Electro Magnetic Field

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Lecture - 39
Reflection at Dielectric boundaries

Good morning. Last time I had introduced the phasor version of point theorem. And then I had stated where the looking at what happens to waves then they enter a lossy dielectric. Now, we looked at the wave in vacuum, and we have looked at the wave in a good conductor, and this is the third case which is the wave in a bad conductor. So, we still have your wave equation.

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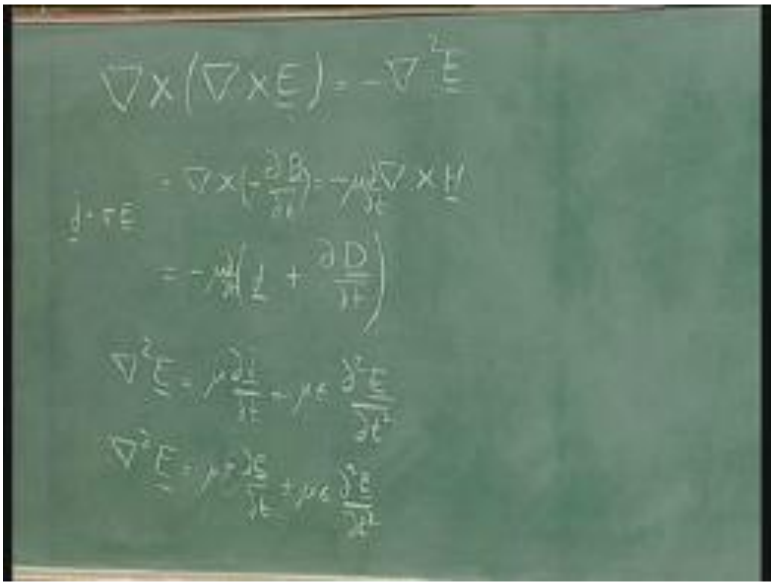

And the wave equation is still curl of curl of E which is minus del squared E, but applying Maxwell's equations to curve of E it becomes curl of del B del t which is minus sign minus mu times curl of H. Now, because it is a material not a vacuum curl of H, gives me 2 terms the current density plus del D del t. Now, in skin effect good conductor I neglected this term in vacuum, I neglected this term. Now, what you are going to do is you want to keep both terms, and we are going to assume that this term is small compare to the other terms in the expression. So, my wave equation becomes del squared E is equal to that this del del t sorry mu del j del t plus mu epsilon del squared E del t squared either converting from E to j or from j to E we get a wave equation. Let us convert from j to E this time last time I detect from E to j. So, that gives me using j equals sigma E and substituting in here I get del squared E is equal to mu sigma del E del t plus mu epsilon del squared E del t squared. So, this is the wave equation it is it includes vacuum where this term is missing, it includes skin effect where this term is missing. And now we are going to do the full equation where both terms are present, but does I said I am going to assume sigma is small. So, this term is less important than these 2 terms.

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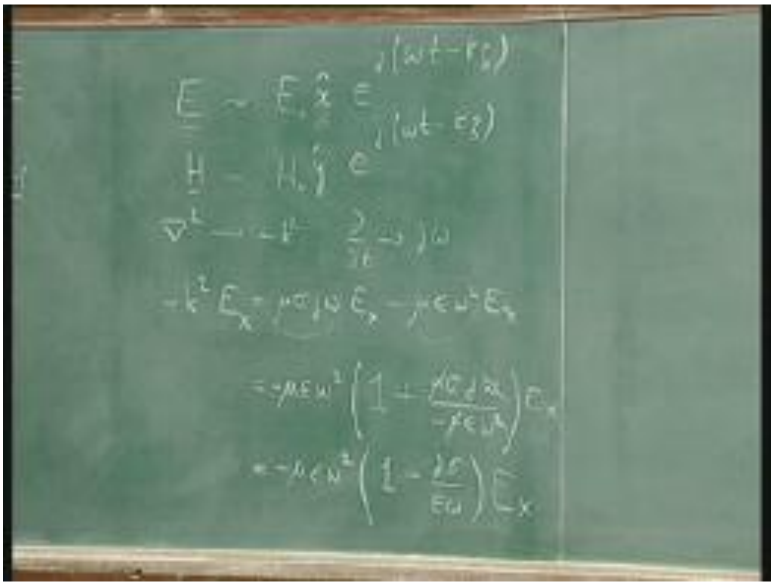

Now, I am going to look for simple waves. So, I am going to assume that electric field E is some E naught along the x direction E to the j omega t minus kz. So, the wave is going along z. So, the frequency omega the wave length 2 pi over k does an amplitude E naught along the x direction. So, therefore, H is going to be some H naught y direction e to the j omega t minus kz. By substitute this in to the wave equation what do I get del squared will becomes minus k squared. Because del del z will pull out a minus j k and minus jk squared is minus k squared del del t will go to j omega because when I differentiate with respect to t I pull out a j omega. So, substituting all that into my wave equation I get minus k squared along the E x direction is equal to mu sigma j omega E x minus mu epsilon omega squared E x. Because if you look back at this equation del squared became minus k squared del del t became j omega and del squared del t squared became minus omega squared.

So, if you look at the equation well you can always solve it, E goes out. So, you get a general expression which is k squared is equal to mu epsilon omega squared minus j omega mu sigma and you can analyze this equation. And solve it as you like, with thus a most way of looking at this equation and that is to pretend that this piece is a part of this piece itself. So, that instead of having that 2 terms I just modify 1 term in this equation. And include this effect for that what I am going to do is I am going to combine this 2 expressions. I know for my material which is a lossy dielectric this term is more important, that is to say it is a high frequency low conductivity case. So, in that case what do I will get is equal to minus mu epsilon omega squared times E x. Now, this term is just 1, because all the terms corresponding to do it or already outside its 1 plus.

