[Music] [Applause] welcome to the lecture module on optics in the last couple of lectures we discussed the young's double slit experiment and brought out some salient features of interference the phenomena of interference today we will discuss another phenomena which is closely related to interference called the diffraction
So diffraction of light diffraction of light diffraction of light refers to
So let me first give a sort of definition of diffraction
So diffraction of light refers to the spreading of light into the geometric shadow of an obstacle or an aperture in the path of propagation of light spreading of light if the beam of light is monochromatic that is if the incident beam of light is monochromatic then one can see bright and dark fringes or rings or patterns depending on the geometry of the obstacle we will try to understand these concepts in this lecture and the following lecture
So let me first try to explain what is the spreading of light into the geometric shadow of an obstacle spreading of light into the geometric shadow of an obstacle consider a parallel beam of light incident on a screen here is a screen a parallel beam of light incident on a screen now what you see here is the bright spot of the light which is incident on this now if we bring a wedge a wedge here a triangular shaped wedge with a sharp edge here a straight edge here we try to bring it from below like this that is to intercept the beam the cut the beam then there will be a shadow the geometric shadow that we get
So let's see let us try to appreciate this if we look at the beam incident in two dimension it will become more clear if we look in two dimension
So let me show you a diagram where we see the incident beam
So the incident beam is here this is a parallel incident beam and we have introduced this wedge from below
So it is cutting or blocking part of the incident beam like this
So part of the beam is incident on the screen and part of the beam is blocked by the wedge which is introduced from below it is an obstacle wedge shaped obstacle which is introduced from here considering ray optics or the rectilinear propagation of light what we expect here is half of it is bright and half of it is dark because this area the area below this dotted line here this region is blocked by this aperture and therefore we should get a shadow here shadow of the aperture we have considered a parallel beam of incident light therefore up to this we must have the shadow and above that we must have bright region in other words if we were to see the intensity distribution we would should have seen a step function like this that is intensity is uniform across here and then here it is 0. oh let me draw here and show it what i mean by this intensity distribution here
So here is the incident light
So i am enlarging it and showing
So this is the parallel beam of light which is incident and we are introducing a wedge from below
So we have introduced a wedge
So the wedges
So this is the wedge
So light which is up to this would all come here onto the screen
So from geometric optics or from the rectilinear propagation of light
So if this is the screen on which light is incident then we would expect a shadow
So this region here is called this region is called the shadow of the obstacle shadow
So i had used this word shadow of the obstacle
So obstacle is this wedge shadow of the obstacle
So this region that is the region below here
So this is the shadow of the obstacle from the rectilinear propagation of light we should have had a shadow here and bright light on the other side in other words if i were to plot the intensity distribution
So suppose this direction is x direction x then if i plot the intensity distribution intensity distribution on the screen
So this is i of x intensity distribution i of x then i should get up to this i must have a uniform intensity if this beam is of uniform intensity in the cross section then i should have uniform intensity up to this point here and then 0 intensity
So beyond this it is 0.
So uniform intensity here and then 0 but what we see actually is that i will let me use a

different color

So what we see is there is some light which comes into the geometric distribution the geometric shadow here the light distribution shows some variation like this and then you have some light entering this shadow this is the shadow region i expect it to be a shadow region but the intent there is some light intensity in this shadow region this is because of the phenomena of diffraction in other words let us see the definition again diffraction refers to the

So spreading of light into the geometric shadow of an obstacle in the path of propagation of light i have now explained it with the help of this path of propagation of light there is an obstacle which has been introduced and light has spread into this regions right has spread that is why you have a finite intensity here intensity is not zero in the shadow there is a certain amount of intensity in the shadow and this is because of diffraction

So the phenomena of diffraction as i defined in the sentence

So diffraction refers to spreading of light into the geometric shadow of an obstacle now we come back to this diagram here

So i will show the pre drawn diagram here

So here is the

So incident beam parallel beam this is the shadow what you see is a part of light is some amount of light

So this is the geometric shadow

So this is the shadow region i have exactly plotted behind this

So this line here is the same i should have had light like a box here but what we see is the intensity distribution across the screen here here it is just like a box intensity is maximum uniform and then zero if i were to plot the intensity across this it would be uniform and 0 outside but what we see is there is some intensity in the geometric shadow of this obstacle and this is diffraction the beam undergoes diffraction at the straight edge please see this is in two d we recall the figure here

