NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Lecture -21 Tutorial
Materials Characterization
Fundamentals of Scanning Electron Microscopy

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Hello everyone welcome to this material characterization course in today's class we will look at some of the problems related to scanning electron micros copy so these problems will be useful for you to solve some of the assignment problems as well as the in the end semester o rend of the course examination so we will look at some of the problems related to the resolution in electronic.

I mean electron optics electron optics as well as the specific system specific problems and also we will look at some of the applications like in ACM how we get the resolution and what are the parameters which influence this resolutions related to that we will look at some of the specific problems so you will appreciate the importance of this concepts and then and then you can we'll just get benefited while solving the assignment problems as well.

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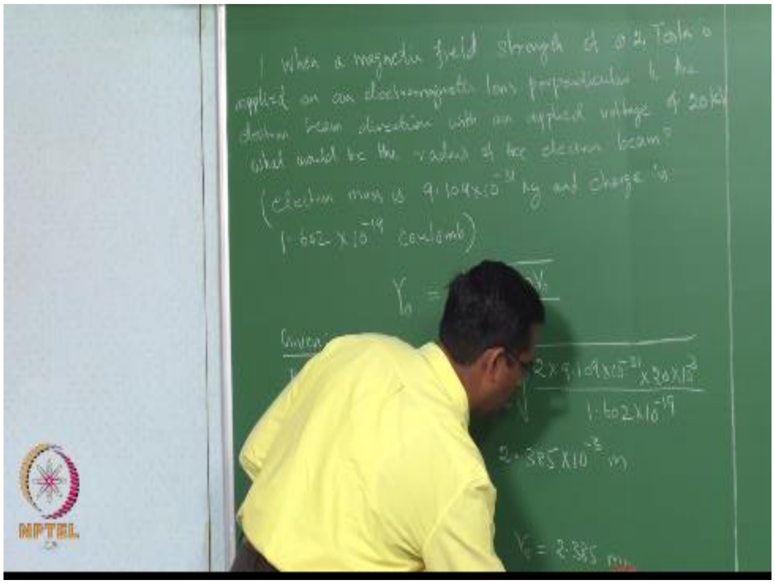

So we will just look at the first problem you so the first problem is when a magnetic field strength of point to Tesla is applied on an electromagnetic lines perpendicular to the electron beam direction with an applied voltage of 20kilo volt what would be the radius of the electron beam the electron mass is9.10 9 into 10^{-19} = 31kilograms and the charges 1.602 into 10to the power minus 19 coulomb.

So what is that clue we have they are now talking about the radius of the beam electron beam so the radius is given using this formula if you recall the electromagnetic lens schematic we have written an expression in terms of this is a formula we can use this to obtain this so let us solve this say simple substitution you can write by simply substituting this one by point to square root of two into 9.10 9 into 10^{-31} into 20 into 10^{3}.

We are keeping in volts and this is the charge so if you work it out what you will get is so you will get something like this or you can write it our 2.385 into 10^{-3}.

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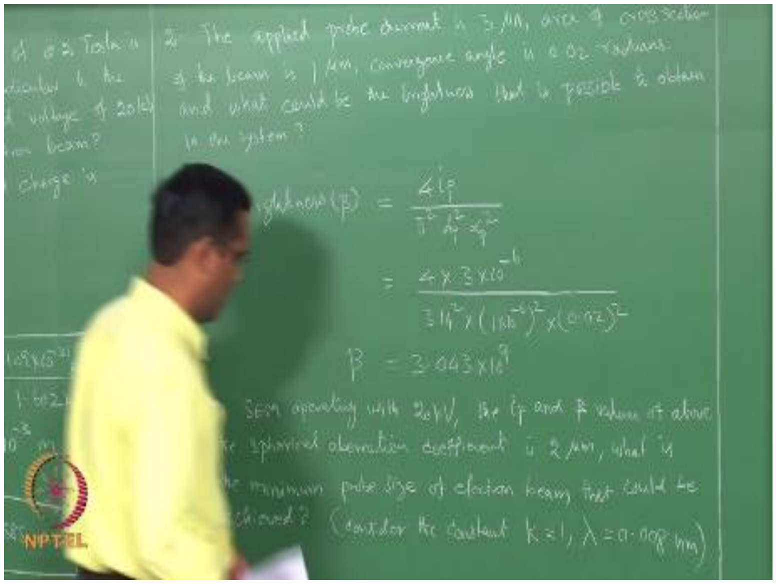

So this is the answer so we move on to the next problem you so in a microscope the applied probe current is 3 micro amperes and area of the cross section of the beam is about 1micrometer convergent angle is about 0.02 radians.

