Industrial Instrumentation
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Lecture - 21
Problems and solutions on Industrial instrumentation

Welcome to the lesson 21 of Industrial Instrumentation. In this particular lesson, we will do some exercises. That means I will give you some problems and also we will provide the solutions. The best way to solve the problem you first do not look at the solution. First try to solve the problem and then see whether the, whatever the answer you got it, that is getting, I mean tally it with the results which we have given, right? So, we will particularly solve in this lesson the problems on the LVDT and then pH probe and McLeod Gauge. As you know, the McLeod Gauge is used for the low pressure measurements, pH is used for the, pH probe is used for the pH measurements and so LVDT, LVDT already we have covered. So we will have, solve different tops of, different types of problems of LVDT, right?

So, let us look at the contents of this lesson. So, these are problems and solutions on industrial instrumentation.

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The contents are the problems and solutions – LVDT, linear variable differential transformer, pH meter as well as McLeod Gauge, right? So, let us look at the problem.

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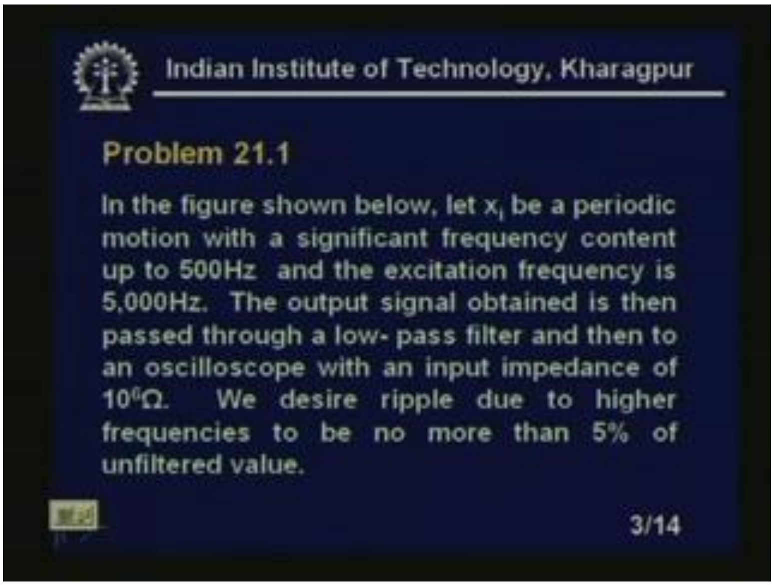

The problem 21.1, you see it is telling, in the figure shown below which will come in the slide 4, let x i be a periodic motion with significant frequency that you can see that is no problem.

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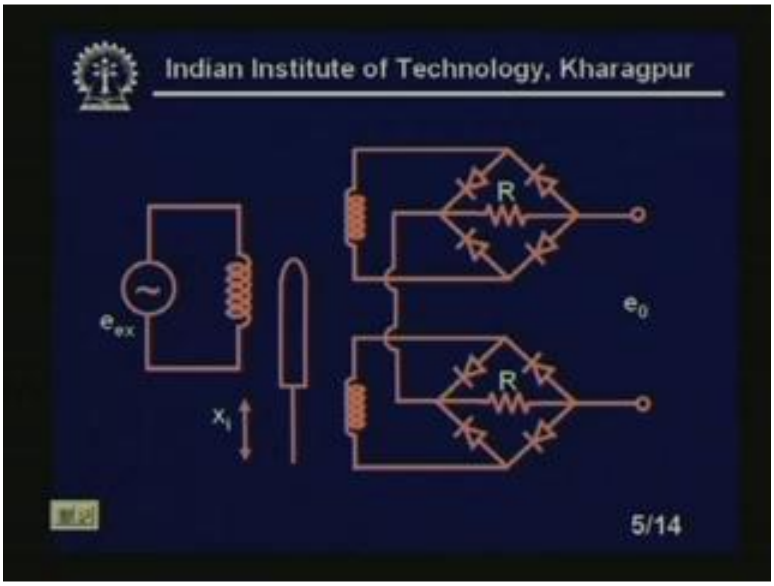

You can see here the, this is our LVDT, right, with a phase sensitivity demodulations. You see the, we have used here four diodes here, four diodes here and we have discussed this in details, right? So, we make the algebraics, I mean summation of the two voltage to get the voltage output and this is the input to the system and this is the excitation. E ex is excitations of our LVDT and x i is the input motions or the input of the system and e y is the output of the system of the LVDT, right? Let us go back.

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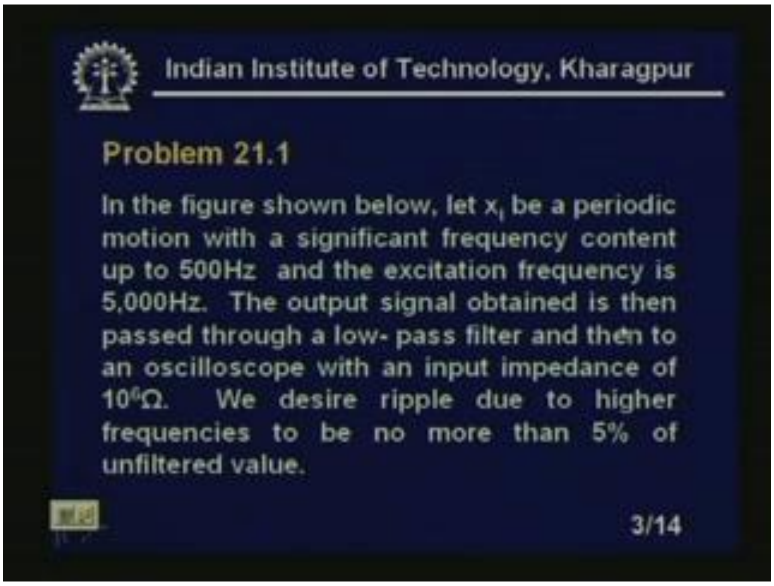

In the figure shown below, let x i be periodic motion. So, this time we are measuring the periodic voltage, I mean periodic signals, right? So, in the figure shown below, let x i be a periodic motion with a significant frequency content up to 500 Hertz and the excitation frequency is 5000 Hertz. The output signal obtained is then passed through a low-pass filter and then to an oscilloscope with an input impedance of 10 to the power 6 ohm. So, just you can see, just for the sake of problem solving you have to take an, usually the input impedance are slightly more or even 10, 10 mega ohm or more. So it is, in this case we have taken 1 mega ohm. We desire the ripple due to higher frequencies to be no more than 5% of the unfiltered value, right?

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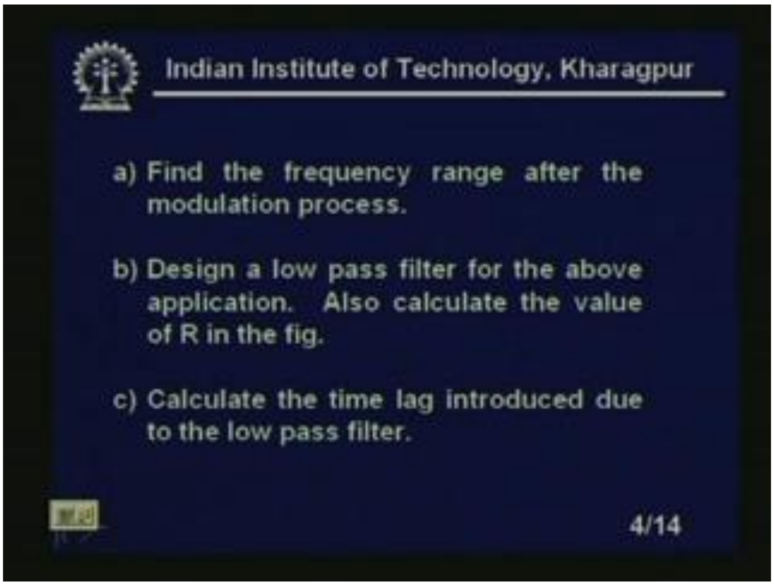

Find, number a find the frequency range after the modulation process, excuse me, design a low pass filter for the above application, also calculate the value of R in the figure. The resistance values which we have shown in the diagram that resistance you have to calculate and c, calculate the time lag introduced due to the low pass filter, right? This is our, all the problems. So, these we will solve one by one, right? So, let us see, let us look at how we can solve this problem, right?

Now, let me take a blank page, right? The diode bridge shown in the figure, as you know, act as a phase sensitivity demodulator. Now, frequency of the motion is 500 Hertz, right?