Well, for this term we will put in the numerator mu sigma j omega. But will have to divide by this term which is extra, so divided by minus mu epsilon omega squared. So, the first term will be E x times minus mu epsilon omega squared that is this term the second term the denominator and enumerator cancel. So, it will be E x type mu sigma j omega which is this term. So, I will cancel out of this few terms there. So, that becomes minus mu epsilon omega squared times 1 minus mu cancels 1 factor of omega will cancel. So, that it leads me with j sigma divided by epsilon omega times Ex. Now, I have done here except collect terms, but I do know that this term is small. Because I have a small sigma and large omega and what I am going to do is I am going to absorb it in 1 of these material constants, by conversion it absorbs into epsilon.

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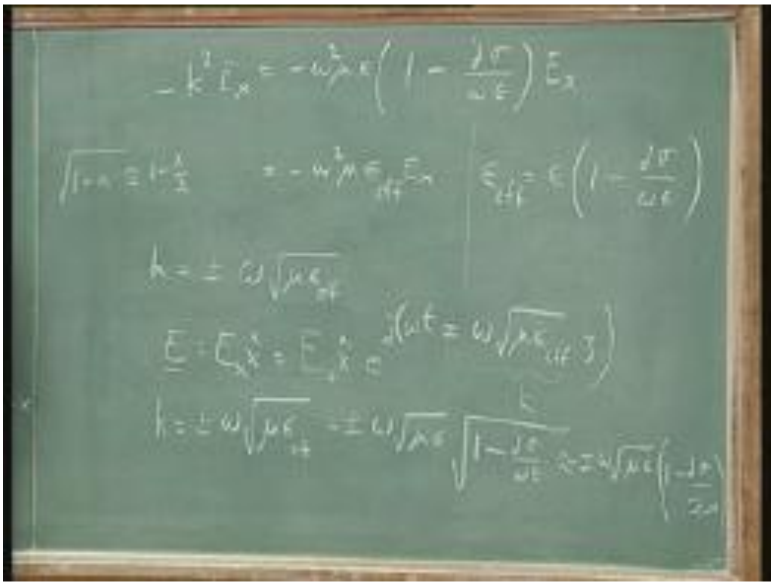

So, I am going to write this equation as minus k squared E x is equal to let me rewrite this minus omega squared mu epsilon times 1 minus j sigma by omega epsilon. And E x is equal to minus omega squared mu epsilon effective time E x where what is epsilon effective? Epsilon effective is the real epsilon times 1 minus j sigma over omega epsilon is just a convenience this nothing in this equation that is not there in this equation there is nothing in this equation there is not there in this equation. What we gain; however, is that this equation we know fully we have already looked at it, you know all about it.

Since, we know all about it we know that the answers can be written down simply. We know that this will give me an answer which says that k is equal to plus minus omega square root mu epsilon effective. So, if I know my frequency I can calculate k and in that case I know my electric field, because electric field E is E x along x which is E naught along x direction e to the j omega t minus, but I have the plus minus here. So, I will put minus plus omega root mu epsilon effective z. So, for given omega I know how the wave depends on z and this is nothing but my expression for k.

Now, we have not achieved anything I mean wave hidden all the complication in epsilon effective. So, what I we gain well we only gain if this term is very small. Let us suppose this term is very small when I can simplify this expression. That is I can say that k which is equal to plus minus omega root mu epsilon effective is actually equal to plus minus omega root mu epsilon epsilon effective. I am writing out times Square root of 1 minus j sigma over omega epsilon. If this is very small I can do a binomial expansion square root of 1 minus x is equal to approximately 1 minus x over 2 that is its 1 minus x times the power of the radical in this case square root is power half. So, half comes out there are other terms this is binomial expansion, but we are assuming x. So, small only the first term is important. So, I can write this as approximately equal to plus minus omega root mu epsilon times 1 minus j sigma over twice omega epsilon that same factor of 2 has come out. What I we gain? Well, what we have gain is the following and write it on the board itself, so that you can see.

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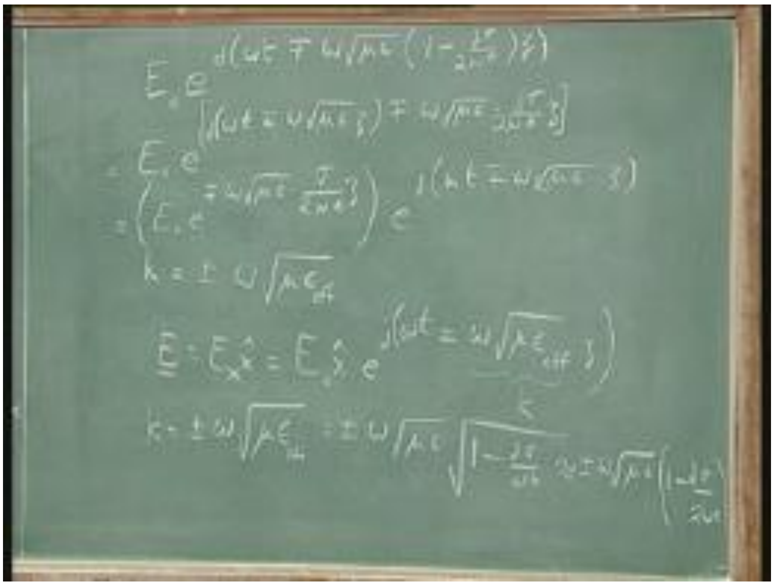

So, the electric field is along x it some E naught e to the j th omega t minus plus omega square root mu epsilon. Now, we write this piece out times 1 minus j sigma over omega epsilon the factor of 2 in the denominator times z. Now, I am going to take this 2 term apart and let us write it out separately its equal to E naught e to the j omega t minus plus omega root mu epsilon z. And then I have this term which is minus j squared j squared is minus 1. So, minus j squared is plus 1. So, I just have the minus plus coming out, omega root mu epsilon times j sigma over omega epsilon twice mu epsilon z. All of this is in the exponent of the exponential sorry there is no j there j has been removed I had j here j there. So, j squared was minus 1 this minus absorbed that. So, this is pure real whereas, these are imaginary terms.

