

welcome to the lecture module on optics we are discussing wave optics and in particular we are now discussing the phenomena of diffraction in the last lecture i have illustrated through various diagrams the phenomena of diffraction and we have seen diffraction by a single slit that is single slit diffraction we have studied single slit diffraction today we will discuss the results of single slit diffraction and also go over to circular diffraction by a circular aperture

So diffraction patterns due to a single slit and a circular aperture

So first let us discuss the results let us recall the results of single slit diffraction which we had studied in the last class we have discussed in the last class

So a parallel beam of light which is incident on a slit here

So we have shown in two d

So a slit here the light gets diffracted here and there is a corresponding intensity distribution on a screen placed at a distance l when the distance l is sufficiently large then we call it as Fraunhofer diffraction the intensity pattern we have seen in the last class the intensity pattern I of θ is given by $I = I_0 \text{sinc}^2 \beta$ and it varies like this

So we have discussed this in the last class with minima at λ/a , $2\lambda/a$ and on the other side of the central maxima $-\lambda/a$, $-2\lambda/a$ and

So on

So this axis is θ or $\sin \theta$ which is very closely equal to θ

So the intensity minima are given by $\beta = m\pi$ because intensity minima are given by zeros of the $\text{sinc}^2 \beta$ function here except when m is equal to zero except when m is equal to zero we have seen in the last class that when m is equal to zero which corresponds to this point we have $\sin x/x$ or $\sin \beta/\beta$ is equal to 1 and therefore except $m = 0$ the minima are given by zeros of the numerator namely zeros of the $\text{sinc}^2 \beta$ function

So that is when $\beta = m\pi$ m is equal to plus minus one plus minus two and

So on which means $\sin \theta$ minimum are given by $m\lambda/a$ where a is the slit width m is equal to plus minus 1 plus minus 2 and

So on that is m on this side is minus m on the other side is plus now as we know that a is typically the aperture size is typically of the order of point one millimeter here and λ/a we have seen in the last class with some typical numbers that λ/a is much less than one which implies $\sin \theta$ can be approximated to θ or the minimum θ minimum is given by $m\lambda/a$ that is why we have written here $m = 1$, $m = -1$, $m = -2$, $m = 1$, $m = 2$.

So the minima of the intensity minima of the diffraction pattern are given by θ_{\min} is equal to $m\lambda/a$ m is equal to plus minus 1 plus minus 2 and

So on what about the maxima this maxima of course we have already seen is I_0 but what about these maxima and where do they occur in the case of interference we know in the case of interference fringes we know that the maxima occurs exactly in between the minima whereas in this case the maxima does not occur exactly in between the two minima and therefore how to find out the intensity positions of intensity maximum

So let's see this

So for that we have to differentiate we have to differentiate the function

So here it is

So we go here

So let us look at this to determine the intensity maxima we have $dI/d\beta$ should be equal to 0 we put this equal to 0 which means $dI/d\beta$ of this is equal to zero you simplify this

So that is one by β^2 into $2 \sin \beta \cos \beta$ minus 2β into $\text{sinc}^2 \beta$ equal to zero

So two is common one by β^2 is common one $\sin \beta$ is common

So what will be left is $\tan \beta = \beta$ the intensity maxima correspond to this equation $\tan \beta = \beta$ this is a transcendental equation it cannot be solved analytically it can be solved either numerically or it can be solved by graphical solutions

So what i have shown here is the graphical solution look at this

So what is plotted along this axis is β there are two functions which have been plotted the $\tan \beta$ and β

So the blue ones are $\tan \beta$ this is standard variation as you know the $\tan \theta$ is 0 here

and $\tan \theta$ goes to infinity at $\pi/2$ and again starts from minus infinity goes to 0 and goes to infinity

So this is the $\tan \theta$ function $\tan \beta$ versus this axis is β and this is y is equal to x that is y is β and x is also β y is equal to x

So left side is β y is equal to β and the left side here is $\tan \beta$ the blue colored function and right side here is β

So the intersection of these two which means when they have both the same value that corresponds to the point of intersection for example here there is a point of intersection there is a point of intersection here there is a point of intersection here So these give us the solutions corresponding to the maxima

