PROPERTIES OF LIGHT

In Figure 1.1, an illustration of wave traveling from left-to-right direction at a given moment of time defines displacement as the vertical distance from the equilibrium position to a point along the wavelength. The amplitude is the maximum displacement of the wave. Wavelength is defined as "the horizontal distance in which the same wave is repeated" and is represented by the Greek character lambda (λ).

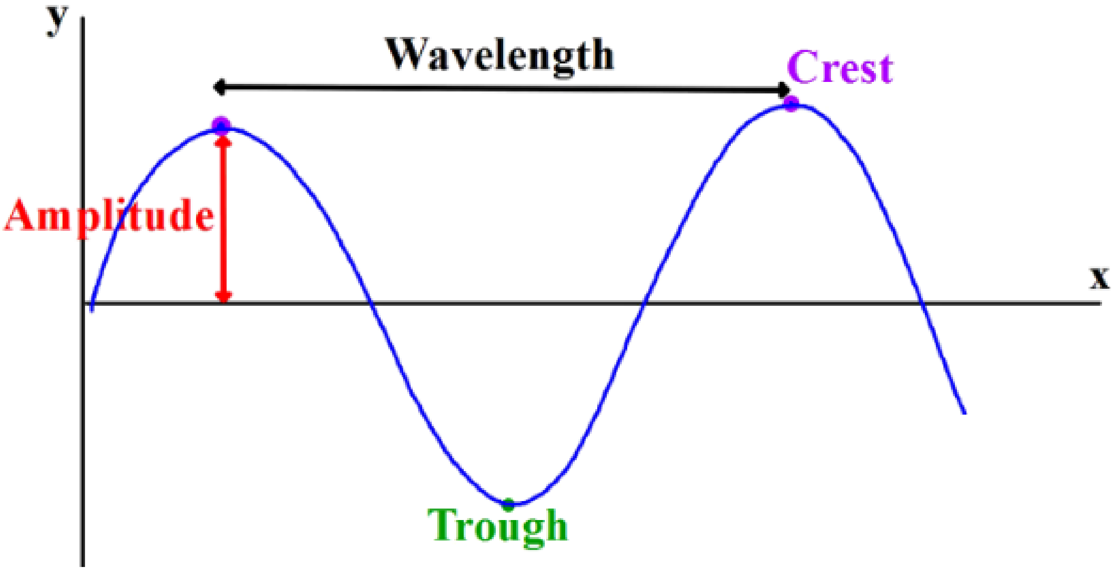


Figure 1.1: curve of Vertical displacement versus horizontal distance

Figure 1.2 illustrates the path of a given point for the same wave as a function of time. The period(T) is the time of which the wave repeats itself, and its the time in which the wave completes one complete cycle. the Frequency is the number of cycles of the wave per second and is symbolized by the letter (f).