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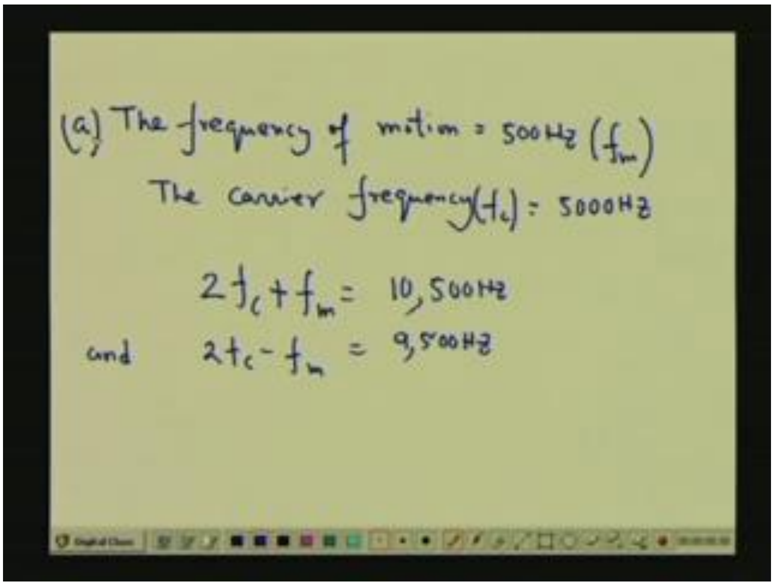

The frequency of motion, frequency of motion is 500 Hertz. This is actually is f m, right? The carrier frequency, the carrier frequency f c, this is 5000 Hertz, right and after the modulation process, other than the motion frequency we will have frequencies, two frequencies we will get. The two frequencies are two f c plus m plus f m equal to, this will become 10,500 Hertz and 2 f c minus f m, this is 9,500 Hertz, right, excuse me. Thus, we can say that the frequency range will lie within these particular signals which we have given. Now, this is a problem, I mean a, we have solved. Now let us look at the part b.

In part b, we are telling that the design a low pass filter for the above application. Also, calculate the value of the resistance R of the phase sensitivity demodulator circuit as shown in the figure, right? You see, let us go to figure, so which will be more clear. So, let us take a new, first go back, right? So, you can see here.

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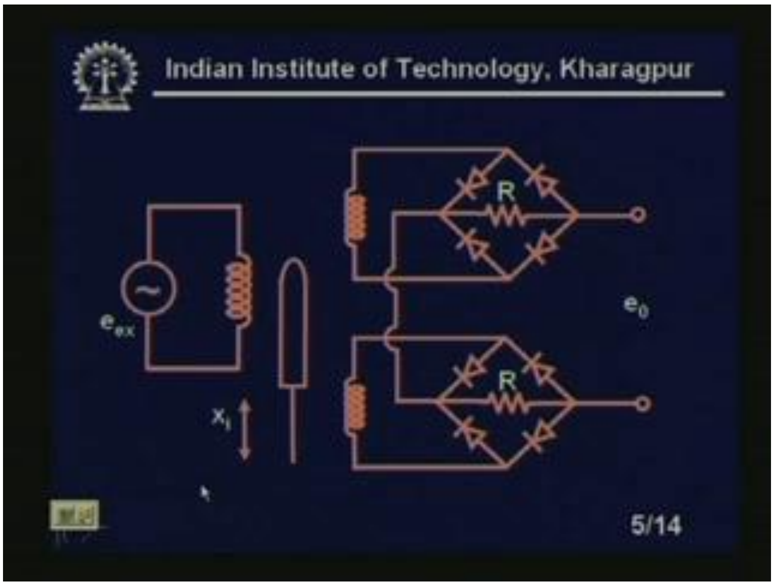

So this is our figure, so this R we have to calculate and the low pass filter, because we need a low pass filter to get the actual signals that we say movement of this one that correspond to that what is the voltage output that we will get? So, we will find that thing. So, let us take a blank page again, right? Now, in order to design the low pass filter, we first need to choose, excuse me, we first need to choose the order of the filter that will give us our desired result. Now, let us first consider a first order filter, right?

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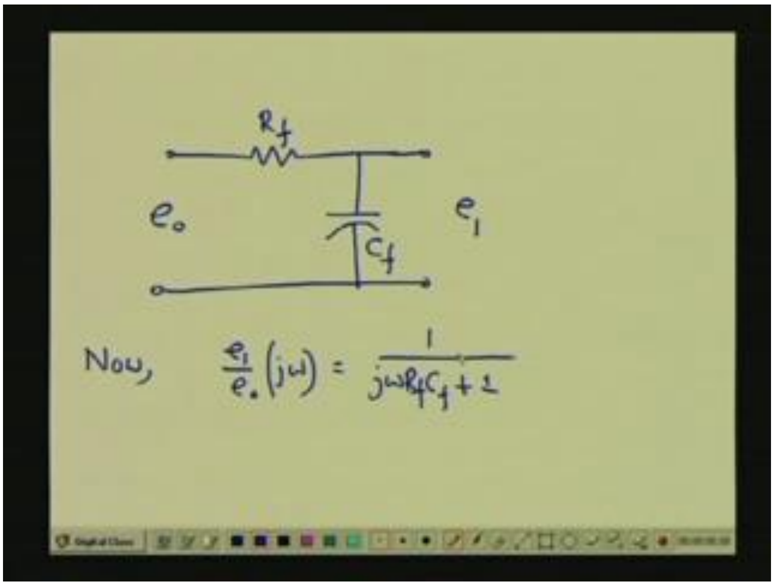

The first order filter will look like, this input is coming from the phase sensitive demodulator output. This output we are designated as e 1 and this resistance is R f and this resistance is C f, right? Let us choose that. Now, as you know we will have e 1 by e o j omega will be given by 1 upon j omega R f C f plus 1. Now, it is given in the problem that the resistance due to higher frequencies to be less than 5% of the unfiltered value. So, for higher frequencies we consider the 9500 Hertz and above. So, if it is 9500 Hertz, then obviously I can write the equation which looks like this.

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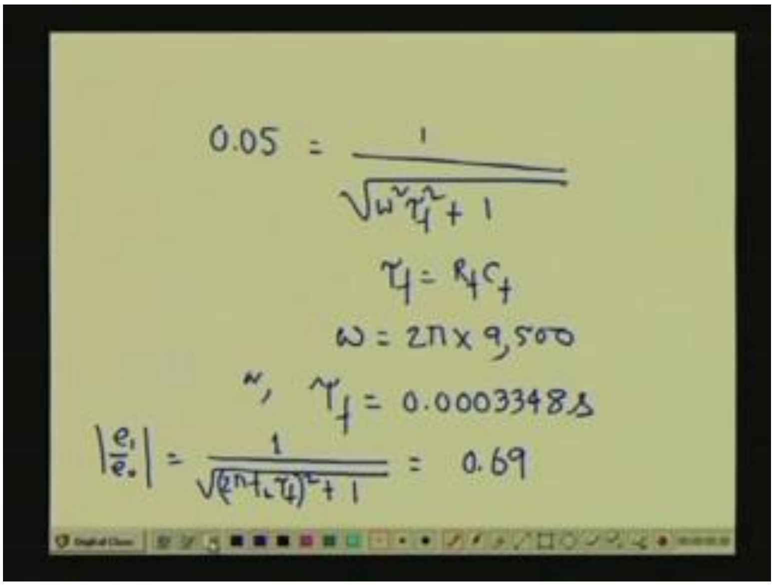

That 0.05 equal to 1 upon root over omega square tau f square plus 1, where tau f equal to R f into C f that is the time constant of the filter circuits just we have drawn and omega, obviously is equal to 2 pi into 500, right? Sorry this is, if I take, so omega is equal to 2 pi into 9500, so or tau f, the time constant of the circuit will be given by 0.0003348 second, right? For this T f we have the amplitude ratio, you know. So, for this T f, the amplitude ratio we will get that means e 1 by e o you take mod of that. It will become 1 upon root over 2 pi f m tau f whole square plus 1. So, this will give you 0.69.

Thus we see that the, that the high frequency portions of the x i will be distorted considerably, right? So, high frequency component of this x i that means the movement x i is the movement to the, our LVDT core. So, that will be distorted considerably. So this, it, inference is that this type of first order section will not be suitable for this type of application. So, let us take a second order section, right? So, if you take a second order section, it will be like this.

