Fundamentals of optical and scanning electron microscopy
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Module – 03
Lecture – 21
Tutorial - Problems related to scanning electron microscopy

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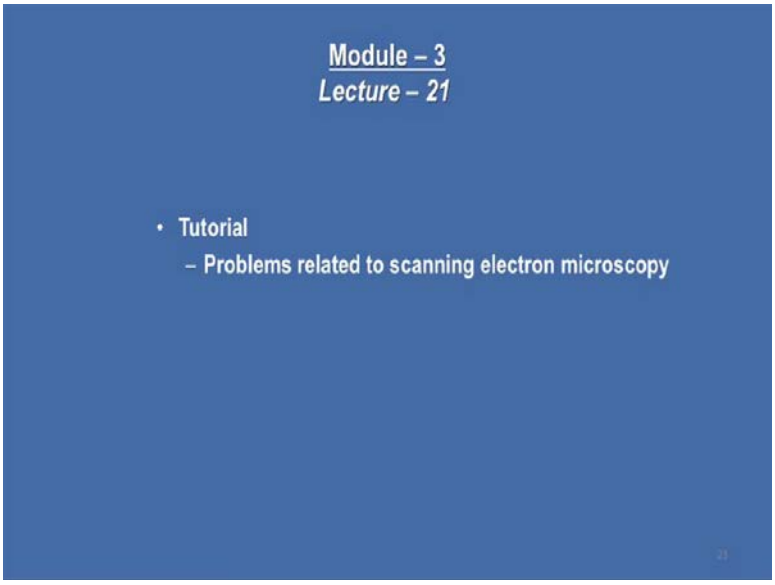

Hello everyone, welcome to this material characterization course. In today's class, we will look at some of the problems related to scanning electron microscopy. So, these problems will be useful for you to solve some of the assignment problems as well as the in end semester or end of the course examination. So, we will look at some of the problems related to resolution in electron I mean electron optics as well as the specific system specific problems. And also we will look at some of the applications like an SEM 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 will just get benefited while solving the assignment problems as well.

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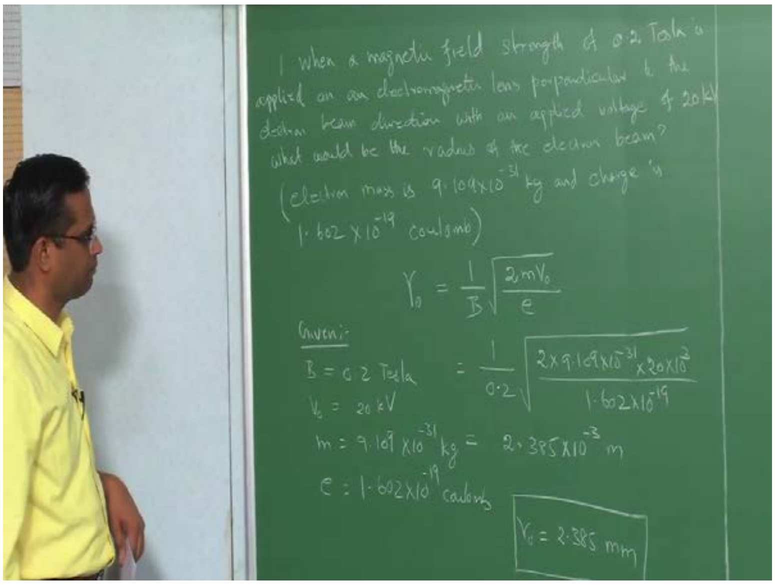

So, we will just look at the first problem. So, the first problem is when a magnetic field strength of 0.2 Tesla is applied on an electron magnetic lens perpendicular to the electron beam direction, you can applied voltage of 20 kilo volt what would be the radius of the electron beam. And the electron mass is 9.109 into 10 to the power minus 31 kilo grams and charges 1.602 into 10 to the power minus 19 coulomb. So, what is that clue we have, we are now talking about the radius of the a 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 so this is the formula we can use this to obtain this. So, let us solve this, so a simple substitution. We can write by simply substituting this 1 by 0.2 square root of 2 into 9.109 into 10 to the power minus 31 into 20 into 10 to the power 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 r naught is equal to 2.385 mm. So, this is the answer.