So this is the straight edge that we are referring to this is a wedge wedge shaped obstacle which has a straight edge here it need not have a straight hat but we have considered for simplicity a straight edge and therefore light enters into the geometric the beam undergoes diffraction at the straight edge at the top end of the wedge at the top end of the bridge i hope i have explained the figure here

So the intensity distribution across the beam on the screen now suppose i had introduced just one wedge from here suppose i introduced another wedge from here from the top suppose i introduce another batch then what we will get is a slit

So we will get a slit here

So if we introduce another wedge we get a slit

So that is what i am showing in the next diagram here that here is the same beam the parallel beam which is incident there was one wedge earlier now we have a second wedge from the top

So this has resulted in a slit here and the rectilinear propagation of light would have seen that light is incident only corresponding to this gap but in practice if you see there will be some amount of light into the geometric shadow here as well as the geometric shadow here shadow of the obstacle here and if you measure the intensity distribution you see some intensity variation here in this region and a intensity a little bit of intensity into the geometric shadow on both the sides recall the earlier figure

So let me show the earlier figure here there was light entering the geometric shadow on one side

So now i have shown the edge wedge from both the sides to make a slit now we see that light enters the geometric shadow here this is a case where i have taken this width of the slit

So this is the slit w or a we will use a later on w the wavelength of light lambda is much less than w and w is less than d d is the beam diameter and the width of the slit is smaller that is why it is blocking part of the beam and this leads to onset of diffraction effects we have started seeing diffraction effects if this were not there we should have got a box type of response that is intensity uniform across this and then 0 outside but we see that there is some amount of intensity entering into the geometric shadow what happens if we further reduce the slit width w if we reduce the slit width further

So that is what we will see and what we will get is the single slit diffraction

So here is what i am showing as the single slit diffraction first look at the diagram
So the parallel same parallel beam of light same two wedges but now the separation
between the wedges is very small i have used the symbol a to be consistent with the book
text book and therefore the wedges are separated by a small separation a the separation a
is now of the order of wavelength of light and then instead of just having a a box like
pattern here what we have is a intensity maxima and minima on the screen we get intensity
we observe intensity maxima and minima on the screen the first minima here as we will see
later is given by lambda by a that is if we plot the angular distribution this is i of
theta this is not x this is i of theta theta is the angle here
So with respect to this aperture if i plot a ray like this then this angle is theta this
is the theta
So i of theta varies like this we will see this shortly but what is important is as you
reduce the slit width you not only see light going into the geometric shadow but also you
start seeing intensity maximas and minimas just like in the case of interference except
that here we see that the maximas do not come back again up to this the maximas are very
small maximas very low intensity maximas but we do see intensity minimas intensity zeros
and small maximas in the geometric shadow and this is called diffraction and because we
have used a slit here a narrow slit with the dimension of the order of wavelength we call
this pattern as single slit diffraction
So what we see
So the front view
So this is the front view now the slit is here and the light is incident normally on to
this and this the screen behind the slit the screen which is behind the slit screen which
So you see intensity maximas here
So the central maxima central bright fringe here has very high intensity as compared to
the sides
So on the screen behind you will see straight line fringes like this on the screen and
this is single this is called single slit diffraction
So i just introduced what is diffraction and what is meant by single slit diffraction
So lets see this in more detail
So let us recall first the young's double slit experiment because here also we have a
slit and in young's experiment we had two slits
So let us recall the young's double slit experiment and see what is the difference here
in comparison to the young's double slit experiment
So recall young's double slit experiment
So i have shown the young's double slit experiment which we had studied in great detail
So first look at this part
So here is the two sources s one and s two point sources s one and s two and then this is
the screen placed at a distance d the sources are separated by a distance small d and we
had r 1 is the path length here r 2 is the path length therefore there was a path
difference at an arbitrary point p there is a path difference between the two sources
here the light reaching from the two sources has a path reference and therefore there is
a corresponding phase difference which is k times r 2 minus r 1 recall that this k is 2
pi by lambda the phase constant k into r 2 minus r 1 gives you the phase difference delta
and then we have seen that the intensity distribution here is given by i of delta we have
derived this expression i of delta is equal to four i zero cos square delta by two and
then it varies like this if you plot the intensity distribution it varies sinusoidally
like this every fringe is of the same intensity as per this expression according to this
expression we have bright dark rings
So i have shown the corresponding intensity pattern here
So the dark ring corresponding to this and the bright ring corresponds to this region
bright dark bright
So we have bright dark bright dark rings or fringes in the case of the young's double
slit experiment and i also showed you a diagram a computer generated diagram here
So which showed the bright dark fringes in a young's double slit experiment i had taken
typical parameters of a typical of experiment experimental arrangement and then i
calculated these fringe patterns which are shown here there is something which we did not
discuss earlier is if you see carefully the central part the contrast is high bright dark
bright dark but as you go further and further the contrast drops down the brightness
becomes lower and lower as you can see this is very bright but if you go to a fringe
which is here the brightness is continuously reducing the darkness is the same is the

