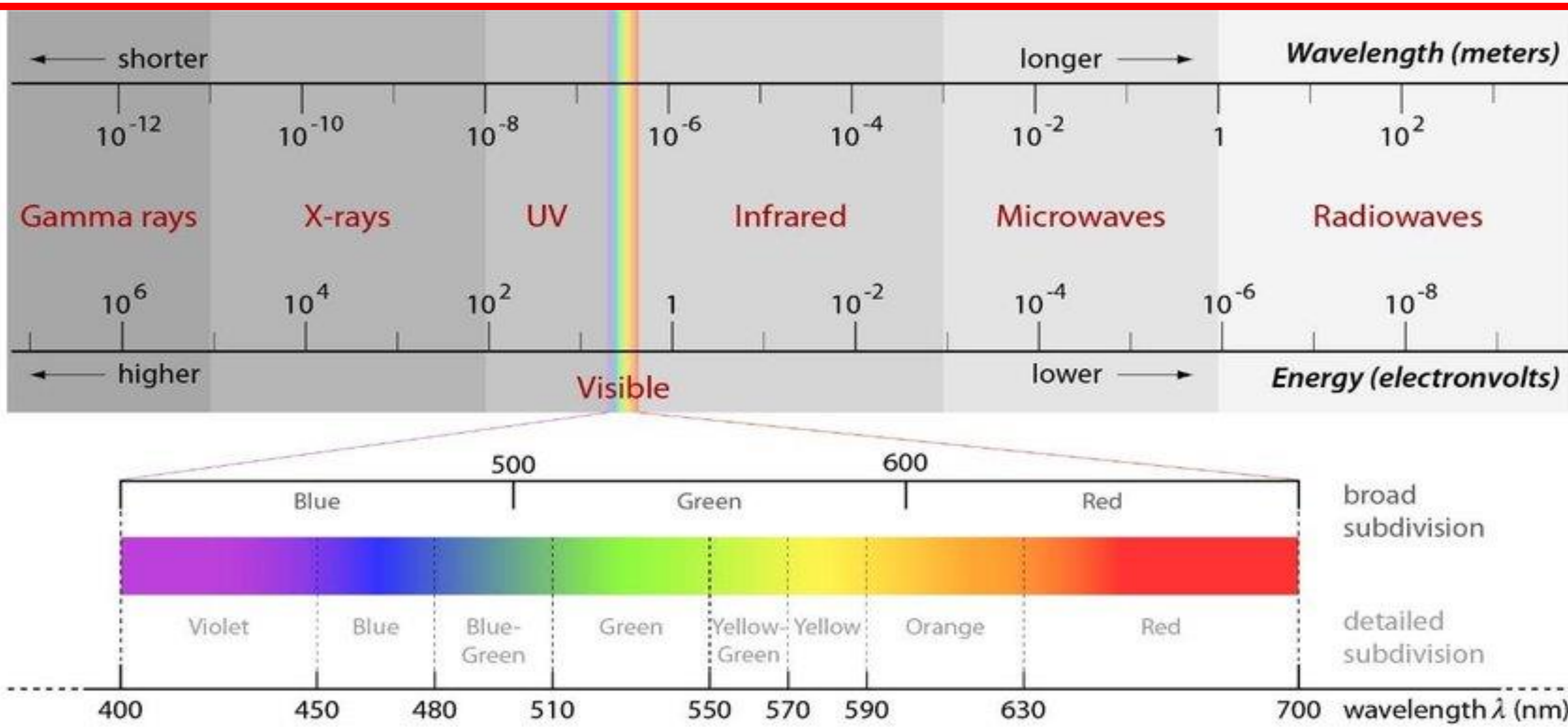
Ray: In geometry, a ray can be defined as a part of a line that has a fixed starting point but no end point. It can extend infinitely in one direction.

The simplifying assumptions of geometrical optics include that light rays:

- Propagate in straight-line paths as they travel in a homogeneous medium.
- Bend, and in particular circumstances may split in two, at the interface between two dissimilar media.
- Follow curved paths in a medium in which the refractive index changes.
- May be absorbed or reflected.

Introduction

Light: Light is an electromagnetic wave and the straight line paths followed by narrow beams of light, along which light energy travels, are called **rays**. Light always travels in straight lines although **its direction** can be **changed** by **reflection** or **refraction.**



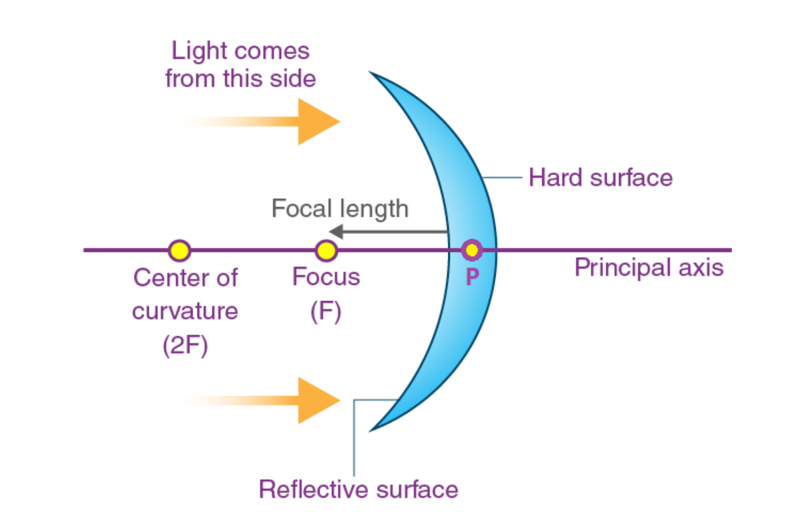
Introduction

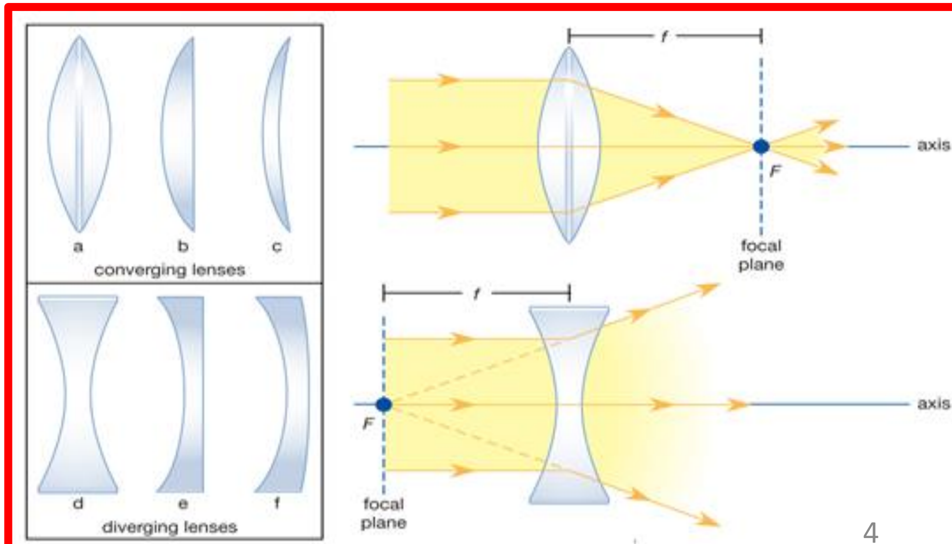
Lens: A lens is an image-forming device. It forms an image by refraction of light at its two bounding surfaces. In general, a lens is made of glass and is bounded by two regular curved surfaces; or by one spherical surface and a plane surface.

Convex Lens: A convex lens is a lens which is thicker in the middle and thinner at the edges. It is also known as Converging Lens.

Concave Lens: A concave lens is a lens which is thinner in the middle and thicker at the edges. It is also known as Diverging Lens.

Mirror: It is a reflective surface that bounces off light, thus producing a real or virtual image.





Introduction

Center Of Curvature (C): It is the center of the sphere of which the mirror is a small segment

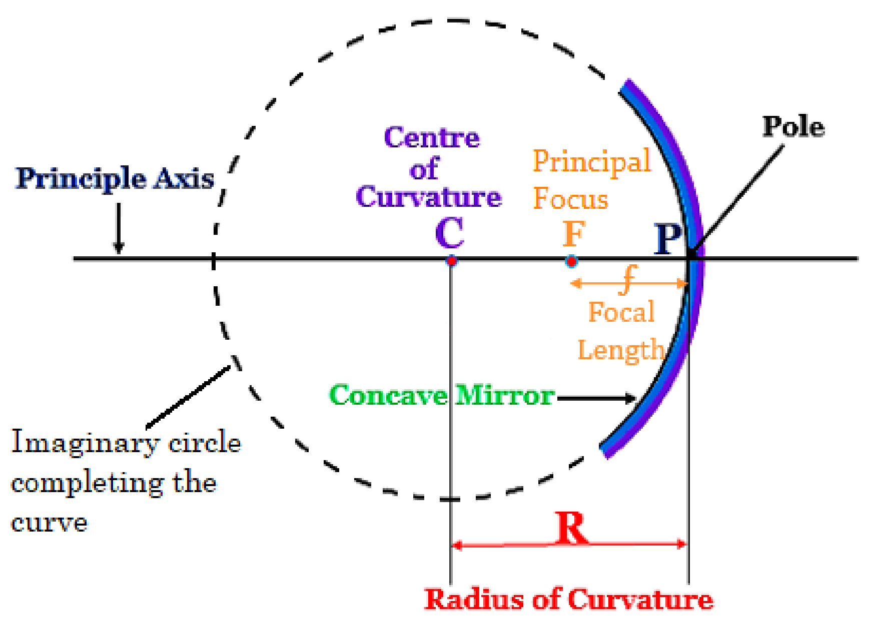
Vertex (Or Pole) P: It is the midpoint of the mirror.

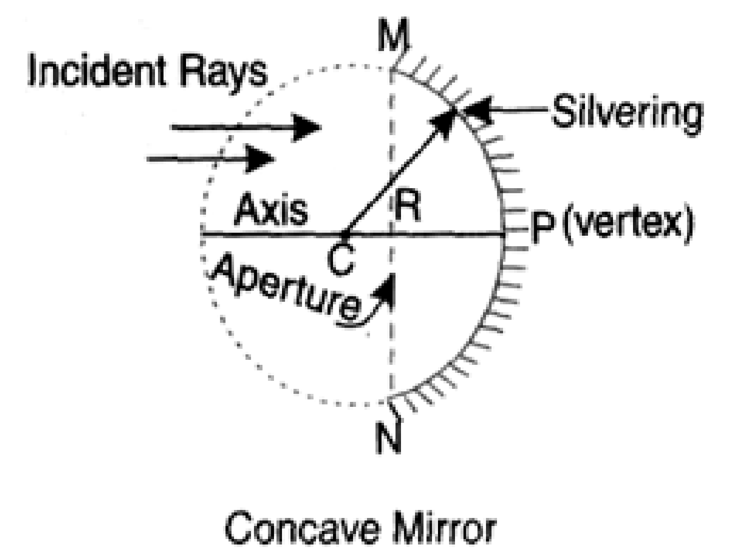
Radius Of Curvature (R): It is the radius of the sphere of which the mirror is a small section.

Principle Axis: It is the line passing through the center of curvature C and the vertex P.

Focal Length: The focal length ***f*** of the mirror is the distance, **PF**, between the vertex **P** and the principal focus **F**.

Aperture: It is the diameter **MN** of the circular outline of the mirror.

