WAVE OPTICS

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Lecture - 30: Diffraction of Light

Hello, student, welcome to the wave optics course. Today we have lecture number 30 and in this lecture, we are going to discuss the diffraction of light. So, we have lecture number 30 today and in this lecture, I am going to describe the diffraction of the light, the basic phenomena. So, in the earlier classes, we discussed one important phenomenon that leads to the wave nature of the light and that is the superposition principle. The two light waves are superposed to each other and the resultant phenomena lead to some pattern. A more detailed analysis of this wave nature or a more profound understanding of this wave nature of the light can be also realized with this phenomenon of light diffraction. What is the phenomena of light diffraction? Simply, if I have a light source here, that emits light like this, and if I put an obstacle here in the form of a window with sharp edges. And if I want to see the pattern of the light here, we will see that our perception suggests that, okay, I want to see only this part to be illuminated. So this is say B and this is C and only this part will be illuminated and that defined by this window and this is the light source and ray optics suggest that light will go in a rectilinear path when it experiences an obstacle it will not go further. So, this dotted region is the region where the light will be illuminated. So, in the screen only the region in between B and C we are going to see the light illumination. Well the region beyond BC, says, suppose I say this region is called the geometrical shadow. This is a geometrical shadow and the name suggests that as per the geometries concern of the light which is coming through this concept of this ray propagation. This region beyond B and C, this region should not be illuminated by the light because of the presence of this obstacle and that is why it is called geometrical shadow. But that is not the full story, if we look carefully here, we will see that some amount of light is still there in this geometrical shadow region. So that means somehow the light is not propagating in a straight line, it bends through the sharp edges and we get some kind of illumination even in the geometrical shadow region.

So, that concept cannot be or that phenomenon cannot be explained by the ray theory. So, ray theory has a limitation and that is the major limitation here it does not explain why we should get some amount of illumination in the geometrical shadow region. So here the concept of the wave comes into the picture which means whatever the property of the light we discussed. So far in the form of ray optics, it suggests that the light is nothing but a ray of light, it is not the full story. That means it has a wave property light is not like a ray, it also has a wave property and due to that there might be a situation where light can bend from the sharp edges. So, this is called diffraction. So, in general bending of light as it passes through some object or aperture is known as the diffraction of light. So this is a very ah this is a very straightforward definition. If I say this, it is a definition that once we have this kind of structure, where light can bend and this bending allows the light to propagate or illuminate the region which we call the geometrical shadow region. So this phenomenon is in general called the diffraction of light. And this phenomenon can only be explained and this phenomenon can only be explained by the wave nature of the light. So here also we are going to see the light will form some kind of pattern like in the superposition of the light for interference cases what we find. Here also we are going to see that wave nature is a major term here which suggests that light can be going in a direction not in a straight line but it bends through these edges and that's why this so-called geometrical shadow region will be illuminated and that is overall the diffraction phenomena of the light. Now, let us have a very rough idea about what is called diffraction. Now it is, we should study this in a more systematic way, and in order to understand how light propagation one can consider in such systems or such cases we need to introduce the Huygens theory, Huygens principle. So what Huygens's principle suggests is that every point on a propagating wavefront. So suppose we have a source here and light is coming out and now instead of drawing the straight line I draw it wave like a cast of this wave. So these are called the wavefronts and every point on the propagating wavefront and they are propagating by the way, they are propagating these things are propagating like this. So these are the wavefront, we have a source and it is propagating and every point on a propagating wavefront serves as the source of the spherical secondary wavefront. Such that the wavefront at the later time is the envelope of these wavelets. So let us try to understand this statement. Whatever, the Huygens principle suggests that we have a wavefront like this and each point on the wavefront serves as the source of the spherical wavefront of the secondary wavefront.

So from here what do we have? We have the wavefront like this and if I join this envelope we will find that this is the envelope, that is having a later time. So in this way again we have another bunch of the secondary wavelet and in this way, the wave is essentially propagating along a certain direction. So, if the velocity we know v and if it takes delta t time from going from there this to this. So, v multiplied by delta t should be the distance between these two wavelets where v is the velocity of the light for a certain frequency. So, that is overall the structure of the Huygens principle. However, one important question that one can ask is what the sound wave is, we can see that the sound wave is easily bent by large objects. So when we have some sounds then what happens? This is also a wave that is propagating and with large objects, it is easy to understand, with large objects it bends like trees and houses etcetera. But, in general, the light does not affect much. The bending of the light cannot be seen in a very effective way for a large object. So, we will always see that the obstacle that we need to put to check how the light is bending through this obstacle would be the order of the wavelength of the light that is an important outcome of or an important property of the light that light will go to bend, but the obstacle that we need to put will be the order of this wavelength. However, in Huygens's principle, we did not mention anything about the wavelength. So, Huygens's principle is independent of any wavelength configuration and would predict the same wavefront in the same situation. So this point needs to be addressed and there should be a modification of this and this modification is done by Fresnel. And what kind of modification? Let me describe, so modification by Fresnel, and the modification is