minima is the same that is minimas are intensity zeros but the brightness is decreasing as you go along x that is on the screen as you go away from the center point then the brightness of the fringes reduce we did not discuss about this variation in the intensity now we will see that this is because of diffraction what we see the intensity variation in the bright fringes in the case of young's double slit experiment as you go away from the central fringe is because of diffraction we will see this carefully ok

So now let me look at this more carefully and why does this happen why do we get in the case of suppose this was the young's double slit experiment in this the most important point to note is we had treated these slits s one and s 2 as point sources but we know that in practice no slit or no aperture can be a point there is a finite area associated with the aperture or with the slit and this we have not considered in treating the young's double slit experiment in analyzing the young's double slit experiment as we did earlier we did not consider the finite width of these sources

So let us now look at the each slit here one slit at a time and see what is the effect of the finite width of the source

So let's see this in the next slide

So here

So what i have shown

So let us look at this diagram here lets look at this diagram the finite width a of the slit

So this is one of the slits s one and s two there are two slits in the young's double slit experiment

So if you look at one of the slits then there is a finite width of the source here which means the secondary source on this slit here the secondary source lets the point sources on the secondary wave secondary wavelets which emanate from this there is a finite path difference at p at the point p this there is a path different this is smaller compared to this distance

So if i call this as r 1 and from this extreme end of the slit

So the upper end of the slit s to the point p and the lower end of the slit to the point p because i am now considering a finite width a for the slit then there is a finite difference in the path because of the finite width of a and therefore if there is a path reference then there is a phase difference if there is a phase difference then the intensity at the point p will get affected by the phase difference

So if i enlarge this

So this is when the screen is kept at a certain distance consider now the screen kept at a large distance

So let us look at this case here the second case the same diagram but i have now shown it enlarged view

So enlarged view when l is large when l this separation is large when this separation is large

So this screen is sitting at a large distance then these rays all the rays which are drawn here all the lines which are drawn here appear almost parallel they appear almost parallel because this l is now very large however what we see is this is the aperture size a this is the incident beam and inside the aperture we have shown different point sources here and therefore if we show these point sources at equal equally spaced point sources if we considered equally spaced actually there are infinite number of point sources but if we consider a finite number of equally spaced point sources and then we can in in the analysis actually this is the way it we start and then we allow n to go to infinity that means initially n number of point sources and then n is allowed to go to infinity now coming back to the discussion if the screen is at a large distance we can treat all these rays emanating from the point sources as parallel rays and then what we see is that there is a if we look at the first ray here and the last ray here then we see that there is an additional path difference here

So there is a path difference this is the path difference between this and this because this is a plane wave front its a parallel beam which is going here because we have considered parallel rays if we consider parallel rays at any particular angle theta that means it has a plane wave front then there is a path difference between this ray here this path and this path and that is this path difference if theta is this angle theta is the angle with the horizontal then this path difference can be shown if this is a then the path difference delta that is the path reference delta is equal to

So you can show that delta is equal to a sine theta

So let me write here itself

So delta here is equal to a sine theta

So we can show that the path difference now i have picked up only these the last one and the first one but there is an equal path difference among these

So between any two adjacent rays there is a finite path difference when there is a finite path difference there will be interference at the other end at the point p there will be interference and interference leads to a fringe system that is depending on the phase depending on the phase we will have intensity maxima or intensity minima

So due to the finite path finite width of the slit please see this due to the finite width of the slit there is a path difference between waves emanating from any two point sources in the aperture of the slit aperture of the slit the corresponding phase shift depends on theta because as i have shown you the phase shift here