So the first maxima the 0 is of course the maxima we know that we are looking at the occurrence the maxima the first maxima on each side of the central maxima

So this maxima occurs at 1.43π and the second maxima occurs at 2.46π

So what are we looking at we are looking at this diagram here this diffraction to this diagram here

So what is the position of these maximum this maxima and this maximum this we know occurs at zero θ is equal to zero $\sin \theta$ equal to zero or θ is equal to zero the central maxima we are looking for the position of the maxima secondary maxima which are here on the sides

So these occur at 1.43π when θ is equal to 1.43π and one more maxima which would come later would occur at θ is equal to two point four six π

So that is the positions of maxima

So we can see here the solutions are given by β is equal to 0 β_1 is equal to 1.43π β_2 is equal to 2.46π and

So on why this is important therefore the intensity of the first maxima is equal to substitute I_1 is the intensity of the first maxima intensity of the first maxima I_1 is this value this is I_0 this value here corresponds to I_1 intensity of the first maxima we want to see how much this is relative to this maxima I_0

So intensity of the first maxima is given by I_1 is equal to I_0 into \sin^2 one point four three π because this is the solution β value where the maxima occurs divided by β^2

So this is $\sin^2 \beta$ divided by β^2 which comes out to be point zero four nine six times I_0 that is less than five percent of I_0

So this value here that is if I show here this value here is less than five percent of the maxima central maxima which means we have a bright central maxima and the maxima on either side of the central maxima are relatively weak they are brighter but they are relatively weak compared to the central maxima similarly if you put the second maxima then we will get I_0 into \sin^2 of 2.46π the second solution and divided by two point four six π whole square gives us zero point zero one six eight I_0 that is less than two percent one point six eight percent is the intensity

So the maximas are the secondary maxima on the both on both the sides are much smaller in intensity compared to the central maxima unlike the case of interference fringes now lets go further

So this is about the maxima and therefore we also recall now the single slit diffraction experiment

So let us recall the single slit diffraction experiment

So lets look at the experiment this is the experiment which we saw in the last class

So there is a laser beam which is incident on a slit here is the slit and it gets diffracted onto a screen which is at a large distance typical numbers I have given the diameter of the laser beam is about one to two millimeter but I have shown it as a thick beam because the diameter of the aperture here the slit the slit width is of the order of point one or point two millimeter therefore compared to the slit width the laser beam is relatively thick that's why I have shown a thick laser beam which is incident here of the order with dimension of the order of two millimeter and getting diffracted at this slit which is an adjustable slit we have seen in the last class that by varying the slit width we can change the diffraction pattern seen on the screen

So the diffraction pattern seen on the screen is given by this

So diffraction pattern on the screen now we see that these minimas correspond to λ by a in angle in θ the angle θ is also given by

So if this for example this corresponds to first minima then this is θ_1 if this is θ_1 then θ_1 is given by if

So this is $2l$ this is the linear width here $2l$ then the $\sin \theta$
So $2l \sin \theta$ is here this is l is the distance to the screen which is much larger it
is one meter about hundred centimeters and therefore $2l$ can be written as l into 2
 θ one twice θ one that is this is θ one which is λ by a minus minus
 λ by a on the other side and therefore the net total angular separation here is 2
 λ by a and therefore l into 2λ by a l into 2λ by a will give us this $2l$
the linear separation to l

So that is how we have written $2l$ by l is equal to 2λ by a or λ is equal to l
into a by capital m now this i have shown because by measuring to determine the
wavelength of light to determine the wavelength of light one can measure the separation
 $2l$ in an experiment we can measure the separation $2l$ using a graph paper for the
screen for example you paste a graph paper on as the screen then you can find out what is
the separation here and measure a the slit width using a travelling microscope using a
microscope we can determine the slit width a and l can be measured because it is a long
length l can be measured easily using a scale to determine the wavelength of the laser
please see that the wavelength is much less than 1 micrometer less than micrometer that
can be determined by making practical measurements of this $2l$ the width of the slit
under a microscope and then l here using escape and this is a standard experiment now in
most undergraduate courses

So you to determine the wavelength of light using single slit diffraction experiment ok
So let us go further lets now come to the double slit experiment lets relook at the
double slit experiment this is the double slit experiment where we have a parallel beam
of light parallel beam i have taken