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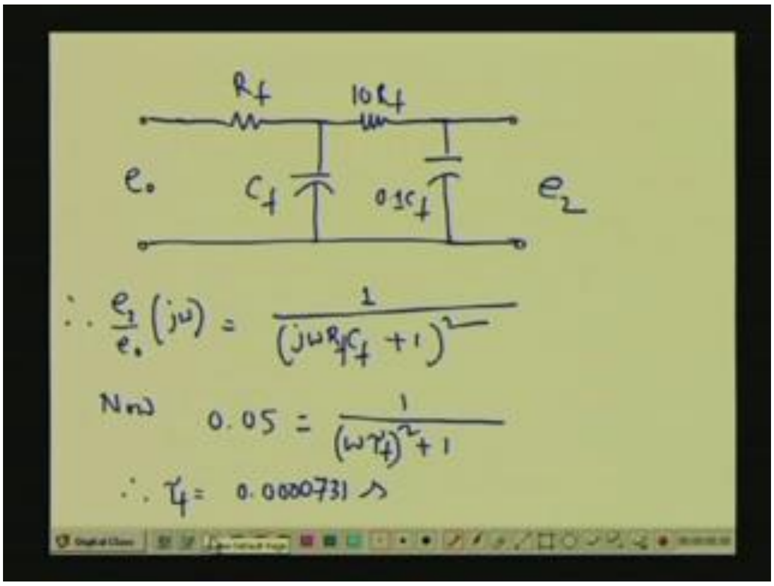

The filter will look like, these are all passive filters. So, most of the cases it will suffice, because if you use the active filter there are some advantages, as well some there are disadvantages also. This is e 2, right? This is R f as before, this is e o, this is C f. So, this is 10 R f we have taken and this is we have taken point C f, right? So, e 2 by, I can write e 2 by e o j omega is equal to 1 upon j omega R f C f plus 1 whole square, right?

Now again let us check whether this, I mean is good for my work. So, .05 that we have done before also for single order filter, omega tau f square plus 1, right, so tau f will come up as, tau f will come up as 0.00731 second, right? So, tau f will come up as, so I can write like there. So, the tau f will come up as 0.000731 second.

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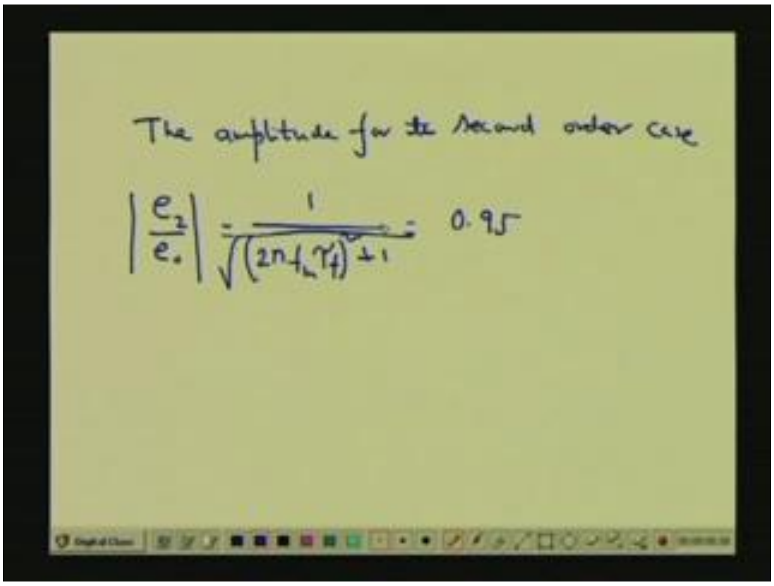

So, if I look at the amplitude ratio for the, for the second order case, so the amplitude ratio for the second order case will be, amplitude ratio for the second order case is given by e 2 by e 0 equal to 1 by 2 pi f m into tau f square plus 1. So, this will give you point, 0.95, right, clear? So, this will give you this value. I think there will be one square root here, is not it? So, this will give you the, thus you see that the amplitude ratio from omega naught will be, so the amplitude ratio 1 by omega naught, I am sorry, so actually this will be, let me write down again.

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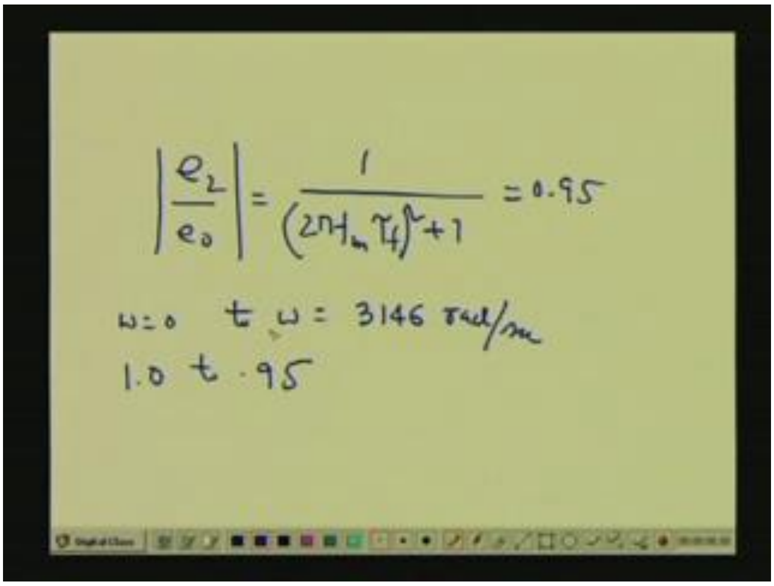

So, the amplitude ratios will be e 2 by e 0, e 2 by e 0 equal to 1 upon 2 pi f m tau f square plus 1, which will give you 0.95, right, clear? So, if this is the case, so I can say that the amplitude ratio from omega 0 to e is nearly flat. That means the amplitude ratio from omega equal to 0 to omega equal to 3146 radians per second is nearly flat. That is from 1 it will be 1 and it will fall to 0.95, right. So, it is reasonably good. Now, in order to determine the, the values of R f and C f, we use the fact that each stage in the process must have an impedance 10 times more than that of the previous stage. Now, you see the oscilloscope has an input impedance of 1 meg ohm, is not it?

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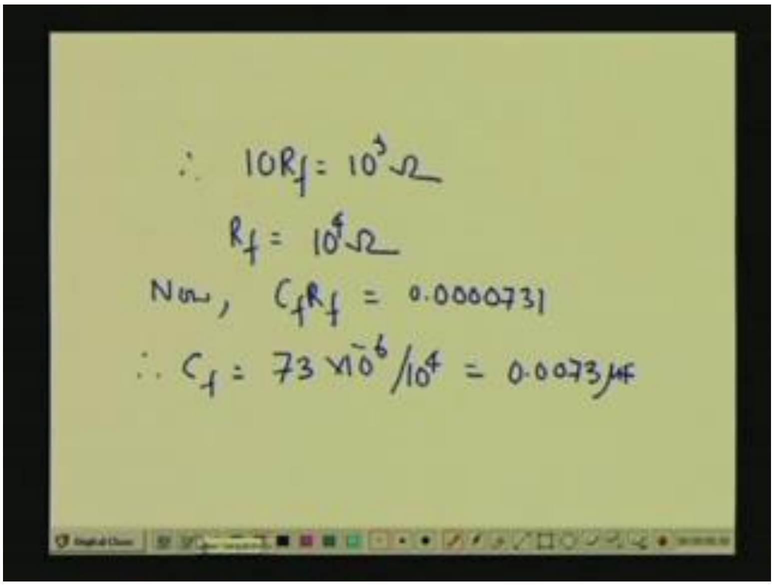

If the oscilloscope has an input impedance of 1 meg ohm, I can write 10 R f equal to 10 to the power 5 ohm. So, R f we can take equal to 10 to the power 4 ohm, right and now C f into R f equal to 0.0000731. So, C f will be equal to 73 into 10 to the power minus 6 by 10 to the power 4. So, it is coming up as 0.0073 micro farad, right? So, ultimately we get the circuit which will look like the filter circuit. Let me take a new page.