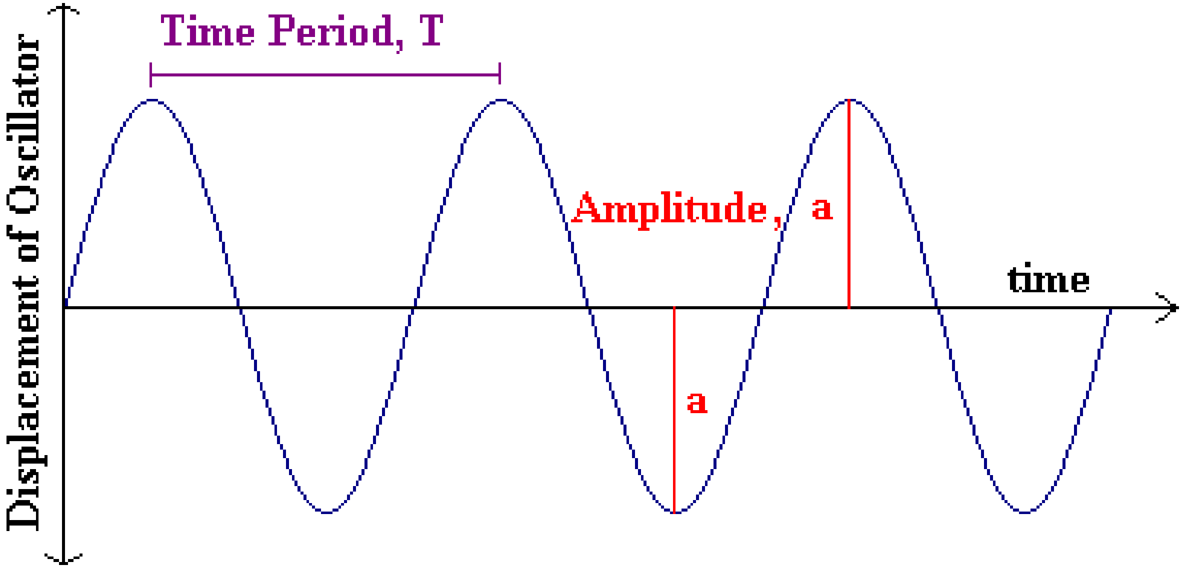


Figure 1.2: curve represents the displacement a function of time and a given point on the wave

Equations 1.3 and 1.4 illustrate how to calculate wave velocity.

$$\boldsymbol{V = \lambda/T}$$

$$\boldsymbol{V = \lambda v}$$

Where: λ= wavelength

V = Speed of the wave

The speed of light in space is denoted by c, which is 3 x 10^8 m / sec and can be replaced by v if light waves pass through physical circles as in Equation 1.4 to obtain equations 1.5, 1.6, 1.7

$$\boldsymbol{c = \lambda v} \quad \ldots\ 1.5$$

$$\boldsymbol{\lambda = c/v} \quad \ldots\ 1.6$$

$$\boldsymbol{v = c/\lambda} \quad \ldots\ 1.7$$

Example:1.1

Calculate the time period (T) and frequency (f) of a wave within the radio spectrum whose wavelength is 30 m

The solution:

$$v = \frac{c}{\lambda} = \frac{3 * 10^8}{30} = 10^7 = 10MHz$$

$$T = \frac{1}{v} = \frac{1}{10^7} = 10^{-7} = 100ns$$

Example 1.2:

Calculate the time period (T) and the frequency (f) of an emitted wave of alternating current oscillating at a frequency (60Hz).

Solution:

$$\lambda = \frac{c}{v} = \frac{3 * 10^8}{60} = 5 * 10^6\ m$$

$$T = \frac{1}{v} = \frac{1}{60} = 16.667\ ms$$

electromagnetic wave energy are emited from accelerating electrical charges or oscilation of the electrical charges . They travel through the vacuum or the physical material in periodic disturbances of both the electric field and the magnetic field at a certain frequency see Figure 1.3, all of which are within the electromagnetic spectrum. Light is part of electromagnetic waves spectram and travels through the vacuum