So, what I have is a wave whose amplitude is E naught there is a phase term which represents the wave and now, I have the real exponent coming out into the equation. So, let me combine the real exponent with E naught. So, I get its E naught e to the minus plus omega root mu epsilon. Now, this omega where cancel actually well I will write that out first sigma over twice omega epsilon z times e to the j omega t minus plus omega root mu epsilon z. This is the wave as we normally know it omega t minus plus kz, but there is a new term here and this new term has come because of this sigma over 2 omega epsilon term. Now, you can simplify this term by canceling out omega and by bringing the epsilon into this square root. Now, I am going to do that in place.

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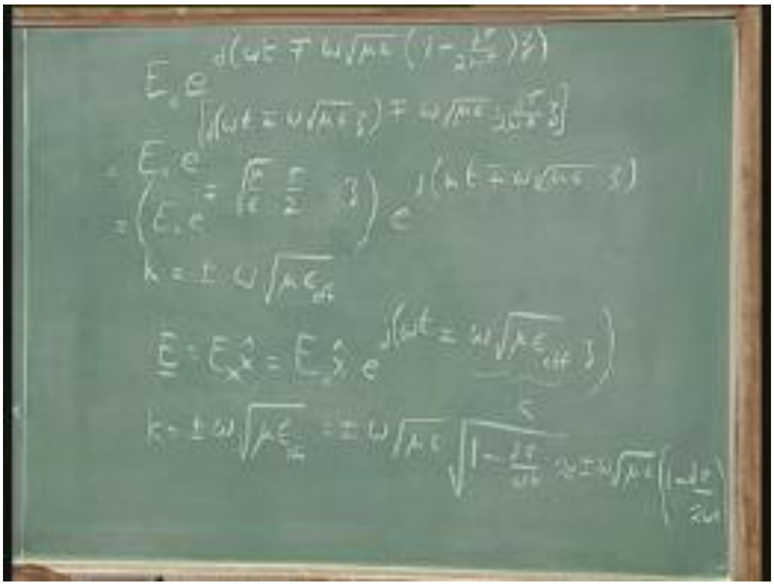

So, I am going to cancel the omega and the square root of epsilon over epsilon is 1 over square root of epsilon. So, this piece is going to become square root of mu over epsilon and sigma over 2 z. So, the omega cancel the mu came out, square root of epsilon over epsilon became a square root of epsilon in the denominator and the factor of 2 is done. So, this exponent does not depend on omega. It does depend on sigma and it depend on the material properties of the media, and you see there is a minus plus to it. So, if I drew this wave, what does it look like?

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Now, if I had a wave with uniform amplitude, amplitude that did not change. I can imagine drawing it like this the uniform amplitude this is z. So, the amplitude remains constant in z. If I took the minus sign here, whenever I have an amplitude that did this that is the amplitude is decaying with z again this is z. If I took the plus sign in this exponent then I am going to starts small it will grow this is now a case where a amplitude grows. That because e to the power of plus x grows with the x E to the power of minus x decays with x.

So, I have a wave whose envelop whose general whose amplitude is either increasing with z or its decreasing with z. But it is the big confusing, because the energy in a wave is whatever we put into it, how can the amplitude increase? I can understanding its decreasing it gives up energy to the medium because of E dot j due to the sigma. Therefore, energy went away therefore, the wave decreased in amplitude, but how can the wave increased in amplitude? Yet both solutions are there is the decreasing solution there is an increasing solution. Well, the answer is not complicated it just has to do with which sign is associated with which sign here.

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Now, if you go back and look they were all together here. So, I could have chosen 1 of the 2 signs at the beginning. So, let say I choose minus in that case I have got E to the j omega t in minus omega square root of mu epsilon z and that, I have also got minus square root of minus epsilon sigma over 2 omega epsilon. So, it means that this minus sign goes with this minus sign and this plus sign goes with this plus sign.

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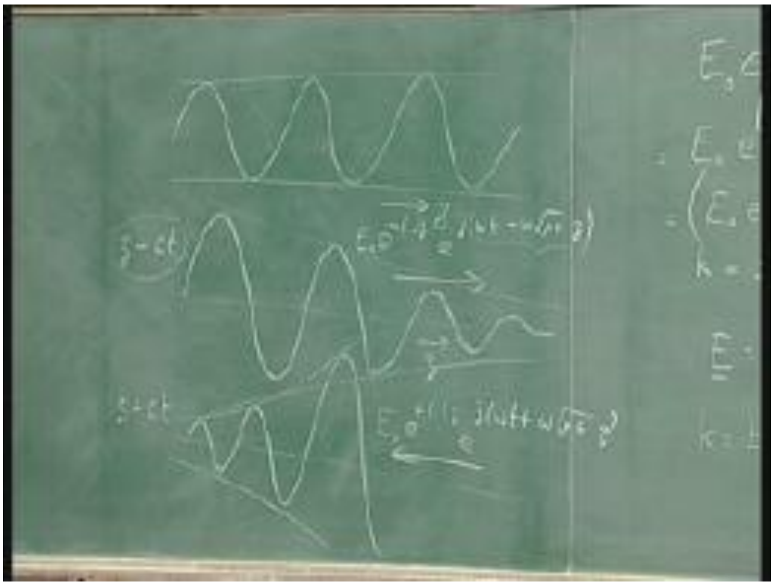

So, actually, I have 2 separate solutions here, and the solution that corresponds to the minus sign is E naught e to the minus something z e to the j omega t minus omega root mu epsilon z. And the plus solution is E naught e to the plus something z e to the j omega t plus omega square root of mu epsilon z. So, the plus and minus is go with each other. Why does this help? If you look at this expression you have seen this before this is the wave of the type z minus ct. And if you look at this expression this is the wave of the type z plus ct. So, for the z minus ct term I get the e to the minus alpha z by this bracket I am calling alpha, for the e z plus ct term ct wave I get an e to the plus alpha z.

Now, it make more sense, because that z minus ct wave travels in the plus z direction and as it travels it decades. The z plus ct waves travel in the negative direction and as it travels it also decays, but it is traveling in the minus z direction and therefore, it must decay in a minus z direction and not in a plus z direction. So, this growth is a fake growth it just out of the mathematics as for as the physics is of the wave is concern whichever the wave is traveling in that direction the wave is decaying, is decaying is going into the dielectric in a positive z direction. And if it happen into a negative z direction its decaying in that direction also, alright.