So that we have one wave front reaching the two sources here s_1 and s_2 the two
holes or two slits s_1 and s_2

So that one wave front reaches it need not be plane wave it can be a spherical wave also
but one wave front has to reach the point here because the point here s_1 and s_2 are
considered in phase and at any arbitrary point p the intensity is given by i is equal to
four times $i_0 \cos^2 \frac{\Delta}{2}$ where Δ is equal to k times r_2 minus r_1 is
the phase difference r_2 minus r_1 r_2 minus r_1 is the actual optical path difference
and k multiplied by the phase constant gives us the phase difference Δ k is equal to
 2π by λ we can see here that if the sources are separated by a distance d
separation d then this angle here is θ then the path difference this is the extra
path difference we can see here this is the extra path up to this this is r_1 and
this is also r_1 but this extra thing makes it r_2 larger than r_1 this extra path
difference r_2 minus r_1 is can be written as $d \sin \theta$ and $\sin \theta$ this
is θ therefore this angle is also θ and therefore this extra distance is $d \sin \theta$
 Δ is equal to 2π by λ into $d \sin \theta$ for large values
of d now why i have written this it will be clear that therefore Δ by two is equal to
 π by λ into $d \sin \theta$ Δ by two is equal to π by λ $d \sin \theta$ now
taking into account when we did this calculations we did not consider the finite width of
the apertures we considered these as two point sources which are in phase s_1 and s_2
where 2 point sources which are coherent that's how we started to get this expression now
we know that whenever the slits here always have a finite width every practical slit will
have a finite width a and we know that whenever there is a finite width of the slit then
there will be diffraction effects which come into play

So light coming through this aperture will diffract light coming through this aperture
will also diffract and therefore the interference pattern the intensity distribution on
the screen will be affected by diffraction at the two sources two holes here or two slits
 s_1 and s_2 taking into account the finite size of the slits s_1 and s_2 the
intensity distribution on the screen is given by an expression of this type i of θ is
equal to $i_0 \sin^2 \beta$ by β^2 square into $\cos^2 \gamma$ the derivation of
this expression is beyond the scope of the discussions that we have here but the results
are important for us and therefore we will discuss the results here

So i of θ is equal to i_0 into $\sin^2 \beta$ by β^2 square into $\cos^2 \gamma$
note that this first term here is nothing but the diffraction term which we have
just seen that this is the intensity distribution in the diffraction pattern due to an
aperture of size a due to a slit of size a this $\cos^2 \gamma$ here is π by
 λ into $d \sin \theta$ which is the same as this Δ by two π by λ into $d \sin \theta$
 θ

So the $\cos^2 \Delta$ by two here is nothing but the $\cos^2 \gamma$

So now we have the intensity distribution which is a function is a product of two functions $I_0 \sin^2 \beta$ by β^2 and $\cos^2 \gamma$ how would this look like we can look at this how would this product look like

So we know the first one

So I want to see what will be the net effect

So I is equal to $I_0 \sin^2 \beta$ by β^2 into $\cos^2 \gamma$ $\cos^2 \gamma$

So γ is equal to $\frac{\pi}{\lambda} d \sin \theta$ $d \sin \theta$ $\Delta \beta$ is equal to $\frac{\pi}{\lambda} a \sin \theta$ $a \sin \theta$ remember that a is much smaller than d d is the separation between the two slits and a is the width of the slits typical number just for our consumption that typical number of a is point one to point two millimeter here and typical number for d is of the order of one millimeter

So you can clearly see that a is much smaller compared to d and therefore if we plot this graph the first part here

So let me plot the first graph

So we have already plotted this graph diffraction

So let me use a different color here

So intensity maximas and minima

So this occurs at $\frac{\lambda}{a}$ and it's a symmetric function

So symmetrically on the other side we have minus $\frac{\lambda}{a}$ the first function and this is zero the second function

So let us plot the second function here how would this look like this is $\cos^2 \gamma$ $\cos^2 \gamma$ varies between zero and one

So this is the level and it varies between \cos^2

So this is zero and one it is symmetric my graph may not be symmetric but it is symmetric variation on both the sides this is 0 and the minim maximas

