1. Characteristics of Diffraction
   When diffraction occurs:
   (i) Wave direction changes
   (ii) Wave velocity changes
   (iii) Wavelength is unchanged
   (iv) Frequency is unchanged
   (v) Speed unchanged
   (vi) The amplitude of the diffracted wave is smaller compared to that of incident wave, as the wave energy is spread out over a larger surface.
2.

No.	Ordinary ray	Extra ordinary ray
i	The ray which obeys Snell's law and laws of refraction is called ordinary ray.	The ray which does not obey the laws of refraction is called extra ordinary ray.
ii.	It is denoted by O.	It is denoted by E.
iii.	It passes undeviated through the crystal.	It deviates after refraction.
iv.	Inside the crystal, speed of O-ray is less than E-ray.	Inside the crystal, speed of E-ray is more than O-ray
v.	The speed is constant in the medium.	The speed is constant in the medium.
vi.	It gives spherical wavefront.	It gives ellipsoidal wavefront.

3. **Differences between polarized light and unpolarized light are given below:**

Polarized light	**Unpolarized light**
1.In polarized light the electric field oscillates in one direction only.	1. It has an electric field that oscillates in every direction.
2.Polarized light is naturally coherent.	2. In nature, unpolarized light is incoherent.
3.The intensity of the polarized light is determined by the type of light used.	4. The intensity of unpolarized light is determined by the source.
4. For **polarized light**, the *x*– and *y*– components of the electric field has a constant phase difference between them.	5. In **unpolarized light**, the phase difference between the *x*– and *y*– components of the electric field changes unpredictably

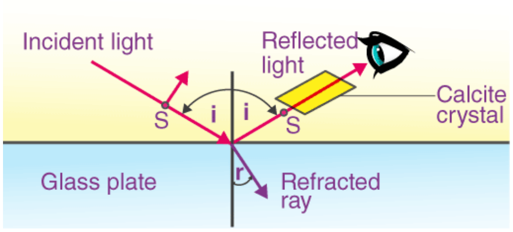
.

3. What is Brewster's Law?

According to Brewster's law,

When an unpolarized light of known wavelength is incident on a transparent substance surface, it experiences maximum plan polarization at the angle of incidence whose tangent is the refractive index of the substance for the wavelength.
Brewster's law is a relationship of light waves at the maximum polarization angle of light. This law is named after Sir David Brewster, a Scottish physicist, who proposed the law in the year 1811. The law states that the p-polarized rays vanish completely on different glasses at a particular angle.

Further, the polarization angle is also called Brewster's angle. It is an angle of incidence where the ray of light having a p-polarization is transmitted through a dielectric surface that is transparent without any reflection. While the unpolarized light at this angle is transmitted, the light is reflected from the surface.



Brewster was able to determine that the refractive index of the medium is numerically equal to the tangent angle of polarization. To know more about Brewster's Law Formula.

$\mu = \tan \; i$

Where,

μ = Refractive index of the medium.

i = Polarization angle.

From Snell's Law:

$\mu = \sin \; i / \sin \; r$……..1

From Brewster's Law:

$\mu = \tan \; i = \sin \; i / \cos \; i$……..2

Comparing both formulas: 1 and 2

$\cos \; i = \sin \; r = \cos \; (\pi/2 \;\; r)$

$i = \pi/2 - r$, or $i + r = \pi/2$

As, $i + r = \pi/2$ <ABCis also equal to the$\pi/2$.

Therefore, the reflected and the refracted rays are at right angles to each other.

Relation Between Brewster Angle and Critical Angle

Brewster's angle is given as:

Θ b = arc tan (n_2/n_1)

tanΘ b = n_2/n_1

The critical angle is given as:

Θ c = arc sin (n_1/n_2)

sinΘ c = n_1/n_2

sinΘ c = 1/(n_2/n_1)

But we know that,

tanΘ p = n/sub>

sinΘ c = 1/tanΘ b

Therefore,

Θc = arc sin (1/tanΘ b)

Application of Brewster's Law

One general example of the application of Brewster's law is polarized sunglasses. These glasses use the principle of Brewster's angle. The polarized glasses reduce glare that is reflected directly from the sun and also from horizontal surfaces like roads and water. Photographers also use the same law to reduce the reflection from reflective surfaces by using a polarizing filter for the lens.

Malu's Law

Malus law is crucial if we want to learn or understand the polarization properties of light. The law helps us to study the light intensity relation of polarizer-analyzer. Malus law is named after Étienne-Louis Malus, who in the year 1808 discovered that natural incident light could be polarized when it was reflected by a glass surface. He used calcite crystal for his experiment.