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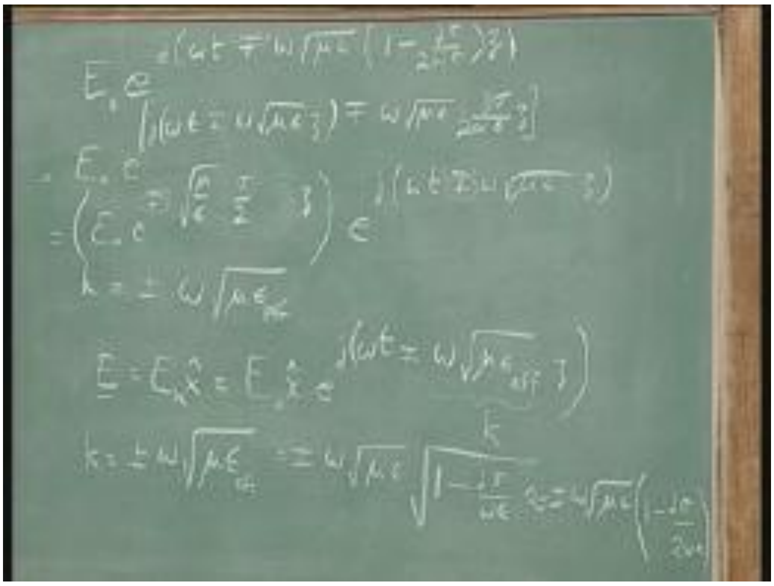

Now, this analysis that we did is a is an approximation the approximation we made was here. If we had not made this approximation you would had this general expression. For example, if sigma over omega epsilon was a order of 1. Then we could not have approximated it like this the sigma over epsilon is much greater than 1 we threw away the 1 and we will get back to the skin effect. And if sigma over epsilon is much less than 1 what we have just done is what is the requirement? But if there comparable to each other then you have to be honest, you have to do the full problem, and how does the full problem differs from this 2 problems? Actually, what is happening is.

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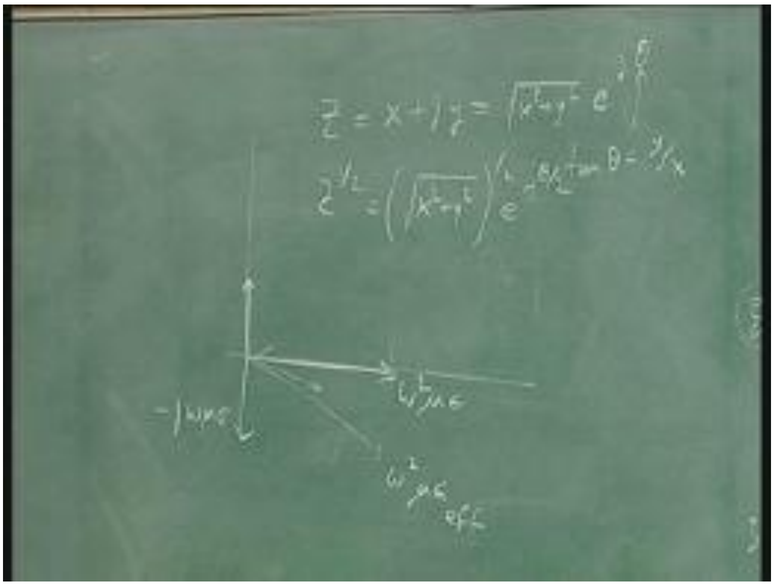

You have a term which is along the real axis which is omega squared mu epsilon. And you have the term along the imaginary axis which is j omega mu sigma. So, we have to take this 2 terms and that combination is the full term which is what we called omega squared mu epsilon effective. Now, I think I got my sign wrong because there will be a minus sign to it. So, let me draw it again, you will have the arrow down wards. So, it will be minus j omega mu sigma and you will have omega squared mu epsilon effective.

Now, when you take this square root of this, you get an answer that bisects in angle and is the square root of the magnitude. That is it if you take any complex number and you take its square root. You know that you always write the complex number as square root of x squared plus y squared e to the j theta where theta is got from tan theta is y over x. So, then z to the power of half is nothing but square root of x squared plus y squared to the power of half e to the j theta over 2. So, that is why I said the square root of this complex number is bisects this angle. So, theta becomes theta over 2 when this angle is very small.

Then the overall magnitude is essentially dominated by the real part. In which case when you take the square root it is like taking the square root of the real part itself. So, that is where we get this kind of solutions where the real part is not affected at all by the presence of the conductivity. The real part only sees the wave part of the equation, but if for example, in skin depth you have very little omega squared mu epsilon. Then you cannot really take square root of omega squared mu epsilon is the dominant part of your real part. In fact, it will be the other part j omega mu sigma that will dominate even the real part of the solution. So, this is an approximation when it is the real problem exactly, you will find that there is also a slight change in the real frequency. The main change is in the attenuation that is this term this is attenuation, but if you do the problem exactly even this term changes a little bit.

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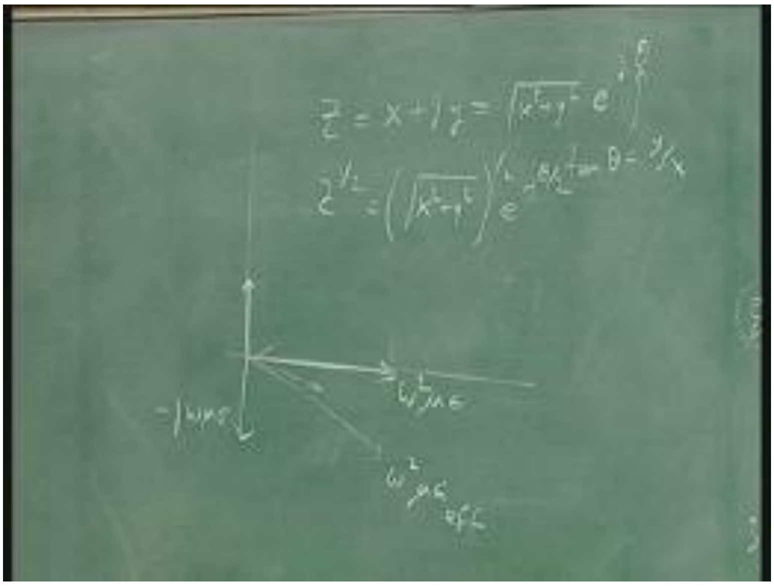

