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Theory and Practice of Non Destructive Testing

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Radiography – 2

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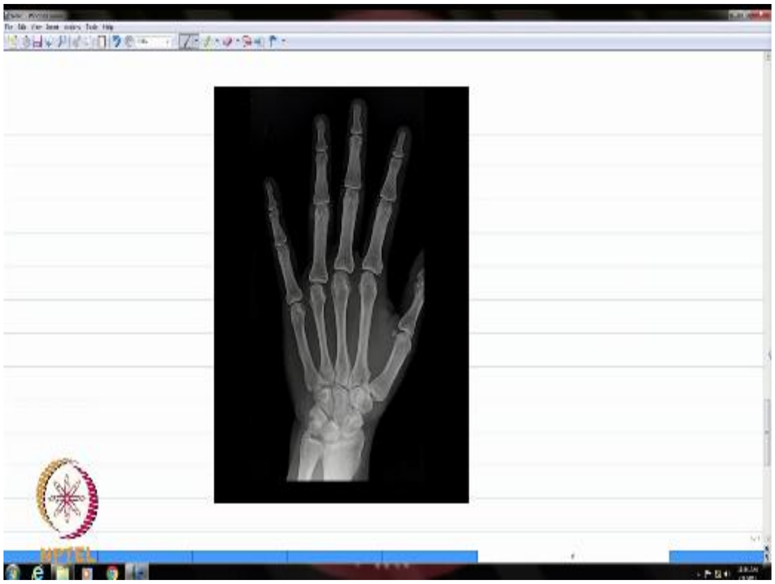

Okay so this is what I showed you in the last class and I told you the basic principle behind radiographic testing lies to the question as to why these bones appear white and we have discussed about it. And now as I told you in the last lecture we can get an expression for this particular phenomena that leads to this kind of contrast or appearance that particular relationship or equation will be forming the basis of radiographic testing.

So let us discuss about that in today's class and see the basic principle behind radiographic testing okay.

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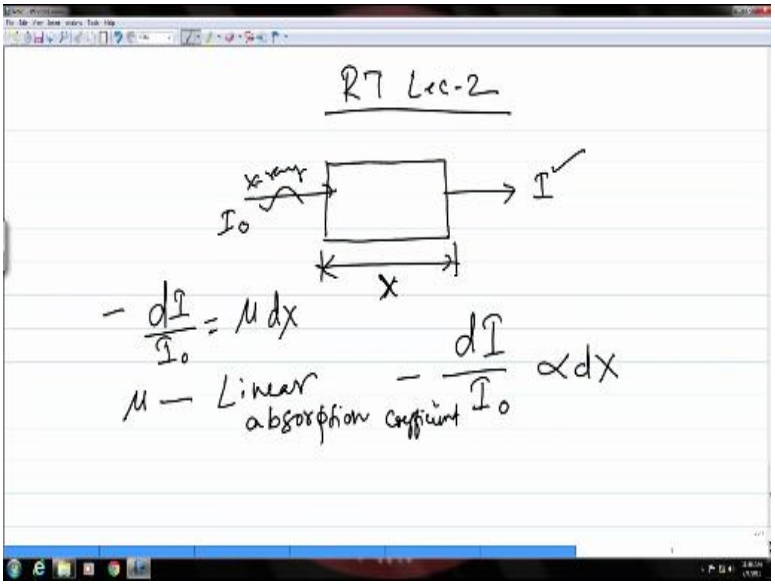

So let us say x rays are traveling through a substance of thickness X so this is the initial intensity I0 and after traveling through this thickness the intensity coming out from this substance is I okay. So as I said when x rays travel through a substance there will be some interaction between the x-rays and the matter and as a result of which some of the energy of the x-rays will be absorbed by the material okay.

So this I which comes out from the material will be lower than the initial intensity I0 okay. So this fractional decrease di/I0 and since it is reduction will use the negative sign this is proportional to the thickness or the distance that the X rays travel through okay. Okay now if you introduce the proportionality constant here, it will call as μ and let us say this travels through a distance DX.