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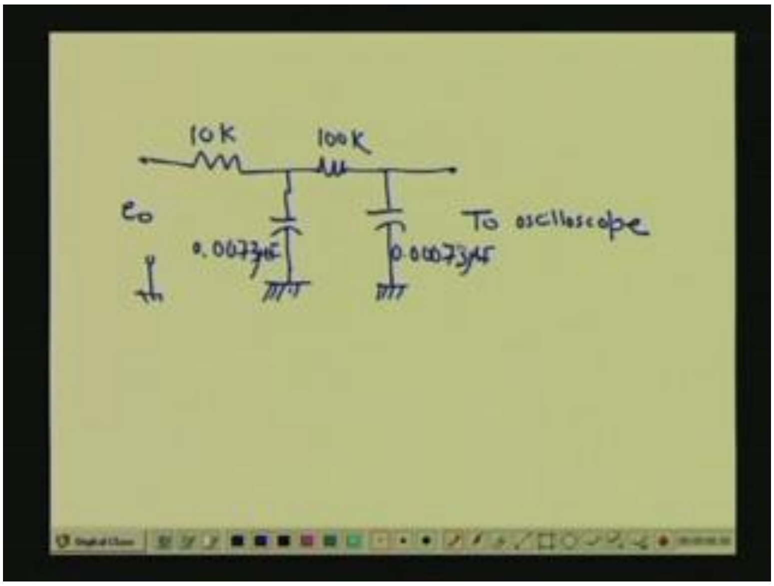

Sorry, this will be again, right, so let us go to pen. So, this will be again resistance. So, let me take the eraser again, so this is gone. So, we take the pen. So, this will be a capacitor, right? So, between this we will take the output, right? Here, I will get the input or I can say or between this and this the output from the phase sensitive demodulator will come and here the output from the, output which will go to the oscilloscope, to oscilloscope, right? The values are 10 kilo ohm, 100 kilo ohm. Then, 0.0073 micro farad, 0.00073 micro farad, right?

Now, the third part, the part c we have to find the phase angle. So, let us do that problem. Let me take a new page.

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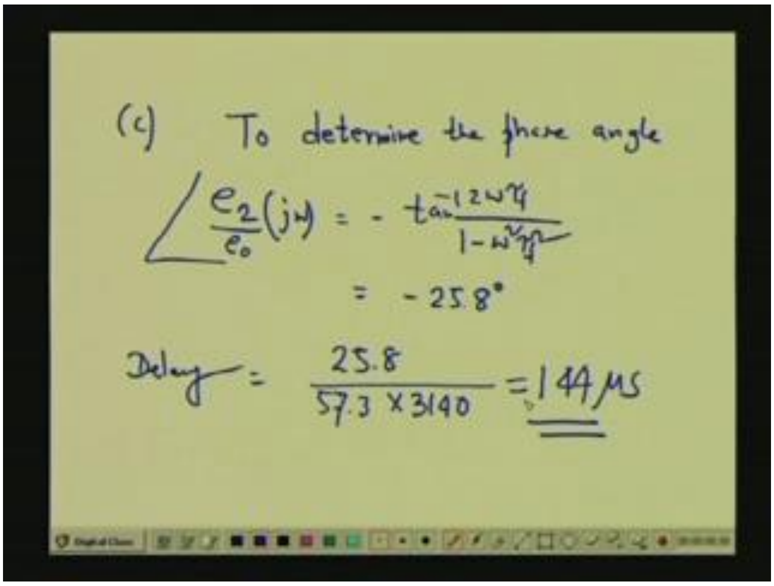

So the problem is, solution to the part c of the problem, problem 21.1, to determine the phase angle, a phase angle e 2 by e naught j omega minus of tan inverse 2 omega tau f upon 1 minus omega square by tau f square, so this will give you minus 25.8 degree, right? So, the phase angle will introduce a delay which can be computed as, so the delay it will produce will be given by 25.8 upon 57.3 into 3140, which is equal to 144 micro second. These are the, all solution to the problem number 21.1.

So, now we will go to problem 21.2 that is also an LVDT. So, let us look at that, right?

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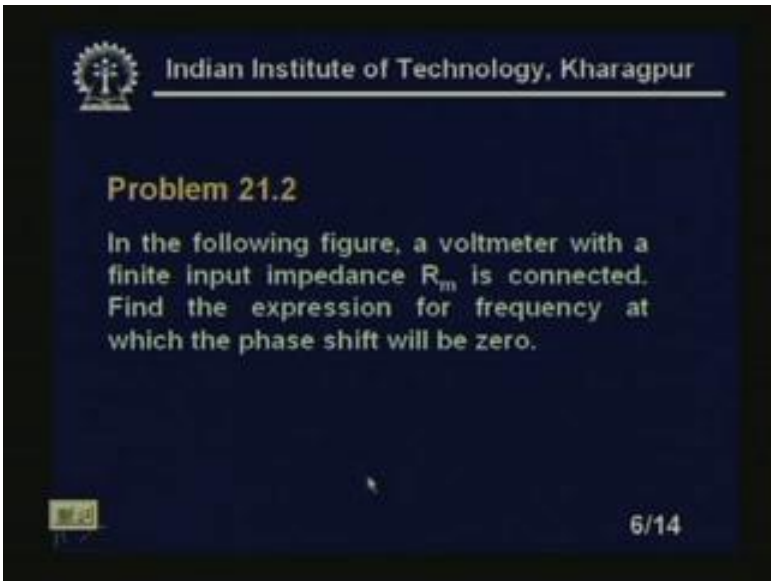

Problem 21.2, in the following figure a voltmeter with a finite input impedance R m is connected. Find the expression for the frequency at which the phase shift will be zero. In many situations this is very good, I mean, I mean problem is to know if the manufacturers also will give you some frequency, manufacturer of LVDT will give you the frequency, where the phase shift will be zero, right? So, it will be utilized, that frequency can utilized to make the input output phase shift zero. Because you see the, we have seen when we discussed LVDT to kill this phase shift we have to use lead lag network.

In the case of leading phase angle we have to use a lag network, in the case of lagging phase angle we need a lead network. So, that type of additional circuitry we can dispense off, if I use a particular frequency of signal when there is no input output phase shift, right? So, it is important in that case. So, how will I know, how will I know what is the frequency, where the phase shift will be, input output phase shift will be zero? Once you solve this particular problem 21.2, so you will find that the, we can find the frequency where the phase shift is zero. Typically the manufactures also supply this particular frequency, right? Let us go now.

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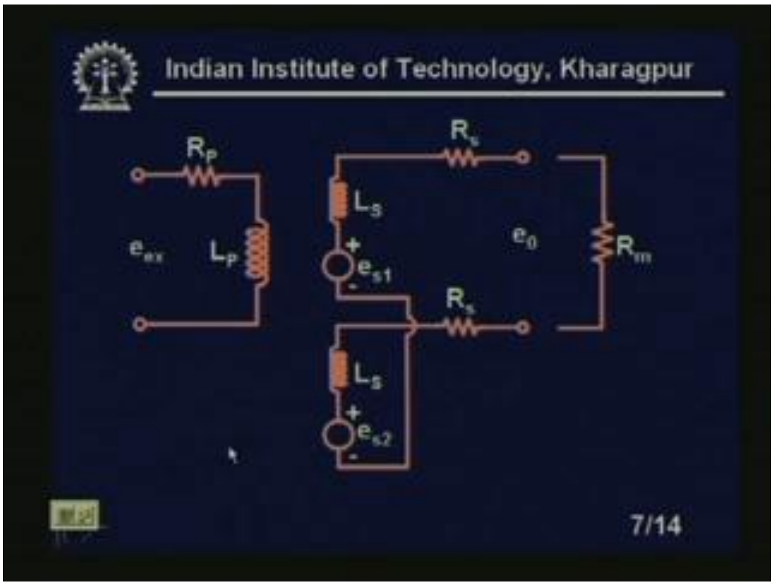

This is our circuit, so let us go back.

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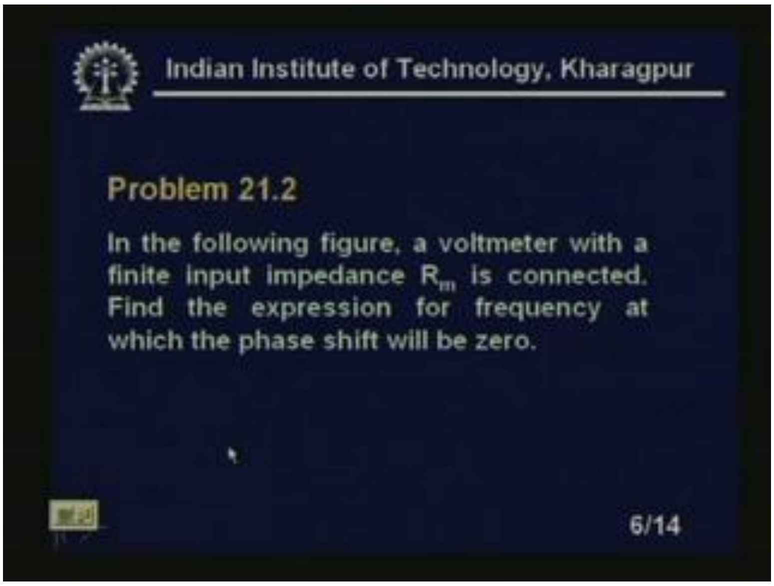

You see, this is our, in the following figure, a voltmeter with a finite input impedance R m is connected. Find the expression for the frequency at which the phase shift will be zero.