So we know that when the maximas occur when γ is equal to $m \pi$ $\cos^2 \gamma$ therefore γ is equal to $m \pi$ gives us the maximas which means the maximas occur at $\frac{\lambda}{d}$

So this is at $\frac{\lambda}{d}$ this is zero $\frac{\lambda}{d}$ the second maxima occurs at twice $\frac{\lambda}{d}$ third occurs at three times $\frac{\lambda}{d}$ and

So on now why did I show this much rapid compared to this because d is much larger than a therefore this is a bigger number compared to this number and therefore the $\cos^2 \gamma$ γ is a bigger number which means the \cos^2 will vary rapidly compared to $\sin^2 \beta$ if β and γ were identical then they will vary identically at this with the same period but because γ is much larger this varies much rapidly here

So $\frac{\lambda}{a}$ may be somewhere here

So $\frac{\lambda}{a}$ in on the same scale I am showing on the same scale

So this point is $\frac{\lambda}{a}$ here because a is smaller and therefore $\frac{\lambda}{a}$ is a larger number compared to $\frac{\lambda}{d}$

So what we have seen is this is nothing but the interference interference fringes

So interference fringes \sin^2 \cos^2 fringes and this is the diffraction pattern due to a single slit diffraction pattern and what is the net result net result is product of this into product of this

So product of the two functions

So when we take product of the two functions wherever any one of the function is 0 the product is 0 and therefore the net result will be

So let me draw the net result now here in the next sheet

So so I have drawn by a dotted line because the diffraction pattern acts like an envelope to the intensity variation here and the net variation will be like this

So intensity varying becoming maximum reducing maximum the amplitude is reducing because the diffraction amplitude is reducing

So this is the

So here intensity is 0 and then again we have intensity variation same thing on the left hand side

So this is the net intensity variation which looks like fringe pattern but it's with the amplitude of the fringes unlike in the case of interference fringes these were all of constant amplitude now the amplitude goes on dropping down

So what I have plotted is intensity here versus the angle θ or $\sin \theta$

So I is equal to this

So this is I_0 this is the interference pattern now what is important is the following

So before i go proceed further let me put a pre drawn diagram here and let me give put a nicely drawn diagram to give a better feeling here of

So here it is

So this is

So what i have shown is the double slit diffraction pattern is our double slit interference pattern you can call it as diffraction pattern or in transparence pattern interference pattern and diffraction pattern both are obtained by superposition of waves superposing the in waves at any given point that is how we get the intensity due to diffraction or due to interference and therefore here i call it as double slit diffraction because we have taken into account the diffraction effect i have plotted this very carefully for a particular separation d is equal to four times a that is the separation between the two slits in the young's double slit experiment is d which is four times the aperture size slit width and then we get as you can see whenever it is half times λ by d look at the blue curve this is the interference fringes whenever it is half times λ by d three by two times π by two times there are intensity minima that is m plus half π by two m plus half π and whenever it is m π we have maximas these correspond to m π therefore λ by d twice λ by d three times λ by d we have the maximas which are here and the envelope here shows the in diffraction pattern the intensity variation due to diffraction pattern which actually modulates or which affects the maximum intensity of these secondary maxima the interference fringes are called the secondary maxima within the first map within the central fringe due to the diffraction pattern now look at this point here by chance for this particular case this happens to be 4 times λ by d as far as interference is concerned we expected a maxima this should have gone up here to a maxima but when λ 4 times this point is when θ is 4 times λ by d this is λ divided by d by 4 d by 4 is a that is it is also equal to λ by a and we know that the diffraction pattern is 0 here the diffraction goes through the minima at λ by a therefore for the case of d is equal to four times a we have the fourth order maxima missing because it coincides with the zero of the diffraction

