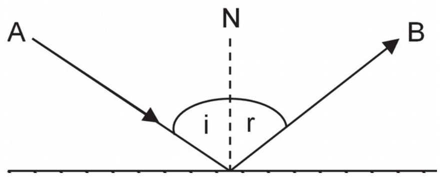
Phenomenon of Light (unit, 4,5,6)

Reflection of light

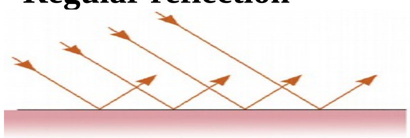
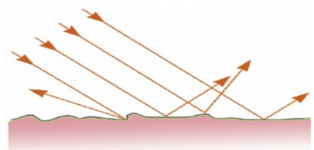
➔ Light falling on the surface of an object comes back to the same medium.



Laws of reflection

➔ Angle of incidence (i) and angle of reflection (r) are equal.

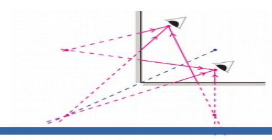
➔ The incident ray, reflected ray and normal to the surface are in the same plane.

Regular reflection	Irregular reflection
	
◆ Happens in smooth surfaces.	◆ Happens in rough surfaces.
◆ If incident rays are parallel, reflected rays are also parallel.	◆ Reflected rays are not parallel.
◆ Image is formed.	◆ Image is not formed.
◆ Angle of incidence and angle of reflection are equal.	◆ Angle of incidence and angle of reflection are equal.

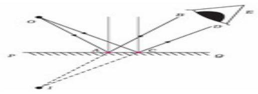
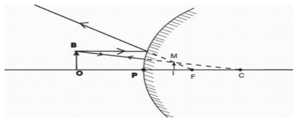
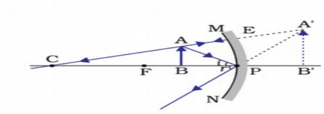
Multiple reflection and Number of images.

Number of images (n) = (360 / θ) – 1

θ = Angle between the mirror



Real Image	Virtual Image
● Image is formed on the screen.	● Image is not formed on a screen.
● Inverted image.	● Erect image.
● Formed in front of the mirror.	● Formed behind the mirror.
● Image is formed at the point on which the reflected rays are actually met.	● Image is formed at the point on which the reflected rays are appear to meet.
● Formed by concave mirror.	● Formed in convex mirror, concave mirror and plane mirror.

Plane mirror	Convex mirror	Concave mirror
		
● Reflecting surface is plane.	● Reflecting surface is curved outwards.	● Reflecting surface is curved inwards.
● The image is always virtual, erect and is of the same size as that of the object.	● The image is always virtual, erect and diminished.	● Magnified virtual image and real images of same size as that of the object, diminished and magnified are formed.
● Used for observing the face and used in the optical instruments Kaleidoscope and Periscope.	● Used as rear view mirror in vehicles and reflector in street lights.	● Used as shaving mirror, make up mirror, mirrors used by dentists. ● Used as reflector in torch, head light of vehicles, street lights and search lights. ● Used in solar concentrators and reflective telescope.

<u>Optical density</u>

- ➔ Optical density is a measure that shows how a medium influences the speed of light passing through it
- ➔ As the optical density of a medium increases, the speed of light through it decreases.