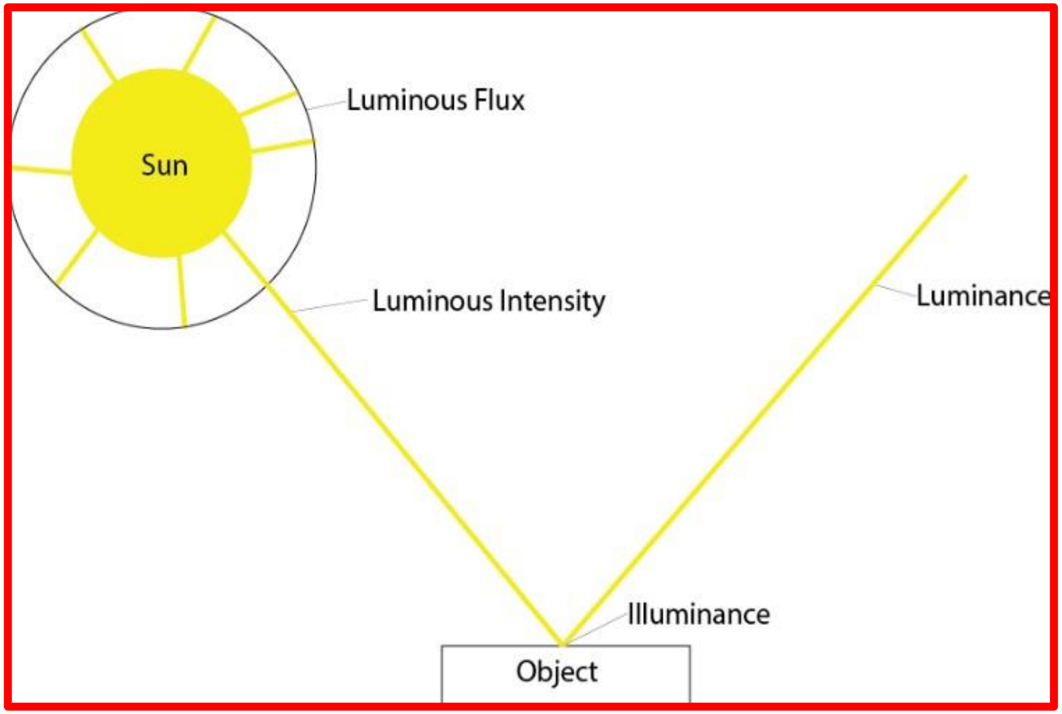




Introduction

Luminance: luminance is the amount of light emitted, passing through or reflected from a surface. It measures in Candela per Square meter (Cd/m^2) or lumen per steradian per meter square $[lm/(sr.m^2)]$.

Illuminance: Illuminance is the intensity of light falling on a surface area, such as a wall or a desk. It is not the same as the amount of light produced by a light source. It measures in lux or (lm/m^2).



Experiment No. (1) Reflection And Refraction Of Light

Aim:

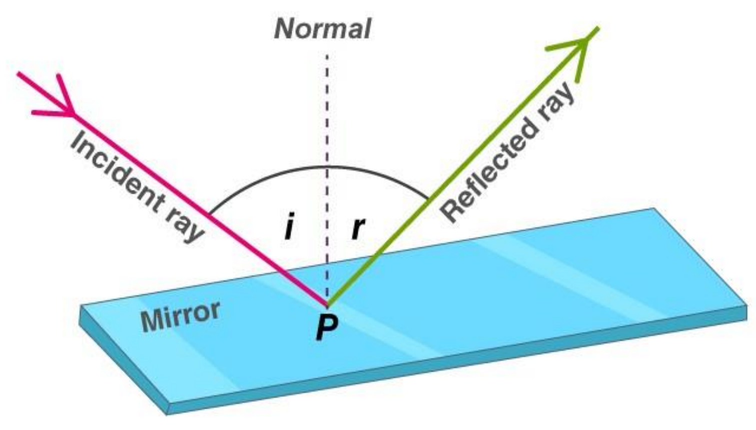
The aims of this experiment are to study:

1) the reflection of light from plane (flat) surfaces.
2) the refraction of light from plane (flat) surfaces.

Part 1: Reflection of Light:

Q/ What is Reflection of Light?

When a ray of light approaches a smooth polished surface and the light ray bounces back, it is called the reflection of light.

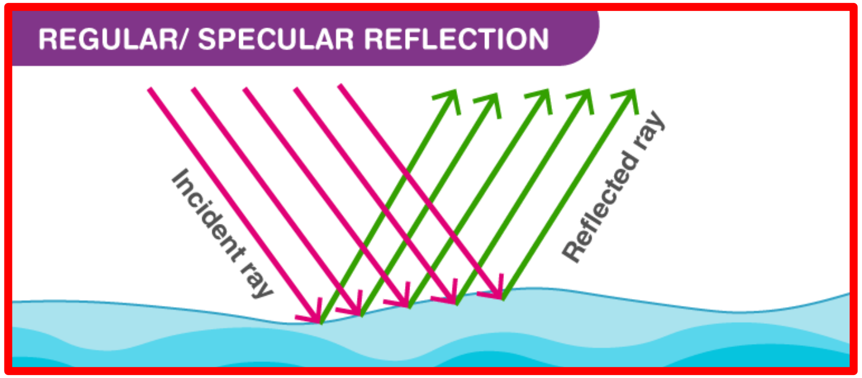


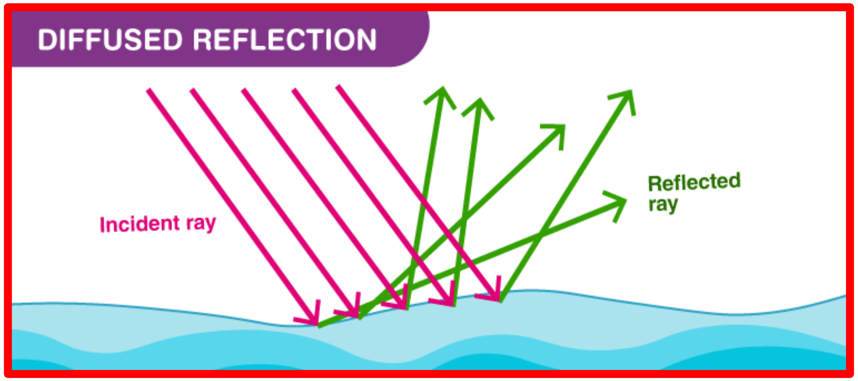
Experiment No. (1) Reflection And Refraction Of Light

Types of Reflection of Light:

1 Regular Reflection (Specular Reflection):

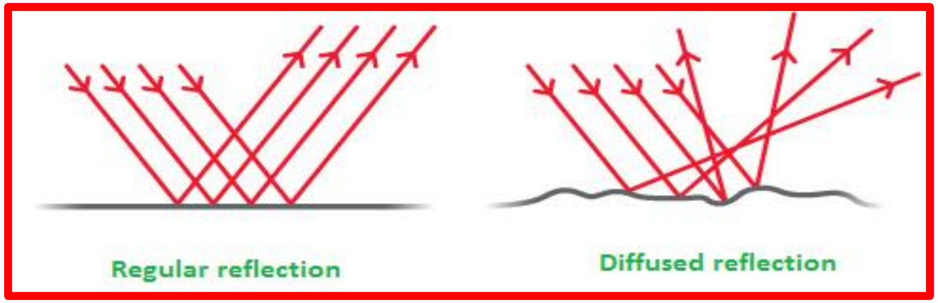
Specular Reflection refers to a clear and sharp reflection, like the ones you get in a mirror.





2 Diffused Reflection:

Reflective surface other than mirrors, in general, has a very rough finish. This may be due to wear and tear such as scratches and dents or dirt on the surface.



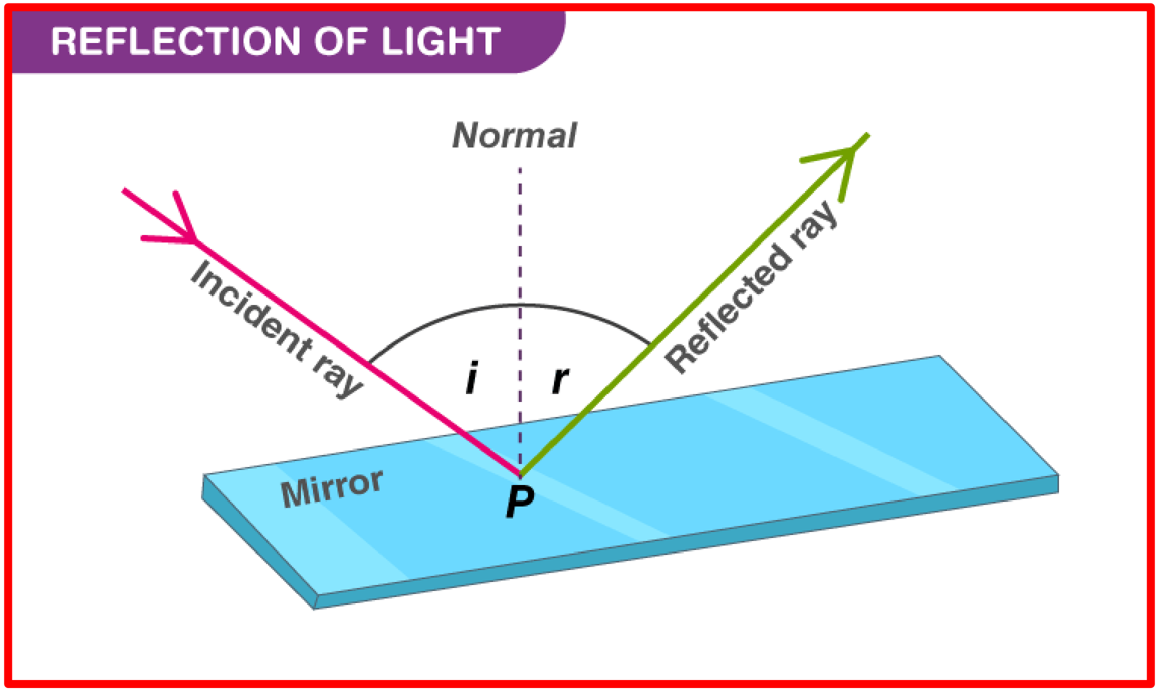
Experiment No. (1) Reflection And Refraction Of Light

Laws of Reflection:

Considering the reflected part of light at an interface, experiments with rays of light show that two laws hold.

1. The angle of reflection equals the angle of incidence, $\theta_i = \theta_r$

2. The incident ray, the reflected ray and the normal ray at the point of incidence, lie in the same plane.



Experiment No. (1) Reflection And Refraction Of Light

Apparatus:

1) Light box, halogen 12V/20 W
2) single-slit/double-slit aperture
3) Mirror on block, 50 mm x 20 mm
4) PHYWE power supply
5) Optical Disk

Procedure:

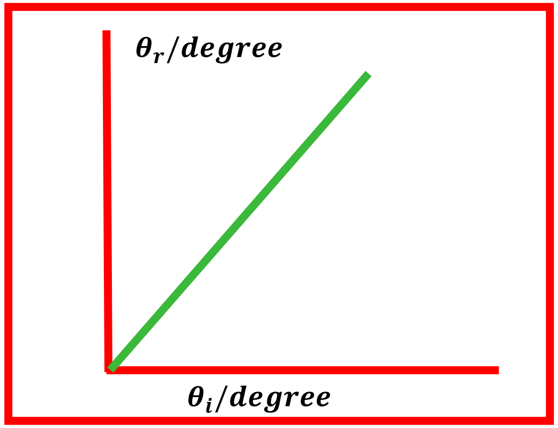
1) Set up the experiment as shown in the figure above.
2) Switch on the power supply.
3) Put the mirror diagonally in front of the light box.
4) Now, the light hits the mirror at an angle (incident angle) and reflected it (reflected angle).
5) Read the incident angle and reflected angle on the optical disk.
6) Change the angle of incident then read the reflected angle.

Experiment No. (1) Reflection And Refraction Of Light

7) Repeat step 6 for different angles and draw a table as shown below.

Incident angle $\theta_i/degree$	**Reflected angle $\theta_r/degree$**
10	
20	
: :	

8) Now, plot $\boldsymbol{\theta_i/degree}$ on x-axis and $\boldsymbol{\theta_r/degree}$ on y-axis then find the slope of the line.



9) The slope must be unity because the incident and reflected angle happen in the same medium and its value are equal ($\theta_i = \theta_r$), this means ($n_i = n_r$).

Experiment No. (1) Reflection And Refraction Of Light

Part 2: Refraction of Light:

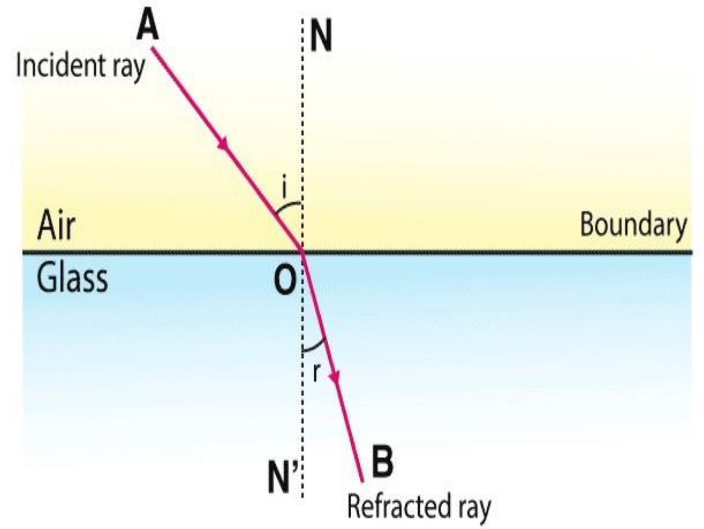
Q/ What is Refraction of Light?