What would be the brightness that is possible to obtain in this system so now you have the if you recall there is a relation between the brightness and the probe current and conversion angles and so on so you have to just look back in the lectures the formula for the brightness and I will write brightness β so i_p is the group grunt and alpha is the invention angle and your dp is the cross section of the beam. So simply as substitution here you so beta β is 3.0 for three hundred and 49 that is the value of the brightness now we will use this brightness value to solve another problem.

So let me write that problem the ACM operating 20 kilovolt the ip and β values of above and the spherical aberration coefficient you of the electromagnetic lines is to micrometer and what is minimum probe size you so the problem is they assume operating with 20 kilo volt having the probe current and beta values of this problem and then spherical aberration coefficient.

SM is about to micrometer and what is the minimum size of the electron beam that could be achieved and you can consider the constant K is equal to 1 and lambda is equal to 0.008nanometers.

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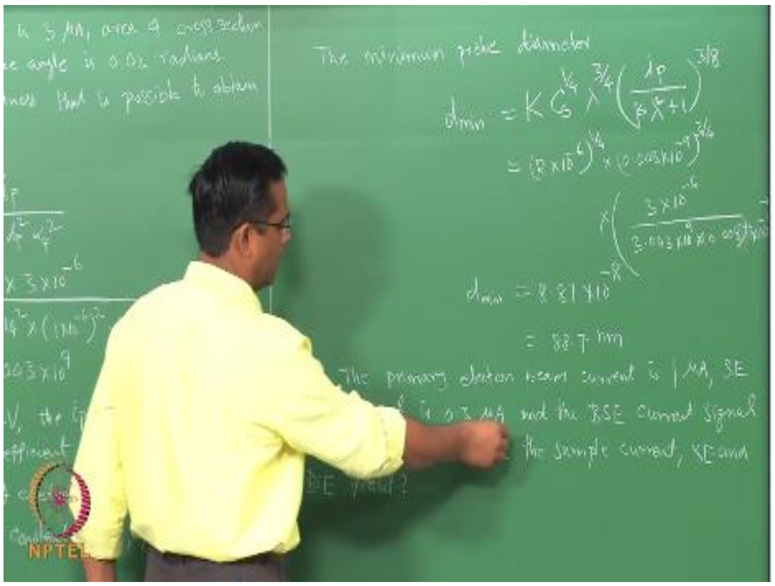

So if you recall the minimum rope diameter considering the abrasion d minimum which is = $C^{1/2}$ and $\lambda^{3/4}$ times you have ip/ $\beta\lambda 1^{3}$ by 8 it is lit this is the formula we have seen for obtaining the minimum diameter so if we can substitute these values let us see what kind of values we getting you so this is a simple substitution here so3 into 2^{-6}/3.0 for 3 into 2^{9} into 0.008^{10} - k+1 ^{3} /2. 3/8.

So basically we are trying to substitute this and then you will get the values in the range d minimum = 88.7into $10^{-8.}$ So I request you to check this with your own calculator or we can simply say that 88.7 nanometer so this is the final minimum probe current you can get if you have the SEM operating parameters in this range we will solve another simple problem.

So let me read the problem the primary electron beam current is 1 micro ampere secondary electron current signal is 0.3micron here and the backscattered electron current signal is 0.2

microampere what could be the sample current secondary and backscattered electron yield so if you recall we have the formula for this a simple formula to calculate this.