<u>Increasing order of speed of light</u>

Diamond < Glass < Water < Air

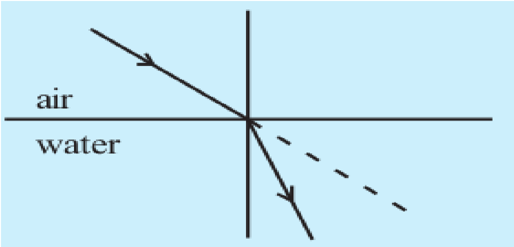
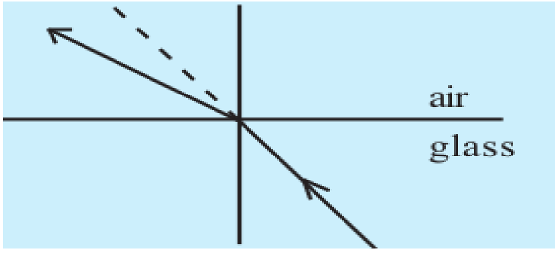
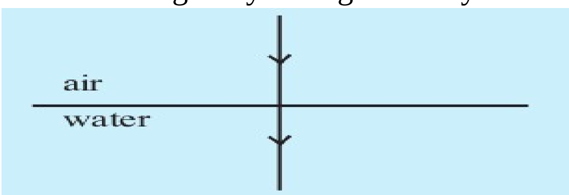
<u>Increasing order of Optical density</u>

Air < Water < Glass < Diamond

<u>Refraction of Light</u>

- ➔ When a ray of light entering obliquely from one transparent medium to another, its path undergoes a deviation at the surface of separation. This is refraction.
- ➔ Cause of refraction – Difference in the optical densities of media

● When light is incident obliquely, from a medium of lower optical density to a medium of greater optical density,	● Refracted ray is deviated towards the normal (Angle of incidence is greater than angle of refraction)

	
● When light passes obliquely from a medium of higher optical density to a medium of lower optical density, 	● Refracted ray is deviated away from the normal (Angle of refraction is greater than angle of incidence)
● When light ray falling normally on a medium, 	● Refraction doesn't taking place.

- ➔ When light passes through different pairs of media, the angle of refraction increases with the angle of incidence

<u>Laws of Refraction</u>

- ➔ The angle of incidence, the angle of refraction and the normal at the point of incidence on the surface of separation of the two media will always be in the same plane.
- ➔ The ratio of the sine of the angle of incidence to the sine of the angle of refraction (sine i / sine r) will always be a constant (Refractive index) - Snell's Law

<u>Relative refractive index</u>- The refractive index of one medium with respect to another is called relative refractive index.

<u>Absolute refractive index(n)</u> – The refractive index of a medium with respect to vacuum is called absolute refractive index.

absolute refractive index (n) = sin i / sin r or   n = c/v
c = speed of light in air/ vacuum (3 X10^8 m/s)
v = speed of light in medium

- Refractive index of a medium, having high speed of light (low optical density), will be low.
- Refractive index of a medium, having low speed of light (high optical density), will be high.

Increasing order of refractive index

Air (1) < water (1.33) < Glass (1.5) < Diamond (2.4)

◆ Increasing order of speed of light.	◆ Diamond < Glass < Water < Air
◆ Increasing order of optical density.	◆ Air < Water < Glass < Diamond
◆ Increasing order of refractive index.	◆ Air (1) < Water (1.33) < Glass(1.5) < Diamond(2.4)

Critical angle.

➔ When a ray of light passes from a medium of greater optical density to that of lower optical density, the angle of incidence at which the angle of refraction becomes 90^0 is the **critical angle**. The critical angle in water is 48.6^0.

Total internal reflection.

➔ When a ray of light passes from a medium of higher optical density to a medium of lower optical density at an angle of incidence greater than the critical angle, the ray is reflected back to the same medium without undergoing refraction. This phenomenon is known as total internal reflection.

Practical applications of total internal reflection in our day to day life

➔ Medical field → **Endoscope.**

➔ In the field of telecommunications → **Optical fibre cables.**

Lens

A lens is a transparent medium having spherical surfaces.

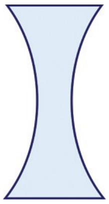
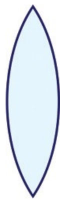
➔ **Optic centre** is the midpoint of a lens (P).

➔ **Centre of curvature** (C) is the centre of the imaginary spheres of which the sides of the lens are parts.