Now, when you write that expression for epsilon down epsilon is equal to an epsilon real which is nothing but the epsilon as we know it. And there is a piece which corresponds to epsilon imaginary which has you can see is in minus j direction and it is equal to epsilon real times sigma over omega and omega epsilon and is in the negative z direction. So, you put a minus sign there. So, you can see that epsilon is a complex number, and you can put and you can talk about a theta the angle that this complex epsilon makes with the real epsilon corresponding to the medium. This angle is called the loss tangent or the loss angle. And it is a important number to know because when you look at material hand books. They will not really tell you in the form that is that you will find these things in equations. They will tell you the loss angle of the material; effectively from the loss angle of the material you are getting the imaginary correction to epsilon real. So, directly you will be write down this piece.

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Now, I want to go on to a new topic now, in that topic is what happens at an interface? We now know that the wave can travel in vacuum. It can travel in a low loss dielectric and a low loss dielectric includes no loss dielectric as well sigma where 0 the same equation would applied. And it can travel in a good conductor that is a skin effect, what I would like to know now is supposing the wave is traveling in a medium. Let see the medium has mu 1 epsilon 1 and epsilon 1 could be complex taking into account a low loss component to the material and its meets suddenly a second medium whose property is a mu 2 and epsilon 2. So, both epsilon 1 and epsilon 2 can include any small amount of loss, by defining an epsilon effective, question is what happens to this medium?

Again let me remind you we sort 2 limiting cases 1 where this was a perfect conductor the wave bounced one where this conductor only differed in sigma and that 2 slightly. Then you found that wave just went through. Now, you want to do the full general problem, why do you want to do it? This is the very important application imagine that this is a light wave, and imagine that this is a piece of glass. So, this could be air this could be glass then the properties of these materials air and glass would determine the amount of reflection that you get. So, for example, it is only by understanding this problem that people can make a sunscreens on your car which reflect most of the light and allow only little light to go in. Therefore, you get very little light on the inner side of the car, or you could have other kinds of effects.

For example, you could have a antiglare coatings on your glasses they again have to do with how you can play of the properties of 2 materials and prevent glare from entering the second materials. Now, we want to do all of this, you are only going to do a very limited introduction to this problem, but I want you to understand what goes into such designs. So, you have some light entering some electromagnetic wave entering some of it is going to reflect some of it going to transmit, and perhaps from some further obstacles some of it going to come right back. So, you have 4 waves that are presented any interface, you have the incoming 1 the reflected 1 the incoming 2 and the reflected 2. These are the 4 waves that are present.

And of course, you do not know exactly what is happening at this interface may be the interface has the few cracks may be it has some non ideal properties. So, this interface is not known we idealize it as the perfect loss less region. Now, what I am going to do is I am going to enclose this entire region in an imaginary cylinder. I am assuming this is 1 dimensional problem that the waves are traveling only in this direction which is z. I am also going to imagine that all the waves have electric field along x which is at this direction coming out of the board is y. So, all the 4 waves have electric field along x and magnetic field along y, you can see that by saying this we are aware that there are possibility. I could as well have electric field along y and magnetic field along minus x. So, it is a these are very more detailed you can add to such a problem. Now, let us write down what pointing theorem tells us about this problem? Pointing theorem tells us that.

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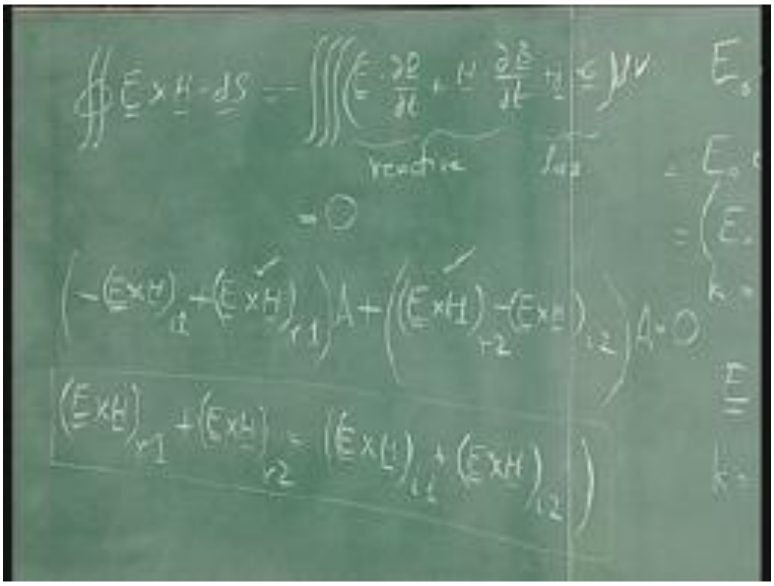

If I take the closed integral of E cross H dot ds its is equal to the negative of the volume integral of E dot del D del t plus H dot del B del t plus j dot E dv. And we looked at it last time in phasors and what we found was that if you looked at the real part of this these 2 did not contribute. That is it we have waves that are sinusoidal waves, then we can write down a phasor equation. And what we found was at these 2 pieces gave only the imaginary part. So, they are reactive and this piece was resistive or loss. If I assume that whatever is happening at this interface is not really lossy that is there is no j and I average this over 1 period. Then what I am going to get is that the whole thing is going to equal to 0. The absence of loss whatever energy I have put in here must come out there are come out here.