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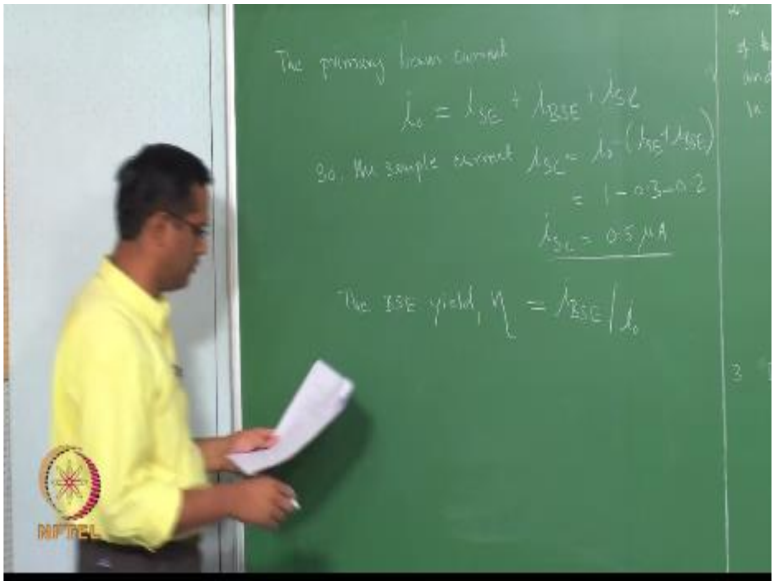

So the primary beam current is written in terms of addition of secondary electron signal current back scattered electron signal current and sample current so we can just rewrite. So this is the first answer the sample current is 0.5 micro amp from the question number two is the back scattered electron e which is given by which is β/i_0 that is the back scattered electron signal current divided by the primary beam current. So again we can simply substitute this you will get again same value.

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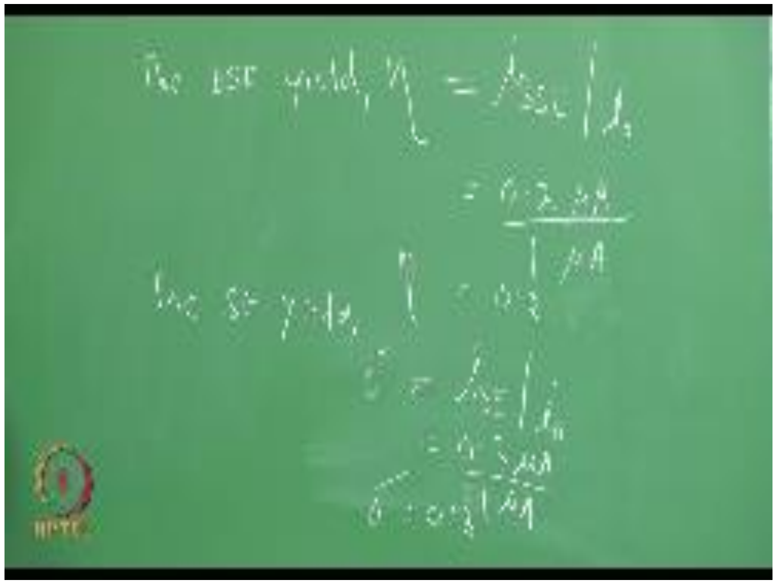

The secondary electron gain which is done as a Θ I SC / I not just nothing but 0.3 micro on here divide by zero point I one micro ampere which is again Θ = 0.3 this is point to the yield is written as point to hear the yield is written point three there is no units here.

So as simple arithmetic which involves the concept of the how the primary beam current is depend on the current of second electron and back scattered electron and a sample current a simple substitution and then we can also workout the yield and we have also seen that the importance of this the yield of BSC and the yield of decides the contrast that we have we have seen in be some of the theoretical concepts so now we will move on to the next problem.

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You so the question is for a given wave length of electron beam λ and the spherical aberration coefficient CS of the lens proved that optimum image aperture represented in terms of α art is proportional to λ by CS to the power 1 by 4 assume that the net resolution is equal to the summation of theoretical resolution that is the discs least confusion plus the disc of confusion created by the spherical aberration so how do we go about this what is the theoretical resolution.

Let us consider this r1 which is =0.61 λ by α So risk of confusion created by spherical aberration by spherical aberration r2 =CS α cube so net resolution if you write so that is consider this expression as one so we have just simply put the respective formula and then as per the assumption here we have written the net resolution in this single formula. Now since this net resolution is depending upon both theoretical resolution plus the spherical aberration we can write something.