When a light ray strikes a smooth interface between two transparent media at an angle, it is refracted. The bending of light as it passes from one medium to another is known as **refraction. Or** Refraction is the change in the direction of a light ray passing from one medium to another.

Refractive Index (n):

The physical significance of refraction index (n) is that it is the ratio of the velocity of light in empty space, c $(3 * 10^8\ m/s)$, to its velocity in the particular medium v.

$$\boldsymbol{n = \frac{c}{v}}$$



Experiment No. (1) Reflection And Refraction Of Light

The laws of Refraction:

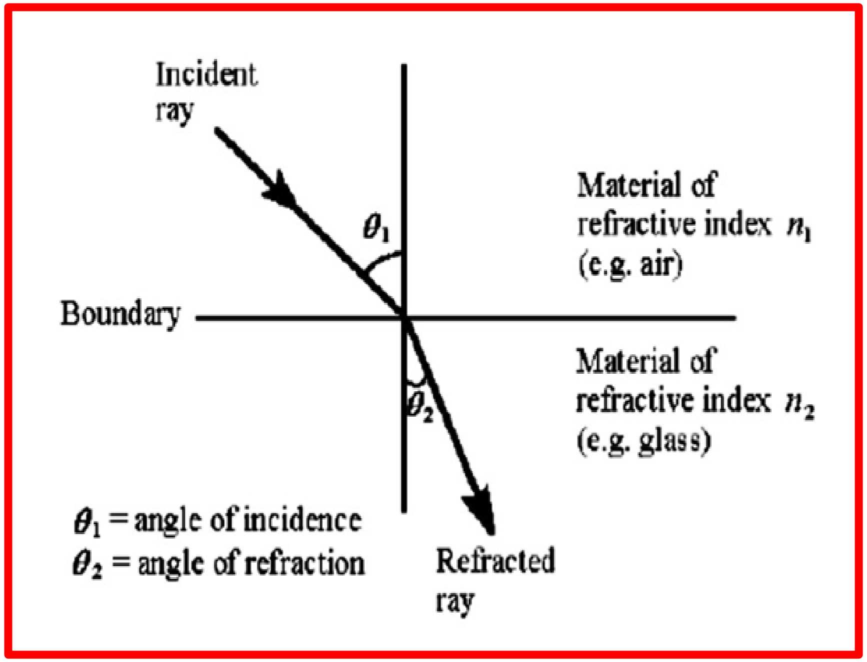
1. The incident ray, refracted ray and the normal at the point of incidence are all in the same plane.

2. At the boundary between any two given materials, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for rays of any particular wavelength .This is known as Snell's law.

$$\frac{\mathbf{Sin}(\boldsymbol{\theta_1})}{\mathbf{Sin}(\boldsymbol{\theta_2})} = \boldsymbol{a}\ (\boldsymbol{constant}) \quad --- (1)$$

The value of the **constant (a)** turns out to be equal to the ratio of the velocity of light in **material (1)** to that in **material (2).** The ratio is known as the **relative refractive index.**

$$\boldsymbol{a} = \frac{\textbf{velocity of light in material (1)}}{\textbf{velocity of light in material (2)}}$$



Experiment No. (1) Reflection And Refraction Of Light

$$a = \frac{\text{velocity of light in material (1)}}{\text{velocity of light in material (2)}}$$

$$a = \frac{\frac{C}{n_1}}{\frac{C}{n_2}}$$

$$a = \frac{n_2}{n_1} \quad ---(2)$$

By substituting Eq. (1) into Eq. (1) we get: $\frac{\text{Sin}(\theta_1)}{\text{Sin}(\theta_2)} = \frac{n_2}{n_1}$

$n_1 \text{Sin}(\theta_1) = n_2 \text{Sin}(\theta_2)$ **This is called Snell's law.**

Substance	*n*	Substance	*n*
Air	1 .00	Glass, flint	1.63
Benzene	1.50	Glycerine	1.47
Carbon disulfide	1.63	Ice	1.31
Diamond	2.42	Quartz	1.54
Ethyl alcohol	1.36	Rock salt	1.54
Fabulite	2.41	Turpentine	1.47
Fluorite	1.43	Water	1.33
Glass, crown	1.52	Zircon	1.92

TABLE 1. Refraction indices of various materials

Experiment No. (1) Reflection And Refraction Of Light

Apparatus:

1) Light box, halogen 12V/20 W
2) single-slit
3) A glass block
4) PHYWE power supply
5) Optical disk

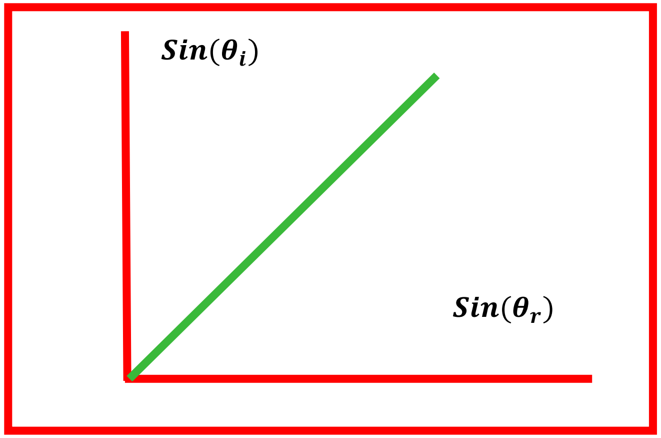
Procedure:

1) Set up the experiment as shown in the figure above.
2) Switch on the power supply.
3) Now, let the light hits the glass at an angle (incident angle) and the light will be refracted (reflected angle) by the glass.
4) Read the incident angle and refracted angle on the optical disk.
5) Change the angle of incident then read the refracted angle.

6) Repeat step 6 for different angles and draw a table as shown below.

Incident angle $\theta_i/degree$	Refracted angle $\theta_r/degree$	$Sin(\theta_i)$	$Sin(\theta_r)$
10			
20			
: :			

7) Now, plot $\boldsymbol{\theta_i/degree}$ on x-axis and $\boldsymbol{\theta_r/degree}$ on y-axis then find the slope of the line.



8) Use Snell's Law ($n_i sin(\theta_i) = n_r \sin(\theta_r)$) to find the slope of the line. The slope is equal to the refractive index of glass (n_r). The calculated value should match 1.52.

Experiment No. (1) Reflection And Refraction Of Light

Questions:

1) Define Refraction of light

2) Define Reflection of light.

3) What are the differences between specular and diffused reflections?

4) State the laws of refraction of light.

5) State the laws of reflection of light

6) When does refraction of waves occur?

7) When is the refraction of light not possible?

8) What is the difference between reflection and refraction in the light?

9) State an example of refraction of light.

10) Explain why light bends when it passes from one medium to another.

11) Is there any angle at which light does not bend when it goes from air into glass? Explain.

12) What will happen to a ray when it goes from a less dens medium (air) to a more dense medium (glass)? Does it refract towards the normal?

13) What will happen to a ray when it goes from a more dense medium (glass) to a less dense medium (air)? Does it refract away from the normal?

Experiment No. (2) Studying The Focal Length Of A Convex Lens

Aim:

The aim of this experiment is to determine the focal length and magnification of convex thin lens, and compare with theoretical prediction.

Q/ What is Convex Lens?

Convex Lens: A convex lens is a lens which is thicker in the middle and thinner at the edges. It is also known as Converging Lens.

Q/ What is thin lens?

A lens is said to be thin if the thickness of the lens can be neglected when compared to the lengths of the radii of curvature of its two refracting surfaces, and to the distances of the objects and images from it.

Q/ What is Focal Length?

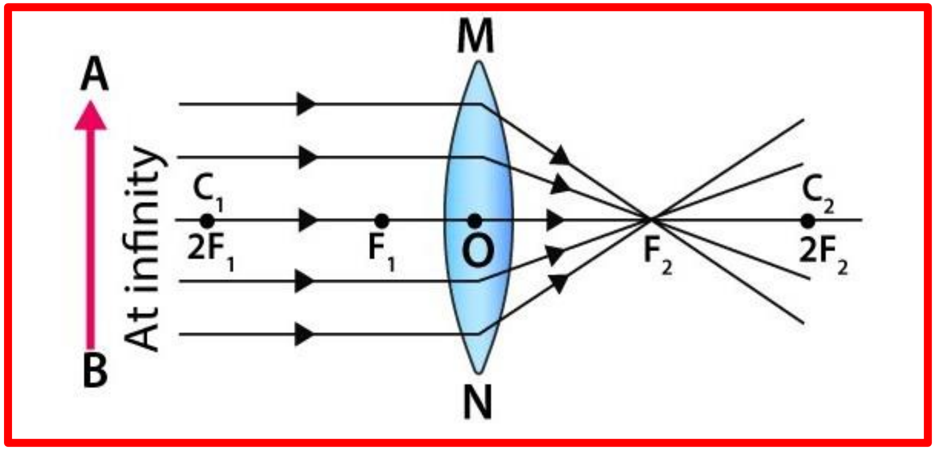
Focal Length: The **focal length *f*** of the lens is the distance between the center of the lens and the principal focus (Focal Point).

Experiment No. (2) Studying The Focal Length Of A Convex Lens

Image Formation By Convex Lens:

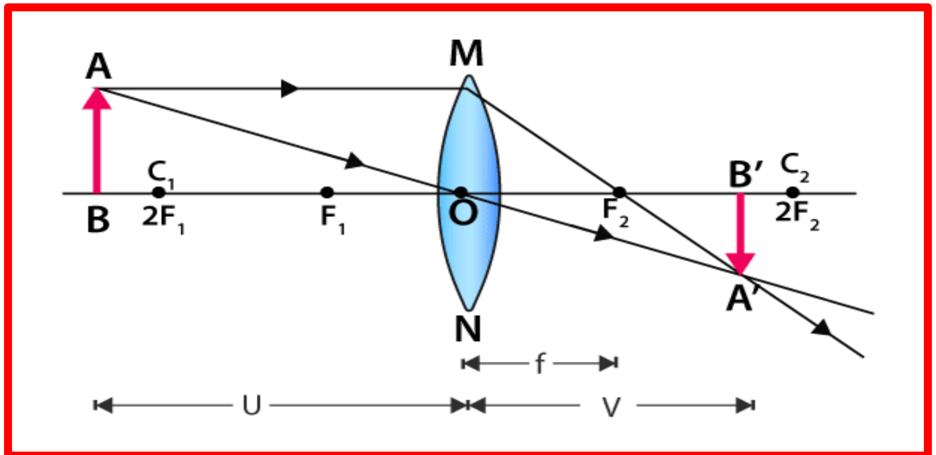
1 Object is placed at infinity:

- The real image is formed at the focus.
- The size of the image is much smaller than that of the object.



2 Object behind the center of curvature, C1 or 2F:

- The real image is formed between the center of curvature and focus.
- The size of the image is smaller as compared to that of the object.
- The Image is inverted.

