PHYSICAL OPTICS
2. DIFFRACTION

POINTS TO REMEMBER

1. $\frac{b^2}{l\lambda} << l$, then Fraunhoffer diffraction is observed.

   $\frac{b^2}{l\lambda} \approx 1$, Fresnel diffraction is observed.

   $\frac{b^2}{l\lambda} >> 1$, condition for geometrical optics.
2. Bending of light at the edges of an obstacle or aperture is called diffraction. The phenomenon of encroachment of light into the geometrical shadow of an obstacle is known as diffraction. Diffraction is exhibited by both transverse and longitudinal waves.
3. Diffraction is due to the superposition of waves originating from different points of the exposed portion of the same wave front.
4. **Zone :** A small area on a plane wave front with reference to a point of observation, so that all the waves from the area reach the point without any path difference is called a zone. As the paths of light rays from successive zones differ by $\lambda/2$ these zones are called half period zones.
5. In case of circular half period zones, the area of half period zone b . The areas of all zones are approximately same. The annular region between the $(n-1)^{th}$ and n^{th} circle is known as n^{th} zone.
6. The radius of n^{th} half period zone is $r_n = \sqrt{nb\lambda}$.
7. **Area of the** n^{th} **half period zone** is $A_n = \pi b\lambda$ Area of the zone is independent of n.
8. **Area of the nth zone:** A= $\pi\left[b\lambda + \frac{\lambda^2}{4}(2n-1)\right]$ As n increases, area of the zone increases.
7. The effective intensity at a point is maximum due to the odd number of Fresnel zones.
8. The effective intensity at a point is minimum due to the even number of zones.

SHORT ANSWER QUESTIONS

1. Explain the main features in which Fraunhofer and Fresnel approaches of diffraction differ**?**

Fraunhoffer Diffraction	Fresnel Diffraction
1) Source of light and screen are at infinite distances.	1) Source of light and screen are at finite distances.
2) Lenses are used.	2) No lenses are used.
3) Angular inclinations are important.	3) Distances are important.
4) Wave fronts are often plane.	4) Wave fronts are spherical or cylindrical.
5) Theoretical treatment is simple.	5) Theoretical treatment is approximate.

2. Mention some (at least three) applications of diffraction? (March2011)

A. i) The wavelength of either monochromatic or composite radiations can be measured accurately by diffraction technique using gratings.
ii) The wavelengths of X-rays are determined by X-ray diffraction.
iii) Crystal or crystalline structures of solids are determined by X-ray, electron and neutron diffraction measurements.
iv) Velocity of sound in liquid (organic or inorganic) can be estimated with the help of ultrasonic diffraction techniques
v) Ultrasound scanning uses the principle of diffraction to assess the size and shape of ulcers, tumors etc., inside the human body.

3. Do sound waves exhibit diffraction? Give reason to your answer

A: Yes, the sound waves also exhibit the diffraction..
This is because the sound waves produced by a source which is enclosed in a closed chamber with an aperture can be heard by the listener who is out of the chamber. This is due to bending of sound waves through the aperture.

4. Radio waves diffract more easily than visible light waves. Give reason.

A: The frequency of the radio waves $(5\times10^9\ Hz)$ is less than the frequency of the visible light $(8\times10^{14}\ Hz)$ .Since $\lambda\propto\frac{1}{v}$, the wave length of the radio waves is greater than wavelength of the visible light. Thus the radio waves different easily than visible light. Because the radio waves can also diffract at large apertures whose size is comparable with wave length of light.

VERY SHORT ANSWER QUESTIONS

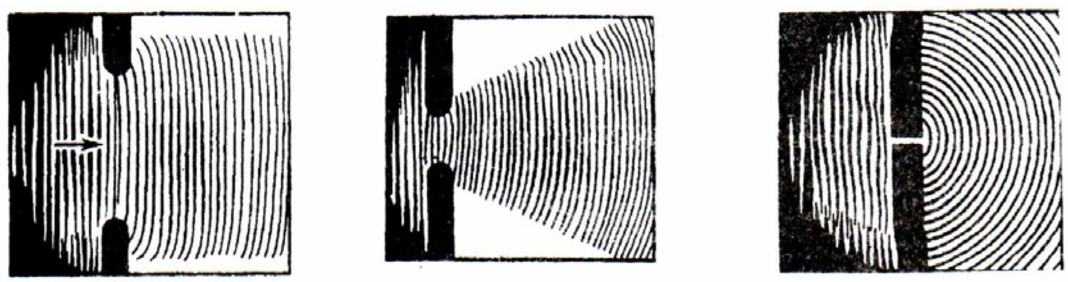
1. Would interference and diffraction effects still be observed if light waves were longitudinal instead transverse?

A: Longitudinal waves can exhibit interference and diffraction similar to transverse waves. Longitudinal waves cannot be polarized whereas, transverse waves can be polarized.

SOVLED PROBLEMS

1. A plane wave the falls on a barrier containing small circular opening of dimension d. what can be said about the behavior of the wave if (i) $\lambda << d$ (ii) $\lambda \approx d$ (iii) $\lambda >> d$.

Sol: i) When $\lambda << d$ i.e., wavelength of the wave is very small when compared to the circular barrier or the diameter of the circular opening is lager than the wavelength of the waves coming out of the opening continue to move in straight lines i.e., the ray approximation continues to be valid and we need not consider diffraction effects or wave nature.
ii) when $\lambda \approx d$, i.e., the diameter of the opening is of the order of the wavelength the wave spread out from the opening in all directions the wave nature is predominant.
iii) $\lambda >> d$ i.e., if the circular opening is very small relative to the wavelength, the opening behaves as a point source of waves, and emits spherical waves diffraction is more pronounced
The above argument is valid for all types of waves



(i) $\lambda <<d$ (or $d>>\lambda$) (ii) $\lambda \approx d$ (iii) $\lambda >>d$ (or $d<<\lambda$)

2. An obstacle such as a telephone pole can cast a clear shadow in the light from a distance source. No such effect is noticed for the sound from a distance car horn. Why?

Sol: Waves of shorter wavelength have fewer tendencies to spread out behind the barrier. Light waves have much shorter wavelength compared to that of sound waves.

Light waves can not spread out behind the telephone pole hence cast a sharp shadow. Here rectilinear propagation of light is considered and diffraction effect is ignored.

Sound waves have wavelength range much greater than the wavelength range of light waves. Hence sound waves can spread behind the obstacle. So no shadow can cast by sound waves, as their diffraction effect is more pronounced.

<u>ASSESS YOURSELF</u>

1. In the figure of the solved problem (1) diffraction effect of water waves for different sizes of the obstacles are shown. Do all kinds of waves behave the same way as far as diffraction phenomenon is concerned?

A. Yes.

2. We can here around the edges of a door way, but we can not see around them. Why?

A. If $\frac{\lambda}{b}$ is very small, diffraction effect will be negligible (light waves). If $\frac{\lambda}{b}$ is large diffraction is more pronounced (with sound waves).Here λ Wavelength of the waves, b size of the aperture or obstacle.