So the fractional decrease will be proportional to DX and this is the proportionality constant μ and μ is known as linear absorption coefficient which is a material property okay.

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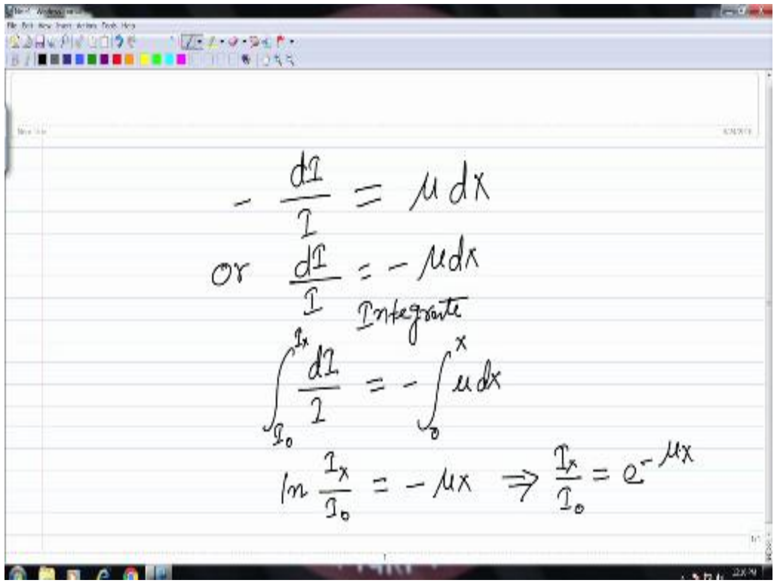

So what we have we have this now this is the fractional decrease which is proportional to the distance R travelled by the x-rays. Now if you integrate this, this is what you will get the intensity I is from the initial intensity which is I0 to an intensity at a distance X which is Ix and on the right hand side U integrate x/ 02 a particular distance X okay. And from this you get on the left hand side Ln Ix/I0 and if you integrate the right hand side you get –μx.

And from this you can write that Ix/I0 is equal to $e^{-\mu x}$ and now this will be the basis of radiographic testing okay. So as you could see the x-ray energy decreases exponentially with the thickness of the material okay, as you could see from here from this particular equation okay. But when we discussed about the radiograph of the hand if you remember we talked about a material property which was density.

And then I also told you the contrast that you see is due to the density difference between the bone and the flesh or the other body parts, but in this case we still do not see that density coming into picture okay. So that means we need to introduce the density and then we can clearly see how this x-ray radiation or the x-ray energy will depend on the density of the material when it comes out from that particular material.

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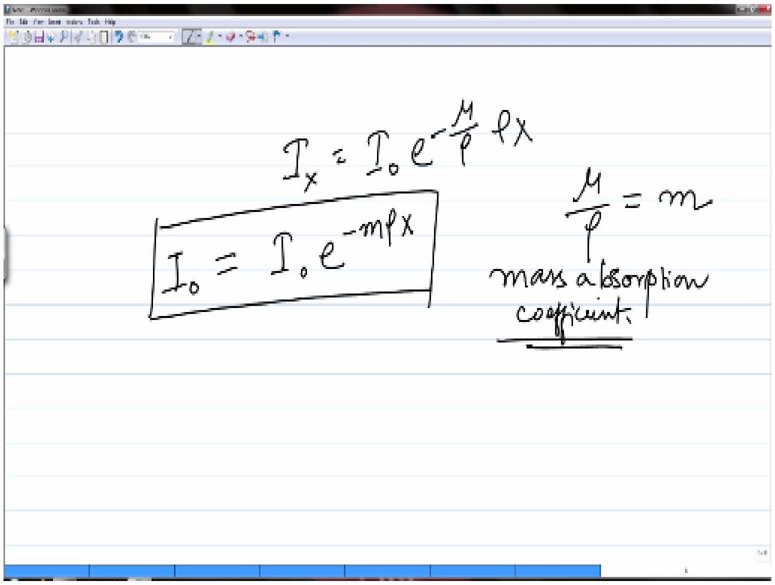

So we will rewrite this equation as, so we will introduce the density ρ and we will rewrite it in this fashion okay. So now we can define another parameter which is known as m and given by μ/ρ and this parameter is known as mass absorption coefficient. This particular parameter is a better representation of the absorption ability of a material because this provides you the volumetric ability of the material to absorb extra energy okay.