So, let me write that statement down, my E cross H dot ds ds points this way here and ds points this way here and ds points this way at the side walls. We can see that E cross H dot ds does not contribute on side walls on this wall. What I get is minus E cross H due to the incident 1 wave plus E cross H due to the reflected 1 wave multiplied by the area area of this cylinder must be equal. Or let me add it out plus the E cross H reflected 2 waves minus the E cross H incident 2 wave again into area must be equal to 0. There is nothing happening in the bulk of that cylinders. So, that is 0, so it must be the net of whatever is entering must be 0. So, I see 2 positive terms and 2 negative terms. So, I am going to take the negative terms to the other side I am going to let area cancel out. So, what do I get I get E cross H reflected on surface 1 plus E cross H reflected on surface 2. So, that is these 2 terms is equal to E cross H incident 1 plus E cross H incident 2 whatever power is leaving the cylinder add it up it is equal to the total power this entering the cylinder.

It is a obvious statement, I am not saying anything profound you could almost I have set it without knowing any electromagnetic theory. So, we shining a torch light at an interface with 1 volt of power going in may be 40 percent will reflect back at you 60 percent will go through. If 2 torch light where both shining each with say let 1 walt and each was reflecting 40 percent and transmitting 60 percent. Then I get 40 percent reflection from torch 1 60 percent transmission from torch 2. So, I will get 1 volt back on either side that is what this is saying it saying that reflected power is equal to total incident power. However, this particular way of looking at it very powerful. And in fact, this is how all advanced treatment of a micro wave system is handled, and the approach is called the scattering matrix. You could imagine that I did not have a torch in region 2 I had only a torch from region 1 and I send in unit among of energy, then I will get some energy back from these 2 regions.

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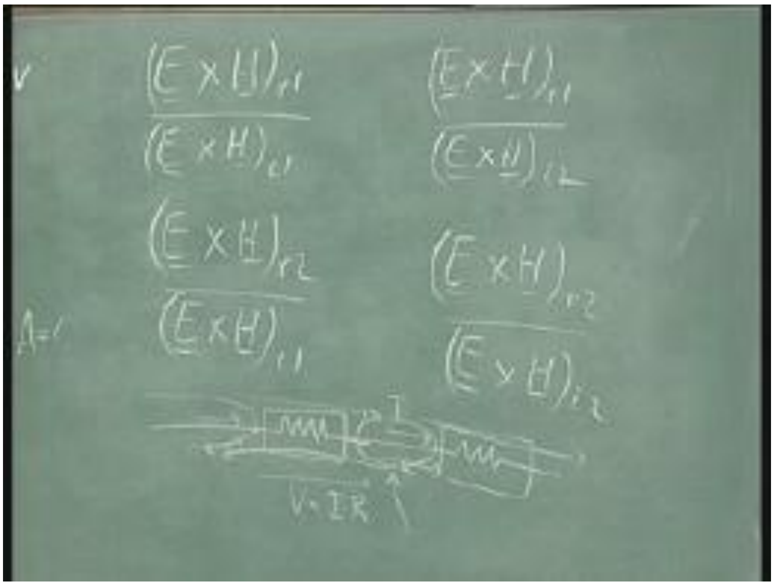

So, I could say E cross H reflected in region 1 due to E cross H incident in region 1 the same E cross H reflected in region 1 due to E cross H incidental in region 2. Similarly, I could talk about E cross H reflected from region 2 due to E cross H incident in region 1 and E cross H reflected from region 2 due to E cross H incident in region 2. So, these are 4 numbers I can come up with, they represent actually the 2 experiments first I shine a torch from the left hand side. And I measure how much reflects how much transmits, actually I do more than that I do not measure just power I measure the phase relationship. So, these are actually complex numbers if you look at number like this, this form something called as scattering matrix. The scattering matrix is exactly these 4 numbers, but they are very close to something like this.

A measure of how much is reflected due to what is incident on side 1 the same due to side 2 how much is reflected in 2 due to incident in 1 and how much is reflected in 2 due to incident in 2. And this way of looking at the problem tells us how different electromagnetic waves are from circuits. If you had a circuit and you had a lump element say a resistor. Then you know that whatever current come in would leave and whatever voltage that was here there would be some drop and so you would say v is equal to IR.

So, the battery supplying some power some amount of that power is lost in a power continues. So, the power is going 1 way there is supply of power and is just slowly getting dissipated and all the elements of the circuit. But here the power actually flows in more complicated ways some of the power from battery is actually is actually reflecting.

And if you had the another resistor in a high frequency network. What will happen is some of power will reflect some of it will transmit some will reflect of the second resistor come back some of it will transmit some will reflect again some of this energy transmits and, so an, so forth. So, you can see you will have very complicated things happening here between elements. And this is where such a formulation is used to simplify design in this you have to use this element to make something useful. You can construct very complex things as I told you can construct antiglared devices you can make polarizer. And you can make also as an interesting components out of such dielectric interfaces. So, in order to understand it properly we have to do something more complicative; however, what we are going to do is something very simple.

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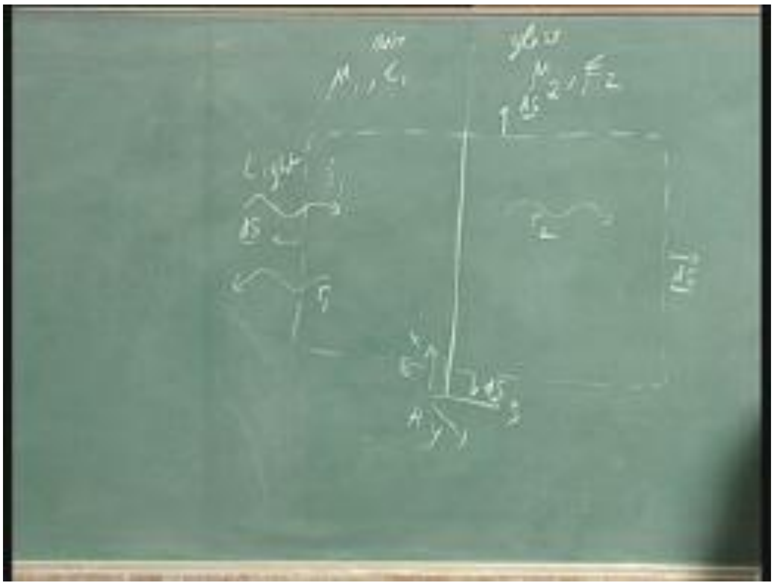

We are going to take just 1 perfect dielectric surface, and we are going to assume that we have only 1 incident wave no wave coming back at us. And we want to know what amount of the wave reflects what transmits this problem is particularly easy to do.