So this is path difference

So to get the phase shift you simply multiplied by k k into delta gives you the phase shift phase difference

So there is a phase shift depends on theta and therefore the intensity at point p depends on theta we will discuss this further and get an expression for the intense in the intensity distribution of a single slit diffraction but before we go that we want to discuss two regimes of diffraction there are two realms two types or two kinds of diffraction basically they are the same there are no two types but actually there are two realms of diffraction depending on the distance from the source to the aperture and aperture to the screen and we will discuss this further

So there are two types of diffraction two regimes of two realms of diffraction basically diffraction is the same but we have two approximations you could say

So there are two types of diffractions they are called frown offered diffraction and fresnel diffraction if the source of light and the observation screen are at a large distance

So let me

So do not lets lets look at this first if the source of light and the observation screen are at large distances from the diffraction aperture

So that the wave fronts arriving at the aperture and the screen may be considered plane then it corresponds to frown over diffraction now let us see the figure

So what it means is if the source here is the aperture here is a slit the aperture is here the source when it is sufficiently far if when it is quite far then the wave fronts of course even if it is a point source here it starts with curved wave fronts but when the distance becomes very large as you can see the wave fronts are almost plane here plane wave front means the rays which are reaching the aperture can be treated as parallel rays or nearly plane wave fronts

So we could consider this as parallel rays which are reaching the aperture similarly if the screen is very far we are interested in finding out the intensity at a particular point p let us say at a particular point p then from the slit here or from the aperture here the rays are coming out in all directions because they act like point sources however the rays which are reaching when the screen is sufficiently far the set of rays which are reaching a particular point p can be treated as almost parallel and therefore the wave fronts can be treated as plane now we repeat what we have read if the source of light and the observation screen are at large distances from the diffraction aperture from the diffraction aperture large distance large distance

So that the wave front arriving at the aperture and the screen may be considered plane then it corresponds to frown over diffraction

So almost parallel rays now on the other hand if when the wave front when the separation between the two sources

So let us read again when the separation between the source and the diffraction aperture and or the diffraction or at the slit and the observation slit

So when the separation between the source and the diffraction aperture or the observation screen

So or the observation screen this has been repeated here or the observation screen are not large enough the curvature of the wave fronts must be taken into account and the plane wave approximation cannot be used in fresnel diffraction

So let us look at this now the source is relatively close and the source is emitting light in all directions if it is a point source we can represent it by spherical wavefronts and when the wave front is reaching here they are still spherical we cannot

treat it as a plane wave front similarly if you see at the point p the the the rays which reach point p i have shown the extreme rays which reach point p

So you can see that it appears as if they are converging to the point or we have to take into account the curvature of the wave fronts and then we have the regime of fresnel diffraction when the separation between the source and the diffraction aperture and or the observation screen are not large enough the curvature of the wave fronts must be taken into account and the plane wave approximation cannot be used in fresnel diffraction

So this is the regime of fresnel diffraction

So lets we are focusing on frown over diffraction and therefore let us see a practical arrangement because i said that when the distances are sufficiently large but in a practical arrangement it is not possible to have large distances suppose you want to do the experiment in lab then it is not possible to have large separations between the screen and the source and the source and the aperture

So a practical arrangement a practical arrangement to observe front offer diffraction is shown here a practical arrangement to observe front of a different let us see it carefully the source if the source if we take a point source for example if we take a point source and place it at the focal plane of a lens then the rays coming from the source will be rendered parallel in effect the rays which reach the the slit here or the aperture here are parallel rays

So we have met that condition for front of our diffraction as far as the distance from the source to the aperture is concerned by simply keeping a lens the distances need not be very large

So if the lens has a focal length let us say 5 centimeter this may be 5 centimeter and another 5 centimeter you can keep the slit here or the aperture here now on the other side again you have diverging wave fronts which are coming from the small aperture here the rays are emanating in all directions now what i have shown here we see the diagram is a set of rays out of all the rays a set of rays which are coming at an angle theta a set of parallel rays which are coming at an angle theta why why am i picking that because in the front of our approximation we need parallel rays reaching the point p

So we are interested in finding out ray plane wave fronts which are reaching the point p