➔ **Principal axis** is the imaginary line that passes through the optic centre joining the two centres of curvature.

➔ Light rays incident parallel and close to the principal axis after refraction converges to a point on the principal axis of a convex lens. This point is the **principal focus of a convex lens.**

➔ Light rays incident parallel and close to the principal axis diverge from one another after refraction. These rays appear to originate from a point on the same side. This point is the **principal focus of a concave lens.**

Concave lens	Convex lens
	
◆ Thinner at its centre, than at its edges.	◆ Thicker at its centre, than at its edges.
◆ Image is always virtual, erect and diminished.	◆ Magnified virtual image and real images of same size as that of the object, diminished and magnified are formed.
◆ Image is always formed at the same side of the object.	◆ Virtual image is formed at the same side of the object and real images are formed on the other side of the lens.
◆ Image is formed at the point on which the refracted rays are appear to meet.	◆ Real image is formed at the point on which the refracted rays are actually met and virtual image is formed at the point on which the refracted rays are appear to meet.
◆ Virtual focus.	◆ Real focus.
◆ Used for resolving the eye defect myopia (Near-sightedness)	◆ Used in microscope, telescope, projector, camera, telescope etc. ◆ Used as magnifying glass. ◆ Used for resolving the eye defects hypermetropia (Long-sightedness) and presbyopia.

Images formed by a Concave mirror and a Convex Lens - Comparison

Concave mirror		**Convex Lens**		**Features of the image.**
Position of the object	**Position of the image**	**Position of the object**	**Position of the image**	
Infinity	At F	Infinity	At F on the other side of the lens.	Real, inverted, diminished.
Beyond C	Between C and F	Beyond 2 F	Between 2F and F on the other side of the lens.	Real, inverted, diminished.
At C	At C	At 2F	At 2F on the other side of the lens.	Real, inverted, same size as that of the object.
Between C and F	Beyond C	Between 2F and F	Beyond 2 F on the other side of the lens.	Real, inverted, magnified.
At F	Infinity	At F	Infinity	Real, inverted, magnified.
Between F and mirror (P)	Behind the mirror	Between F and lens (O)	At the same side of the object.	Virtual, erect, magnified.

