Kunthavai Naachiyaar Goverment Arts College for Women, Thanjavur.

Department of Physics

LASER PHYSICS

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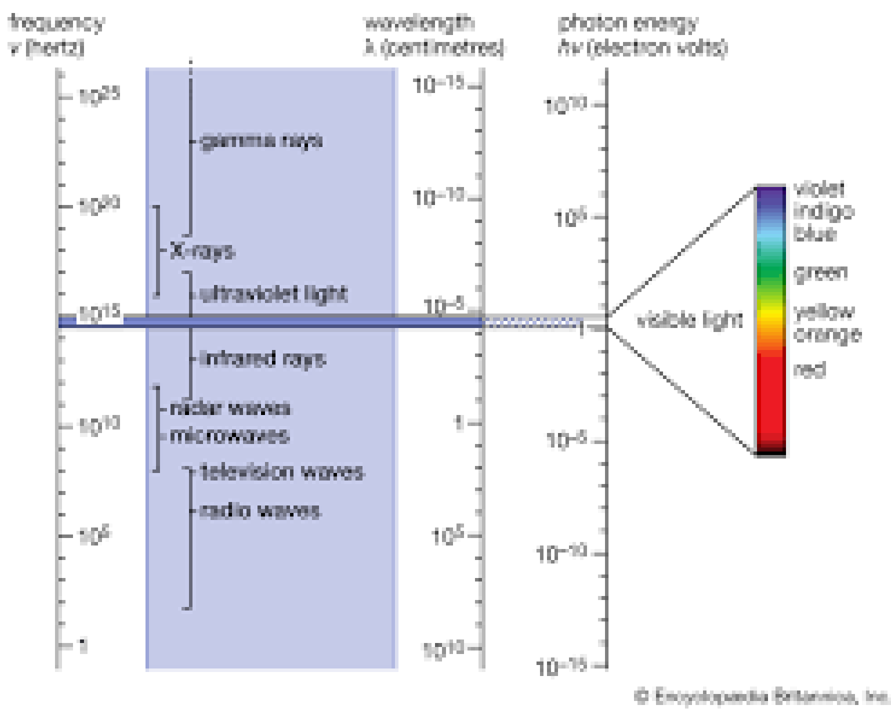
UNIT I : LIGHT

Electromagnetic spectrum

The **electromagnetic spectrum** is the range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.

The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below one hertz to above 10^{25} hertz, corresponding to wavelengths from thousands of kilometers down to a fraction of the size of an atomic nucleus. This frequency range is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names; beginning at the low frequency (long wavelength) end of the spectrum these are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays at the high-frequency (short wavelength) end. The electromagnetic waves in each of these bands have different characteristics, such as how they are produced, how they interact with matter, and their practical applications.



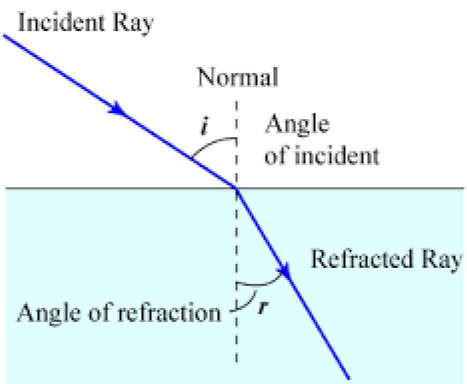
RECTILINEAR PROPAGATION :

Rectilinear propagation describes the tendency of Electromagnetic waves (light) to travel in a straight line. Light only deviates from a straight line when the medium it is travelling through changes density. This is called refraction. Light does not deviate when travelling through a homogeneous medium, which has the same refractive index throughout.

Even though a wave front may be bent, (e.g. the waves created by a rock hitting a pond) the individual waves are moving in straight lines. With the sense of the scattering of waves by an inhomogeneous medium, this situation corresponds to the case **n ≠ 1**, where **n** is the refractive index of the material. An experiment can be set up to prove this. Three cardboard squares are aligned with a small hole in the center of each. A light is set up behind the cardboard. The light appears through all three holes from the other side. The light is blocked if any one of the cardboard squares are moved even a tiny bit. This proves that waves travel in straight lines and this helps to explain how humans see things, among other uses. It has a number of applications in real life as well.