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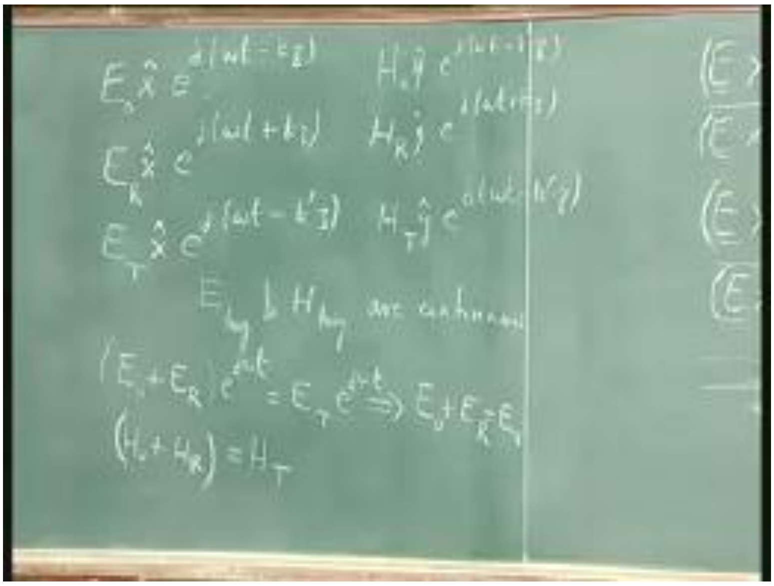

So, we have an incident wave which is E naught along the x direction e to the j omega t minus kz. Because of the minus sign it is moving in the forward direction some amount that energy is reflected I am going to call it ER also along the x direction e to the j omega t plus kz. So, because there is a minus sign is going in a plus z direction, because there is a plus sign is going in a minus z direction. And then there is a wave here also this reflected 2 wave I am going to call it is the transmitted wave. So, I will call it ET also along x e to the j omega t minus k prime z k prime, because the wave length of light in medium 2 may not be the same thing as the wave length of light in medium 1. So, I have 3 waves and corresponding to these 3 waves. I have H naught x hat e to the j omega t minus kz HR sorry this is y hat y hat e to the j omega t plus kz and HT along the y hat e to the j omega t minus k prime z. I have my e field I have my H field.

Now, I know that at this interface assuming it is a nice ideal interface E tangential and H tangential are continues. I know this from what we had discussed earlier namely, that if I draw strokes line at this interface. I draw a strokes curve and integrate H dot dl or E dot dl. I can show that as I make this very very thin the amount of the surface integral goes to 0. So, I have got that the integral on the left hand side is equal to the integral on the right hand side which is the same thing as saying E tangential and H tangential are continues. So, now, what is E tangential? E tangential at this interface the interface I am going to put at z is equal to 0 is going to be this electric field plus this electric field. So, E naught plus ER along the x direction I am going to drop this common x direction at z is equal to 0 both of them where multiplied by E to the j omega t.

So, I need to keep this z component the both into the j omega t is equal to the electric field on the right hand side which is e tangential, in the right hand side is transmitted again into E to the j omega t I can this z goes to 0. So, this term does not come I can remove the E to the j omega t. So, what I get is E naught plus ER is equal to ET a very straight forward equation this is like saying voltages is continues. It is the generalization of saying that the voltages on 2 sides of a (( )) joint are equal. Now, I want to know continuity of H. So, I say H naught plus HR same arguments is equal to HT exactly the same argument as are used for E. So, I have 2 equations the only problem is I have 2 equation in 6 unknown which is not very useful, but of course, that is not really true. Each of these electric and magnetic fields are related from my faradize law or from any other where you put it.

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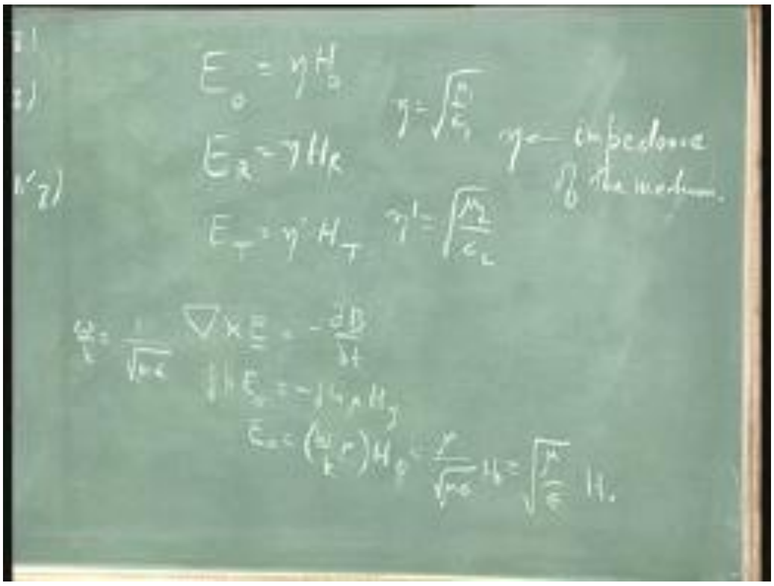

You know that the electric field E naught is equal to eta H naught ER is equal to eta HR and sorry ER and ET is equal to eta prime HT where eta is equal to square root of mu over epsilon. And eta prime is equal to mu 1 over epsilon 1 mu 2 over epsilon 2 where does this come from? It come from the fact that you say take curl of E is equal to minus del B del t then I can write this down as ik Ex, so E naught is equal to minus jk j omega mu H. I can take this I can cancel the j is out take the k that side that gives me E naught is equal to the sign is not important omega over k mu times Hy or H naught omega over k is the velocity. So, omega over k is equal to 1 over square root of mu epsilon. So, it is equal to mu over square root of mu epsilon H naught which is equal to square root of mu over epsilon H naught.