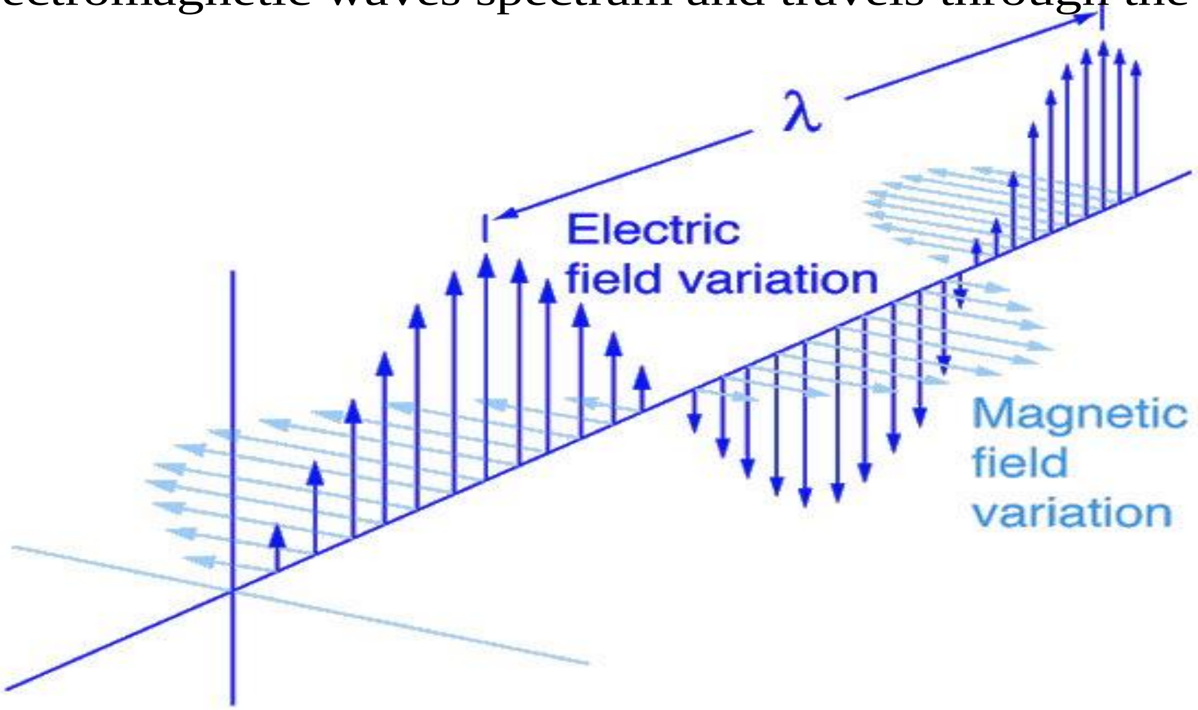


Figure 1.3: The electromagnetic wave is Generate when the electric field is simultaneously coupled with the magnetic field

