Course Title

Course Code PHS 102 / Department: PHYSICS

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LEARNING MANAGEMENT SYSTEM
LMS

Diffraction is the deviation of light from a straight line path when the light passes through an aperture or around an obstacle. Diffraction is due to wave nature of light.

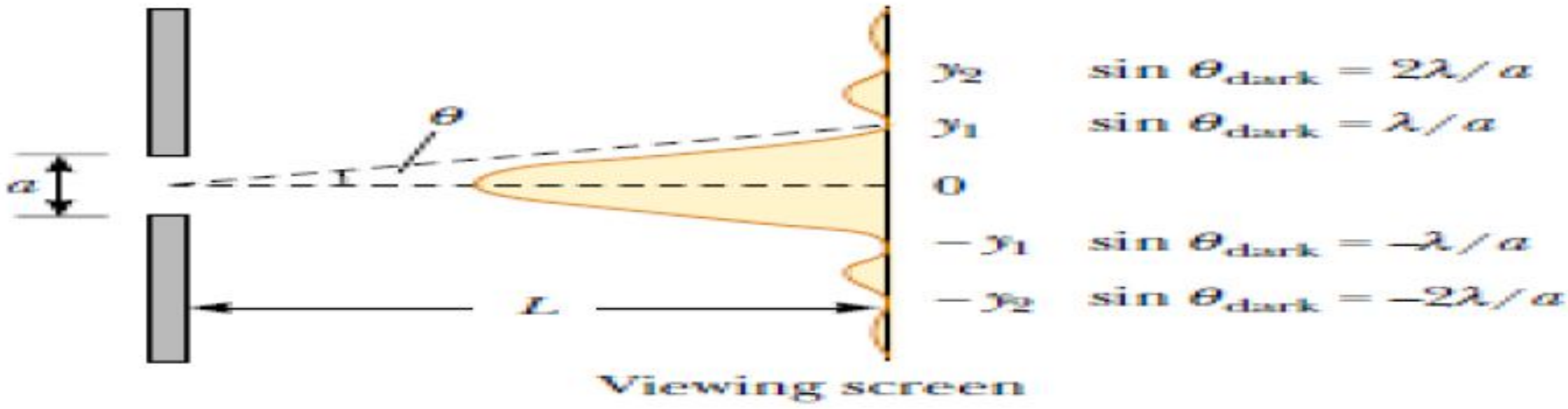
In physics of single slit diffraction experiment, the single slit is of width 'a' as two slit each with a width of $^{a}/_{2}$. Waves from one side of the slit when $^{a}/_{2}$ Sinθ = $^{\wedge}/_{2}$ where both ʌ and **a** are of the same unit or $\sin\theta = \frac{\lambda}{a}$, θ is the angle subtended from the normal line of the slit into four parts instead of two, then $\sin\theta = \frac{2\lambda}{a}$, θ now giving the angle to the second dark band, or six parts instead of four, $\sin\theta = \frac{3\lambda}{a}$, with θ giving the angle to the third dark band e.t.c

.: The general condition for destructive interference for a single slit of width ‘a’ is

$$\sin\theta_{dark} = \frac{m\lambda}{a},\ m = \pm1, \pm2, \pm3 \ldots\ldots\ldots\ldots$$

This equation gives the values of θ_{dark} for which the diffraction pattern has zero light intensity i.e when a dark fringe is formed.