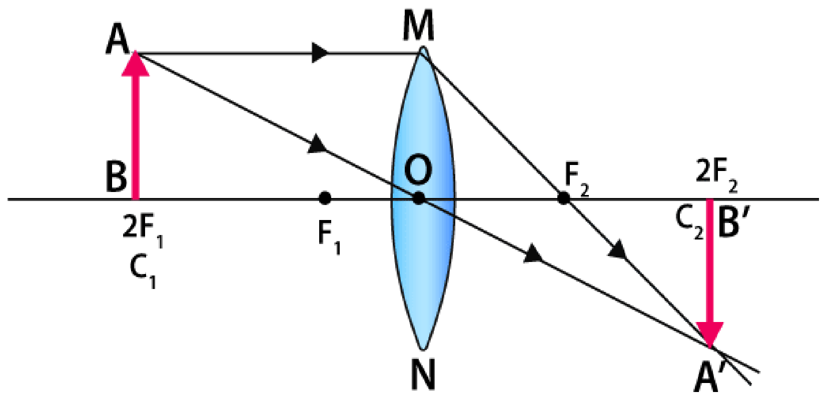


Experiment No. (2) Studying The Focal Length Of A Convex Lens

Image Formation By Convex Lens:

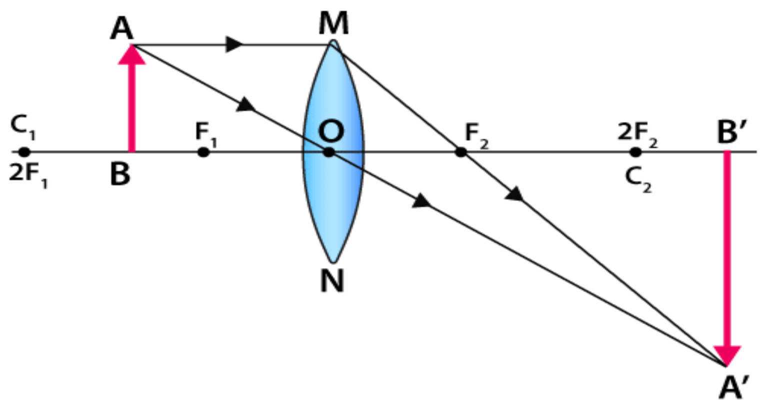
3 Object is at the center of curvature C1 or 2F:

- the real image is formed at the other center of curvature or 2F’.
- The size of the image is the same as compared to that of the object.
- The Image is inverted.



4 Object is placed in between the center of curvature C1 or 2F and focus F1:

- The real image is formed behind the center of curvature C2 or 2F’.
- The size of the image is larger than that of the object.
- The Image is inverted.

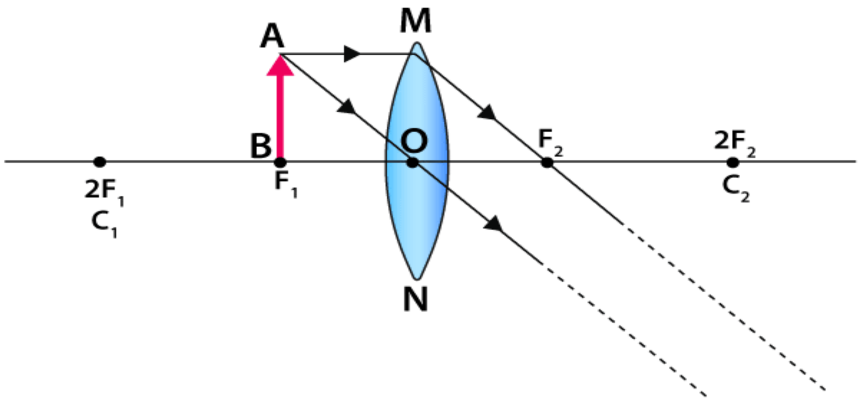


Experiment No. (2) Studying The Focal Length Of A Convex Lens

Image Formation By Convex Lens:

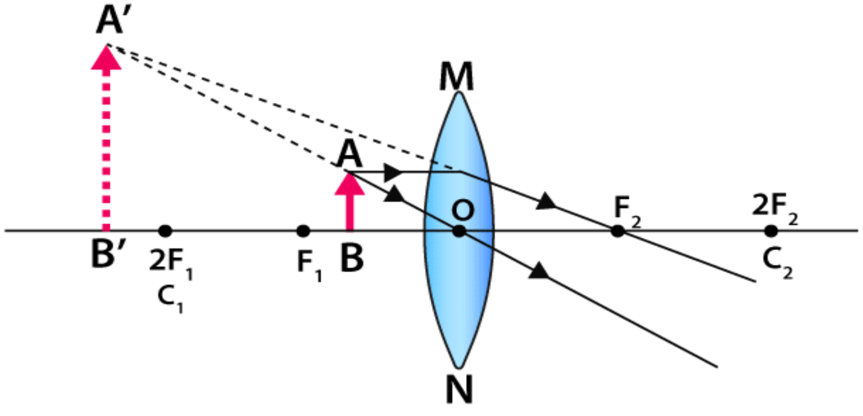
5 When an object is placed at the focus:

- A real image is formed at infinity.
- The size of the image is much larger than that of the object.



6 When an object is placed in between focus and pole:

- A virtual image is formed.
- The size of the image is larger than that of the object.



Experiment No. (2) Studying The Focal Length Of A Convex Lens

Image formation by Convex Lens			
Object location	**Image location**	**Image nature**	**Image size**
Infinity	At F2	Real and Inverted	Diminished
Beyond 2 F1	Between 2F2 and F2	Real and Inverted	Diminished
Between 2F1 and F1	Beyond 2F2	Real and Inverted	Enlarged
At F1	At infinity	Real and Inverted	Enlarged
At 2 F1	At 2F2	Real and Inverted	Same size
Between F1 and 0	On the same side as the object	Virtual and Erect	Enlarged

Experiment No. (2) Studying The Focal Length Of A Convex Lens

Lens defects in image formation:

1 Chromatic Aberration:

Chromatic aberration is a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, and/or when wavelengths of color are focused at different positions in the focal plane.

Q/ What causes Chromatic Aberration to be occurred?

Chromatic aberration is caused by **lens dispersion**, with different colors of light travelling at different speeds while passing through a lens. As a result, the image can look **blurred or noticeable colored edges** (red, green, blue, yellow, purple, magenta) can appear around objects, especially in high-contrast situations.

with no Chromatic aberration

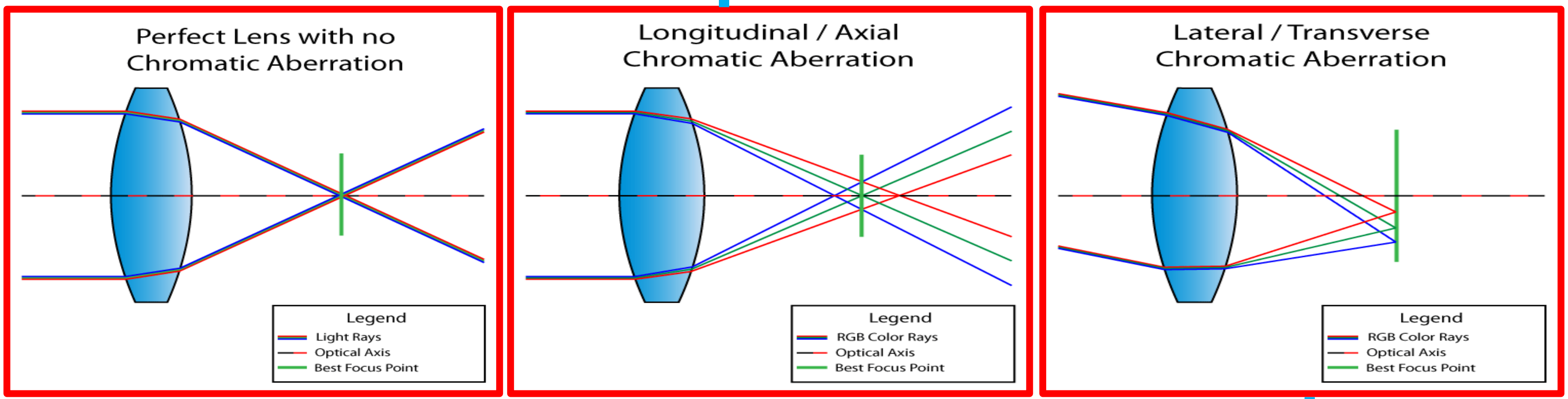
with Chromatic aberration

Experiment No. (2) Studying The Focal Length Of A Convex Lens

Types of Chromatic Aberration:

A Longitudinal or Axial Chromatic Aberration

Longitudinal or Axial Chromatic Aberration occurs when different wavelengths of color do not converge at the same point after passing through a lens, as illustrated below.



B Lateral or Transverse Chromatic Aberration

Lateral or Transverse Chromatic Aberration occurs when different wavelengths of color coming at an angle focus at different positions along the same focal plane, as illustrated above.

Experiment No. (2) Studying The Focal Length Of A Convex Lens

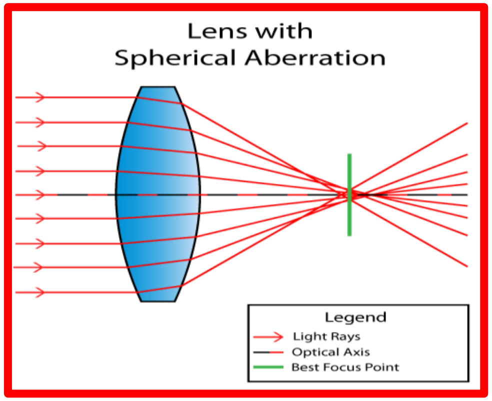
How to reduce (minimize) Chromatic Aberration?

By using two or more lenses of different materials, the chromatic aberration can be reduced. A combination of two lenses is called an **achromatic combination**, to have an achromatic combination of two lenses, one of the lenses should be convex (crown) and the other concave (flint).

2 Spherical Aberration:

Spherical Aberration occurs when **all incoming light rays** end up **focusing at different points** after passing through a spherical surface.

- Light rays passing through a lens near its **horizontal axis** are **refracted less** than rays **closer to the edge** of the lens and as a result, end up in different spots across the optical axis.
- Because of this, Spherical Aberration can affect **resolution and clarity**, making it hard to obtain **sharp images**. Here is an illustration that shows Spherical Aberration:



Experiment No. (2) Studying The Focal Length Of A Convex Lens

How to reduce (minimize) Spherical Aberration?

Spherical aberration is minimized by the following methods:

1) Spherical aberration can be minimized by using **stops,** which reduce the effective lens aperture.
2) Spherical aberration can be minimized using a **biconcave lens** which the ratio between $\mathbf{R_1}$ and $\mathbf{R_2}$ is $(\frac{1}{6})$.
3) **Plano-convex lenses** are used in optical instruments so as to reduce the spherical aberration.
4) Spherical aberration can also be made minimum by using **two Plano-convex lenses separated by a distance equal to the difference in their focal length.**
5) Spherical aberration for a convex lens is +ve and that for a concave lens is -ve. By a suitable **combination** of **convex and concave lenses** spherical aberration can be made minimum.
6) Spherical aberration may be minimized by using **axial-GRIN (Gradient Index)** lenses.

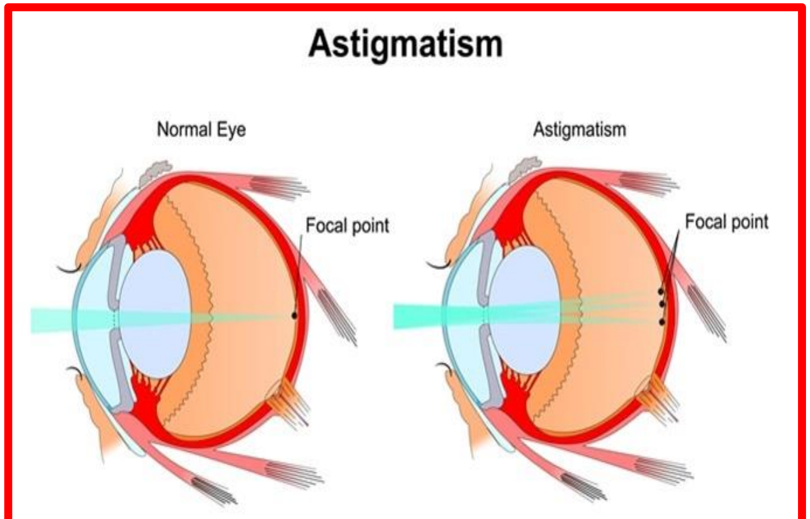
Experiment No. (2) Studying The Focal Length Of A Convex Lens

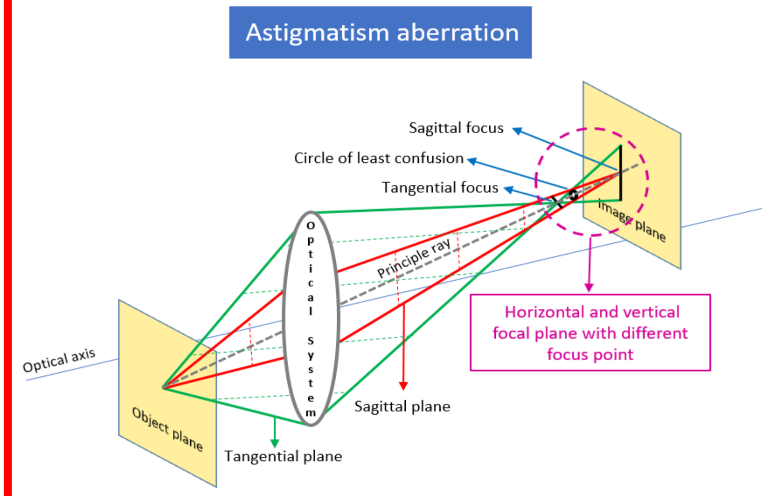
3 Astigmatism:

Astigmatism occurs when the curvature (or the thickness) of a lens is not the same in all planes which pass through the optical axis. Or
Astigmatism aberration is a result of an off-axis image of a point of specimen which appears as an ellipse of a line rather than a point. The image of line can be pointed in any of the two directions, tangentially or sagittally.