called the Huygens-Fresnel principle. So this modified version suggests that every unobstructed point of a wavefront at a given instant serves as a source of spherical secondary wavelets. The amplitude of the optical field at any point beyond is the superposition of all these wavelets. So, what is suggested is that every unobstructed point on a wavelet at a given instant serves as a source of spherical secondary wavelets that we already discussed but the amplitude of the optical fit at any point beyond is the superposition of all these wavelets. So that means if I try to understand that this is the wavelet, that is moving and that is unobstructed and if it is unobstructed this is the structure of the wavelet that is moving here in this way. Now what do we do? We put an obstacle here with a sharp edge. This is my obstacle: we put a window with a sharp edge, then from here it changes its structure, and whatever we get here is the contribution P which is a superposition of all the contributions. So, the maximum optical path length here is, so this when we call about the superposition of this wave, we now go to the interference some sort of interference concept of the interference pattern and the maximum path difference here that is happening if it is A and it is B, so the maximum path difference is lambda max big lambda max and that is BP minus AP. But in between, there are many other points that also contribute here in this path difference. And that is the principle that suggests that it should be a superposition of all these wavelengths. The contribution of the amplitude here, if I want to find out, should be the superposition of the contribution of all the waves. So we have a situation something like this, where we have point A and point B and this is the point P, and lambda max here has to be less than equal to AB to get a pattern and that is the condition to get a pattern here at P. So, note that when this maximum path difference is equal to AB then the point P will be on the AB line. So, that condition is, so, here we can see that the light intensity at point P depends on the relative phase difference between two points A and B. We consider these two points as two sources A and B because as per the Huygens principle, each wavelet, each point on the wavelet is a secondary source. So, for these two points A and B, if these are two sources, then the intensity at P will depend on the relative phase between the two sources A and B. So, what we try to understand with this class, so we do not have much time to discuss more about diffraction. What we try to understand here is that if we have a diffraction phenomenon, then in diffraction phenomena light will go to bend and the propagation of the light is modeled by the Huygens principle, where we say that, when the wavelet is propagating the disturbance is propagating over this wavelet all the points that are again producing the secondary wavelet and the envelope is going to propagate and this envelope we call that this is the wavefronts.
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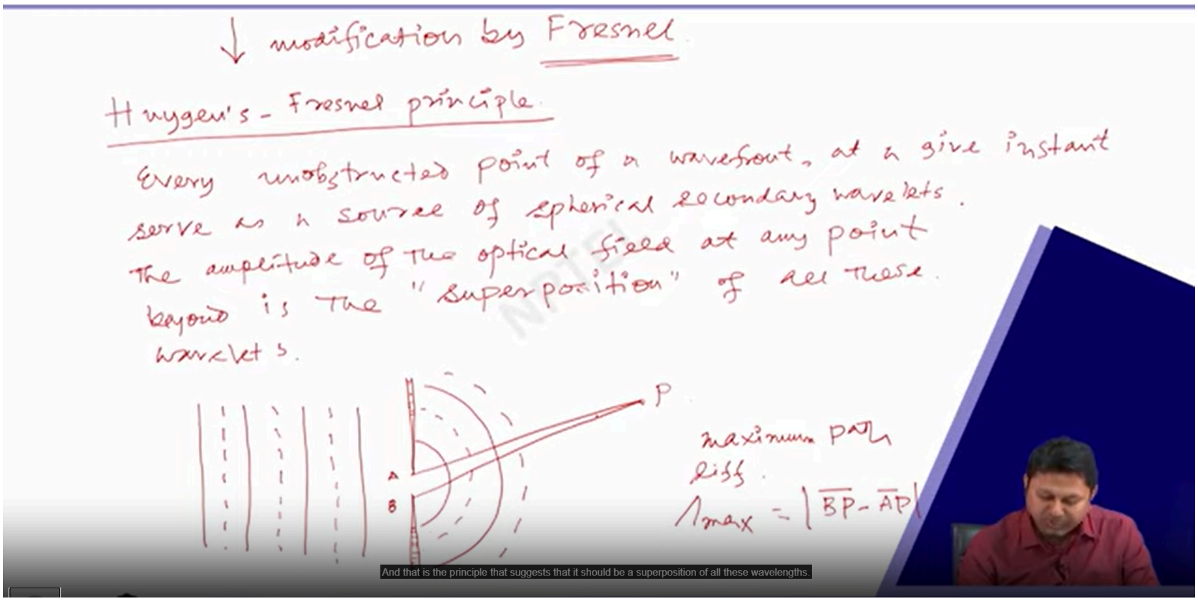