> After observing the results, he further put forth a concept that natural light consisted of the s- and p-polarization and that they were perpendicular to each other. Today, this law is used to define the intrinsic connection between optics and electromagnetism as well as demonstrate the transverse nature of electromagnetic waves.

What is Malus Law?

Malus' law states that the intensity of plane-polarized light that passes through an analyzer varies as the square of the cosine of the angle between the plane of the polarizer and the transmission axes of the analyzer.

Malus Law Formula

The law helps us quantitatively verify the nature of polarized light. Let us understand the expression for Malus' law.

Point 1 – When Unpolarized light is incident on an ideal polarizer the intensity of the transmitted light is exactly half that of the incident unpolarized light no matter how the polarizing axis is oriented.

Point 2 – An ideal polarizing filter passes 100% of incident unpolarized light, which is polarized in the direction of the filter's (Polarizer) Polarizing axis.

From point (1) and point (2) we can assume $I = I_o \cos^2 \phi$

The average value of I $(\langle I \rangle)$:

We know

$\langle I \rangle = \langle I_0 \rangle \langle \cos^2\phi \rangle$

$\langle \cos^2\phi \rangle = 1/2$

Which satisfies point (2) mentioned above.

To show point (1), let us consider $\phi = 0$

That implies $\cos^2\phi = 1$

$I = I_0$

To determine the direction of polarization we need one polarizer which is known as analyser oriented making an angle (p) with the polarizer.

What happens, when the linearly polarized light emerging from a polarizer passes through a second polarizer (analyser) in general the polarizing axis of the second polarizer (analyser) makes an angle (d) with the polarizing axis of the first polarizer.

Since the intensity of an electromagnetic wave is proportional to the square of the amplitude of the wave, the ratio of transmitted to incident amplitude is cos ϕ, so the ratio transmitted to incident intensity is $\cos^2\phi$

$$\cos\phi = \frac{A}{A_{max}} = \frac{\text{Transmitted amplitude}}{\text{incident amplitude}}$$

$$\cos\phi = \frac{A}{A\max} = \sqrt{\frac{I}{I_{max}}}$$

$$then\ \frac{I}{I_{max}} = \cos^2\phi$$

$$I = I_{max}\cos^2\phi$$

6. Optical Activity

Polarisation plays an important role in explaining the wave nature of electromagnetic waves. While studying the polarisation concept we encounter many interesting concepts regarding the wave nature of the electromagnetic waves, one among them is optical activity. Optical activity is a phenomenon that describes the ability of rotation, thus optical activity is also known as optical rotation. Optical activity is different from polarisation. The optical activity corresponds to the property of some materials to rotate the plane of polarization of light waves.

Optical rotation

- Optical activity or optical rotation is the ability of a compound to rotate the plane of polarized light, and the compounds having this ability to rotate the plane of polarized light are known as optically active materials.
- The optical rotation of substances is due to the interaction of the electromagnetic radiation of polarized light with the unsymmetric electric fields generated by the electrons in a chiral molecule. Optical activity is usually found in organic substances. For example, the sugar solution is optically active, it exhibits optical rotation on observing through the polarimeter. Other examples of optically active substances are turpentine, sodium chlorate, cinnabar, etc...
- Any substance or compound is said to be optically active when the linearly polarized light is being rotated when it is passing through it.
- The optical rotation or optical activity is the angle through which the plane of polarization is rotated when polarized light passes through a layer of a liquid (such as sugar solution or in other words diluted sugar solution).
- Optical rotation is the effect that is determined by the concentration of chiral molecules and their molecular structure in a substance. Every optically active substance will have its specific rotation. Depending on the concentration level the optical activity will be either increasing or decreasing.

What is Optical Activity - Define Optical Activity
In 1811, French physicist Francious Arega observed that when a plane polarised light passed through some materials in particular through some crystals such as quartz, the plane of emerging light is not the same as the plane of the incident light. These crystals rotated the plane of polarization of incident light. This phenomenon of rotation is known as an optical activity or optical rotation.

Optically Active Meaning
The substances that exhibit such rotations are known as optically active substances. To understand what is optical activity or optical rotation we will explain a unique experiment. The optical rotation is measured through a polarimeter.