LAWS OF REFRACTION:

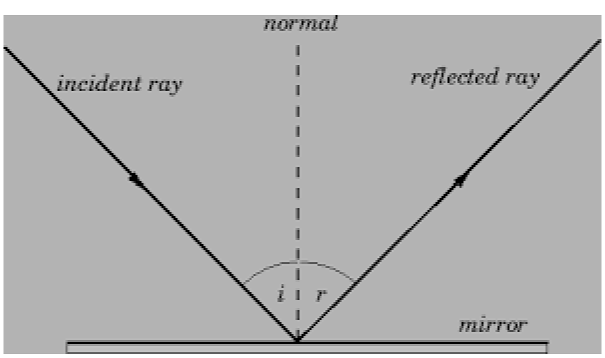
- The incident ray, reflected ray and the normal, to the interface of any two given mediums; all lie in the same plane.
- The ratio of the sine of the angle of incidence and sine of the angle of **refraction** is constant.



LAWS OF REFLECTION:

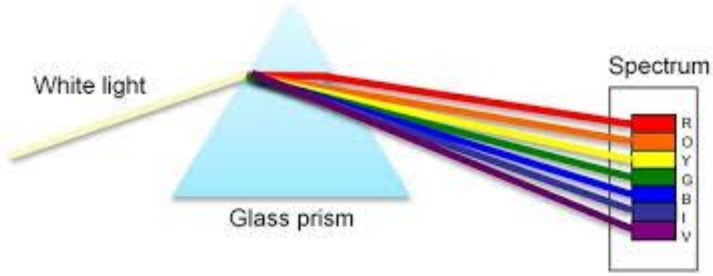
(i) the incident ray, the reflected ray and the normal (at the point of incidence), all lie in the same plane.

(ii) the angle of reflection (*r*) is always equal to the angle of incidence (*i*)
$\angle r = \angle i$



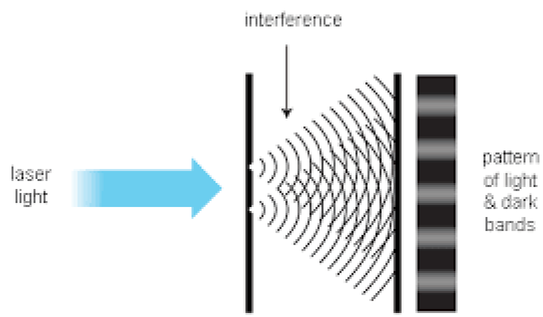
DISPERSION OF LIGHT:

The process of splitting of white **light** into seven colours is called **dispersion of light**.
Example: Formation of Rainbow during a cloudy day.



INTERFERENCE :

Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude. Constructive and destructive interference result from the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves,



DIFFRACTION:

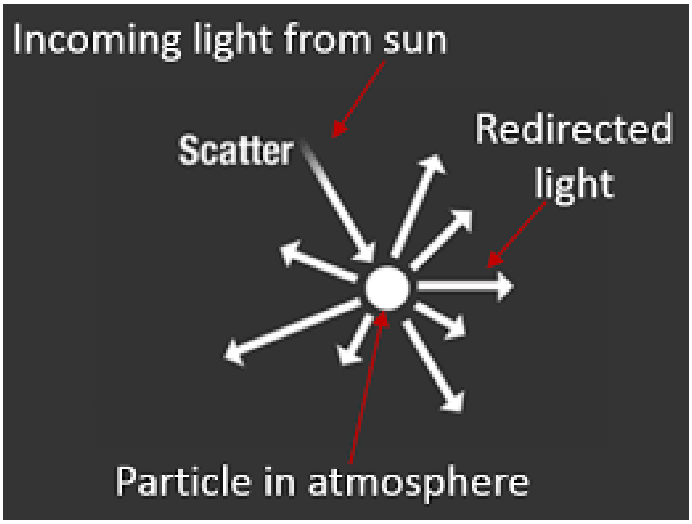
Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture. The diffracting object or aperture effectively becomes a secondary source of the propagating wave

POLARIZATION:

Polarization (also **polarisation**) is a property applying to transverse waves that specifies the geometrical orientation of the oscillations. In a transverse wave, the direction of the oscillation is perpendicular to the direction of motion of the wave.