How to reduce Astigmatic Aberration?

By using a convex and a concave lens of suitable focal lengths and separated by a distance, it is possible to minimize the astigmatic difference and such a lens combination is called an anastigmatic.





Experiment No. (2) Studying The Focal Length Of A Convex Lens

4 **Coma**

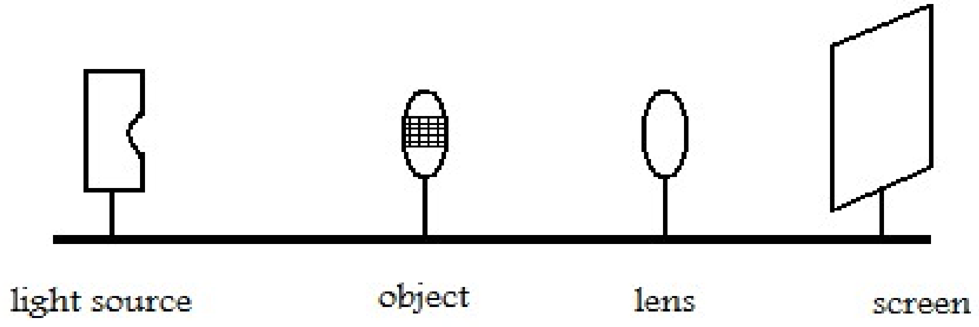
5 **Field Curvature**

6 **Distortion**

→ **We do not focus on these three types of aberration.**

Apparatus:

1) Optical Bench
2) Illuminated object with holder
3) Ground glass screen in holder
4) Convex lenses



Experiment No. (2) Studying The Focal Length Of A Convex Lens

Procedure:

1) Adjust the equipment on the optical bench.
2) Turn on the optical source.
3) Place the convex lens in between the screen and the object then find a suitable image. Record this location on your data sheet.
4) Change the position of the lens then find a best image of the object. Record the distance between the object and the lens let it be u and record the distance between the lens and the screen let it be v. Record this value on your data sheet.
5) Repeat step 4 for different position of the object.
6) Put your data in the below table:

u (cm)	v (cm)	1/u (cm^{-1})	1/v (cm^{-1})

Experiment No. (2) Studying The Focal Length Of A Convex Lens

7) Plot a diagram between 1/u on the x-axis and 1/v on the y-axis, the intersects on the 1/u axis and 1/v are numerically equal to 1/f.

8) On $(1/u)$-axis, $(1/v = 0)$then find $f_1$by using equation (1). On $(1/v)$-axis, $(1/u = 0)$ then find $f_2$by using equation (1). Find the average of f_1 and f_2 this will be the focal length of the lens.

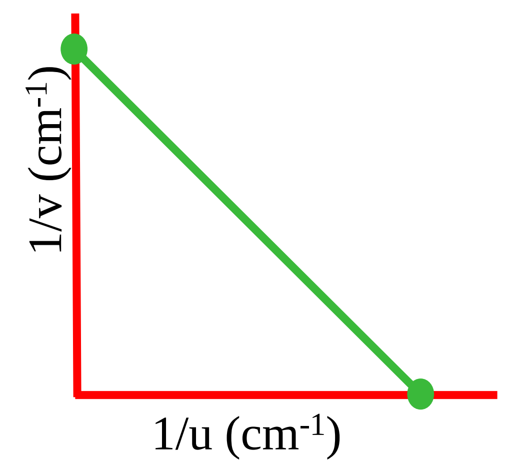
9) Use **lens equation** to determine the focal length of the lens.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

u is the distance btween and lens

v *is the distance btween lens and screen.*

f *is the focal length of the lens.*



Hint:

The theoretical value of the focal length is written on the lens.

Experiment No. (2) Studying The Focal Length Of A Convex Lens

Questions:

1) Define the focal length
2) What is the unit of focal length?
3) Define a convex lens
4) What is the difference between convex lens and concave lens?
5) What is the benefit of using convex lens in the optics lab.?
6) Write an equation for finding the focal length of a convex lens?
7) What are the main parameters that the focal length of a less depends on?
8) How the image formed by a convex lens?
9) Is the image formed by a convex lens real or virtual? Explain?

Experiment No. (3) Studying the Focal Length of a Concave Mirror

Aim:

The aim of this experiment is to determine the focal length of a concave mirror.

Q/ What is Mirror?

A mirror is a reflective surface that bounces off light, thus producing a real or virtual image.

Q/ What are the most prominent types of Mirrors?

A Plane Mirrors

A plane mirror is a flat, smooth reflective surface. A plane mirror always forms a virtual image that is upright, and of the same shape and size as the object, it is reflecting.

B Spherical Mirrors

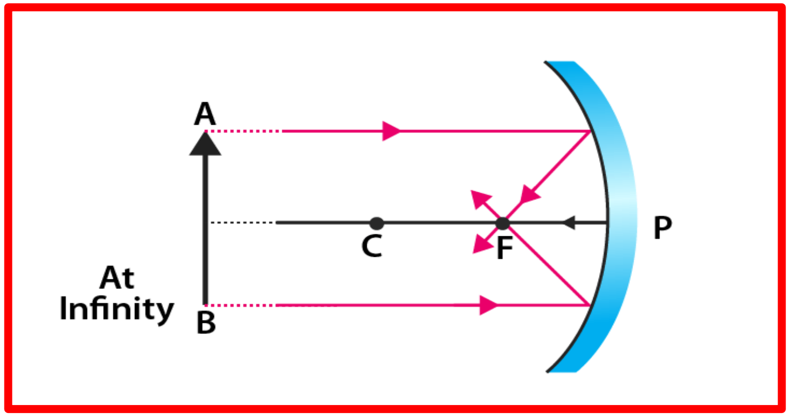
A spherical mirror is a mirror that has a consistent curve and a constant radius of curvature. The two types of spherical mirrors are; 1) Concave Mirrors 2) Convex Mirrors

Experiment No. (3) Studying the Focal Length of a Concave Mirror

Image Formation By Concave Mirror:

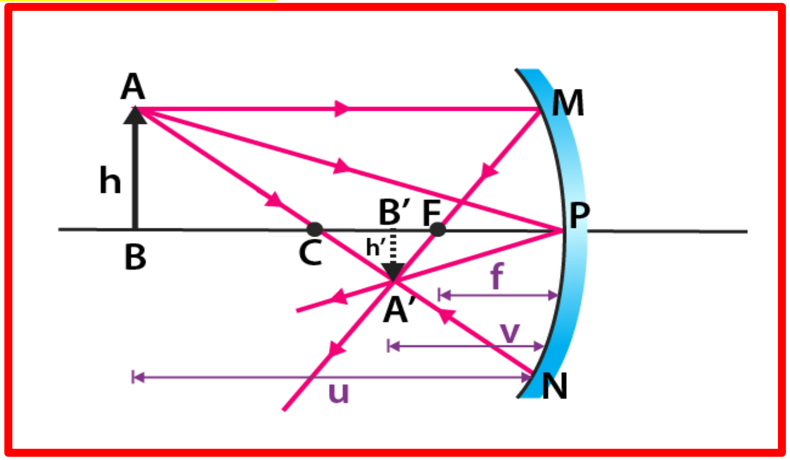
1 Object is placed at infinity:

- The formed image is highly diminished, point size.
- Real and inverted.



2 Object behind the center of curvature, C or 2F:

- The formed image is diminished,
- Real and inverted.

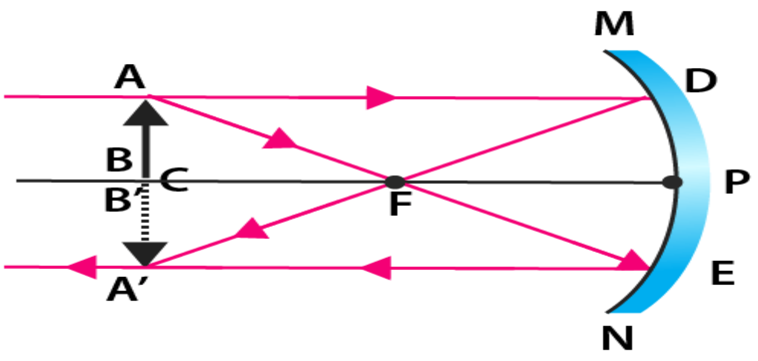


Experiment No. (3) Studying the Focal Length of a Concave Mirror

Image Formation By Concave Mirror:

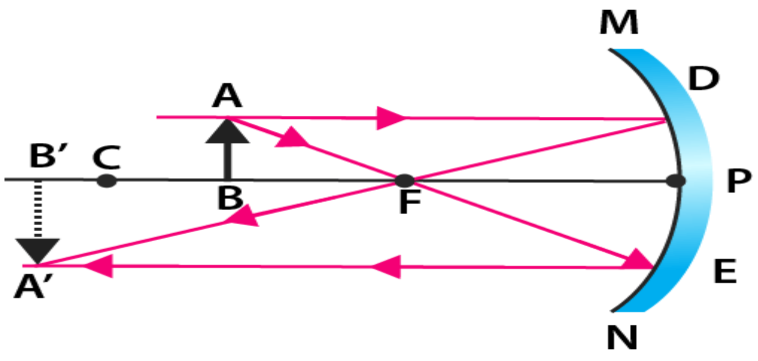
3 Object is at the center of curvature C or 2F:

- The formed image has the same size as that of the object.
- Real and inverted.



4 Object is placed in between the center of curvature C or 2F and focus F:

- The formed image is larger compared to the size of the object.
- Real and inverted.

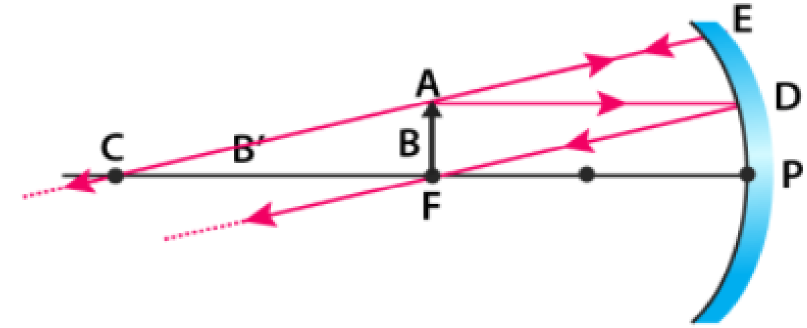


Experiment No. (3) Studying the Focal Length of a Concave Mirror

Image Formation By Concave Mirror:

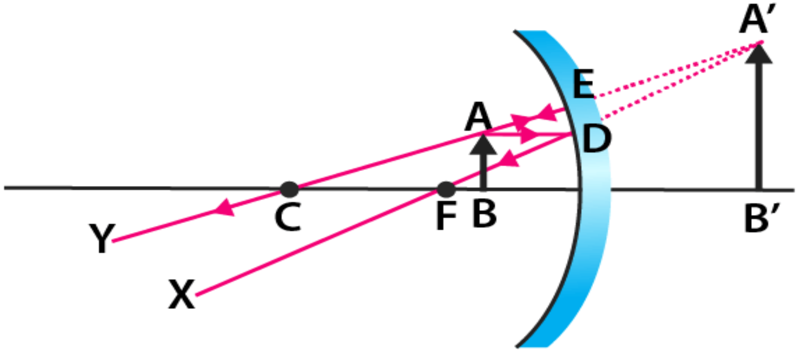
5 When an object is placed at the F focus:

- The formed image is highly enlarged
- Real and inverted, at infinity.