Ray diagrams of image formation by a convex lens

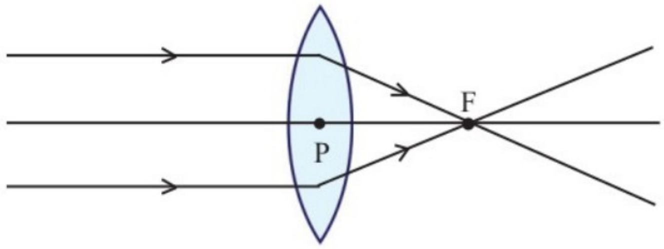
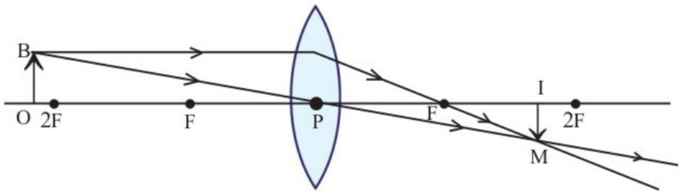
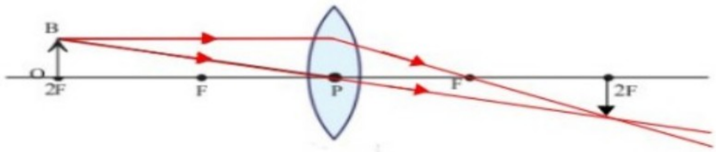
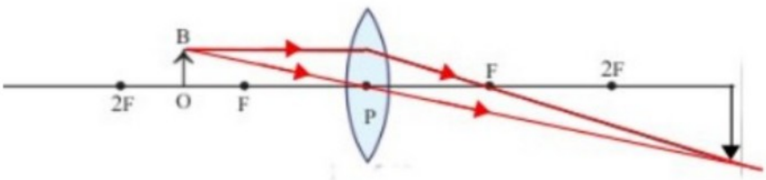
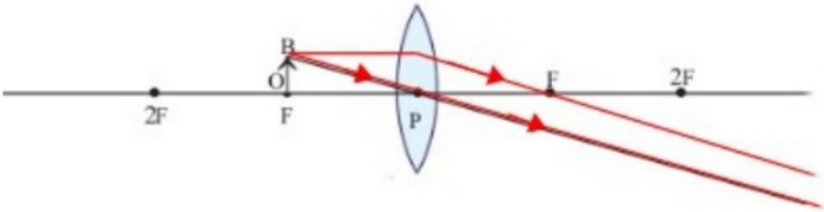
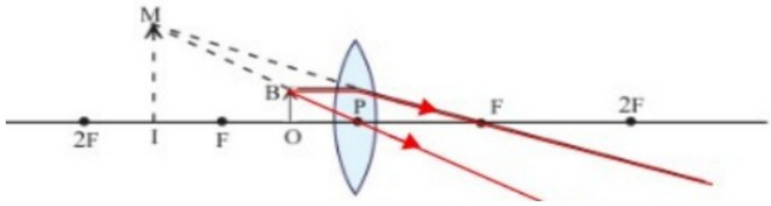
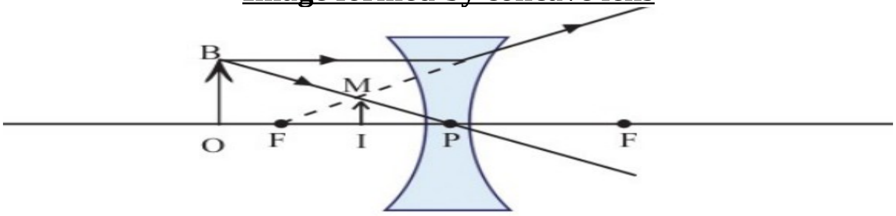
Object is at infinity	
Object is beyond 2F	
Object is at 2F	
Object is between 2F and F	
Object is at F	
Object is between F and lens.	

Image formed by concave lens



New Cartesian Sign Convention

Mirror	Lens
• Pole of the mirror is considered as the origin (O).	• Optic centre is considered as the origin (O).
• All distances are measured from the origin.	• All distances are measured from the origin.
• The incident ray is to be considered as travelling from left to right.	• The incident ray is to be considered as travelling from left to right.
• Those measured to the right from O are positive and those in the opposite direction are negative.	• Those measured to the right from O are positive and those in the opposite direction are negative.
• Distances measured upwards from X axis are positive and those downwards are negative.	• Distances measured upwards from X axis are positive and those downwards are negative..

	Plane mirror	Convex mirror	Concave mirror	Convex lens	Concave lens
Distance to the object (u)	Negative	Negative	Negative	Negative	Negative
Distance to the image (v)	Positive	Positive	Real image – Negative Virtual image-Positive	Real image – Positive Virtual image-Negative	Negative
Focal length (f)		Positive	Negative	Positive	Negative
Height of object (ho)	Positive	Positive	Positive	Positive	Positive
Height of image (hi)	Positive	Positive	Real image – Negative Virtual image-Positive	Real image – Negative Virtual image-Positive	Positive

Mirrors	Lenses
Mirror equation, 1/f = 1/u + 1/v	Lens equation, 1/f = 1/v - 1/u
f = uv / u+v	f = uv / u-v
v = uf / u- f	v = uf / u+f
u = vf / v-f	u = fv / f-v
magnification, m = hi / ho = - v / u	magnification, m = hi / ho = v / u

Magnification

- ➔ Magnification is the ratio of the height of the image to the height of the object. It shows how many times the image is larger than the object.
- ➔ Magnification (m) = Height of image (hi) / Height of object (ho)

◆ If magnification is negative,	◆ Image is real and inverted.
◆ If magnification is positive,	◆ Image is virtual and erect.
◆ If magnification is 1,	◆ Height of image and height of object are equal.
◆ If magnification is less than 1,	◆ Height of image is less than height of object.
◆ If magnification is greater than 1,	◆ Height of image is greater than height of object.