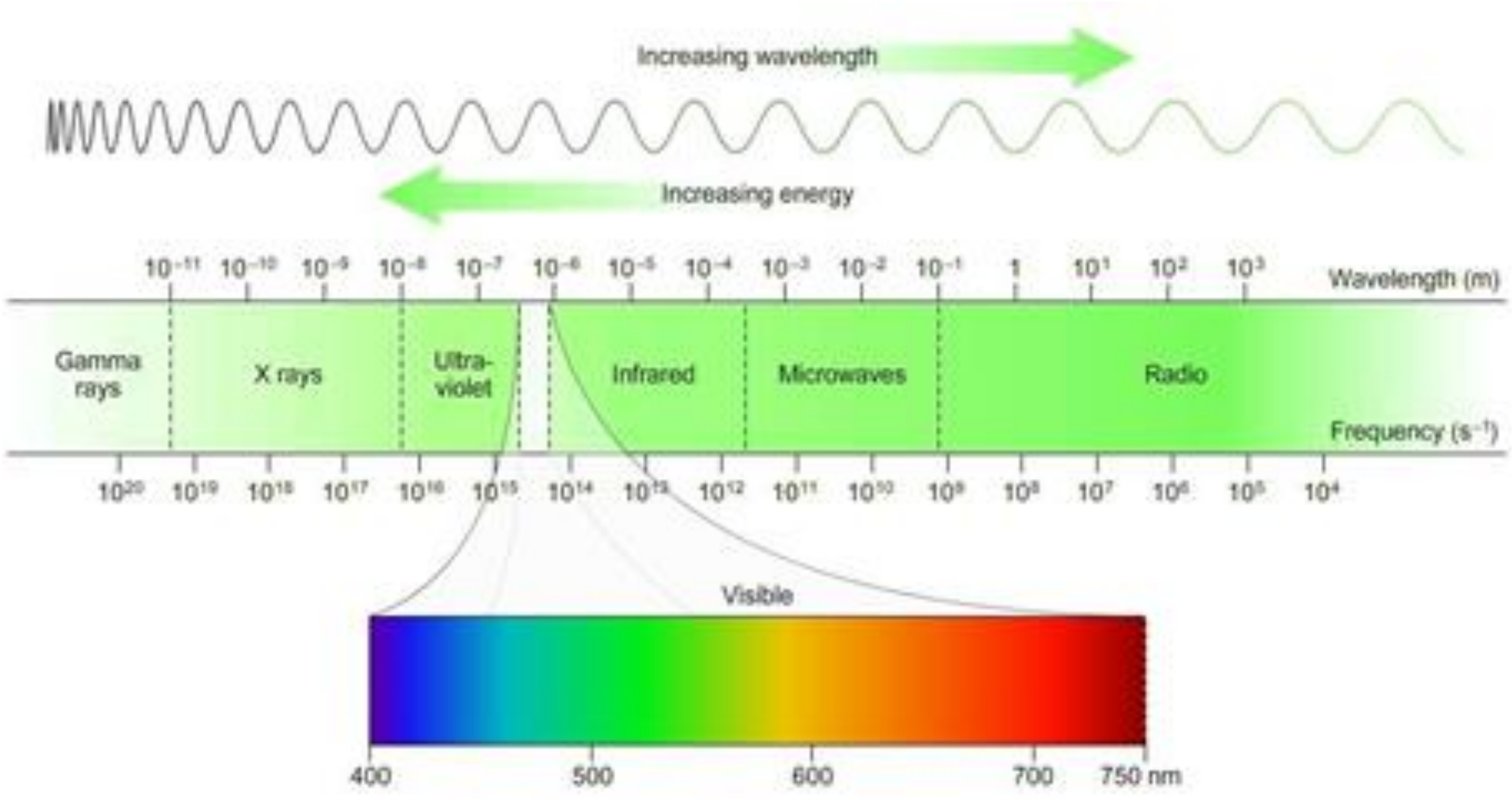


Figure 1.4: spectrum the electromagnetic wave

All electromagnetic waves propagate during the vacuum at a constant speed of c = 3 × 108 m / sec. Its speed is reduced when these waves spread through transparent medium. The refractive index of a material is defined as the ratio of the velocity of light in the vacuum to its velocity in that material. In optics, the refractive index n for a given material is a mere number of units where it shows how the light is propagating through that medium.

$$n = \frac{c}{V}$$

where: n = Index of refraction
V = Speed of light inside material

For example, the refractive index of water is 1.333, which means that the speed of light in the vacuum is more than 1.333 of its velocity within the water.

The refractive index can be expressed (Equation 1.9) as the ratio of the wavelength in the vacuum to the wavelength within the material

$$\boldsymbol{n = \lambda_0 / \lambda_i}$$

where: $\boldsymbol{\lambda}_0$ = Wavelength in vacuum.

$\boldsymbol{\lambda}_i$ = Wavelength in material.