Now, if these wavefronts are propagating, it depends on the wavelength of the light and the relationship between these obstacles and the wavelength and the relation is the obstacle should be of the order of the wavelength to get a descent figure related to this diffraction. So we want to have light in the geometrical shadow region that we explained. But we should appreciate this bending of light if the obstacle is the order of the wavelength of the light that is exposed to the system. Well, here also we mentioned that the light produced in the geometrical shadow region is essentially the superposition of all the wavelets, all the waves that are coming out from this wavelet point. Two extreme points if I considered here for example A and B and we find that the maximum path difference should always be less than this AB to get a decent diffraction pattern. So with that note, I would like to conclude here. In the next class, we discuss more about the diffraction difference. We divide the diffraction pattern into diffraction phenomena into two different categories, one is called the Fresnel and another is called the form of a diffraction type. What is the Fresnel diffraction type, and what is the form of a diffraction type, we will discuss this in detail. So with that note, I conclude here, thank you very much for your attention and see you in the next class

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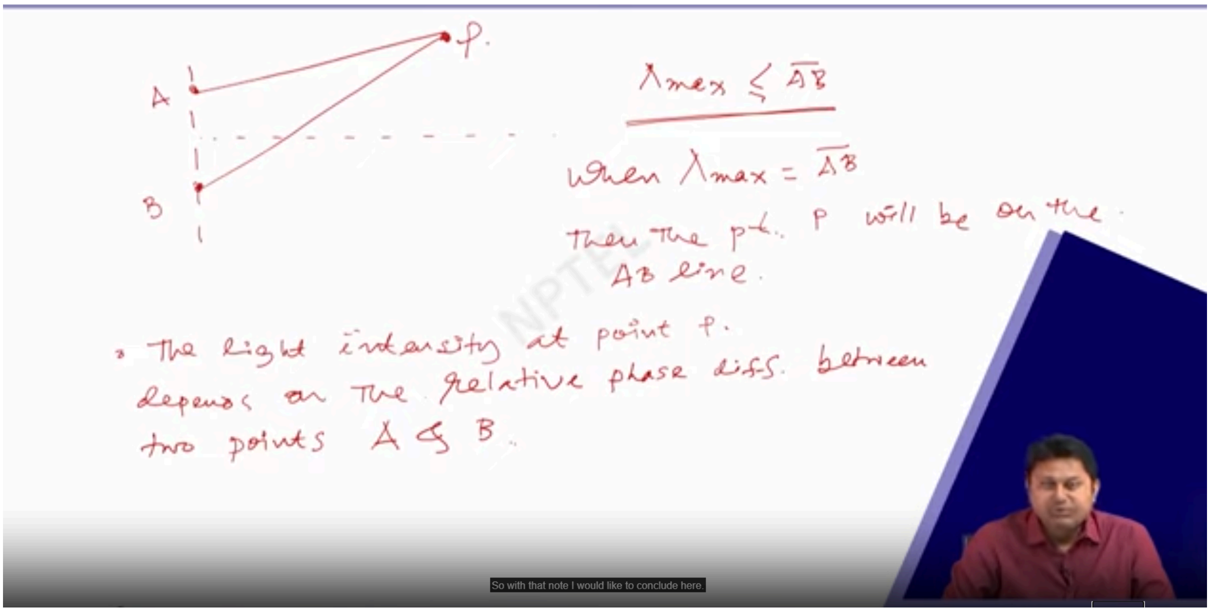
P.
A
B
λmax ≤ AB
When λmax = AB
then the pt. P will be on the AB line.
• The light intensity at point P. depends on the relative phase diff. between two points A & B.
NPTEL
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