So if i consider a set of parallel rays out of all the rays and place a lens here and place the screen on the focal plane the distance from here to here is the focal length then we call this as the focal plane the screen is placed at the focal plane on the focal plane of the lens then all the rays will be focused to a particular point p

So we have shown that it is focused at a particular point p now why do we go for this what is this

So let me explain this a little bit more carefully and then we come back to the same diagram here

So if i consider for example a lens and parallel rays incident on the lens then on the focal plane we know that they all focus at the focal point

So this if this distance is f then all the rays focus to this point here which is o on the axis suppose i take the same lens again here and incident a set of parallel rays travelling at an oblique angle theta a set of parallel rays but now travelling at an angle theta

So where will they focus on the focal plane let us say this is the focal plane then they will focus but they will focus at the point how do we determine the ray which passes through the pole here or from the midpoint here of the lens will travel undeviated to a point p and all other parallel rays focus to that point

So this is the point p where the rays will focus and if i have a source here if i consider a set of plane waves or parallel beams which are travelling like this

So set of parallel rays travelling like this and if i keep a screen here

So this is the screen then they will all focus at this point because the ray which passes through the midpoint here or the pole does not deviate and therefore others will all focus to that point

So provided this is the focal plane

So what is the meaning of it which means raise each ray lets say this ray was making an angle theta here then all the rays parallel rays which make a particular angle theta are focused at a point p similarly here we have another set of rays making an angle theta

So t if this is theta one this may be theta two in this case it is minus they will all be focused at a new point p dash here

So rays set of parallel rays which are incident on the lens will focus at different

points on the screen placed at the focal plane a screen placed on the focal plane and parallel set of parallel rays making different angles theta will be focused at different points on the plane why am i spending some time on this is to because what we will determine is the intensity pattern due to a single slit the angular dependence of the intensity pattern due to a single slit and if i say that the intensity pattern is theta dependent and every theta uniquely reaches a unique point p on the screen on the screen then it is sufficient for me to determine i of theta here i of theta then i get the corresponding intensity pattern on the screen

So that is why i have shown this diagram

So let me put the pre drawn diagram here

So i will come back again out of all the rays or plane wave fronts travelling in all directions after diffraction at the aperture the red colored rays represent a set of parallel rays making an angle theta with the axis they will focus at a point p

So now let us see

So the intensity distribution therefore the intensity distribution on the focal plane here i just showed you rays coming at three different angles

So i have drawn a diagram here a clearer diagram simultaneously i have shown all the rays

So parallel rays here in black color reaching the point o this is our familiar focusing the parallel rays focused on to the point o along the axis if you put parallel rays tilted it reaches a point here and if you put parallel rays tilted in a different direction it reaches a separate point therefore here it is every point p on the screen corresponds to a different angle theta and the intensity distribution if this is the x direction the intensity distribution along the x therefore will be identical to the intensity distribution if i of theta where theta represents the angle at which the rays are coming out from the aperture

So the lens does not introduce any additional path difference or phase difference among the interfering parallel set of rays this is an important sentence

So i just want to explain this sentence a little bit more

So because there is a diffraction pattern which is coming here

So we showed the practical arrangement here for observing frown over diffraction there is a diffraction pattern which is coming beyond the aperture here now we have introduced a lens and how do we know that the intensity pattern that you get here is not affected by the lens it is not affected by the lens provided the lens does not introduce any additional phase difference

So that is the statement which is made here the lens does not introduce any additional path difference or phase difference among the interfering parallel set of rays i will explain this a little bit more now consider a set of parallel rays which are incident on a lens

So there is a lens a set of parallel rays which means parallel rays means they are represented by plane wave fronts what is a wave front wave front is a surface of constant phase

So these are plane wave fronts now after refraction through the lens they will all be focused at the point focus

So this is the point f

So they will all focus to the point f now when after passing through this this converging set of rays converging set of rays is represented by a curved wavefront the wavefronts are curved now and they reach this point which is the focus but the wavefront here represents surface of constant phase the wavefront here represents surface of constant phase there is and all of them finally reach the point f or the point p in our case but all of them reach in the same phase if there was or additionally originally if there was a constant phase difference then that constant phase difference will be maintained here if all the rays are in phase then all the rays will reach in phase here there is the lens does not add any difference to a set of parallel rays that is the meaning of this and therefore the role of the lens why do we then need this lens the role of the lens is to bring the intensity pattern onto a common screen onto the screen which is quite close