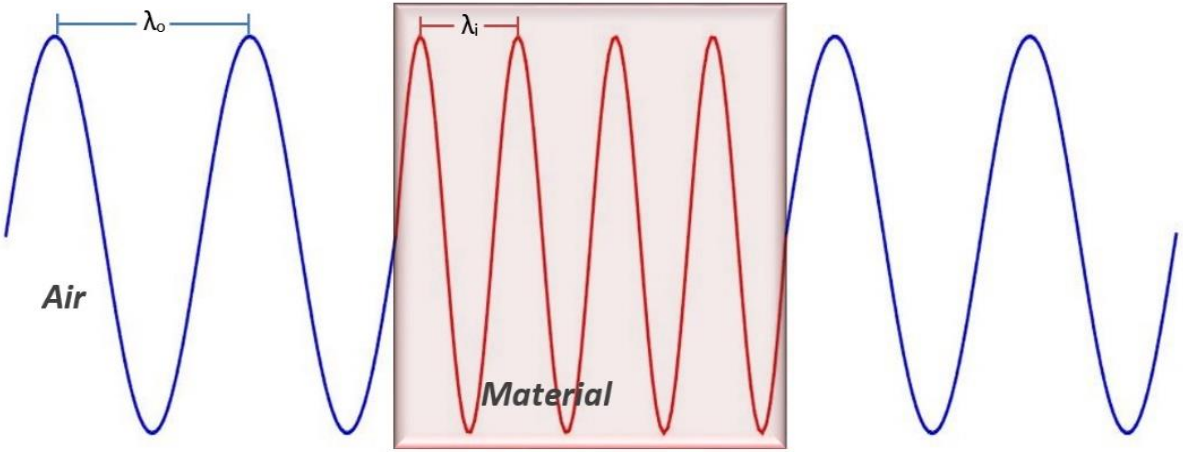


Figure 1.5: Shows how the wavelength in the material is reduce

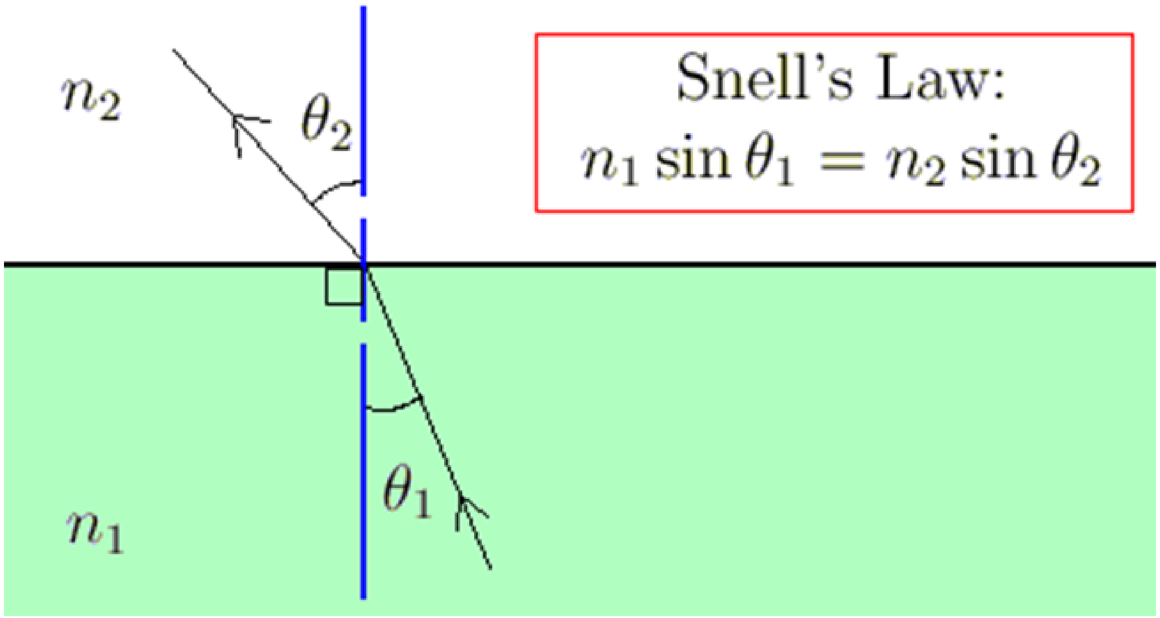
When the light leaves the material and its continue to propagate in the vacuum, it returns to its speed c and to the wavelength λ_0. The refractive index of air is about 1.0003, but in most applications it can be rounded to 1.0.

decrease in the speed of light within the material and the shortness of the wavelength leads to a change in the path of the beam during the crossing of the boundary between the two different material and the result is a change in the direction of the path of the propagation of the light goes outside according to the equation called the law Snell:

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

n_1 and n_2 refractive index for the two intermediates in Figure 1.6. substance, the angle of incident θ_1 and the refraction angle θ_2, these angles made by the incident beam and the reflected beam with the perpendicular (or normal) on the reflecting surface (the boundary between the two materials). Because the ratio between n_1 / n_2 is constant at any wavelength of light, the ratio of the two sines is also constant to any angle.