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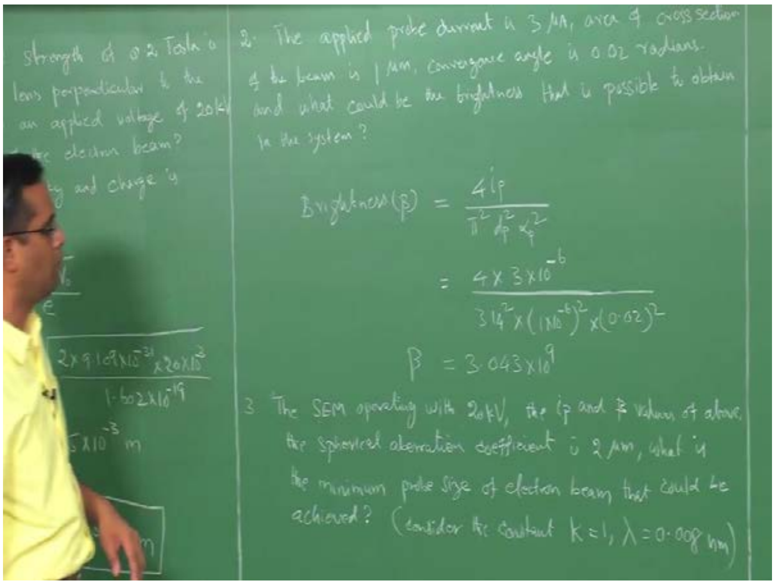

So, we will move on to the next problem. So, in a microscope, the applied probe current is 3 micro amperes, and the area of the cross section of the beam is about 1 micrometer, convergence angle is about 0.02 radians and what would be the brightness that is possible to obtain in the system. So, now you have, if you recall, there is a relation between the brightness and the probe current, and convergence angle and so on, so you have to just look back in the lectures the formula for the brightness. And I will write brightness beta, so ip is the probe current, and alpha is the convergence angle, and your dp is the cross section of the beam. So, simply a substitution here, so beta is a 3.043 into 10 to power 9 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 SEM operating 20 kilovolt, the ip and beta values of above and the spherical aberration coefficient of the electromagnetic lens is 2 micrometer, and what is minimum probe size. So, the problem is the SEM operating with 20 kilovolt having the probe current and beta values of this problem, and then spherical aberration coefficient is about 2 micrometer, and what is the minimum probe 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 0.008 nanometers.

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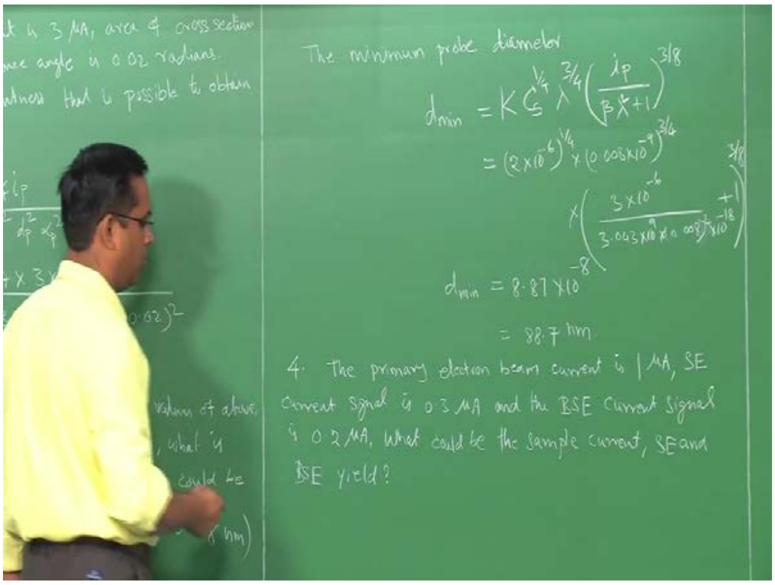

So, if you recall the minimum probe diameter considering the aberration d minimum is equal to K Cs to the power 1 by 4 and lambda to the power 3 by 4 times you have ip divided by beta lambda square plus 1 to the power 3 by 8. This is the formula we have seen for obtaining the minimum probe diameter. So, if we can substitute this values let us see what kind of values we are getting, so this is a simple substitution here. So, 3 into 10 to the power 6 divided by 3.043 into 10 to the power 9 into 0.008 square multiplied by 10 to the power minus 8 plus 1 to the power 3 by 8.