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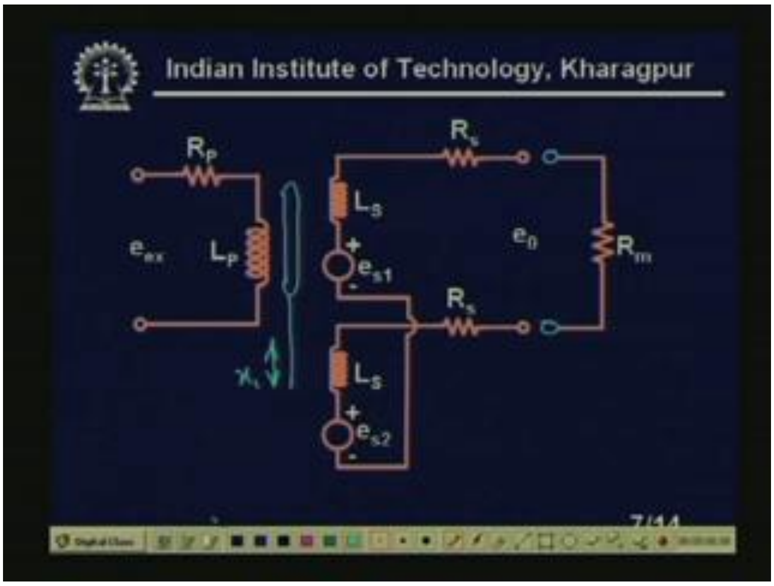

This is our circuit. You can see here, so we have connected a voltmeter here actually, see, we have connected a voltmeter here. We have connected a voltmeter here, right, to get a phase shift, I mean to measure this voltage, right? So, let us first compute, right, all the values are given. L p is the inductance of the primary side, in the resistance of the primary side. L s is the inductance of the one secondary, L s is the inductance of another secondary. So, we should have one core here which we have not shown, right, which has a moment x i, right? So, this is our problem. So, let us solve the frequency, let us find the frequency when the phase shift will be zero, right? Let us take a blank page, right? You see, what will happen here? Anyway, let us first go back to the, let us take a blank page.

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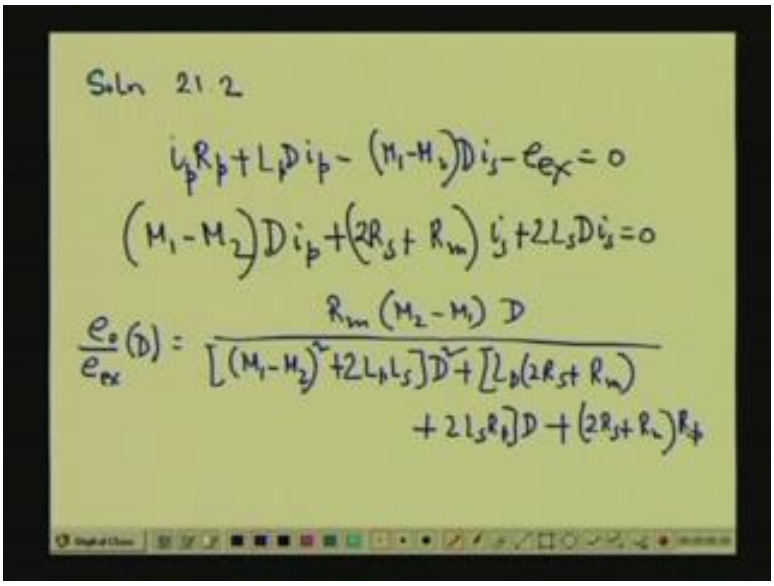

So, this is a problem number, solution to the, sorry, solution to the problem 21.2, right and analyzing the, our circuit we have seen that we can write the circuit equations like this. i p R p plus L p Di p, D is the delta operator, we have seen that thing many times before, M 1 minus M 2 D that means D means as you know d by dt, right? So, in this case you see what is that you see here? This is D means d by dt, right? So, it will be, in this case it will be di s by dt. In this case it will be di p by dt, right, right? Let us take the pen again, fine. Di s minus excitation voltage equal to zero, right and M 1 minus M 2 in the secondary side also we can write into Di p that colour, the pen colour changed, it does not matter, R s plus R m into i s plus 2 L s Di s is equal to zero. So, this will give you the output which will look like, let us take this pen, e naught by excitations D equal to R m, meter impedance M 2 minus M 1 D upon M 1 minus M 2 whole square plus 2 L p L s D square plus L p 2 R s plus R m plus 2 L s R p D plus 2 R s plus R m R p, right? Let us take new page.

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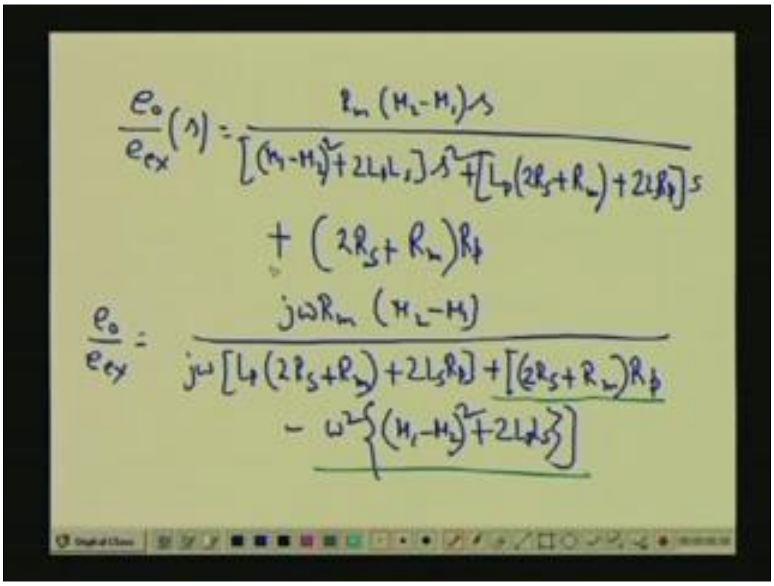

So, the e naught by e x I can write in s domain equal to R m M 2 minus M 1 s upon M 1 minus M 2 whole square plus 2 L p L s multiplied by s square, second order system plus L p into 2R s plus R m plus 2L s into R p s plus 2R s plus R m into R p, right? This equations if I write in the j omega domain, so it will look like ex equal to j omega R m M 2 minus M 1 upon j omega L p 2 R s plus R m plus 2 L s R p plus 2 R s R m … L p L s, like this one. See, now if I want to make the phase shift, input output phase shift zero, then you see that this term that means if I take a different pen, this term, this term, this term and this term will be zero. Then, j omega, j, j will cancel out. So, it will be only the imaginary parts. So, there is no phase shift between input and output. Otherwise there will be phase shift, right?

So, this entire term that means 2 R s R m multiplied by R p minus omega square M 1 minus M 2 whole square plus 2 L p L s should be zero, right? So that, obviously then I can make that I can say that to make the phase shift zero that to make the input output phase, phase shift zero, the last term of the denominator is to be zero. So, let us do that. Take a new page, fine.

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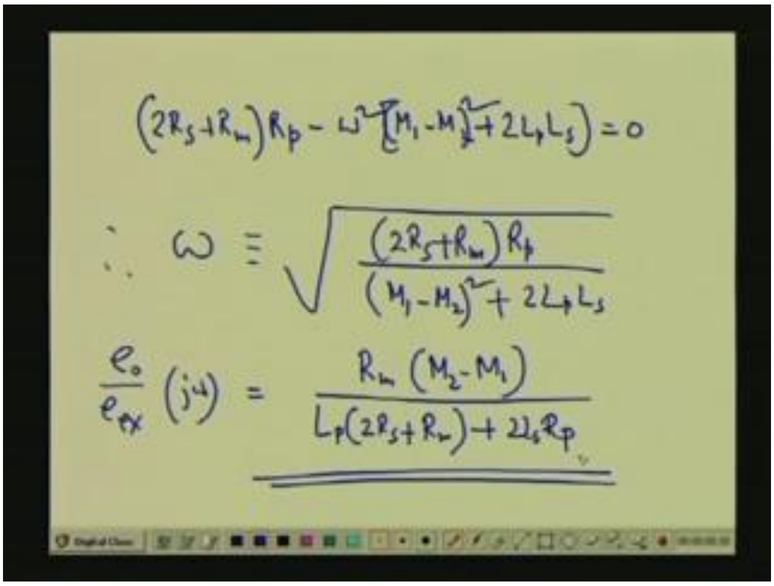

So that means to make phase shift zero I will make 2, sorry take another new page, so that to make phase shift zero, 2R s plus R m R p minus omega square M 1 minus M 2 whole square plus 2L p, 2Lp, let me take eraser that means 2L p L s will be equal to zero. Therefore, omega will be equal to root over 2R s plus R m R p by M 1 minus M 2 whole square plus 2L p L s, right? So, obviously at that frequency when there is no phase shift between input output, our input output relations will be e naught by ex j omega will be equal to R m M 2 minus M 1 upon L p 2R s plus R m plus 2L s R p, right? So, this is our final expressions, clear?