As a result, the path of the beam of light bent towards the normal (perpendicular) when entering a material with a refractive index higher than the refractive index of the material that came from it. In the opposite case, when the light enters material with lower refractive index than the material from which it came, the light beam is bent away from the normal



Snell's Law:

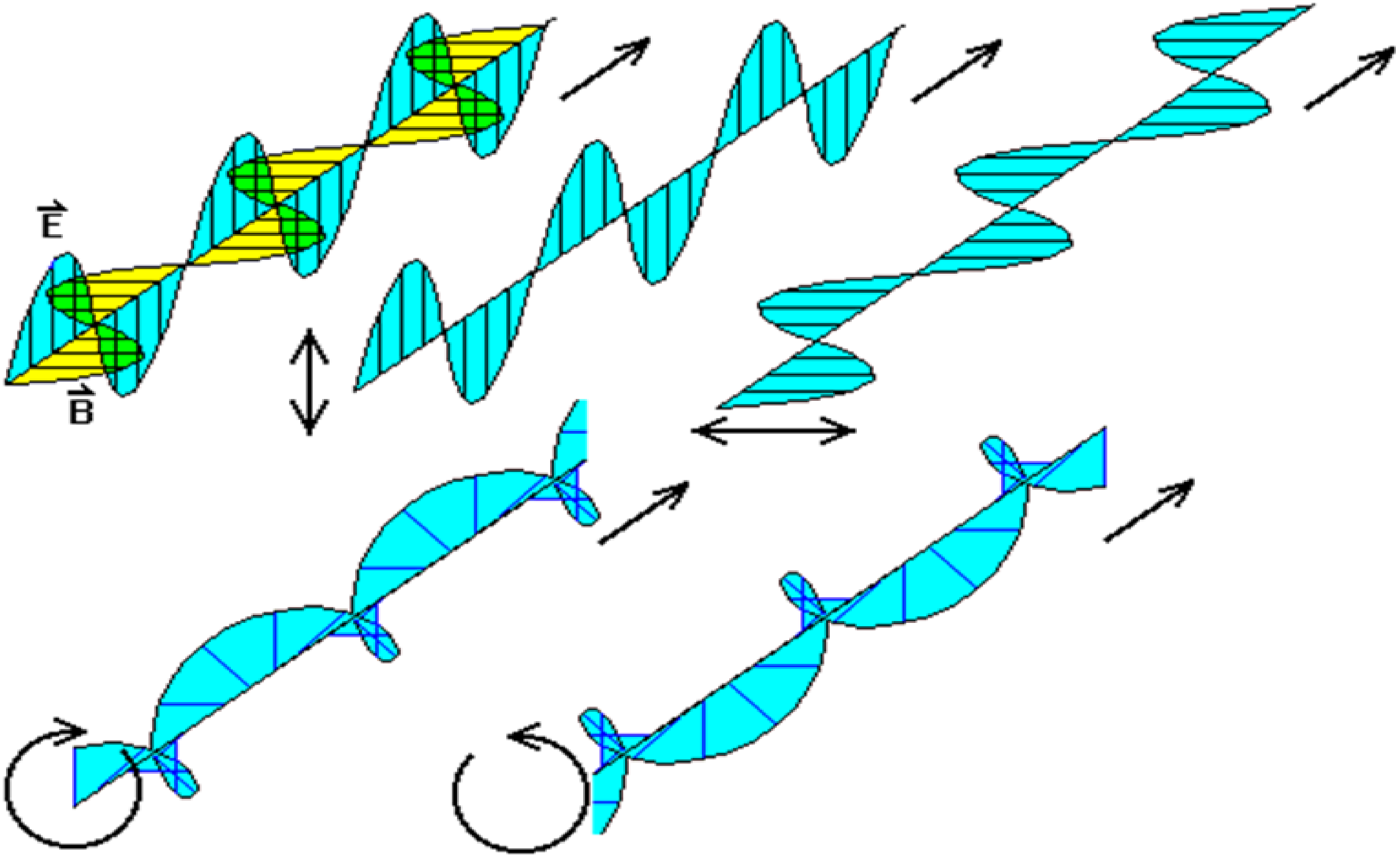
$n_1 \sin\theta_1 = n_2 \sin\theta_2$

Polarization

All light waves are transverse: that is, the vibrating electric vector associated with each wave is perpendicular to the direction of propagation, and these waves consist of vibration in the electric and magnetic fields that form these waves. In the natural state, the light beam consists of a mixture of waves whose electrical and magnetic fields vibrate in all directions and perpendicular to their propagation line. But for some reason if the oscillations of magnetic and electric field remain fixed in a certain direction, it is said that this light is polarized. In many applications there is a need to be oscillating for electric and magnetic field in a specific direction.