So that is why i have written here that it is also called the missing fourth order there is a missing order because the diffraction zero zero of the diffraction pattern eliminates or makes the intensity at here zero because it is a product of the two functions now if d where four point five times a then the fifth minima here four point five times a is nine by two times λ by d is a minima here interference minima and the diffraction minima would have coincided here if d were 4.5 times a both the interference minima and diffraction minima would have coincided here and we would have got an intensity maximum here and then minima there would not have been any missing secondary maxima its quite simple and we can try to understand this very easily by looking at the product of the two functions an important point here is if a is much smaller than d then this point will start moving away and as it moves away the diffraction minima would go far away and we have many more fringes within the first diffraction maxima this within the central diffraction maxima and the case would look like this the case would if a is much smaller than d then there will be a large number of secondary maxima between $\sin \theta$ is equal to θ is equal to plus minus λ by a that is the first zeros of diffraction and then the interference pattern would look like this it is slowly going towards 0 but before it reaches 0 before it reaches 0 there are many many fringes which are nearly equal in 10 they are almost look like of the same intensity the double slit interference fin

So this if we look only at this portion it looks as if we are looking at the young's double slit interference experiment there is a small variation in the amplitude of the bright fringes as we move towards the periphery as we can see this is what i had shown earlier that a computer generated interference pattern double slit young's double slit interference pattern you can see that the brightness of the fringes decrease as we go to the periphery brightness of the fringes decrease and this is because of the diffraction effects the diffraction effects taking into account the finite width of the aperture finite width of the

So it is the same as you can see here

So the intensity goes on decreasing from the central maxima intensity goes on decreasing as you go to the periphery now we come back to the basic idea of frown over diffraction where if you want to perform a frown of a diffraction in the experiment in in the in a laboratory you cannot have large distances to the screen and then as we already said that

we use a convex lens and place the screen on the focal plane of the convex lens

So let us see therefore how would the fringe pattern look like

So we want to see now

So I have now come to a laboratory setup where we have a parallel beam of light incident on the slit of size a and a lens here a convex lens helps us in collecting parallel beams it at different points p here therefore the intensity distribution here correspond for different θ will correspond to an intensity distribution here with different x coordinate here different x positions x

So if the point p on the screen here

So you can see that this corresponds to intensity minima

So there will be a diffraction pattern on the screen which is on the focal plane of this lens which would look like this the intensity pattern and what I have shown is if we flip this is a $2d$ but if we flip the screen

So we can see that there will be intensity maximas and intensity minimas the dots here I have used dots to show that the high dot density means intensity is high and low dot density means intensity is low and no dot means it is a intensity minima here because it is a continuous variation

So we cannot exactly say that a bright and dark bright and dark but it is a continuous intensity variation

So the dot density corresponds to the magnitude of the intensity here

So if the point p corresponds to an intensity minima here corresponding to this

So we are looking at this width here the width of the central bright fringe then

corresponds the first intensity minima then $\sin \theta$ is equal to λ/a and since λ/a is much less than one we have discussed this several times λ/a is much less than one $\sin \theta$ is nearly equal to $\tan \theta$ equal to θ and

approximation is a very good approximation here is equal to λ/a now $\tan \theta$ here is w that is the position of this point the distance of this point with respect to the central maxima here center w then w divided by f gives you $\tan \theta$ $\tan \theta$ is equal to w/f therefore we have equated w/f is equal to λ/a w/f is equal to λ/a the what is w w is the linear width on the screen please see till now we have been seeing the intensity distribution as a function of θ that is as an angular distribution but now we are seeing a linear distribution linear distribution of the intensity along x here and therefore we want to find out what is the separation linear separation not angular separation linear separation between these two which is $2w$ in the figure

So we have therefore the linear width of the central fringe on the screen here is $2w$ is equal to $2 \times f \times \lambda/a$ please see here w is equal to $f \times \lambda/a$ therefore $2w$ that is the width of this central maxima here is $2 \times f \times \lambda/a$ now before I proceed to the circular aperture I want to take a couple of examples to make us familiar with the numbers involved as I have already told you the application of a single slit diffraction experiment where we can determine the wavelength of light if we perform the diffraction experiment and measure the separation between the first two minima

So here is an example in a single slit diffraction experiment a parallel beam of laser light is incident normally on a long narrow slit of width 0.1 millimeter the diffraction pattern is observed on a screen placed at a distance of one meter on the other side of the slit if the separation between the first intensity minima on either side of the central maximum is 13 millimeters as observed on the screen determine the wavelength of the laser

So this is an example which illustrates the which illustrates the application of single slit diffraction