The general feature of intensity distributions are shown in figure below

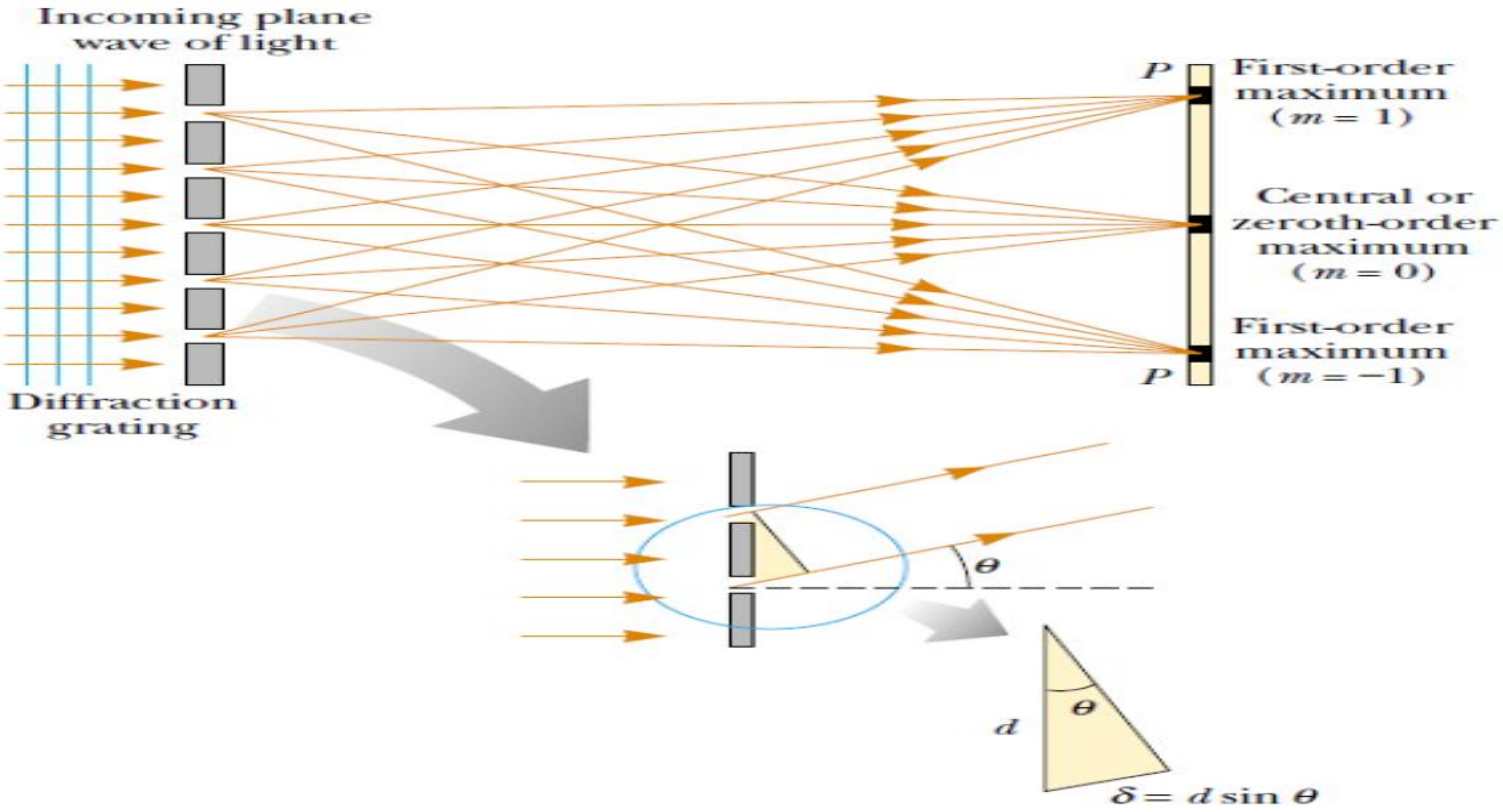


DIFFRACTION GRATING

Note that diffraction will occur either for light passing through narrow slits, or for light travelling around thin obstacles. It is this second type of diffraction that is used to construct diffraction gratings.

Diffraction grating is a useful device for analyzing light sources, it consists of a large number of equally spaced parallel slits. A section of a diffraction grating is shown in

Incoming plane



A plane wave is incident from the left, normal to the plane of the grating. The pattern observed on the screen is the result of the combined effects of interference and diffraction. Each slit produces diffraction, and the diffracted beams interfere with one another to produce the final pattern. The waves from all slits are in phase as they leave the slits but must travel different path lengths before reaching the screen. If the path difference δ between rays from any two adjacent slits equals one wavelength or some integral multiple of wavelength, a bright fringe is observed.

The condition for maxima in the interference pattern at the angle θ_{bright} is

$d \sin\theta_{bright} = m\wedge$, $m=0, \pm1, \pm2, \pm3, \ldots\ldots\ldots\ldots\ldots$ where d is the grating spacing.

Example

Example

Light of wavelength 600nm falls on a 0.40nm wide slit and forms a diffraction pattern on a screen 1.5m away.

(a) Find the position of the first dark band on each side of the central maximum

(b) Find the width of the central maximum.

Solution:

Dark bands will occur where $\sin\theta = m\left(\frac{\lambda}{a}\right)$

For the first dark band, m =1

From $y_1 = L\, tan\theta \approx L\, sin\theta = L\left(\frac{\lambda}{a}\right)$

$$\therefore y_1 = 1.5m\left(\frac{600 \times 10^{-9}m}{0.4 \times 10^{-3}m}\right) = 2.25 \times 10^{-3}m = 2.3mm$$

The width of the central maximum is just $2y_1$= 2(2.25mm) = 4.5mm

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Example: Monochromatic light from a helium-neon Laser (λ=632.8nm) is incident normally on a diffraction grating containing 6000 grooves per centimeter. Find the angles at which the first and second-order maxima are observed.