If the direction of vibration of one of these fields is known, the direction of the other is known as long as the two fields are always orthogonal. The direction of polarization of light was usually described in the direction of the oscillation of the electric field in space. The polarized light was also defined in the following terms،

- Linear (or plane) polarize light is the light whose electrical field vibrate at one plane only.
- unpolarized light does not have a specific direction. The direction of the oscillation of its electric field in different directions and in a random way, as shown in Figure 1.7a.
- The vertically polarized light as shown in Fig. 1.7B, where the electric field oscillates vertically up and down and at the plane of the paper as shown in vertical arrows.
- Horizontally polarized light as shown in Fig. 1.7c), the level that contains the electrical field oscillation horizontally and vertically at the plan of the paper.
- Circular polarized light, the direction of the electric field is not oscillating at random and is not limited to one level. But the direction of the oscillation of the electric field of circular polarized light sweeps a circle during each time period of the wave path as shown in Figure 1.7d.



(a) Unpolarized Light

(b) Vertically Polarization

(c) Horizontally Polarization

construction of oscillation of its electric field at the plane parallel to the surface of the reflective material and often show a case of glare if the degree of polarization as high as shown in Figure 1.9

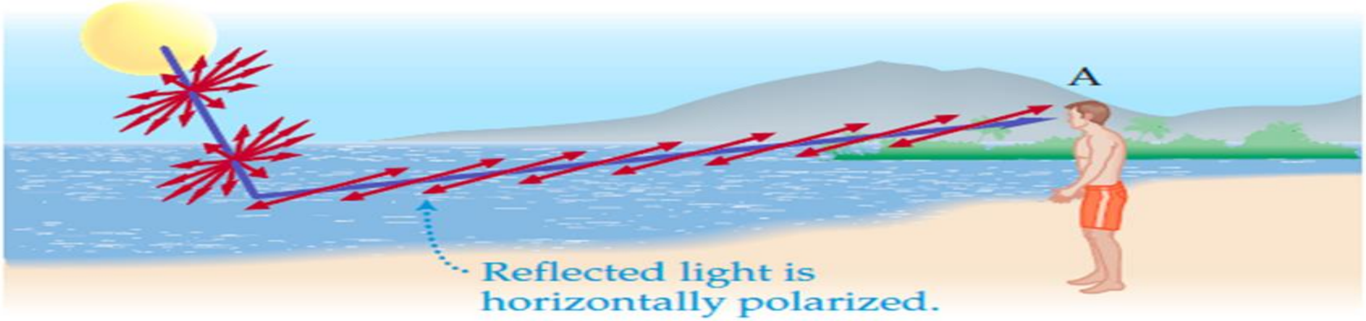


Figure 1.9: Polarization by reflection on the water surface

Figure 1.10 illustrates the polarization process by reflecting from the surfaces. If a unpolarized light falls on the surface of glass material (transparent) at angle of incident Φ, a part of this light is reflected and the other part is transmitted through the material. The plane of polarization of each component reflected if it is vertical (symbol ⊥) or parallel with the symbol ll) depends on the angle of incident. ", The direction of polarization indicates the plane of incident.