So let us work this out let us understand the problem

So there is a slit here

So a slit whose width is given the slit width is given

So slit width given that a is equal to 0.1 millimeter a is equal to point there is a parallel laser beam which is incident here and which undergoes diffraction and we see the intensity distribution on a screen placed at a distance l is equal to 1 meter this hundred centimeter l is equal to one meter what is given is we know that on the screen we due to single slit we get a diffraction pattern like this

So here and in terms of angles this corresponds to λ/a and minus λ/a here minus λ/a by this is l and therefore we have we are asked to determine what is the

wavelength of light determine the wavelength of light

So what do we know the minima here what is the theta

So the angle theta from here to here

So this is given theta

So theta is equal to λ by a here we are given this separation here this separation $2w$ is given

So we are given $2w$ the separation $2l$ or $2w$ is equal to 13 millimeters

So please see the question again a long narrow slit of width 0.1 mm the diffraction pattern is observed on a screen placed at a distance 1 meter l is equal to 1 meter if the separation between the first intensity minima on either side of the central maximum is 13 mm as observed on the screen which means linear this is 13 mm if it was angular separation it would not have been 13 mm it would have been some degree or some arc of a second or something like that it will not be in millimeter the fact that it is given as 13 mm tells us that it refers to the linear separation here from here to here therefore this angle theta we know

So this theta

So $\tan \theta$ is equal to therefore $\tan \theta$ is equal to this half we know

So this is l and l this is given is equal to l by capital l l by l which is equal to thirteen by two that is six point five half of this separation divided by one meter

So this is millimeter thirteen by two millimeter

So ten power minus 3 meters and this is 1 meter here

So this is $\tan \theta$ and theta is equal to λ by a

So this is also equal to λ divided by a a is point one millimeter point one into ten power minus three millimeter and therefore therefore λ is equal to

So let's find out therefore λ is equal to 0.1 into 10 power minus 3 minus 3 here into 6.5

So this is 13 by two six point five into ten power minus three millimeter

So that is meters now all are in meter divided by in the denominator we have one meter

So all are in meter

So this much

So therefore we get

So many meters

So that is 6.5 into 0.1 is 0.65

So we have 0.65 into 10 power minus 6 meters 0.5 into 10 power minus 6 meters

So let me write here itself

So this means it is 6.65 micrometers

So that is equal to 0.65 micrometer or equal to 650 nanometers

So 650 nanometers this corresponds to what is this color this is red color

So this corresponds to this is actually a typical wavelength of visible red color diode lasers which are used in laboratory

So 650 nanometer is a red colored diode laser

So we have got the wavelength of light as 650 nanometers

So this is clearly this is an experiment which can be performed in the lab to determine such small numbers as wavelength of light ok

So let us take one more example let us take a second example in a single slit frown over diffraction experiment using sodium lamp wavelength is given λ is 589 nanometer the separation between the two first minima on either side of the central maximum is found to be five mm found to be means it is measured to be five millimeter if the observation screen was placed on the focal plane of a convex lens of focal length 15 centimeter determine the slit width determine the slit width slit width is a

So we are given

So this now corresponds to the the discussion that we had

So here is the on the focal plane

So let me recall this diagram which we have shown

So we have a source and a screen is placed on the focal plane screen is

So what is said is the difference between the two first minima on either side of the central maxima is found to be five millimeter this separation $2w$ is five millimeter if the observation screen was placed on the focal plane of a convex lens of focal length 15 centimeter which means f is 15 centimeters we are given f we are given $2w$ we are given wavelength and you are asked to determine the slit width a slit width is a

So a has to be found out

So we already have

So let me instead of deriving this again i use this formula here right here which is given

So we have $2w$ is equal to 2 times f into λ by a or a is equal to we have to determine a

So a is equal to 2 times f f is given 15 centimeter

So 15 centimeter

So let me write in centimeter right now into λ divided by a divided by two w two w would come here that is five millimeter

So two w is given as 5 millimeter this is given f is given as 15 centimeter and therefore a is equal to you better use all same units therefore 2 times a is equal to 2 times 15 centimeter

So 15 into 10 power minus 2 meters into λ λ is given 589.5 eighty nine nanometers that is ten power minus nine meters divided by five millimeter five