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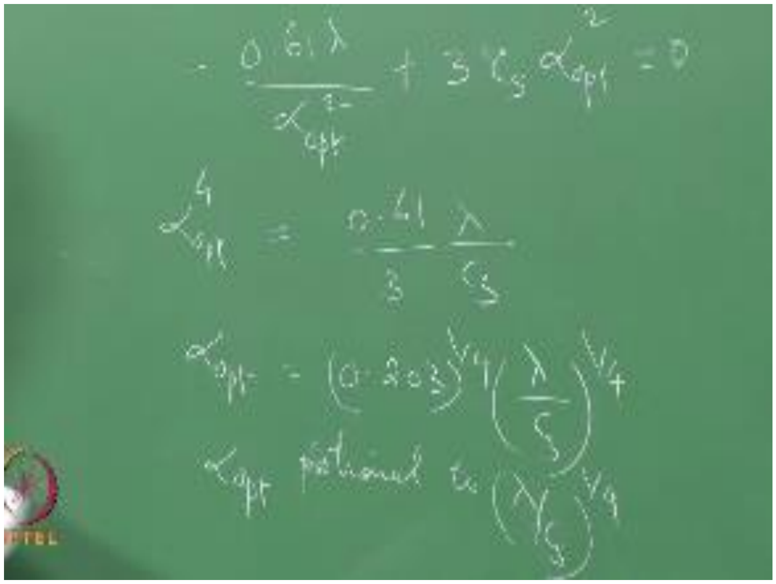

You so what we are now saying here is when the spherical aberration is minimized by the use of small aperture that is α R diffraction limited resolution becomes worse with the decrease in α so we have to make a compromise so what we can do is you so we are trying to see or we are trying to differentiate the this expression with respect to α and see what we get so you get this so from this we can write α apt to the power 4 equal to 0.6 1 by 3 λ by CS α apt is equal to 0.203or4 λ/CS 1 by 4 or simply we can write α R proportional to λ x SI s to the power.

So you can substitute this into the equation one you will get our apt proportional to λ 3 x 4 + CS 14 so for optimum the solution so our opt proportional to λ to the power 3/4 and C s to the power 1/ 4 which gives the expression for this given condition if you assume this and the disco fries least confusion will be proportional to these quantities so that is what the physical meaning here the assumption made here will result this kind of an expression so now you look at another simple problem involving the depth of focus and depth of field so what is the depth of focus when semi aperture angle α is equal to 0 point1 gradients and the magnification m of 15,000 X.

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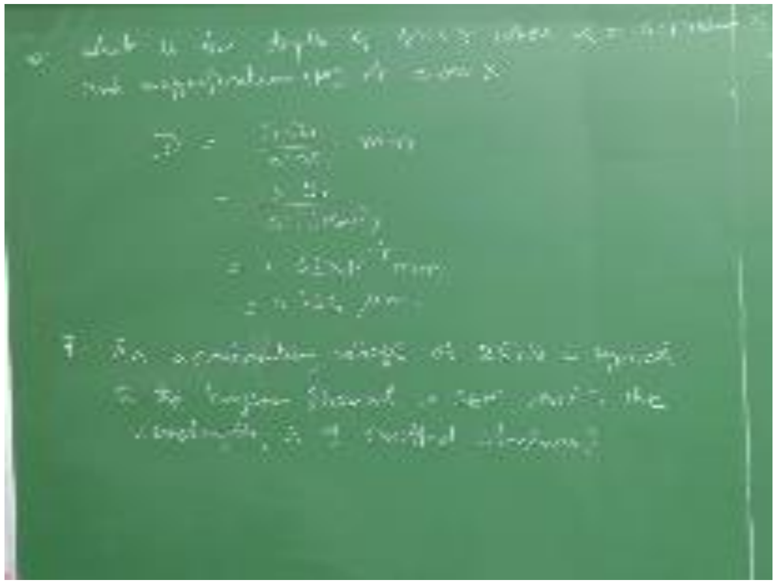

So we have seen and this in fact we have derived this in the seam class with the schematic you can recall the depth of focus can be related to this so you simply substitute this will be in mm so 1.33 in 10 to the power minus 4 mm or point 133 micro meter that is very simple problem another problem let us quickly right so an accelerating voltage of 25 kilovolts is applied to the tungsten filament in ACM what is the wavelength lambda of the emitted electrons so it is again very straightforward formula you have lambda which is relating to the acceleration voltage so very standard formula.