Mirror / Lens	Magnification
◆ Plane mirror.	◆ + 1
◆ Convex mirror.	◆ Positive, less than 1.
◆ Concave mirror.	◆ - 1, Negative (less than 1 or greater than 1), Positive (greater than 1)
◆ Convex lens.	◆ - 1, Negative (less than 1 or greater than 1), Positive (greater than 1)
◆ Concave lens.	◆ Positive, less than 1.

Power of a lens

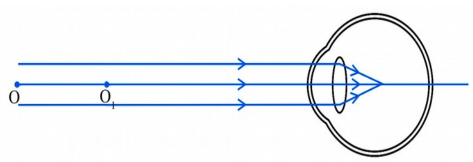
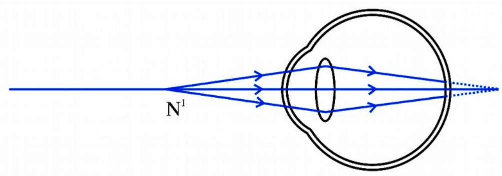
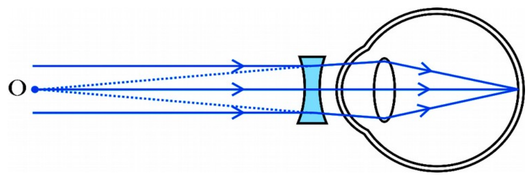
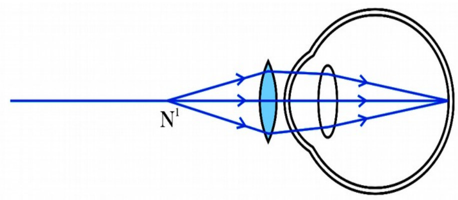
- ➔ Power of a lens is the reciprocal of focal length expressed in metres. **(p=1/f)**
- ➔ Unit of power is **dioptre**. It is represented by **D**
- ➔ Power of a Convex lens – **Positive.**
- ➔ Power of a Concave lens – **Negative**

Near point	Far point
● Nearest point at which the objects can be seen distinctly	● Farthest point at which the objects can be seen distinctly
● For healthy vision - 25 cm.	● For healthy vision - infinity

Power of accommodation.

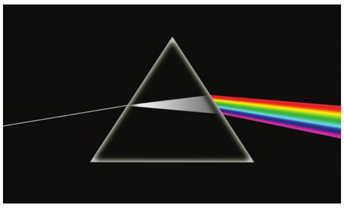
➔ The ability of the eye to form an image on the retina by adjusting the focal length of the lens in the eye, by varying the curvature of the lens, irrespective of the position of the object, is the power of accommodation.

Look at nearer objects	Looking at far objects
◆ Ciliary muscles are contracted.	◆ Ciliary muscles are relaxed.
◆ Curvature of the lens increases.	◆ Curvature of the lens decreases.
◆ Focal length decreases	◆ Focal length increases.

Myopia or Near-sightedness	Hypermetropia or Long-sightedness
	
● Can see nearby objects clearly.	● Can see distant objects clearly.
● Can't see distant objects clearly.	● Can't see nearby objects clearly.
● Near point is 25 cm, far point is not infinity.	● Far point is infinity, near point will be greater than 25 cm.
● Image of distant object is formed in front of the retina.	● Image of nearby object is formed behind the retina.
● Size of the eye ball may increased.	● Size of the eye ball may decreased.
● Power of the eye lens may increased. (focal length decreased).	● Power of the eye lens may decreased. (focal length increased).
● Solve this defect by using concave lens of suitable focal length. 	● Solve this defect by using convex lens of suitable focal length. 