Now, let us go to the problem number 22.3, right?

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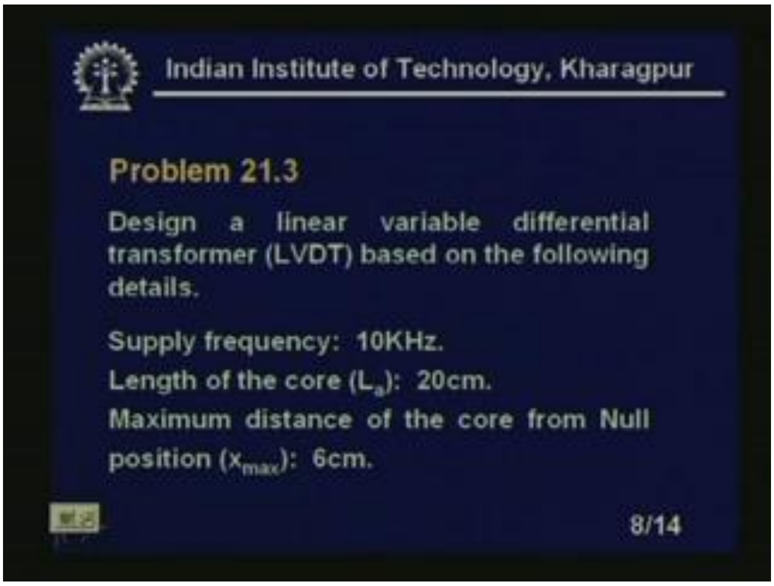

Now 21.3, I am sorry, design a linear variable differential transformer LVDT based on the following details. What are the details let us look at? Supply frequency is 10 kilo Hertz, length of the core L a should be 20 centimeter, maximum distance of the core from null position that is that means maximum movement of the core from the null position is 6 centimeter.

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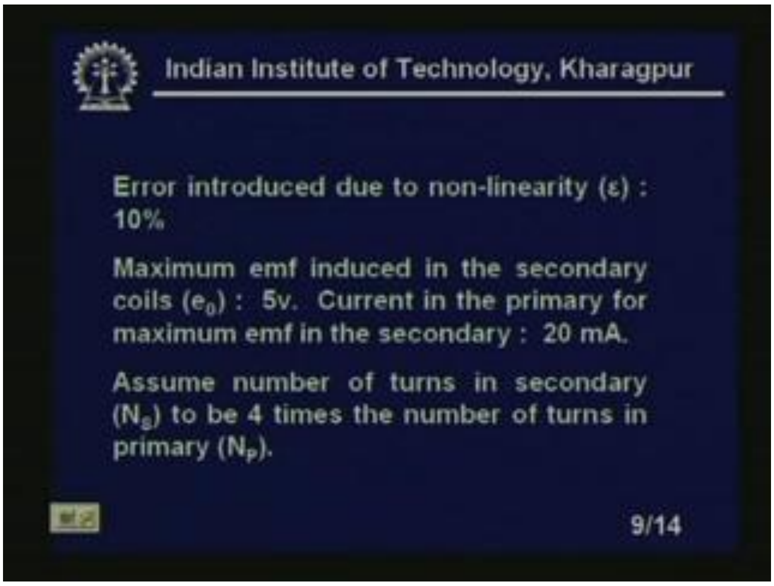

Error introduced due to non-linearity is 10%, maximum emf induced in the secondary coils e 0 that is .5 volt, I am sorry. Current in the primary for maximum emf in the secondary is fixed also, 20 milliampere. We assume that number of turns in the secondary to be the, which is the N s, 4 times the number of turns in the primary.
As you know, the number of turns in the secondary is always higher, right? So, you have to design this LVDT, right? So, let us proceed in this particular design, Let us take a blank page.

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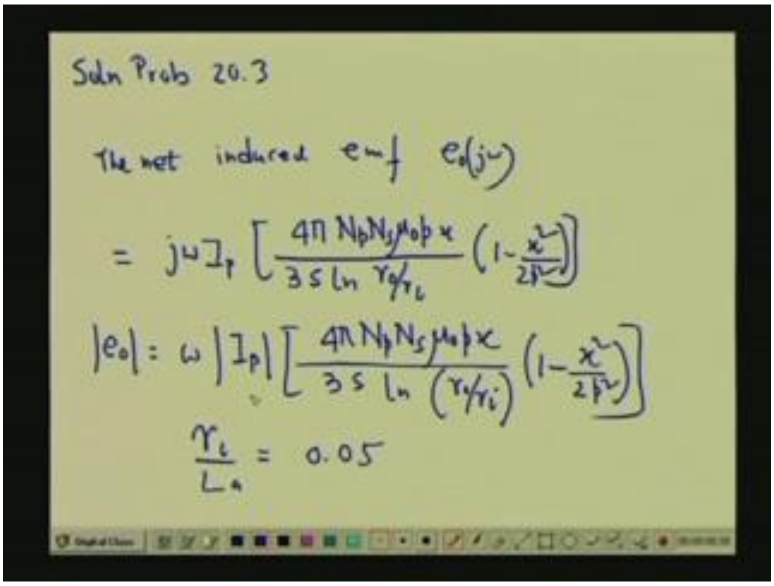

So, the net induced emf e j omega of the secondary coil is given by e j omega. So, this is the problem, solution to problem 20.3, right? So, the net induced emf, so the net induced emf, emf e j omega of the secondary coil is given by j omega I p 4 pi N p N s mu naught p x upon 3 s natural log r o by r i multiplied by 1 minus x square by 2 p square, right? Now, we have taken the standard notations for this and we can write obviously that that e naught if I take the mod of this, so this will be, we have used all the standard notations. As you know that to solve this problem we must refer to the, our, our lessons on the LVDT, right?

So, because I do not like to repeat all these notations which I have used, so if you, once the person attended to that particular lesson, he can also solve this problem. So, same notations we have used in solving the problem also, right? Now, e naught, I have, obviously I can write omega I p equal to 4 pi N p N s mu naught p x 3 s natural log r o by r i 1 minus x square by 2 p square, like this. We know from the text that the ratio r i by L a is about right is a, the ratio r i by L a, that means r i by L a typically is 0.05, right? Both are in meters or in centimeters.

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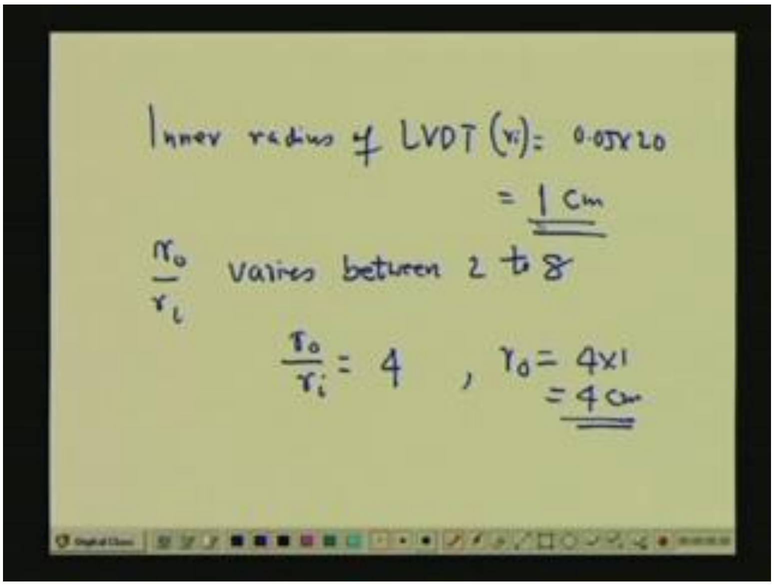

Then it is, therefore the inner radius of the LVDT assembly, so the inner radius of LVDT assembly will be that means r i will be equal to .05 into 20, because 20 is the length, already given length of the, I think primary, right? Length of the primary is 20 centimeter. So, it is coming as 1 centimeter, right? The ratio r o by r i varies between 2 to 8. So, let us take that means ratio r o by r i it is also given, varies between 2 to 8. Let us take r o by r i 4, then the outer radius of the LVDT assembly is equal to 4 centimeter, right? Now, length of the primary winding, so the outer radius let me write r o. So, since this is 1 centimeter, so 4 into 1, so it is 4 centimeter, right? Now, length of the primary winding will be given by, take a new page.