So now if you use this particular relationship between m and μ and the density of the material this equation comes down to this form okay. So now you can see that when you vary the density of the material what is going to happen to the extra intensity which will come out from this material okay. So as you could see as you increase the density the x-ray intensity will reduce exponentially for a given material thickness okay.

And that is why you see the bones white on a radiographic image because the bones have the highest density in our body. So they will have the maximum ability to absorb x-ray energy compared to any other part in human body okay. So this explains that particular contrast that you see on a radiographic film based upon the density of the part which is being imaged in the radiograph okay.

So this will be the basis for our radiographic testing okay, but the question here is why does the intensity of x-rays decrease when they travel through a particular material okay. So that means some kind of interaction must have happened inside the material when x-rays are going through them okay. So let us talk about those interactions which is the x-ray matter interaction and then we will see due to this kind of interactions which are known as scattering of x-rays are responsible for this particular phenomena of absorption that we talked about and that is how it forms the basis for radiographic testing.

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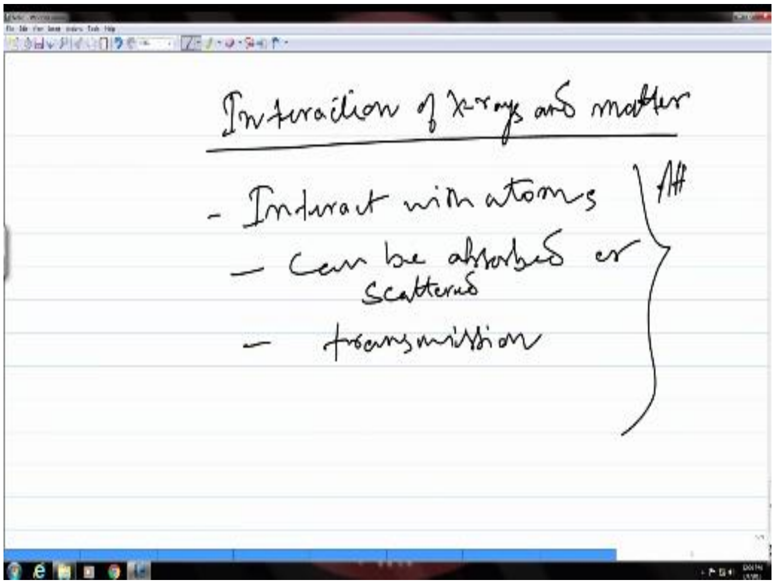

So when you talk about radiography you have to talk about interaction between x-rays and matter. And we all know that any substance is composed of atoms so that means when you say that x rays interact with matter or a substance it essentially means that the x-rays are interacting with the atoms when they are traveling through a substance. So x-rays will interact with the atoms and they can be absorbed due to this interaction or scattered.

And then a part of it will be transmitted to the substance with a reduced intensity okay. So all this thing the interaction between the atoms and the x-rays we lead to attenuation or reduction in the x-ray energy okay. And this is why you see that fractional reduction and that is how that particular equation comes into picture which you just now talked about okay. So let us see what kind of atomic absorption phenomena happens when x-rays travel through matter.

So these are primarily scattering events that means scattering of the x-rays by the atoms of the material and there are different forms of atomic scattering.