6 When an object is placed in between F focus and P pole:

- The formed image larger than the object.
- Virtual



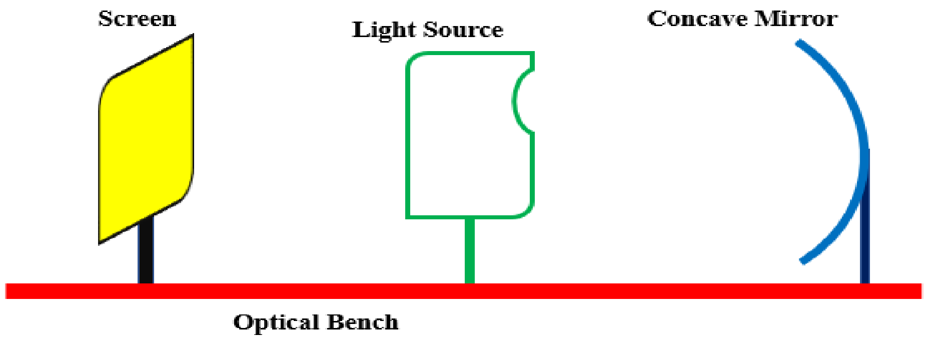
Experiment No. (3) Studying the Focal Length of a Concave Mirror

Apparatus:

1) Light source
2) Optical bench
3) Screen
4) Concave mirror lens
5) Object

Procedure:

1) Setup the experiment as shown in diagram below.



2) Adjust the equipment on the optical bench.
3) Turn on the light source.

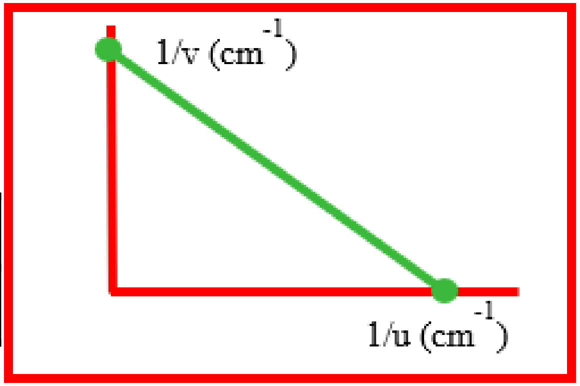
Experiment No. (3) Studying the Focal Length of a Concave Mirror

4) Change the position of the concave mirror then find a best image of the object. Record the distance between the object and the concave mirror let it be u and record the distance between the concave mirror and the screen let it be v. Record this value on your data sheet.

5) Repeat step 4 for different position of the object.

6) Put your data in the below table:

u (cm)	v (cm)	1/u (cm^{-1})	1/v (cm^{-1})



7) Plot **1/u (cm^{-1})** on x-axis and **1/v (cm^{-1})** on y-axis.

On $(1/u)$-axis, $(1/v = 0)$then find $f_1$by using equation (1). On $(1/v)$-axis, $(1/u = 0)$then find $f_2$by using equation (1). Find the average of f_1 and f_2 this will be the focal length of the mirror.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Experiment No. (3) Studying the Focal Length of a Concave Mirror

Questions:

1) Define concave mirror.
2) What is principal focus of a concave mirror?
3) What is the position of the object for which we get enlarged virtual image?
4) What are the differences between concave mirrors and convex mirrors?
5) What are the properties of the image the object is placed at **a)** C (center of curvature), **b)** infinity, **c)** F and **d)** beyond C (center of curvature)?
6) Define center of the curvature.
7) What is plane mirror?

Experiment No. (4) Studying the Chromatic Aberration of a Lens

Aim:

The aims of this experiment are to study the principal defects of chromatic aberration of a lens and find the dispersive power of the glass of the lens.

Q/ What is Chromatic Aberration?

Chromatic aberration is a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, and/or when wavelengths of color are focused at different positions in the focal plane.

Q/ What causes Chromatic Aberration to be occurred?

Chromatic aberration is caused by **lens dispersion**, with different colors of light travelling at different speeds while passing through a lens. As a result, the image can look **blurred or noticeable colored edges** (red, green, blue, yellow, purple, magenta) can appear around objects, especially in high-contrast situations.

with no Chromatic aberration

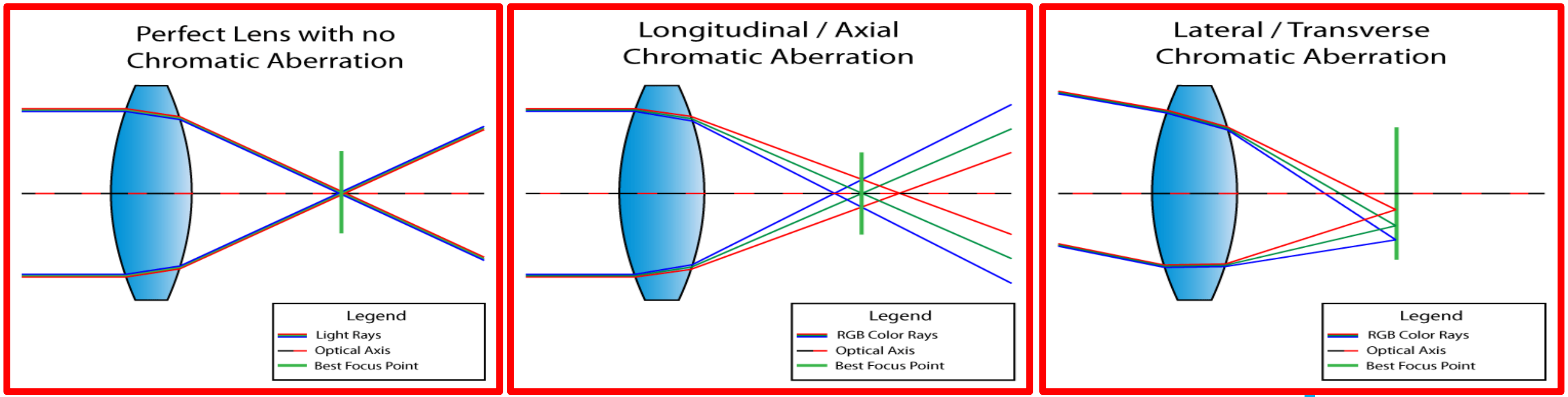
with Chromatic aberration

Experiment No. (4) Studying the Chromatic Aberration of a Lens

Types of Chromatic Aberration:

A Longitudinal or Axial Chromatic Aberration

Longitudinal or Axial Chromatic Aberration occurs when different wavelengths of color do not converge at the same point after passing through a lens, as illustrated below.



B Lateral or Transverse Chromatic Aberration

Lateral or Transverse Chromatic Aberration occurs when different wavelengths of color coming at an angle focus at different positions along the same focal plane, as illustrated above.

Experiment No. (4) Studying the Chromatic Aberration of a Lens

Q/ How to reduce (minimize) Chromatic Aberration?

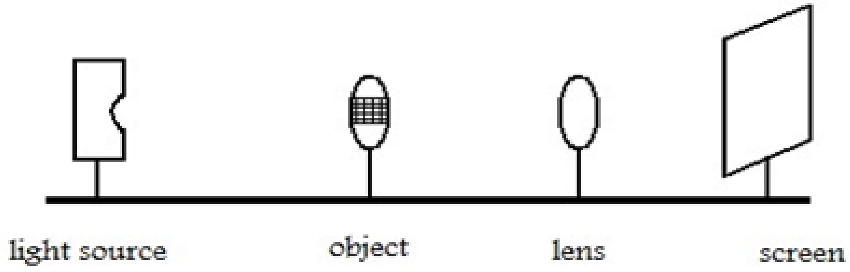
By using two or more lenses of different materials, the chromatic aberration can be reduced. A combination of two lenses is called an **achromatic combination**, to have an achromatic combination of two lenses, one of the lenses should be convex (crown) and the other concave (flint).

Apparatus:

1) Optical bench
2) Light source
3) Screen
4) Convex lens
5) Color filters (blue and red)

Procedure:

1) Setup the experiment as shown below.



Experiment No. (4) Studying the Chromatic Aberration of a Lens

2) Attach and fix the red filter centrally to the lens.

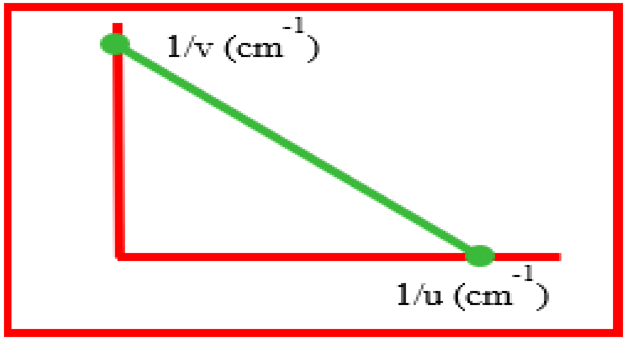
3) Switch on the light source and adjust the lens and the screen until the image of the net appears on the screen.

4) Measure the distance between the object and the lens let it be u. Measure the distance between the lens and the screen let it be v.

5) Repeat step 4 for different position of the lens.

6) Draw a table and write your data in.

u (cm)	v (cm)	1/u (cm^{-1})	1/v (cm^{-1})



7) Plot **1/u (cm^{-1})** on x-axis and **1/v (cm^{-1})** on y-axis.

8) Find the focal length of the lens for red filter by using the equations below.

9) On $(1/u)$-axis, $(1/v = 0)$then find $f_{R1}$by using equation (1). On $(1/v)$-axis, $(1/u = 0)$then find $f_{R2}$by using equation (1). Find the average of f_{R1} and f_{R2} this will be the focal length of the lens.

$$\frac{1}{f_R} = \frac{1}{u} + \frac{1}{v}$$

Experiment No. (4) Studying the Chromatic Aberration of a Lens

9) Repeat the experiment but now use the blue filter instead of the red filter and find f_B.

Find longitudinal chromatic aberration by using the equation below. The result should be in the range of mm.

$$\text{longitudinal chromatic aberration} = f_R - f_B$$

10) Find the dispersive power $(w)$of the lens by using the equation below.

$$w = \frac{f_R - f_B}{f}$$

where f is the mean value of f_B *and* f_R.

Questions:

1) Define the chromatic aberration
2) What is the reason behind chromatic aberration?
3) How can we minimize the spherical aberration?
4) What are the types of aberration?
5) Explain the types of chromatic aberrations.
6) Which lens will produce smaller chromatic aberration, thick lenses or thin lenses?

Experiment No. (5) Studying the Relation between Intensity of Light and the Distance from the Light Source (Inverse Square Law)

Aim:

The aim of this experiment is to verify the inverse square law.

Apparatus:

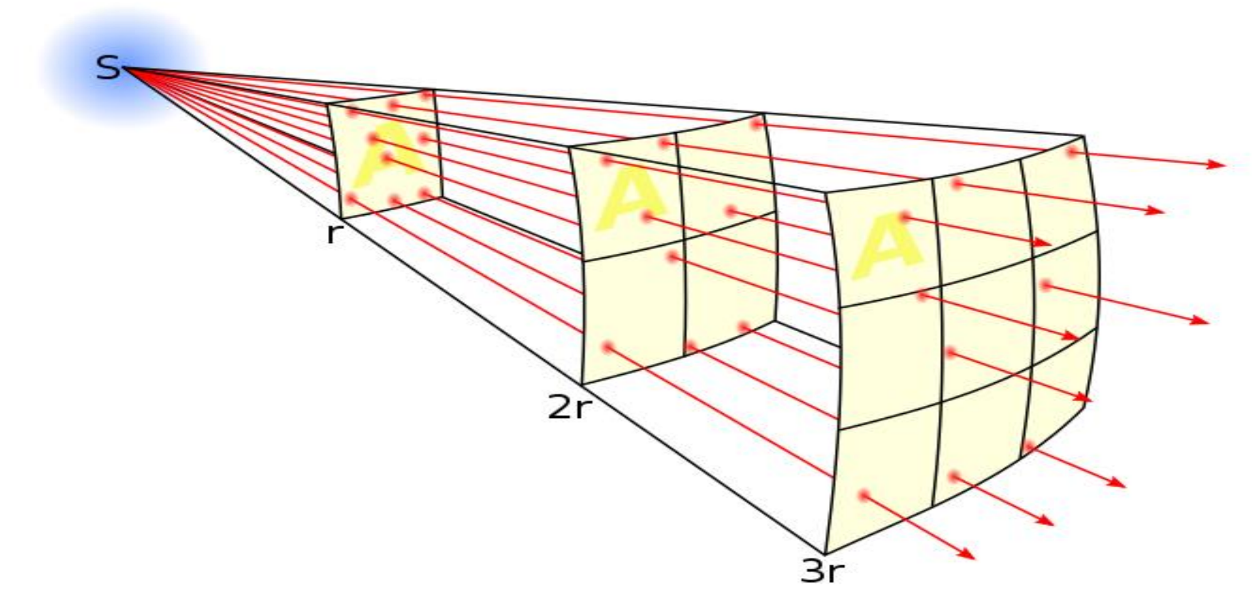
1) Luxmeter probe
2) Luxmeter
3) Polarizer
4) Optical bench
5) White light source

Experiment No. (5) Studying the Relation between Intensity of Light and the Distance from the Light Source (Inverse Square Law)

Q/ What is Inverse Square Law?