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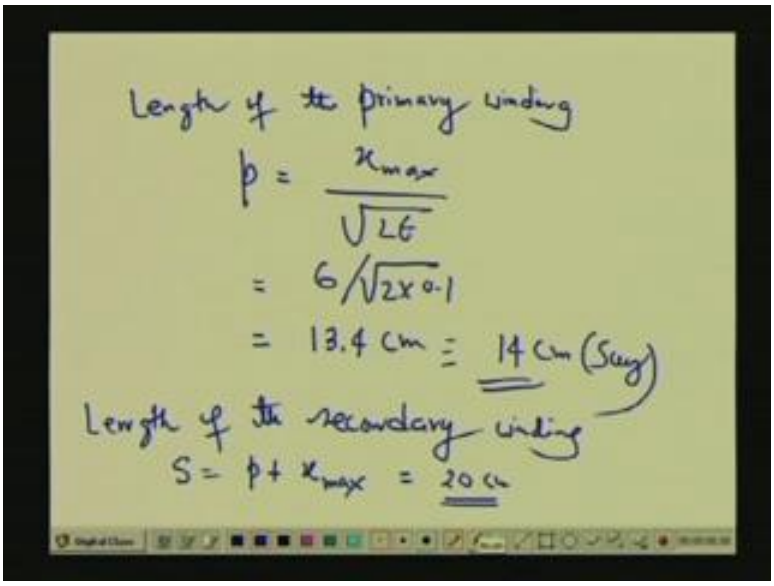

Length of the primary winding, primary winding will be equal to p equal to x max upon 2 epsilon. So, this will come up as 6 upon 2 into 0.1, right, right 2 into 0.1, where epsilon is a non-linearity, so which is we are saying 10%, right, 10% non-linearity. So, .1; so, it will give you the value of and since it is, 6 is the maximum displacement of your LVDT core, so it is coming up as 13.4 centimeter. So, let us take it 14 centimeter, right, say right?

Now, length of the secondary windings will be, so the length of the secondary winding, secondary winding S will be equal to p plus x max is equal to 20 centimeter, right, 14 plus 6, it is 20 centimeter, right?

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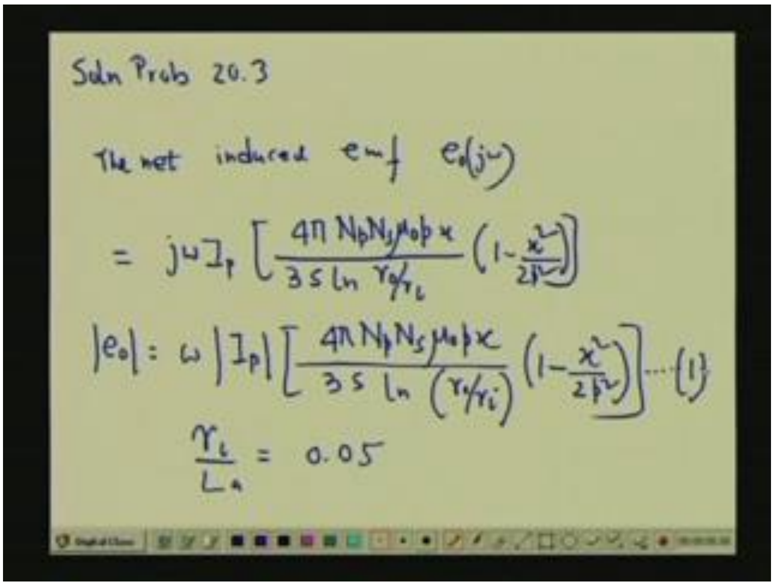

Now, in equation 1, if I go back, the equation 1 means that the, which is a mod 1, right, see if I go back whether you can see, yes so this is the equation 1, right? So, so the equation 1, let me take a new page.

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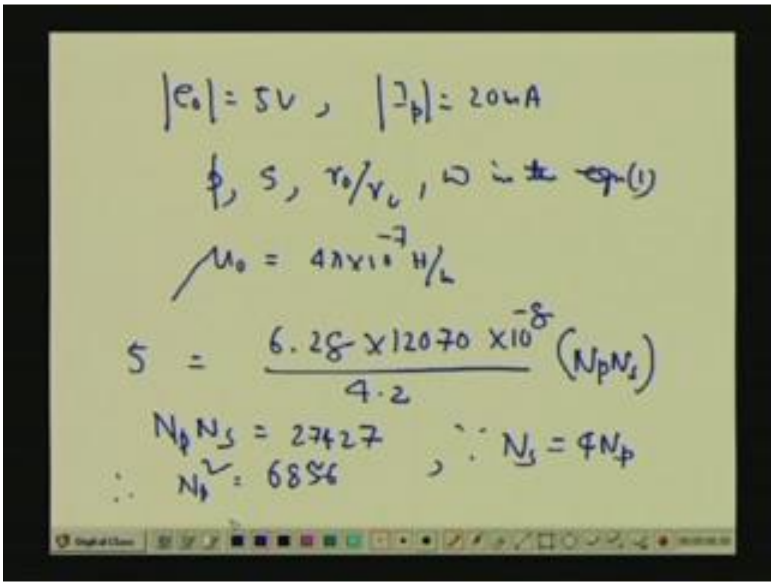

Now from the equation 1, when e naught, mod of e naught equal to 5 volt, I p equal to 20 milliampere, putting the values of p, s, r o by r i and omega that means putting the value of p, s, r o by r i, omega in the equation 1, equation 1 and noting that the maximum emf is induced at the maximum distance from the null positions, we find that taking permeability of the free space as mu naught as 4 pi into 10 to the power minus 7 Henry per meter, so we will get the, the value of, we can write down that means in the left hand side if e naught is 5 volts, so 5 volt it will come up as six point, after plugging in all these values p, s, r o by r i, omega in equation 1 and putting mu naught equal to 4 pi 10 to the power minus 7 Henry per meter, we will get, on the left hand side we will get 5, because e naught is 5 volt.

That will be equal to 6.28 into 12070 into 10 to the power minus 8 upon 4.2 N p N s, right? Now, N p N s we will get 27427, right or because N s we have given that N s is equal to 4 times of N p it is given already, right? So, I can right that N p square I will get equal to 6856, right?

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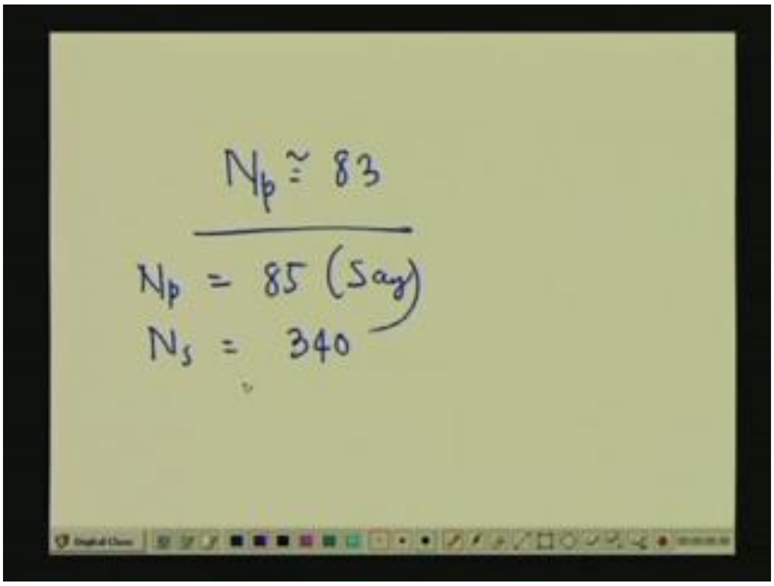

So, Np will be equal to, so N p almost equal to 83, right? We take N p, now we take N p equal to 85, say and N s we have taken equal to 4 times, 340, right? So, if I write down all the design parameters of the LVDT which have we have designed, so it will look like this.