SCATTERING:

Scattering is the redirection of electromagnetic energy by suspended particles in the atmosphere. The type and amount of **scattering** that occurs depends on the size of the particles and the wavelength of the energy. There are three main types of **scattering** that impact incoming solar radiation: Rayleigh **Scatter**.



Unit:2

Interaction of light

1) Difference between ordinary and laser light

Both ordinary light and laser light are electromagnetic waves. Ordinary light is a mixture of electromagnetic waves of different wavelengths. Laser light is monochrome. Ordinary light is non-directional and inconsistent, while laser light shows directional and highly consistent distribution. This is the main difference between ordinary light and laser light.

Laser light is a focused beam in which all photons move at the same wavelength and in the same direction. Laser lights are spectrally pure. Ordinary light, on the other hand, is a wide spectrum of light that moves irregularly at different wavelengths.

Sunlight, fluorescent light bulbs and incandescent light bulbs are ordinary light sources. According to theories, any object with a temperature higher than absolute zero (0 Kelvin) emits electromagnetic radiation. This is the basic concept used in incandescent bulbs.

The term laser is an abbreviation for light amplification by stimulated emission of radiation. The main advantages of laser light are its consistency, directional distribution and narrow frequency range. Ordinary light is natural, laser light is an induced emission. Ordinary light is inconsistent (not containing photons of the same frequency) whereas laser light is consistent. Ordinary light is diffused, while laser light is extremely directional. The coherence length of ordinary light is only a few meters. Laser light can travel hundreds of meters without being scattered. Since ordinary light is diffused, it cannot focus on a sharp point. Laser light can focus on a point with high intensity thanks to its directional structure.

The intensity of ordinary light decreases rapidly with distance. For this reason, you can look at the ordinary light source without harming the eyes. In contrast, laser light is emitted in a narrow beam. Since the energy is concentrated in a very narrow area, looking at the laser light with the naked eye can damage the eye.

Ordinary light sources are used for area illumination. Laser light is used in metal cutting machines, laser printers, eye surgeries, tattoo removal, barcode readers and fiber optic technology.

Today, lasers are used in many different applications, and more and more new applications are being developed every day.

2) Interaction of light with materials

Light can be reflected, transmitted, or absorbed.

EM waves can interact with a material medium in the same ways that mechanical waves do. Three forms of interaction play an especially important role in how people see light. One form is reflection.Most things are visible because they reflect light. The two other forms of interaction are transmission and absorption. (trans-MIHSH-uhn) is the passage of an EM wave through a medium. If the light reflected from objects did not pass through the air, windows, or most of the eye, we could not see the objects. (uhb-SAWRP-shun) is the disappearance of an EM wave into the medium. Absorption affects how things look, because it limits the light available to be reflected or transmitted.

How Materials Transmit Light?

Materials can be classified according to the amount and type of light they transmit. Transparent (trans-PAIR-uhnt) materials allow most of the light that strikes them to pass through. It is possible to see objects through a transparent material. Air, water, and clear glass are transparent. Transparent materials are used for items such as windows, light bulbs, thermometers, sandwich bags, and clock faces. Translucent (trans-LOO-suhnt) materials transmit some light, but they also cause it to spread out in all directions. You can see light through translucent materials, but you cannot see objects clearly through them. Some examples are lampshades, frosted light bulbs, frosted windows, sheer fabrics, and notepaper.