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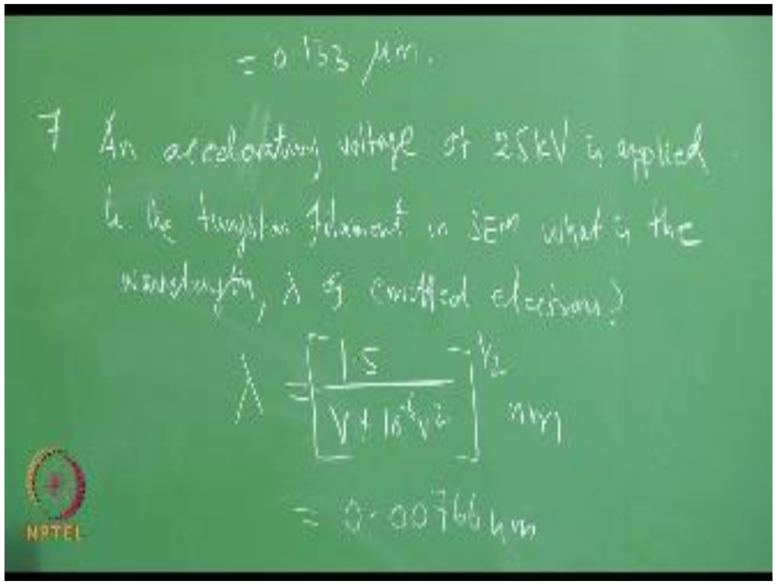

We have seen that so straight away you will get 0.00766 animation for this kind of a voltage for25 kilo volt you will get in this range and finally the question is an electron beam refracts at an angle of point 1 radians when the angle of incidence is 0.025Arians on passing through a region of potential difference V 2 minus p1 does the beam retard or accelerate through this potential difference if you look at the or if you recall the very beginning of the electromagnetic lenses.

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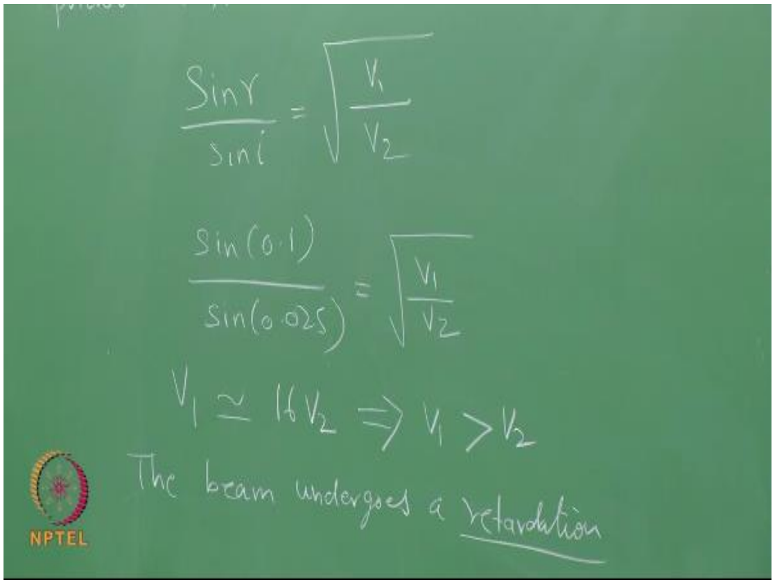

We talked about the Snell's law and then we said that there is no difference between light or the behavior of light optical system as well as the electron optical system they are also the same so in that respect if you recall we have written a formula like this so Sinai and we sign our by Sinai is equal to the square root of v1 by v2 and then if you recall that schematic where the electrons are passing through the electro potential lens how whether it is retarding or accelerating depending upon the voltage of the way apply the voltage applied to this system.

So we can simply substituent see what happens here sign so you get V1 is approximately equal to16 times of v2 that is V 1 is greater than v2 so then what happens beam and goes yeah garnish so that is what we will see when the voltage v2 is greater than I mean V 1 is greater than V 2 then the beam will undergo retardation so with all this small numerical problems suppose you are able to solve the assignments as well as you are able to solve small numerical problems and I hope these things this exercise will help you in the final examination also if you have any specific queries you are welcome to interact with us and we will respond to your queries thank you.

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