The law states that the **intensity of light** from a given source **varies inversely** with the **square of the distance of the source**. In short, as the distance increases the intensity of the light from the source decreases. Mathematically, the formula can be written as:

$$I \propto \frac{1}{r^2}$$



Experiment No. (5) Studying the Relation between Intensity of Light and the Distance from the Light Source (Inverse Square Law)

Procedure:

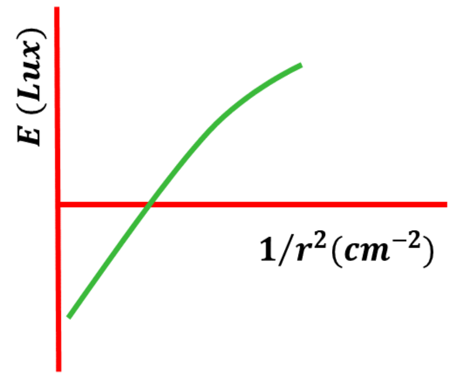
1) Setup the experiment as shown below.
2) Adjust the luxmeter probe and the illumination of the lamp so that the luxmeter gives full scale deflection for the shortest distance (r), about (20cm), between the sensitive surface of the cell and the filament of the light source. This type of a cell has an appreciable tine lag. Do not take readings until the current has had tine to settle to a steady value. Record the distance (r) and the luxmeter deflection (E) which proportional to the photo-current (I).

Experiment No. (5) Studying the Relation between Intensity of Light and the Distance from the Light Source (Inverse Square Law)

3) Vary the distance of the light source from the photo cell in, say (10) steps. In each steps, record (r) and(E). Tabulate your readings as in table below.

$r\ (cm)$	$E\ (Lux)$	$1/r^2 (cm^{-2})$

4) Plot (E) against ($1/r^2$)
does this graph verify the inverse square law?



Questions:

1) Define the inverse square law
2) Write an equation for the inverse square law.
3) What is the relation between intensity of light and the distance from the source?
4) Why we use Lux-meter in the optics lab.?
5) If we use a laser source instead of an ordinary light, what will be the effects on the inverse square law?

Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

Aim:

The aims of this experiment are:

1) to determine the emitted luminous flux which is reflected by a diffusely reflecting surface as a function of the angle of observation.

2) to verify Lambert's law (cos-law) using the graph of the measurement values.

Apparatus:

1) Housing for experiment lamp
2) Halogen lamp, 12 V/50 W
3) Double condenser, f 60 mm
4) Lens holder
5) Lens, mounted, f +200 mm
6) Zinc sulfide screen
7) Right angle clamp –PASS Tripod base PASS Barrel base –PASS Stand tube
8) Support rod, stainl.steel, 100 mm
9) Support rod -PASS-, square, l 250 mm
10) Support rod -PASS-, square, l 1000 mm
11) Articulated radial holder
12) Graduated disk, f. demonstration
13) Power supply 0-12V DC/6V, 12V AC
14) Lux meter, hand-held
15) Measuring module lux

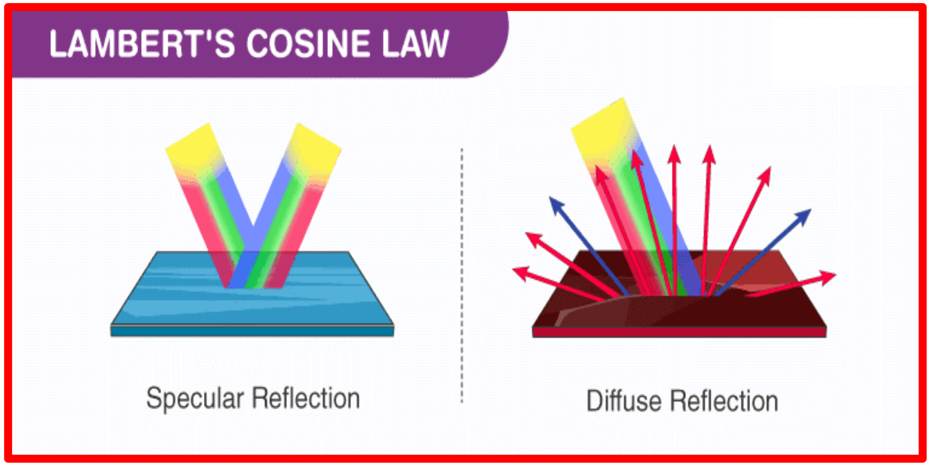
Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

Q/ What is Lambert's Cosine Law?

Lambert's cosine law states that the **radiant intensity** from the ideal **diffusely reflecting surface** and **cosine of the angle θ** between **the direction of incident light and surface normal are directly proportional.** This law is named after Johann Heinrich Lambert and it is also known as Lambert's emission law or cosine emission law.

Diffuse Reflection

Diffuse reflection can be defined as the type of reflection of light or an incident ray where **scattering happens** at **many angles** and **not just at one angle**.



Lambertian Reflection

Lambertian reflection is the property exhibited by the diffuse reflecting. It is defined as **the appearance of luminous** such that when **viewed from all the angles is equal**.

This is the main difference between specular reflection and diffuse reflection.

Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

The **Luminous Intensity** of a Light Source in Candela is given by:

$$I = \frac{d\varphi}{d\omega}$$

- I → **Luminous Intensity (Cd)**
- $d\varphi$ → **Light Flux (Lumen/lm)**
- $d\omega$ → **Spatial Angle**

For **extended light sources**(also such which are **not luminous by themselves**, but **reflecting**):

$$B = \frac{dI}{dA}$$

- B → **Luminous Intensity For Reflected Source (Cd/cm^2)**
- dI → **Luminous Intensity (Cd)**
- dA → **Surface Area (cm^2)**

The **Illuminous Intensity** of a Light Source in Lux is given by:

$$E = \frac{d\varphi}{dA^*}$$

- E → **Illuminous Intensity (*Lux*)**
- $d\varphi$ → **Light Flux (Lumen/lm)**
- dA^* → **Surface Area (cm^2)**

Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

The luminance of a surface which reflects diffusely and uniformly in all directions (Lambert-Reflector) in the direction of an **angle (φ)** against the normal to the surface is given by the following relation:

$$B = \frac{dI_{\varphi}}{dA^{*}} = \frac{dI_{\varphi}}{dA\,Cos\varphi} \frac{dI_{o}}{dA}$$

For **angle (φ) = 0**,

Then; $$dI_{\varphi} = dI_{o} Cos\varphi$$

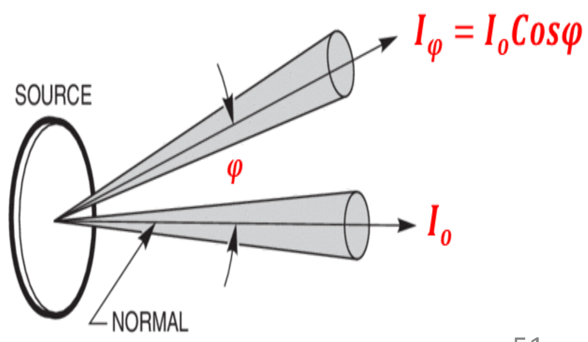
Or; $$I_{\varphi} = I_{o} Cos\varphi$$

This is called Lambert's Cosine Law or Lambert's Emission Law.

I_{o} = the maximum illuminance intensity along the normal.

I_{φ} = the illuminance intensity at an angle.

φ = the angle between the direction of the incident light and the normal to the plane.



Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

Procedure:

1) Set up the experiment as shown in figure below.

2) Calibrate the luxmeter before carrying out the actual measurement and record background light
3) Switch on the power supply adjust the lenses until a sharp circle appears on the zinc sulfide screen.
4) The screen is then turned so that a line perpendicular to its surface forms an angle of 15° with the optical axis.
5) The luxmeter probe now points towards the center of the circle.
6) Luminous intensity is measured for angular steps of 5°–10°, keeping the screen stationary. For every step, the residual background light must be measured with the lamp switched off and the obtained value taken into account for evaluation.

Experiment No. (6) Studying the relation between intensity of Light and Angle of Reflection (Lambert's law)

7) Draw a table as shown below to write your data in.

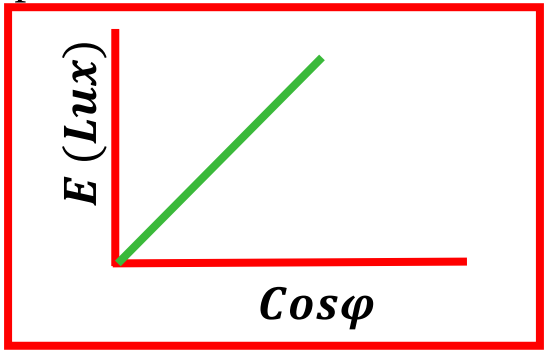
$\varphi(degree)$	$E\ (Lux)$	$Cos\varphi$

8) Plot $Cos\varphi$ on X-axis and $E\ (Lux)$ on Y-axis. Find the slope of the line and it will equal to the (I_o).

$$Slope = I_o$$

$$I_\varphi = I_o Cos\varphi$$

$$y = mx$$



Questions:

1) State lambert's emission law?
2) Define Lambertian Reflection?
3) Why you calibrate the luxmeter before taking the measurements?
4) What the difference between luminance and illuminance?

Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

Aim:

The aim of this experiment is to study the astigmatic aberration of a Plano Convex lens.

Astigmatism:

Astigmatism aberration occurs, "If focal points in the horizontal plane and vertical plane of an image does not coincide".