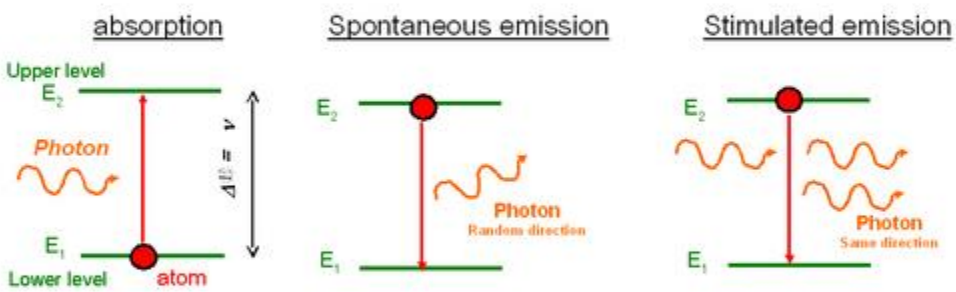
Opaque (oh-PAYK) materials do not allow any light to pass through them, because they reflect light, absorb light, or both. Heavy fabrics, construction paper, and ceramic mugs are opaque. Shiny materials may be opaque mainly because they reflect light. Other materials, such as wood and rock, are opaque mainly because they absorb light. A light filter is a material that is transparent to some kinds of light and opaque to others. For example, clear red glass transmits red light but absorbs other wavelengths. Examples of light filters are the colored covers on taillights and traffic lights, infrared lamp bulbs, and UV-protected sunglasses. Filters that transmit only certain colors are called color filters.

Scattering

Sometimes fine particles in a material interact with light passing through the material to cause scattering. is the spreading out of light rays in all directions, because particles reflect and absorb the light. Fog or dust in the air,mud in water, and scratches or smudges on glass can all cause scattering. Scattering creates glare and makes it hard to see through even a transparent material.Making the light brighter causes more scattering, as you might have noticed if you have ever tried to use a flashlight to see through fog. Scattering is what makes the sky blue. During the middle of the day, when the Sun is high in the sky, molecules in Earth's atmosphere scatter the blue part of visible light more than they scatter the other

wavelengths. This process makes the sky light and blue. It is too bright to see the faint stars beyond Earth's atmosphere. At dawn and dusk, light from the Sun must travel farther through the atmosphere before it reaches your eyes. By the time you see it, the greens and blues are scattered away and the light appears reddish. At night, because there is so little sunlight, the sky is dark and you can see the stars.

1. Absorption: An atom in a lower level absorbs a photon of frequency hν and moves to an upper level.
2. Spontaneous emission: An atom in an upper level can decay spontaneously to the lower level and emit a photon of frequency hν if the transition between E2 and E1 is radiative. This photon has a random direction and phase.
3. Stimulated emission: An incident photon causes an upper level atom to decay, emitting a "stimulated" photon whose properties are identical to those of the incident photon. The term "stimulated" underlines the fact that this kind of radiation only occurs if an incident photon is present. The amplification arises due to the similarities between the incident and emitted photons.



Einstein's co efficient A and B

Einstein suggested that under certain conditions, it is possible to force an excited atom to emit a photon b another matching photon. According to Einstein, an atom in an excited energy state under the influence of the electromagnetic field of a photon of frequency ν incident upon it, jump to a lower energy state emitting an additional photon of same frequency ν.

The emission of atomic line radiation at frequency ν may be described by an emission coefficient with units of energy/(time × volume × solid angle). $\varepsilon\ dt\ dV\ d\Omega$ is then the energy emitted by a volume element in time into solid angle . For atomic line radiation, where Einstein coefficient for spontaneous emission, which is fixed by the intrinsic properties of the relevant atom for the two relevant energy levels.

The absorption of atomic line radiation may be described by an absorption coefficient with units of 1/length. The expression $\kappa' \, dx$ gives the fraction of intensity absorbed for a light beam at frequency ν while traveling distance dx. The absorption coefficient.

Einstein coefficients for photon absorption and induced emission respectively. Like the coefficient , these are also fixed by the intrinsic properties of the relevant atom for the two relevant energy levels. For thermodynamics and for the application of Kirchhoff's law, it is necessary that the total absorption be expressed as the algebraic sum of two components, described respectively , which may be regarded as positive and negative absorption, which are, respectively, the direct photon absorption, and what is commonly called stimulated or induced emission. The above equations have ignored the influence of the spectroscopic line shape. To be accurate, the above equations need to be multiplied by the (normalized) spectral line shape, in which case the units will change to include a 1/Hz term.

Books for Reference:

1.Engineering physics – Dr.P.Mani (Dhanam Publications)

2.A text book of Optics – Brijlal and Subrahmanyam (S.Chand&co.)