So, basically we are trying to substitute this, and then you get values in the range d minimum equal to 8.87 into 10 to the power minus 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 a 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 microampere, secondary electron current signal is 0.3 microampere, and the back scattered electron current signal is 0.2 microampere, what could be the sample current, secondary, and back scattered electron yield. So, if you recall, you have the formula for this, a simple formula to calculate this.

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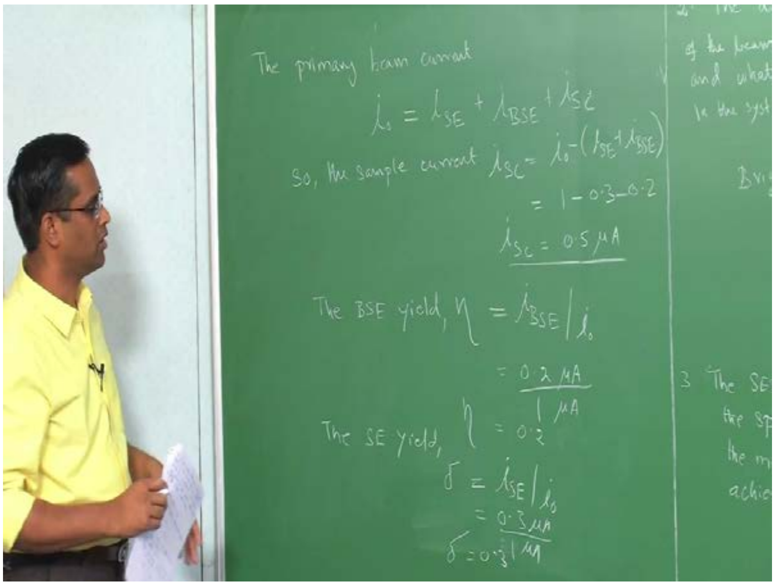

So, the primary beam current is written in terms of addition of secondary electron signal current, back scattered electron signal current and sample current. So, we can just rewrite. So, this is the first answer, the sample current is 0.5 microampere. From the question number two is the back scattered electron yield which is given by which is eta is equal to i BSE divided by i naught 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 the same value.

The secondary electron yield which is written as delta i SE by i naught which is nothing but 0.3 microampere divided by 1 microampere which is again delta is equal to 0.3. This is 0.2, the yield is written as 0.2; here the yield is written 0.3, there is no units here. So, a simple arithmetic which involves the concept of how the primary beam current is dependent on the current of secondary electron and back scattered electron and sample current, a simple substitution and we can also work out the yield. And we have also seen that the importance of this the yield of BSE and the yield of SE decides the contrast that we have seen in the some of the theoretical concepts.

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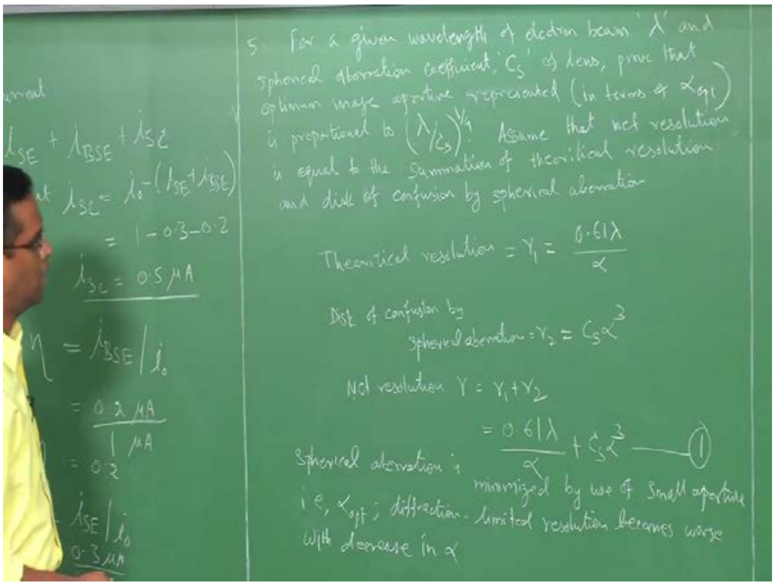