Solution: Slit separation $(d) = \frac{1}{no\ of\ grooves\ per\ cm} = \frac{1}{6000} cm$

$$= 1.667 \times 10^{-4} cm = 1667nm$$

For the first-order maximum (m=1) , $sin\theta_1 = \frac{\lambda}{d} = \frac{632.8nm}{1667nm} = 0.3796$

$$\therefore sin\theta_1 = 0.3796$$

$$\theta_1 = 22.31^o$$

For the second-order maximum (m=2), we find $sin\theta_2 = \frac{2\lambda}{d} = \frac{2(632.8nm)}{1667nm}$

$$sin\theta_2 = 0.7592$$

$$\therefore \theta_2 = 49.39^o$$

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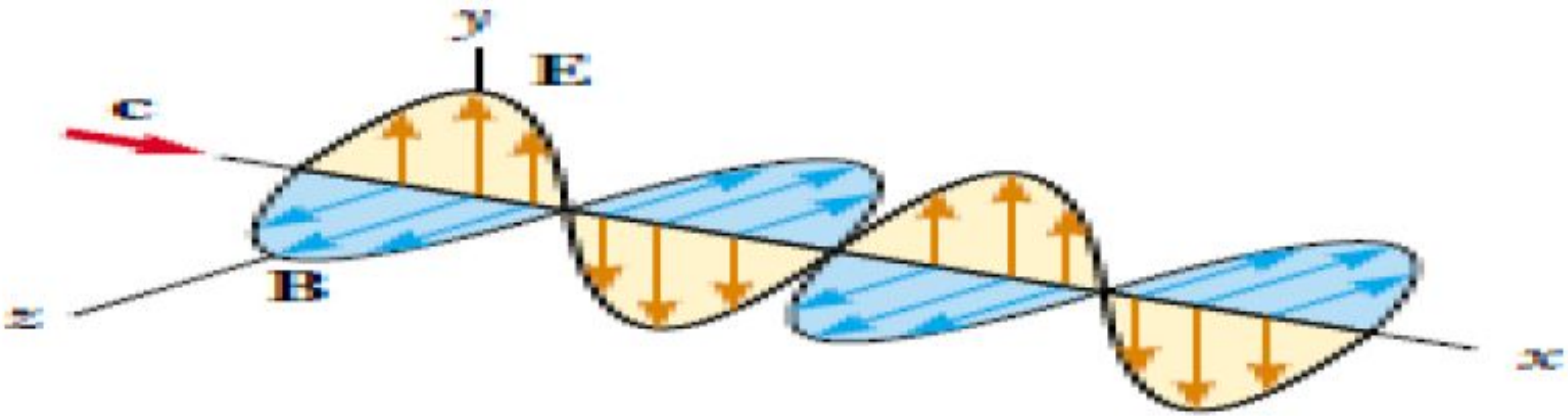
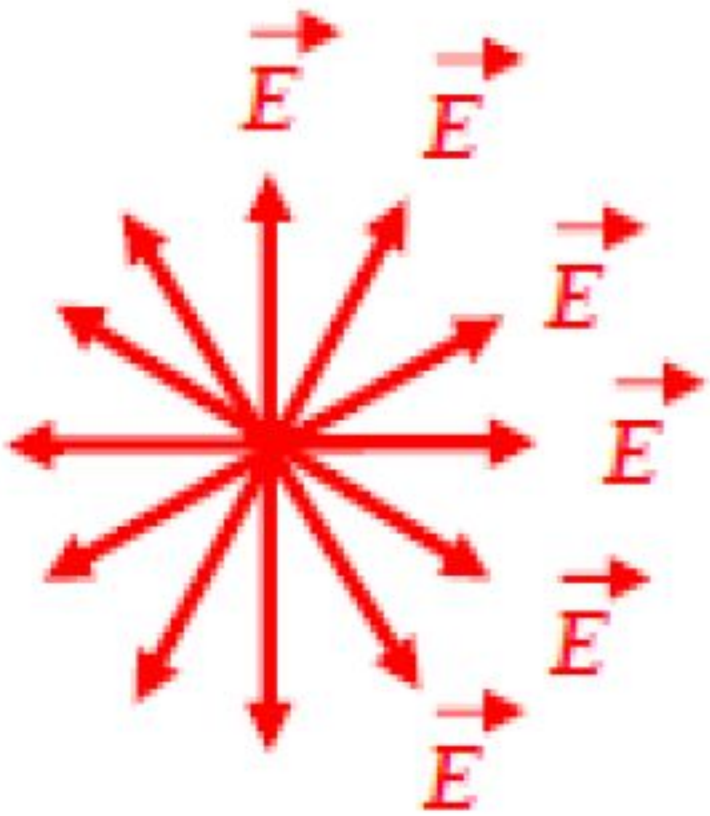
POLARIZATION