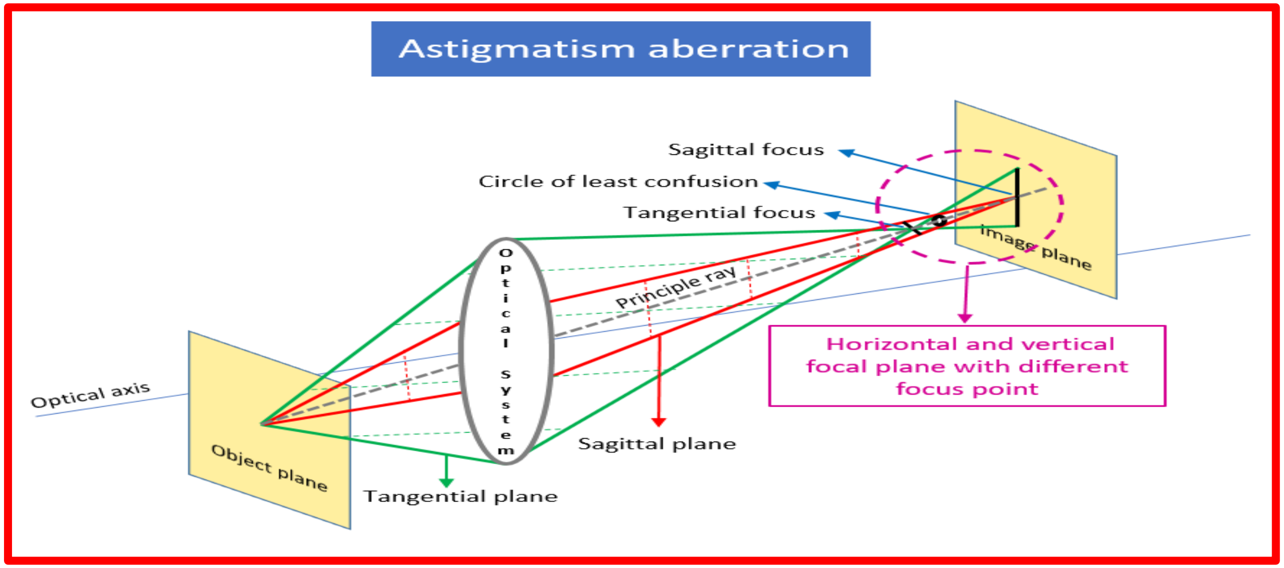
Or

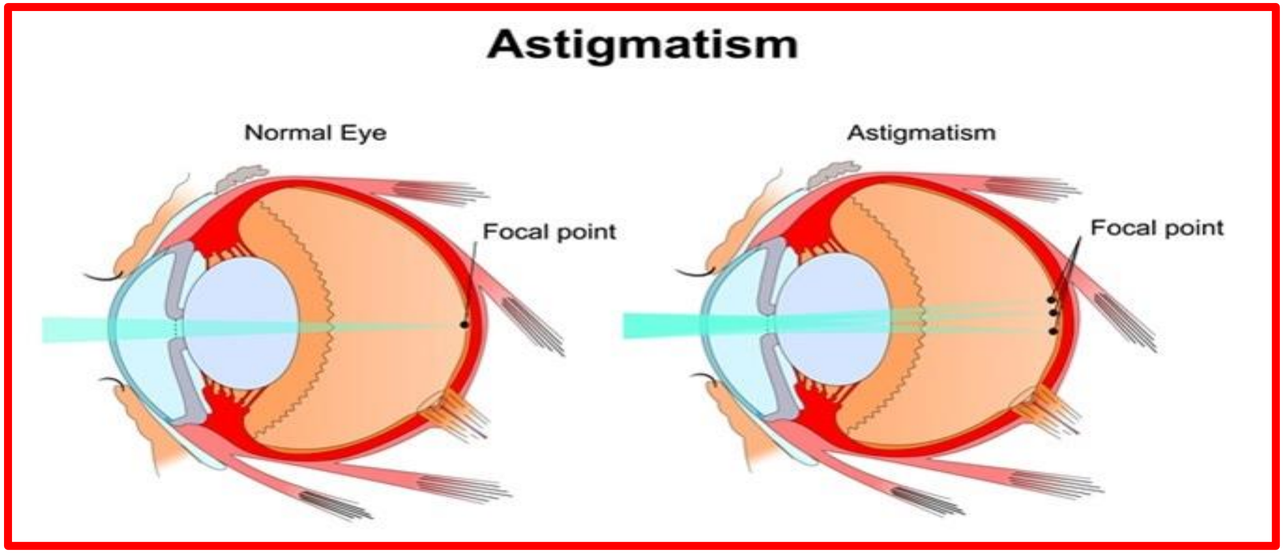
Astigmatism occurs when the curvature (or the thickness) of a lens is not the same in all planes which pass through the optical axis.

Or

Astigmatism aberration is a result of an off-axis image of a point of specimen which appears as an ellipse of a line rather than a point. The image of line can be pointed in any of the two directions, tangentially or sagittally.

Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)





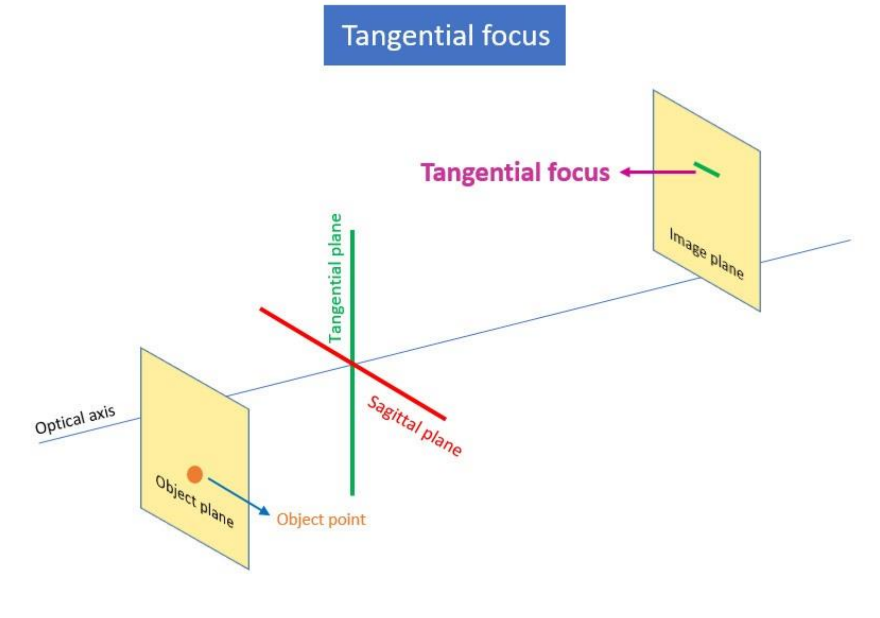
Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

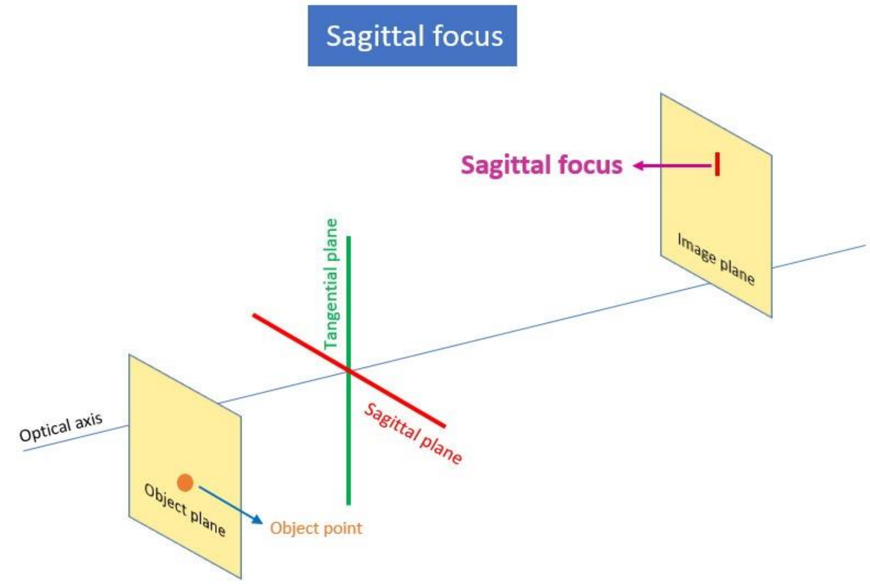
Tangential Focus:

Tangential focus is perpendicular to tangential plane which has proper focus in tangential plane. To avoid confusion look at the below diagram.

Sagittal Focus:

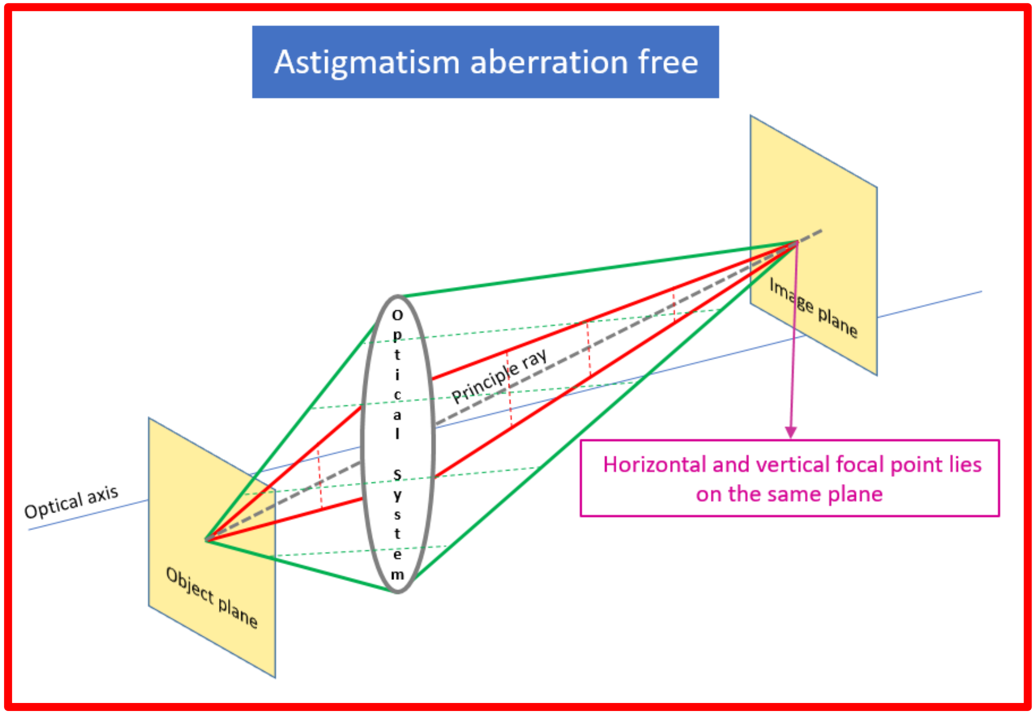
Sagittal focus is perpendicular to sagittal plane which has proper focus in sagittal plane. To avoid confusion look at the below diagram.





Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

❖ In case of a system with no aberration, the tangential and sagittal focus of an image lies on the same surface.



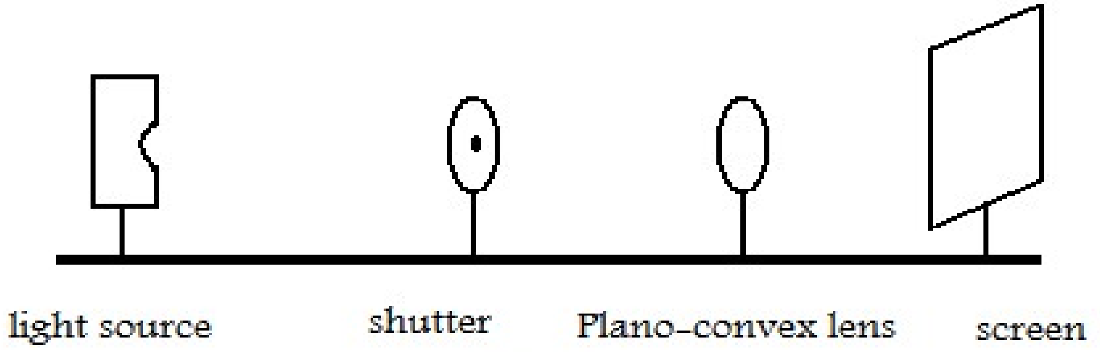
How to reduce Astigmatic Aberration?

By using a convex and a concave lens of suitable focal lengths and separated by a distance, it is possible to minimize the astigmatic difference and such a lens combination is called an anastigmatic.

Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

Procedure:

1) Place the Plano-convex lens on the rotating table with its Plano face toward the source as shown in the diagram below.



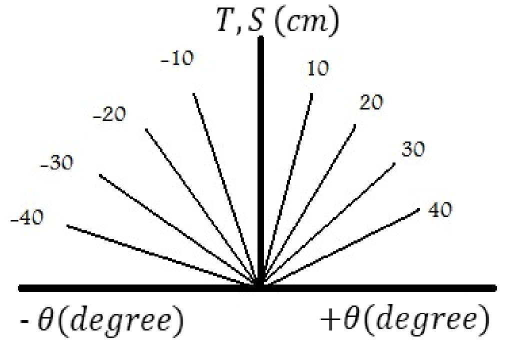
2) Use the collimator to obtained parallel beams.
3) Move the screen to locate the images of the source.
4) Rotate the lens so that it makes an angle of 5° with the axis move the screen to obtain the sagittal and tangential lines.
5) Measure the focal length for each case.
6) Repeat with $\theta = 5^{\circ}$.
7) Repeat the process for values of θ up to -70° in steps of 50°.
8) Repeat with convex lens facing objects.

Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

9) Draw a table as shown below and write your data in.

$\theta(degree)$	$T\ (tangentail)/cm$	$S(Sagittal)/cm$

10) Plot $\theta(degree)$ on X-axis and $T and\ S\ (cm)$ on Y-axis.



11) Determine Astigmatism (A) value for $\boldsymbol{\theta = 20^{\circ}\ and\ 40^{\circ}}$ by using the followings:

$$\boldsymbol{A = \frac{f\ (n-1)cos\theta}{-cos\theta + (n^2 - sin^2\theta)^{1/2}}}$$

$$\boldsymbol{Sagittal\ f = \frac{A}{cos\theta}}$$

$$\boldsymbol{Tangentail\ f = A * cos\theta}$$

$\boldsymbol{\theta} = angle\ of\ the\ axis$

$\boldsymbol{f} =\ the\ parxial\ focal\ length$

$\boldsymbol{n} = refractive\ index\ of\ glass = 1.53$

Experiment No. (7) Studying the Aberration of a Plano Convex Lens (Astigmatism)

Questions:

1) Define Astigmatic aberration?
2) How to reduce astigmatism?
3) What cause an astigmatism?
4) What is the relation between tangential and sagittal focal length with angle of incident ray?

References

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