So, now we will move on to the next problem. So, the question is for a given wavelength of electron beam lambda and a spherical aberration coefficient C s of lens, prove that optimum image aperture represented in terms of alpha opt is proportional to lambda by C s to the power 1 by 4. Assume that the net resolution is equal to the summation of theoretical resolution that is disk of least confusion plus the disk of confusion created by the spherical aberration. So, how do we go about this, what is the theoretical resolution. Let us consider this r 1, which is equal to 0.61 lambda by alpha.

So, disk of confusion created by spherical aberration r 2 just is equal to C s alpha cube. So, net resolution if you write, so let us 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 the single formula. Now since this net resolution is depending upon both theoretical resolution plus the spherical aberration, we can write something. So, what we are now saying here is when the spherical aberration is minimized by the use of small aperture that is alpha opt, diffraction limited resolution becomes worse with the decrease in alpha. So, we have to make a compromise.

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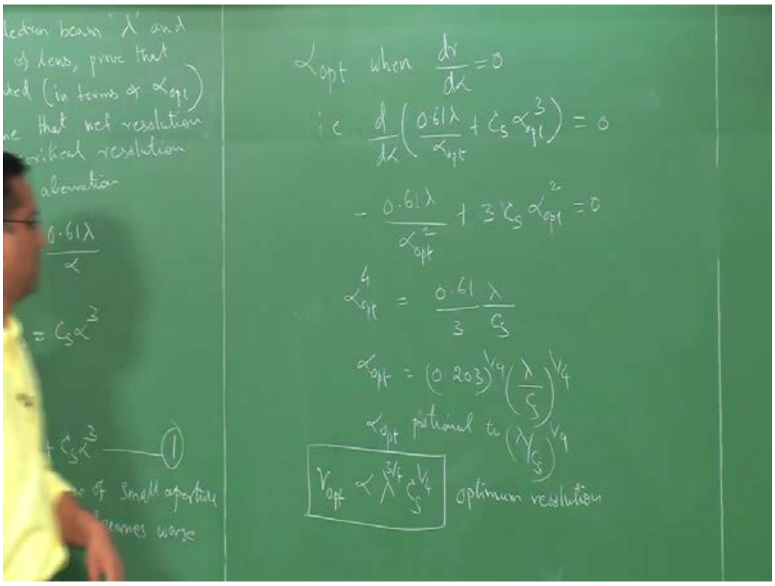

So, what we can do is, so we are trying to see or we are trying to differentiate this expression with respect to alpha and see what we get. So, you get this. So from this, we can write alpha opt to the power 4 is equal to 0.61 by 3 lambda by C s, alpha opt is equal to 0.203 to the power 4 lambda by C s to the power 1 by 4 or simply we can write alpha opt proportional to lambda by C s to the power half.

So, you can substitute this into the equation one you will get r opt proportional to lambda 3 by 4 and C s 1 by 4 for optimum resolution. So r opt is proportional to lambda to the power 3 by 4 and C s to the power one by four which gives an expression for this given condition. If you assume this and the disk of least confusion will be proportional to this quantities. So, that is what the physical meaning here. The assumption made here will result in these kind of an expression.