So this is two w

So five into ten power minus two

So millimeter minus three millimeters

So we can simplify this as you see that this is five goes three times here and 3 into 2 is 6 and this leaves 10 power minus 10 in the denominator here minus 1 in the denominator and here we have 10 power minus 9 therefore 1 minus 1 cancels with 1 minus 1 here leaving minus 8 behind

So 6 into 589 into 10 to the power of minus 8 meters we can simplify this you can multiply by 6

So 6 into 9 is 54

So 6 into 48 is 48 plus 5 fifty three six into five is thirty

So thirty five

So thirty five into ten to the power of minus eight meters or thirty five point thirty four into 10 to the power of minus 6 meters

So this is micrometers

So the answer depending on the requirement you may have to write

So this is micrometers you can also write this in millimeter which is equal to zero point zero three five three four millimeters you have to be familiar with all the units

So any one of in terms of meters here this is in terms of meters and this is micrometers and this is millimeters

So you note that the slit width typically i was mentioning that this is approximately 0.1 millimeter typically

So this is a little less than that

So this is point zero three five millimeter or

So so we have taken these two these are two simple examples which we have taken the objective being to become familiar with the kind of numbers which are involved and the fact that diffraction experiment can be used to determine unknown quantities such as wavelength of light or the slit width if you know the wavelength of light now we proceed further and now we take the diffraction due to a circular aperture diffraction due to a circular aperture

So again i am illustrating first what is diffraction due to a circular aperture recall that diffraction due to a single slit in a single slit diffraction we had a slit of certain width and when parallel beam of light is incident because of as this width of the street decreases light will diffract in this direction to give you intensity maximas and minima that is we had a parallel beam and then i had introduced recall how i have introduced diffraction i introduced to two wedges cutting the beam till they become come to a narrow slit now we are looking at a circular aperture there is a parallel beam of light coming if you have a circular aperture the beam passing through the aperture will fully pass through when the aperture is fully open but as you close the aperture as you reduce the dimension of the aperture it will start cutting the beam that is it will start blocking portions of the beam and then as the aperture becomes narrower and narrower the light which is coming on the other side will move more and more into the geometric shadow leading to the diffraction pattern

So that is what is illustrated here

So come to diffraction by a circular aperture a parallel beam of light incident on a circular aperture here diffraction takes place and on the other side you see what is called as an airy pattern an airy pattern where there is an intensity maxima and minima

then again secondary maxima minima and

So on if you take a longitudinal section that is if you see a section of this along this line let us say along this plane if you see the section then it looks like this it looks exactly like the single slit diffraction experiment this is the slit actually this two a is the diameter of this circular aperture two a is the diameter and here we have intensity distribution along this line which is plotted here I of θ as a function of v there is the intensity distribution due to a circular aperture where v is π by λ into two a sin θ now this area pattern

So let's see what is this airy pattern the diffraction the detailed analysis is beyond the scope of our discussions here however it is important to know these results for us that the area pattern that is the intensity distribution due to fraunhofer diffraction by a circular aperture is given by I is equal to I_0 into two times J_1 one of v by v whole square where v is given by this and what is this J_1 J_1 of v is the Bessel function of the first order as I mentioned that Bessel function is a special function and at this level we are not familiar with you are not familiar with the Bessel functions but we still need the result and why I introduce this I will let you know in a minute

So if you plot the intensity distribution you get an intensity distribution like this So which has minimas at 3.832 v is equal to 3.832 and v is equal to 7.016 on both the sides here this also a symmetric function

So we get here at minus 3.832 and minus 7.06

So what I have shown here is the intensity distribution here here is the intensity maxima it is 0 at 3.832 v and here it is 7.016 and this intensity distribution is called the airy pattern the corresponding intensity pattern here on on the screen is shown here that intensity is maximum at the center and goes on decreasing the boundary which I have shown here the boundary corresponds to these points here in other words within this region between the two zeros this within the boundary between the two zeros what we have is this region and this is called the airy disk the airy disk which is here almost 84 percent of the energy in the diffraction pattern is contained in the airy disc and therefore the diameter of the airy disc can be considered as equivalent to the spot the spot size of the diffraction pattern that is why this point is very important we will see applications where we have to consider these this diameter of the airy disc in the subsequent classes we will discuss the applications of the airy pattern and diffraction due to circular aperture in the next class thanks you