So the role of this lens in the case of front of a diffraction pattern is to bring the intensity pattern onto a screen at a practical distance in the laboratory where we can perform the experiment

So that is the role of this second lens

So if the the intensity distribution on this plane is proportional to i of theta but the diffraction pattern is given by i of theta

So let us come back to the single slit diffraction intensity distribution
So here is the diagram i have left the other part of the diagram because thats only to make a set of parallel rays which are incident
So please see the distribution here the intensity pattern
So which is incident i have taken a particular set of rays travelling at a angle theta please see there are rays travelling at different angles but i have taken a particular set of parallel rays reaching a point p f
So this is the arrangement for the single sheet diffraction the intensity distribution the intensity distribution is given by i of theta is equal to i zero into sine square beta by beta square where beta is given by pi by lambda into a sine theta a is the slit width theta is this angle here theta
So this is the intensity distribution the derivation is not difficult but it is beyond the scope of the discussion that we have and therefore we are interested in the result and therefore i am not doing the derivation of this expression here but i of theta you assume that i of theta is given by this expression where i zero is the intensity for theta is equal to zero now i want to see what kind of intensity distribution that i would get with this kind of an expression
So i zero is the intensity at theta equal to zero
So lets just discuss this here
So i is equal to i of theta is equal to is equal to i of beta because beta is related to theta is equal to i zero into sine square beta divided by beta square where beta is equal to pi by lambda into a sine theta now first i said that i zero is the intensity at theta is equal to zero now at theta is equal to zero beta is zero but beta is in the denominator therefore this is undefined
So how do we say i zero because sine beta by beta sin x or sine beta by beta as beta tends to 0 then this is equal to 1 i am sure you know this that you simply differentiate this then we get cos beta by 1 and cos beta if you put beta is equal to beta is equal to 0 then cos beta is 1 and therefore therefore at theta is equal to 0 i of theta is equal to 0 is equal to i zero
So i zero is the intensity at theta is equal to zero recall what is theta equal to zero
So theta equal to zero means on the axis that is at the point o i zero is the intensity at theta is equal to zero now let us look at the intensity distribution of this
So there are two functions one is i zero sine square beta
So i can write this as a product of two functions one by beta square we know how sine square this first function varies
So if you plot with respect to beta lets say this is 0 beta is equal to 0 and beta is equal to pi beta is equal to 2 pi beta is equal to 3 pi then and similarly on the other side minus pi minus 2 pi then we know that sine beta is 0 for beta is equal to m pi and therefore the pattern would look like this
So is the sin square x curve
So we have zero and in between maxima zero maxima
So this is i zero sin square variation
So we have zero
So on is completely symmetric
So this is the i zero sign
So this level here is i zero that's the first function how would the second function look like
So let me draw that again that is a cos square function which i was plotting
So this is beta versus
So this is 0 minus pi minus two pi pi two pi three pi
So at
So it is zero here this is the level i zero what i am plotting is the first function i zero sin square beta
So first function is zero here maxima at pi by two zero at pi maxima at three pi by two zero at two pi
So this is the sine square function
So maxima here zero maxima here 0 and
So on the second function which is the second function is
So there is is a product of two functions and i have said this is the first function which i plotted
So the second function is 1 by beta square that is like 1 by x square x square is