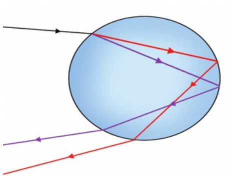
Presbyopia

- For elderly people the distance to the near point is greater than 25 cm. This defect is presbyopia.
- **Reason –** Due to the diminishing ability of the ciliary muscles, power of accommodation will be less.
- **Remedy** - Using convex lens of suitable focal length.

● Any light that is composed of more than one colour is a **composite light**	● **Dispersion** is the phenomenon of splitting up of a composite light into its constituent colours 	● The regular array of colours formed by dispersion is the **visible spectrum.**

Reason for dispersion

- Light undergoes refraction when it enters the prism obliquely and when it comes out of the prism. The extent of deviation depends on the wavelength. Therefore waves undergo deviation at different angles and get separated. This is the reason for dispersion.
- Light ray of shortest wavelength (Violet) - Deviated more.
- Light ray of longest wavelength (Red) - Deviated less.
- Order of colours from the base of the prism – Violet, Indigo, Blue, Green, Yellow, Orange, Red.

◆ Rainbow 	◆ Dispersion of light caused by the water droplets in the atmosphere causes rainbow.
	◆ Sunlight passes through the water droplets in the atmosphere **refracted twice,** and has **one internal reflection** also.
◆ Colour seen at the upper edge of the rainbow-	◆ Red
◆ Colour seen at the lower edge of the rainbow-	◆ Violet
◆ Rainbow is seen in the morning at -	◆ West.
◆ Rainbow is seen in the evening at -	◆ East.
◆ When viewing from an aeroplane rainbow is seen as a -	◆ Circle.

<u>Persistence of vision</u> ● When an object is viewed by a person, its image remains in the retina of the eye for a time interval of 0.0625s (1/16 s) after seeing it. This phenomenon is called **persistence of vision.**	◆ A torch rotated rapidly appears as an illuminated ◆ circle. ◆ Newton's colour disc appears white, when it rotated fast. ◆ Raindrops appears like glass rode. ◆ A fan appears like a disc, when it rotated fast.

<u>Scattering of light</u> ● Scattering is the change in direction brought out by the irregular and partial reflection of light when it hits the particles of the medium.	● We get light in our classrooms and homes during daytime ● Sky appears in blue colour. ● Blue colour of see.
● Colours of smallest wavelength-	● Scattered more.
● Colours of longest wavelength-	● Scattered less.
● As the size of the particle increases -	● Rate of scattering also increases.
● If the size of the particles is greater than the wavelength of light -	● scattering is same for all colours.
● Sun appears red during sunset and sunrise.	● During sunrise and sunset, light reaching us from the horizon has to travel long distances through the atmosphere. During this long journey, colours of shorter wavelength would be almost fully lost due to scattering. Then, the red light which undergoes only less amount of scattering decides the colour of the horizon
● Red colour has been given to the tail lamps of vehicles and signal lights.	● Because of its high wavelength, red can travel long distances without scattering.
● Sky appears in blue colour.	● Colours like violet, indigo and blue have the smallest wavelengths in sunlight. They undergo maximum scattering while interacting with atmosphere particles.
● Sky in moon appears in dark colour-	● There is no atmosphere in moon. So scattering of light doesn't happens in moon.

<u>Tyndal Effect</u>

➔ When rays of light pass through a colloidal fluid or suspension, the tiny particles get illuminated due to scattering. Because of this, the path of light is made visible. This phenomenon is Tyndal Effect

Light Pollution - The use of light in excess in a non - judicious manner is referred to as light pollution

Prepared by

Joji George, HST, St. Johns Syrian HSS Vadakara