The optical activity of optically active substances is studied by the polarimeter. Polarimetry Gives the measurement of rotation of plane-polarized light by an optically active substance. The instrumentation of the polarimeter is given below -

- So let us understand how optical activity works. Now, Consider an ordinary source of light that is placed in front of a single to provide rectilinear unpolarized light. The unpolarized light is further passed through a polarizer (Which is a combination of Nicol prism).
- As soon as the light enters the Nicol prism they undergo a double refraction process i.e, incident light gets split into two ordinary rays and the extraordinary ray. Both E-ray and O-ray are plane polarised and perpendicular to each other. After passing through the polarizer we get plane-polarized light.
- The vibrations of the ordinary ray will be perpendicular to the plane of paper through which we are observing and the vibration of the extraordinary ray will be in the direction of the plain paper.
- So, the ordinary gets eliminated after getting total internal reflection inside the Nicol prism and an extraordinary ray will be passed through the Nicol prism such that the vibration of its electric field will be in a single direction.
- On passing the plane-polarized light through an analyzer, we get to see no emerging light. For the same experimental set up if we place an optically active substance between polarizer and analyzer we get to see an emerging light. It explains the fact that the plane-polarized light is rotated.

Generally, the ordinary light is unpolarized which means each light wave oscillates randomly. In the polarimeter experiment, initially, the unpolarized light is converted into polarized light by using polarizing filters or Nicol prism polarizer. Later this polarized light is passed through the polarimeter tube in which the sample (optically active) is kept. This polarized light gets rotated and gives the result on a Nicol prism analyzer.

Optically Active Substances are Classified in Two Types :

1. **Dextrorotatory Substances:** The dextrorotatory substances are also known as the right substances. Dextrorotatory Substances are those optically active substances that rotate the plane of polarization of the light towards the right and are known as right-handed or dextrorotatory. In other words, if a substance rotates the plane-polarized light to the right or clockwise direction, such substances are known as the Dextrorotatory substances.
2. **Laevorotatory Substances:** Laevorotatory Substances are the type of substances that rotate the plane of polarization of the light toward the left and are known as left-handed or Levorotatory. The Levorotatory substances are those optically active substances that rotate the plane of polarization of the light toward the left are known as left-handed. In other words, if a substance rotates the plane-polarized light to the left or counterclockwise direction, such substances are known as the Dextrorotatory substances.

The Optical Rotation Definition

The phenomenon of optical rotation was studied in detail by Biot in the year 1815, and he proposed the laws corresponding to optical rotation. The laws of optical rotations are given as follows:

I. The amount of optical rotation produced by optically active crystals or substances is directly proportional to the thickness of the crystal or the path length traversed in its rotation.

$\theta \propto l$
Where,

θ - The angle of optical rotation

l - The path length

II. The amount of optical rotation is directly proportional to the concentration of the optically active solution.

$\theta \propto C$
Where,

C - Concentration of the optically active solution

III. The angle of optical rotation is inversely proportional to the square of the wavelength of the light used.

θ

α1λ2α1λ2

Where,

λλ

- The wavelength of the light used
Combining all these points we find that the angle of rotation or formula for rotation is given by:

$\theta \propto Cl$
Where,

θ - The angle of optical rotation

l - The path length

C - Concentration of the optically active solution

Further, the proportionality constant is replaced by a constant S known as the specific rotation. Then the formula for optical rotation or angle of optical rotation is given by:

$\theta = S\ Cl$

Where,

S-Specific rotation

Note: The angle of rotation is also depending upon the temperature and nature of the optically active substances.

Specific Optical Rotation

Specific rotation is a characteristic property of an optically active substance and it is the standard measurement for optical rotation for that optically active substance. Specific rotation gives the change in the orientation of plane-polarized light per unit distance of the cell and per unit concentration of the sample when light is passed through that sample. Specific rotation is an intrinsic property of the substance.

So specific rotation of an optically active substance is given by:

$$S=\theta Cl S=\theta Cl$$

Where,

$$\theta\theta$$

-The angle of optical rotation
l - The path length

C - Concentration of the optically active solution

S - Specific rotation

The basic difference between optical rotation and specific optical rotation is that the optical rotation of the substance is the rotation of plane-polarized light by a substance. The optical rotation can be either clockwise or anticlockwise. The compounds that are capable of exhibiting this rotation are enantiomers. The standard measurement for the amount of optical rotation of a specific substance is called specific rotation.

Applications of Optical Rotation or Optical activity

- Optical rotation is used to determine the percentage of the optically active substance in the solution.
- The sugar level in the urine of a diabetic person is determined by calculating the angle of rotation of the plane of polarization.
- Optical activity is a function of time and it is used to determine kinetic reactions.
- The optical rotation is also utilized to plot optical rotatory dispersion curves for various ranges of wavelengths; this helps in analysing molecular structure.

7. The optical activity is measured on a layer of suitable thickness at the wavelength specified in the monograph.