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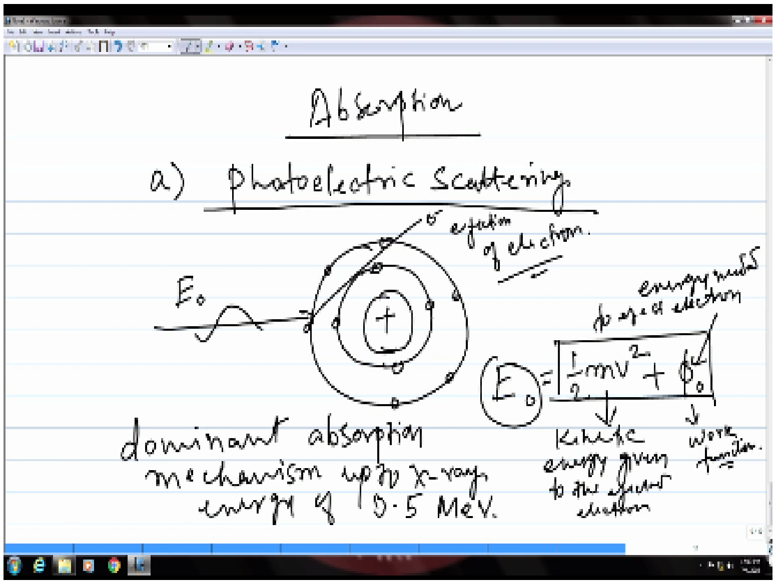

And one of them is known as photoelectric scattering. So this is the atom you have the nucleus and then electrons around it the orbital's and when the x-ray photons enter the material with a certain energy E0 they will encounter these atoms and with the electrons inside the atoms okay.

So in this case what happens the x-ray photon will eject on outer electron and as a result the x-ray photon would lose energy okay. So if you see the energy balance in this case this is the kinetic energy which is given to the electron when it is ejected from the outer shell of the atom okay.

So the electron will not only be ejected it will also be given a kinetic energy because of the high-energy x-ray photons and this is the energy needed to eject the electron from the outer cell and this particular parameter is called work function which is the energy needed to eject an electron from an atom okay, so a portion of the extra photon energy is going into ejecting the electron first it is this fine art or the work function and the other portion is going into providing the kinetic energy to the ejected electron so that is why this extra photon energy not is being balanced by these two, okay.

So this kind of absorption phenomena is a dominant absorption event in up to extra energy of 0.5 mega electron volt, okay so this is one such atomic scattering events which leads to absorption of x-rays.

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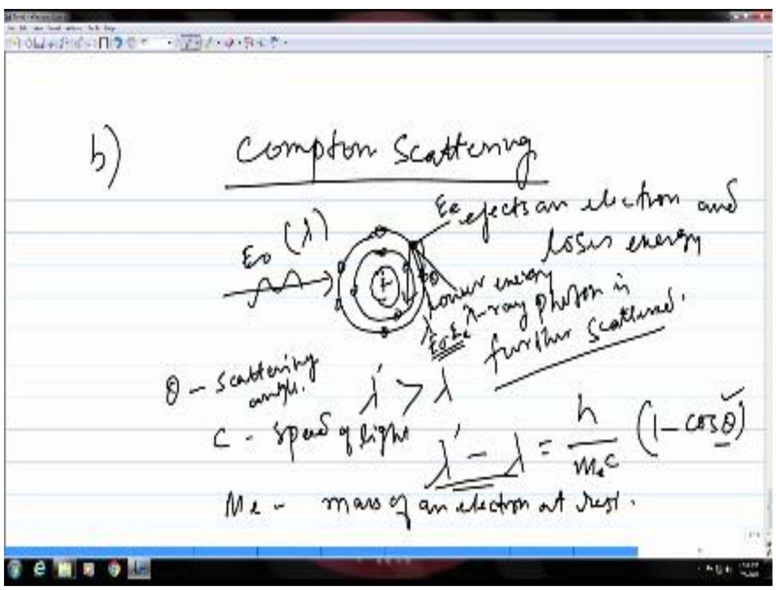

The second one that we have is known as Compton scattering, so in this case also again the x-ray photons are going to interact with the electrons in the atom. So in this case what happens the extra photon first eject an electron and loses energy in the process this low energy photon is then further scattered by the atom, okay.