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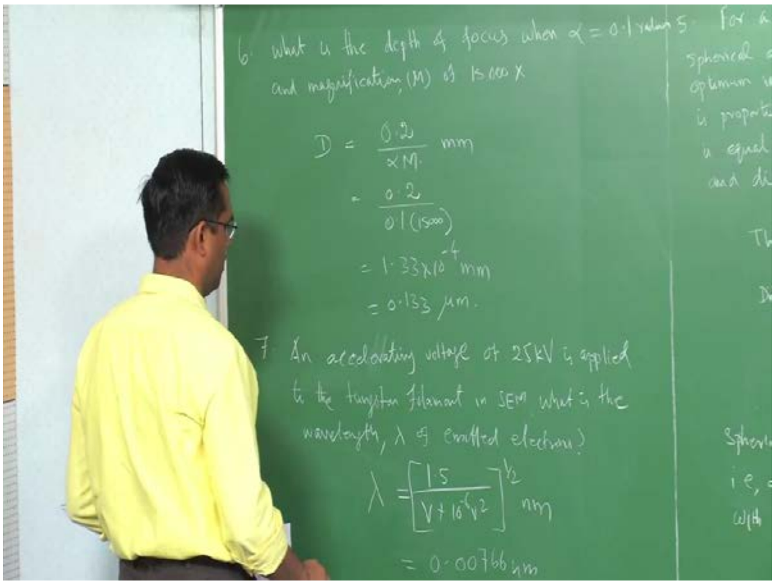

So, now, we look at another simple problem involving the depth of focus and depth of field. So, what is the depth of focus when semi aperture angle alpha is equal to 0.1 radians and the magnification m of 15,000 x. So, we have seen and this in fact, we have derived this in the SEM class with the schematic, you can recall the depth of focus can be related to this. So, you simply substitute, this will be in mm; so 1.33 into 10 to the power minus 4 mm or 0.133 micrometer. So, that is very simple problem.

Another problem let us quickly write. So, an accelerating voltage of 25 kilovolts is applied to the tungsten filament in SEM, what is the wavelength lambda of the emitted electrons. So, it is again a very straight forward formula you have, a lambda which is relating to the acceleration voltage is very standard formula we have seen that. So straight away, you will get 0.00766 nanometer for this kind of a voltage; for 25 kilovolt, you will get in this range.

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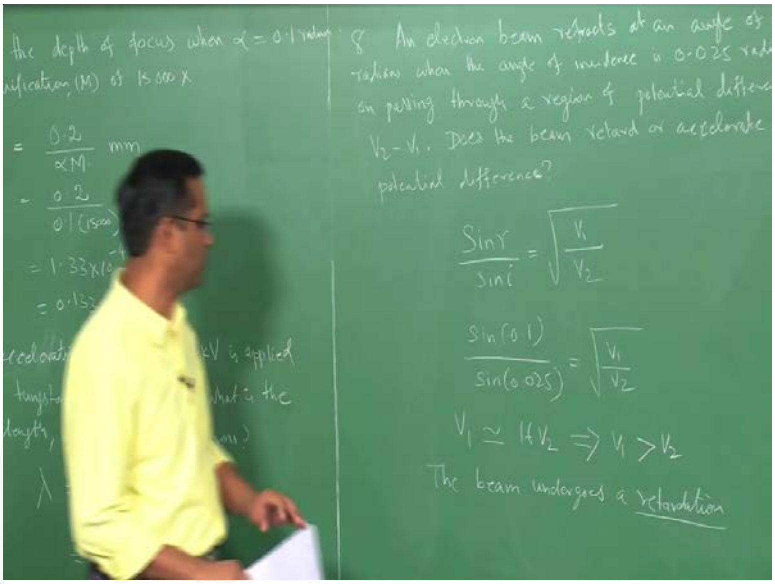

And finally a question is an electron beam refracts at an angle of 0.1 radians, when the angle of incidence is 0.025 radians on passing through a region of potential difference V 2 minus V 1. Does the beam retard or accelerate through this potential difference. If you look at the or if you recall the very beginning of the electromagnetic lenses we talked about the Snell's law and then we said that there is no difference between a light or the behavior of light optical system as well as the electron optical system, there also the same. So, in that respect if you recall we have written a formula like this. So, sin i and I mean sin r by sin i is equal to square root of V 1 by V 2. And then if you recall that schematic where the electrons are passing through the electro potential lens how, whether it is a retarding or there are accelerating depending upon the voltage applied to the system.

So, we can simply substitute and see what happens here; sin, you get V 1 is approximately equal to 16 times of V 2 that is; V 1 is greater than V 2. So, then what happens beam undergoes here at retardation, so that is what we will see when the voltage V 2 is greater than I mean V 1 is greater than V 2 then the beam will undergo retardation. So, with all this small, small numerical problems, I suppose you are able to solve the assignments as well as you are able to solve small, small numerical problems. I hope these things these 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.