parabolically increasing and 1 by x square is dropping down like this
So if this is beta 1 by x square
So here is the zero level
So this is x is beta is equal to zero
So it will go to infinity here and then drop like one by x square
So it drops down to very small values it goes to infinity here and if you take a product of this at therefore now the product of the two functions is the
So this is now i of theta or i of beta is given by i zero i zero is here
So at theta is equal to zero because this goes to infinity this goes to zero we have seen that it becomes i zero at theta equal to zero at any other point its a product of the value here and here product of the value here that is 1 by beta square into sin square beta and
So on
So if you plot this graph then we see that wherever this is 0 the product has to be 0 which means the first 0 will be here
So the function will vary like this and then
So this is continuously dropping 1 by beta square therefore the amplitude drops down it becomes maximum again becomes zero
So the function becomes maximum and becomes zero the function becomes maximum and becomes zero why the maximas are decreasing because this value is continuously decreasing unlike the case of an interference fringe where you have sine square fringes that is cos square delta by 2 fringes you have similar fringes in terms of minima but the amplitude is dropping down there is an amplitude decaying because of this and therefore the in the diffraction pattern would look like this
So the diffraction pattern will have a maxima minima
So what is the value of this
So this is when beta is equal to pi the first minima is when beta is equal to pi
So this is the intensity distribution due to a single slit intensity distribution due to a single slit or i of theta or i of beta now we are interested in finding the positions of minima minima and maxima
So the central maxima occurs at beta is equal to zero that is theta is equal to zero which means on the axis of the slit
So lets see the positions of maxima and minima
So the position i of theta
So here i of theta is given by i zero sin square beta by beta square beta is this positions of minima are given by when the numerator is zero sin beta is equal to 0 except when beta is equal to 0 we have already seen this discussion at beta is equal to 0 it is equal to i0 otherwise the positions are of minima are given by sin beta is equal to 0 or that implies beta is equal to m pi except m not equal to 0 that is for a sine theta beta is equal to m pi beta is given by this which implies a sine theta is equal to m lambda are the positions of minima where m is equal to plus minus 1 plus minus 2 and
So on thus the first intensity minima will occur at an angle theta 1 from this angle where if you put m equal to 1 theta 1 is equal to sine inverse lambda by a and at at minus theta 1 when minus sin inverse lambda by a on either side of the central maxima at theta is equal to 0. now let us just see a little bit more by putting some numbers theta 1 the first minima appears sine theta 1 that is theta min for the first minima is equal to lambda by a now lets see what kind of numbers are we talking of if we use visible light lambda is approximately equal to lets say we are taking the blue green region then lambda is equal to 5 500 nanometers which is equal to 5 into 10 to the power of minus 5 centimeters that is 0.5 micrometers or phi into 10 to the power of minus y let us just see as an example this just example and let us say a the width of the slit typically if a is equal to 1 millimeter for example a is equal to one millimeter or second will then we have lambda by a lambda by a is equal to five into ten power minus five one millimeter is ten power minus 1 millimeter then minus 1
So this is equal to 5 into 10 power minus 4 radians minus 4 radians therefore theta this is very small number this number is very small and therefore theta sin theta this is a very small sin theta is a very small number therefore we can easily use this sin theta nearly equal to theta where theta is in radians this approximation is a very good approximation because sine theta is extremely small if you use a is equal to point one millimeter point one millimeter even then you will see lambda by a is equal to five into ten power minus five divided by point one millimeter

So ten power minus two which is equal to five into ten power minus three which is still very small sin theta this is sin theta and therefore we can easily use the approximation sine theta is equal to theta now what is theta theta is the angle corresponding to the maxima corresponding to the minima in this case please look at the interference diagram theta here is the angles where the minimas will appear and therefore the first thing to note is whatever intensity distribution that we will get
So i have just drawn the intensity distribution for you here
So here the angles where they appear are very very small in other words if you see this on a screen if you see the diffraction pattern on a screen then you will see that the the maximas and minimas are closely packed and therefore in a practical experiment you will have to keep the screen sufficiently far if you want to see the maximas and minima
So lets see the experiment lets see the simple single slit diffraction experiment now what i am going to show is the single slit diffraction experiment
So in a simple laboratory arrangement what we have here is a helium neon laser this tube here is the helium neon laser tube
So as you can see here that the there is a diffraction pattern which is coming on this paper here paper screen but since the diffraction pattern comes at small angles we have to take it backwards
So i take the paper back then it is becoming more and more clear that there is a central maxima and there are minimas on the other side
So now i leave it on the screen reducing the slit width
So you start the retraction pattern coming slowly and as i reduce again you can see the intensity maximas and minimas and the two adjacent minimas about the central maxima are spreading outward
So the diffraction pattern is spreading and as i close it the intensity reduces the central maxima becomes very wide again if i open the slit they start coming down
So through this demonstration what we can clearly see is what the diffraction pattern is and how the diffraction pattern spreads as we change the dimensions of the slit
So what we have seen is as we reduce the width of the slit then the diffraction pattern spreads the two minima on either side moves away in angular spread spreading we are talking in terms of angular spread and if we open the slit then the diffraction pattern shrinks and if we completely open then the beam will pass through the slit you