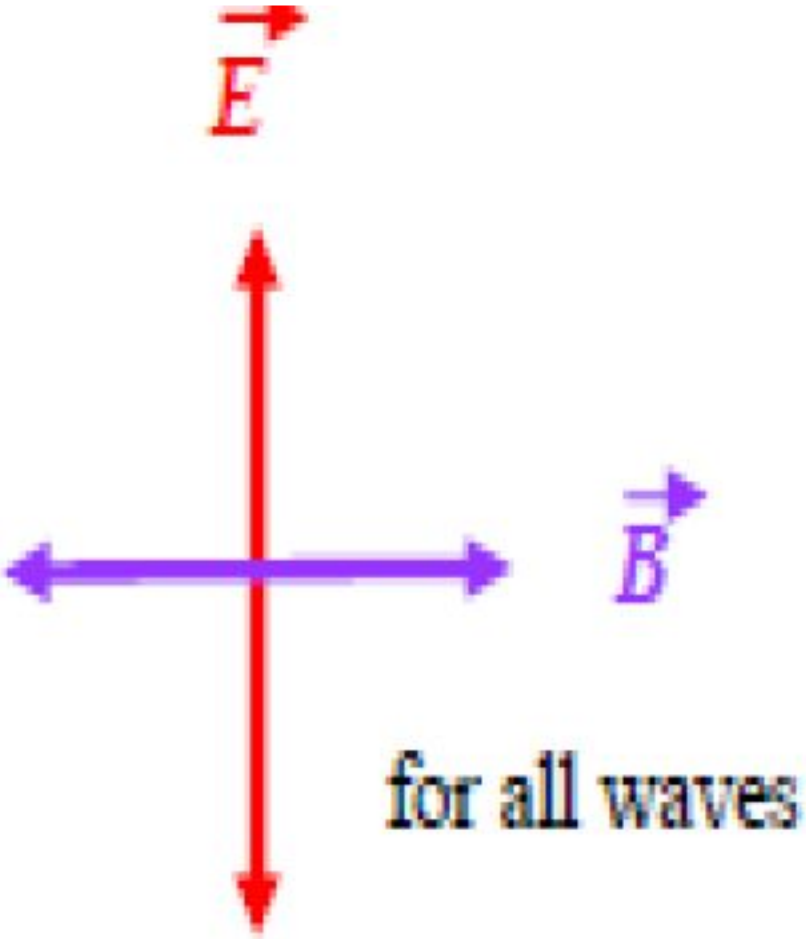
An ordinary beam of light consists of a large number of waves emitted by the atoms of the light source. The direction of polarization of each wave is defined to be Electric field $\vec{E}$ direction which lie along y axis. However, an individual EM wave could have its E vector is the yz plane, making any possible angle with the y-axis. This is shown in below



When light is polarized, the electric field $\vec{E}$ always points in the same direction but if the electric field pointing along all directions perpendicular to the direction of propagation, the resulting light is unpolarized. A wave is said to be linearly polarized if the resultant E field vibrates in the same direction at all times at a particular point. Such a wave is often reffered to as being plane polarized as shown below.



Unpolarized



Linearly polarized

Unpolarized light can be changed into a polarized light by passing the light through or reflecting off of a special material called a Polarizer. In 1932, E.H. Land discovered such a transmitting material called a POLAROID that polarized light through selective absorption by molecules oriented in a specific manner in the material as unpolarized light passed through it.

POLARIZATION BY SCATTERING

When light is incident on any material, the electrons in the material can absorb and reradiate part of the light. Such absorption and re-radiation of light by electrons in the gas molecules that make up air is what causes sunlight reaching an observer on the earth to be partially polarized.

For example, the N_2 and O_2 molecules in the Earth atmosphere are very effective at polarizing the sun's light through a process known as Rayleigh Scattering. The amount of Rayleigh Scattering that an atom or a molecule will perform is proportional to $\frac{1}{\lambda^4}$. This is why the sky is blue as the blue light from the sun is scattered much more efficiently than red light.

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Malus's law gives the intensity **I** after light goes through polarizers/Analyzers. (Note: Polarizer is used when input is unpolarized light and Analyzer when input is polarized light (it gives direction of polarization).

The polarizer output is polarized light with amplitude E_0 while the Analyzer output is component of E_0 along analyzer transmission axis. The Amplitude of analyzer output is $E_0 \cos\theta$.

But Intensity **I** is proportional to $|E|^2$ $\therefore I_{trans} = I_0 \cos^2\theta$.

If $\theta = 90^0$, then there is no transmission through the analyzer.

.: The intensity of the polarized beam transmitted through the analyzer varies as $I = I_{max}Cos^2\theta$

or $I_{trans} = I_0Cos^2\theta$

Where I_{max} rep the intensity of the polarized beam incident on the analyzer.

The figure below represent an unpolarized light beam incident on the polarizer while the transmitted beam (polarized) is being intercepted by the analyzer.