So I have two different phenomena simultaneously are taking place first the ejection of the electrons and due to that process the x-ray photon loses some energy and that lower energy photon is further scattered by the atom, so if in the beginning if it is λ so this lower energy photon will have a different wavelength λ' and λ' is greater than λ because it has now lost some energy okay. So this energy balance now if you take this is this is the energy loss and this energy shaped depends on this scattering angle θ okay, it can you know get scattered again by different angles like this or like this and so on.

So how much energy it will lose that depends on the scattering angle and that is why you see this scattering angle θ coming into picture in this case, so λ in this case is the length of the incident x-ray photons λ' is the scattered wave length H is Planck's constant, m_e is known as mass of an electron at rest, c is again the usual parameter which is the spirit of light and θ is the scattering angle, so you E_e amount of energy is being absorbed by the ejection of the electrons then the remaining energy is $E\text{-}E_0$. So this energy saved as I told will depend on the scattering angle.

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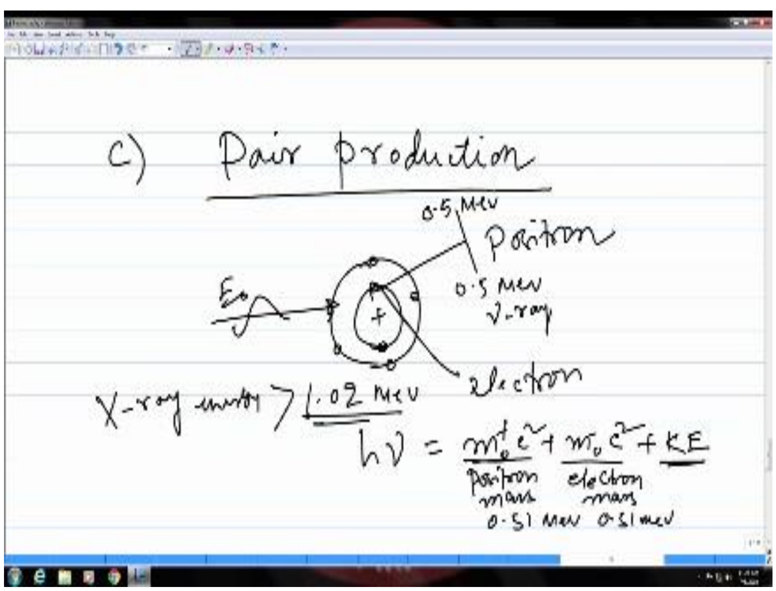

The next one is known as pair production, so in this case what happens you have the atom and the electrons, so in this case what happens when the extra photon comes in it ejects an electron and a positron pair and that is why the name pair production, okay and if you see the energy balance for this so the energy of the photon is absorbed to create this masses for the positron and the electron mass and for creating this mass the minimum amount of energy which is needed for itch is 0.51 1mega electron volt and that is why the x-ray energy in this case must be above 1.02 mega electron volt.

If pair production has to happen because that is the minimum energy needed for creating the mass for the positron and the electron okay, and any extra energy that directs I will have that will go into providing this kinetic energy to the electron and the positron, okay. These positrons are not stable so they disintegrate into two photons of γ rays of energy 0.5 mega electron voltage, okay so this is how this particular process happens.