So, that is where these factors coming and these factors are called impedance of the medium. That is because if you look at it you know that well I will come back to why it is called impedance of the medium little later because it is a fairly important issue. So, I have 3 connection between electric field and magnetic field and I have 2 equations connecting this 6 quantities. So, I have 5 equations in 6 unknowns which is much better because 1 equation I know just from saying the input energy is 1 Walt. So, I can have 1 free parameter any way my torch you can shine brightly or you can shine dimly that is under my control. So, one of the quantities E naught say can be put to any value. So, I have 6 equation in 6 unknowns. Let me write out those equations E naught plus ER is equal to HT sorry ET H naught plus HR is equal to HT. Now there is 1 problem with this equation if you look at what we have done when you write down the connection between E naught and ER.

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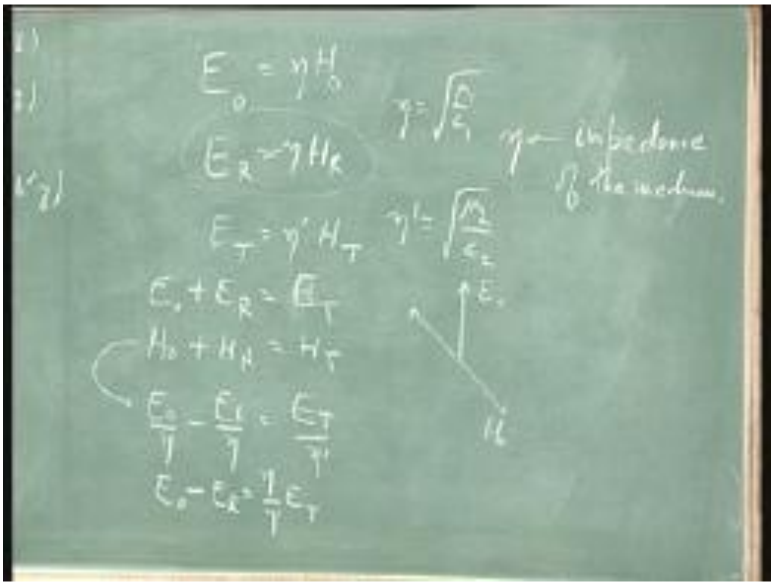

E naught is this way H naught is this way. So, when I say E naught is equal to eta H naught I mean E naught along x is H naught along y multiplied by eta. But when I connect ER and HR my H is in the opposite direction, because E cross H must be the other way. So, I need a minus sign for any reflected wave any wave going in the opposite direction must have a minus sign. So, now let me substitute for the H is through these equal and get a second equation in E is alone. So, what I get from this equation is E naught over eta minus ER over eta is equal to ET over eta prime. So, I can clear this denominator or I can write E naught minus ER is equal to eta over eta prime ET. So, I am going to write those 2 equations out just take a look at it.

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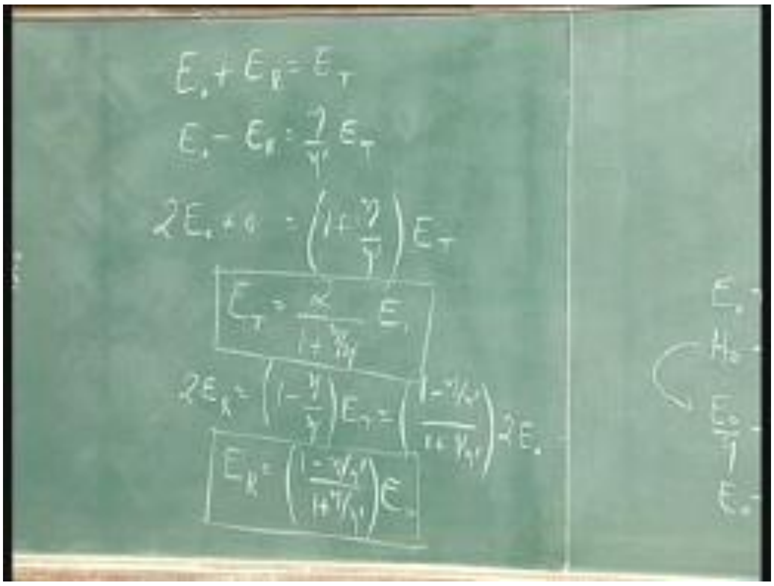

My first equation is E naught plus ER is equal to ET continuity of electric field. And then I have E naught minus ER is equal to eta over eta prime ET continuity of the magnetic field. Now, if I add this 2 equations ER will cancel out. So, I will get a relationship between E naught and E transmitter. So, I get twice E naught and just adding this 2 plus 0 is equal to 1 plus eta over eta prime ET or ET is equal to 2 over 1 plus eta over eta prime E naught. Now, what about Er? Well, let me subtract these 2 equations then E naught cancels out and I can get ER in terms of ET. So, I will get twice ER is equal 1 minus eta over eta prime ET that is I subtracted this equation from this equation. So, E naught canceled ER added.

So, you can twice ER and subtracting this equation from this equation give me 1 minus eta over eta prime ET. But ET is known this can be written as 1 minus eta over eta prime over one plus eta over eta prime time's twice E naught. So, this 2 equation allow me to solve the whole problem because it gives me ER is equal to 1 minus eta over eta prime 1 plus eta over eta prime E naught. Now, what are these equation saying will first of all let us try some special cases supposing I have the same medium on both sides, supposing the glass is really air. Then clearly mu over epsilon is same on both sides. So, eta is equal to eta prime. So, 1 minus eta over eta prime is 0 does no reflection 1 plus 1 2 this total transmission.

So, if there is the same medium is on both sides, there is no reflection all the energy is transmitting. Supposing on the other hand you have eta over eta prime going to 0 then there is only reflection and there is no transmission. I hope I got that right and I will have to verify that if I have to check the sin of that. So, you can try various different special cases. We will do that next time that is we will try the case of the super conductor. We will try the case of very good conductor and we will try the case a normal dielectric. But is all there in this equations; this 2 equation tell us how much is transmitter how much is reflected. I will stop here for now.