It should be noted that the plane of incident contains the line normal to the reflector surface and the ray of the incident light. (It is not at the plane of paper) as seen in Figure 1.10, points (●) indicate orthogonal polarization; short arrows (↔) refer to parallel polarization

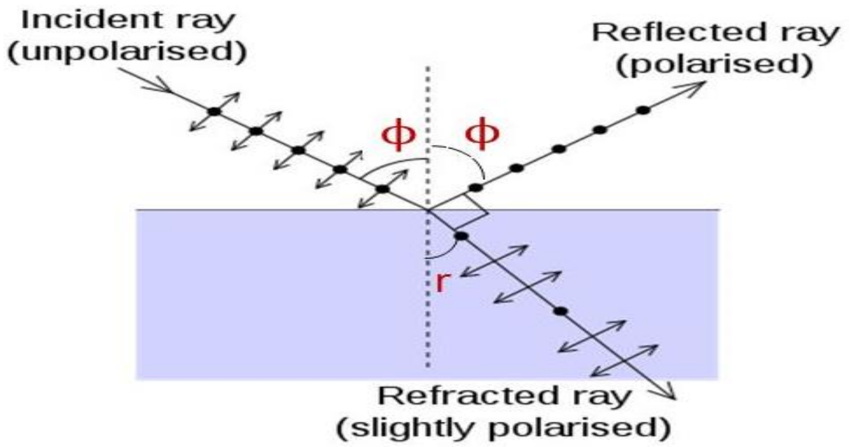


Figure 1.10: Polarization by reflection

Figure 1.10 shows the reflectivity of a reflective surface of glass as a function of angel of incident the light consisting of two compounds, one of which is orthogonal to the plane of the incident (⊥) and the other is polarized parallel to the plane of incident (||). The vertical polarization (⊥) is always reflected more than orthogonal polarization. There is an exception when the light falls vertically on the reflector surface, in which case the two components are equally reflected. Thus, the reflected light from most surfaces tends to partially polarize. The angle indicated in Fig. 1.10 is called the "Brewster angle", at this angle, neither of the parallel polarities light (||) is reflected. The angleϕ in Figure 1.10 is equal to the Brewster angle where the reflected

The relation of the Brewster angle to the refractive index is given in by Equation 1.11.

$$n = tan\phi$$

This equation shows that the Brewster angle for the material in the air is equal to the refractive index of that material

EXAMPLE 1.6:

Refractive index of the HeNe laser tube window of fused quartz 1.45. Find the Brewster angle of that material when placed in the air.

Solution:

$$n = tan\phi$$

$$\phi = \tan^{-1} n = \tan^{-1} 1.45 = 55.4^{o}$$

Problems

1. Define the following terms:

   a. Frequency b. Wavelength c. Wave speed d. Period
   e. Phase f. Amplitude g. Polarization h. Hertz
   i. kHz j. MHz k. THz l. GHz
   m. Micrometer n. Nanometer o. Index of refraction
   p. Angstrom q. Wave front r. Brewster's angle
   s. Temporal coherence t. Spatial coherence
   u. Constructive interference v. Destructive interference.

2. Draw and label a sketch of a plane-polarized electromagnetic (EM) wave at one instant of time at different points along a line in the direction of propagation. Indicate the wavelength of the EM wave in the drawing.
3. Prepare a sketch that represents the infrared, visible, and ultraviolet regions of the electromagnetic spectrum; and identify the wavelength and frequency ranges of each.
4. Calculate the frequencies of the following wavelengths of EM radiation:

   a. 633 nm. b. 1.06 µm. c. 6943 Angstroms.
   d. 10.6 µm. e. 3 m. f. 4.88×10^{-7} m.

1. Calculate the wavelengths of the following frequencies of light. Express each answer in µm, nm, and A.

   a. 1.34×10^{14} Hz. b. 260.8 THz. c. 5.83×10^{14}Hz.

2. Calculate the periods of the waves in Problem 5.

3. The indices of refraction of several materials situated in the air are given below. Calculate the velocity of light in each and Brewster's angle for each.

   a. Fused quartz at 643 nm: n = 1.457.

   b. Zinc crown glass at 434 nm: n = 1.528.

   c. Fused quartz at 397 nm: n = 1.471.

4. The wavelengths given in Problem 7 are in a vacuum. Calculate the wave lengths inside the materials.