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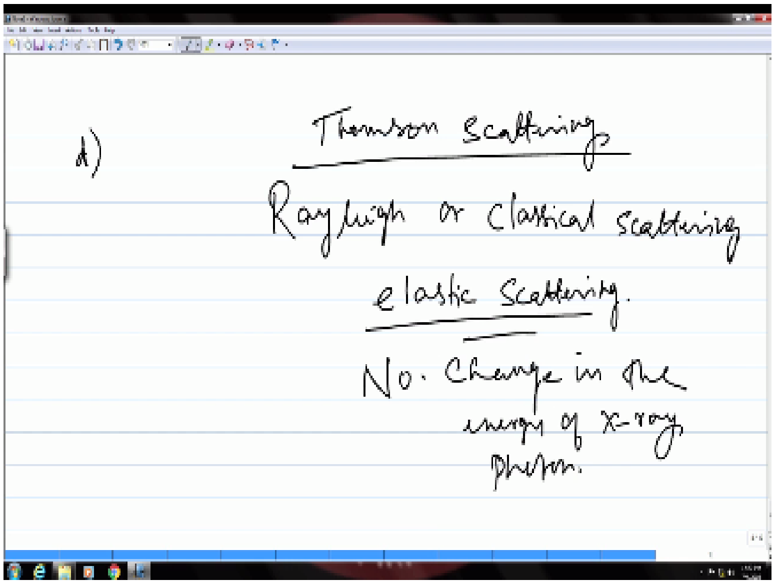

The next one that we have in this series is known as Thomson scattering this is also known as Rayleigh or classical scattering and in this case there is no loss in the energy because the scattering is elastic scattering meaning the x-ray photon does not lose any energy when it is going through the material, okay. So it just goes through without losing any energy and that is why this is known as elastic scattering as there is no change in the energy of the extra photon.

Therefore this kind of scattering event is not really relevant for radiography because radiography as we have understood by now is based upon some amount of absorption into the material which gives you that contrast that you see on the radiographic image.

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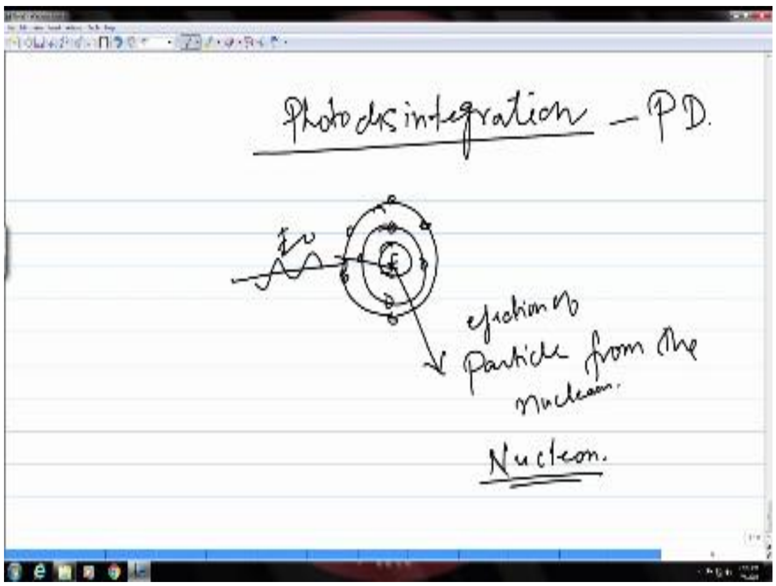

And the last one that we have is known as photo disintegration, so if you have very high energy into the x-rays they can penetrate through the atomic orbitals and go all the way down to the nucleus, so in that case instead of interacting with the electrons of the atom the x-rays can interact directly with the nucleus, okay and in the process they will eject a particle from the nucleus which is known as a nucleon, okay.

So in this case what happens if you have higher energy as I said the x-rays can penetrate through the electrons and go all the way to the nucleus and from there it can eject a particle from the nucleus and this particle is known as nucleon and this can happen when the x-ray can have enormous amount of energy okay, and because of this enormously high energy which is needed for this process this is again not relevant for practical radiography because that kind of x-ray energy levels are not generally used in the x-ray source which is used in radiographic testing, okay.

But if you have energy in that level this kind of phenomena can happen which is known as photo disintegration or in short it is also known as PD, okay. So these are the different types of phenomena that can happen inside a material when the x-rays pass through it and because of all these scattering events some of the energy of the x-ray will be absorbed by the material and that is how it forms the basis for redeveloping testing as we have already discussed before, okay. So with this I am going to stop here today the rest of the things that we have for this technique will be discussed in the next few lectures in the coming days so for today I will stop here, thank you for your attention.

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