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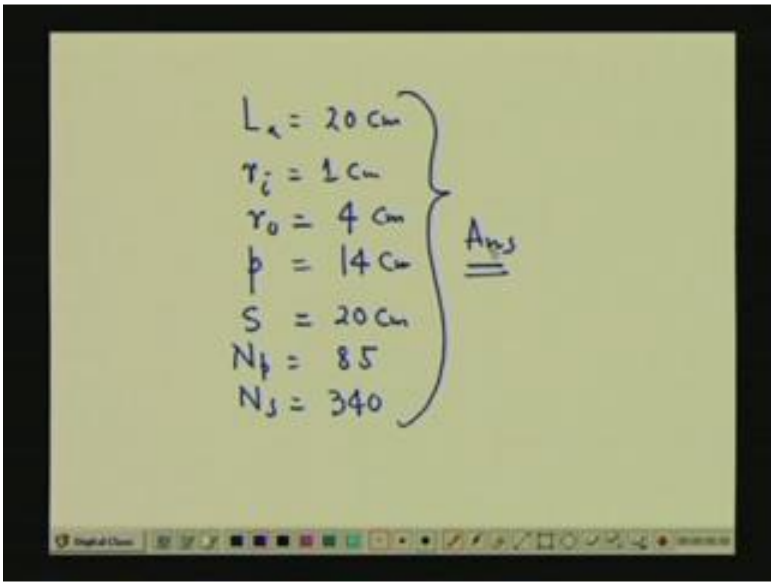

So, complete design of LVDT L a equal to 20 centimeter, right? r i equal to 1 centimeter, then r o equal to 4 centimeter. Then, p primary length 14 centimeter, s is 20 centimeter, number of turns in the primary is 85, number of turns in the secondary is 340, right? So, this is a complete solution to the problem number 12.3, right?

Now, let us do one problem on the pH meters. We have solved the problem on the pH meter, we have already done pH sensors in the lesson, I think 20. So, we will solve some problems on the pH also. Let us go back.

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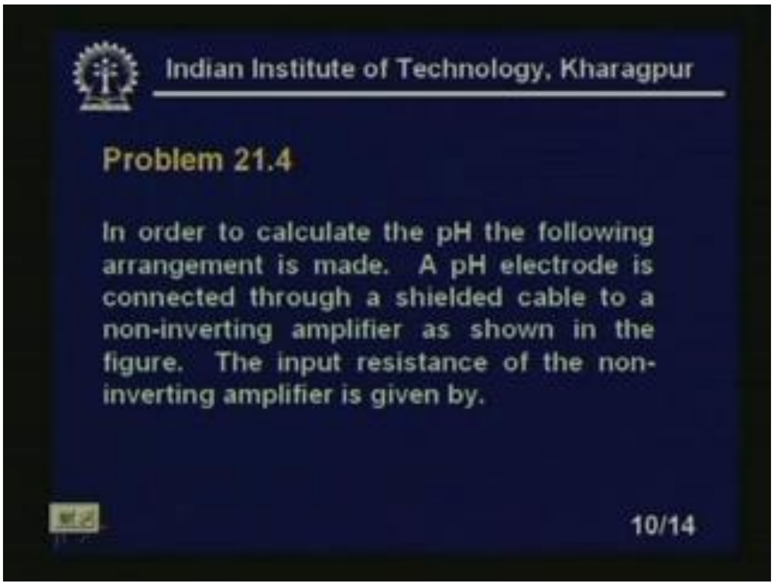

Problem number 21.4: the problem is in order to calculate the pH, the following arrangement is made. A pH electrode is connected through a shielded cable to a non-inverting amplifier as shown in the figure, we will show the figure.

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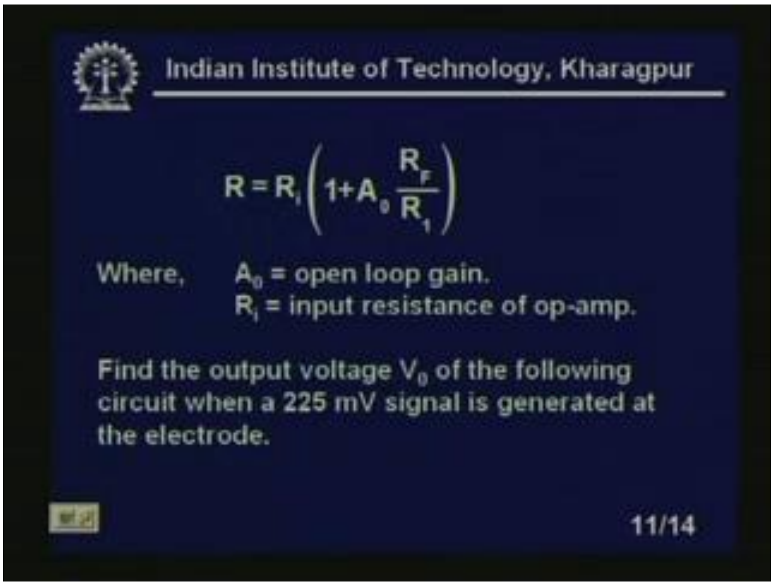

The input resistance or impedance of the non-inverting amplifier is given by R equal to R i 1 plus A naught R f by R 1. Everything will be clear in the circuit, so let us go back.

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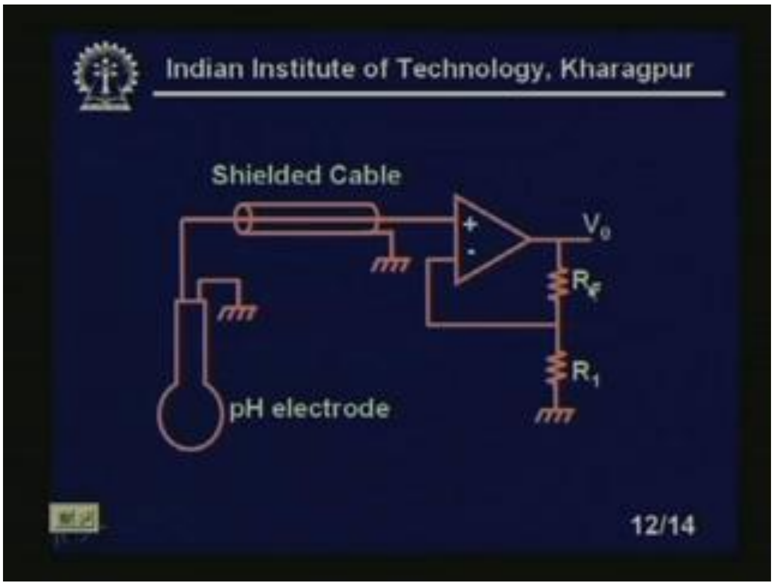

Let us look at the circuit once again, R 1, R f.

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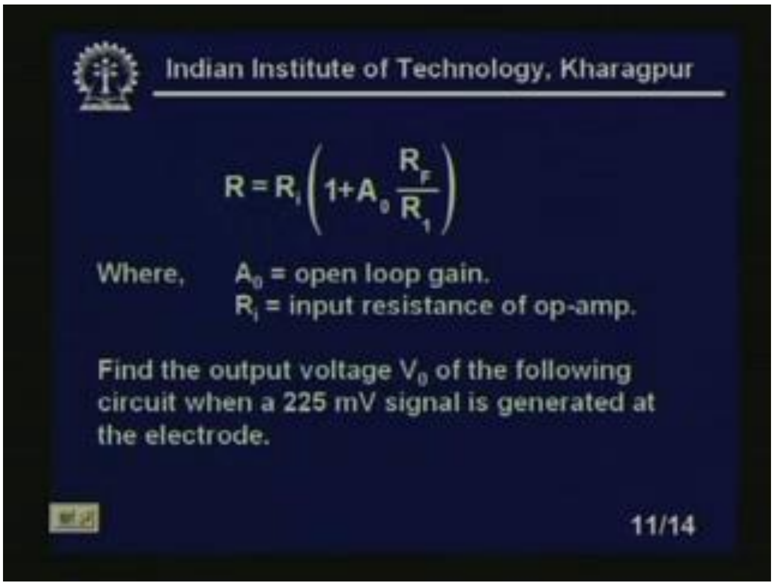

Now R f, R equal to R i 1 plus A naught R f by R 1. A naught is the open loop gain and R i is the input resistance of the op-amp. Find the output voltage V naught of the following circuit when 225 millivolt signal is generated at the electrode.

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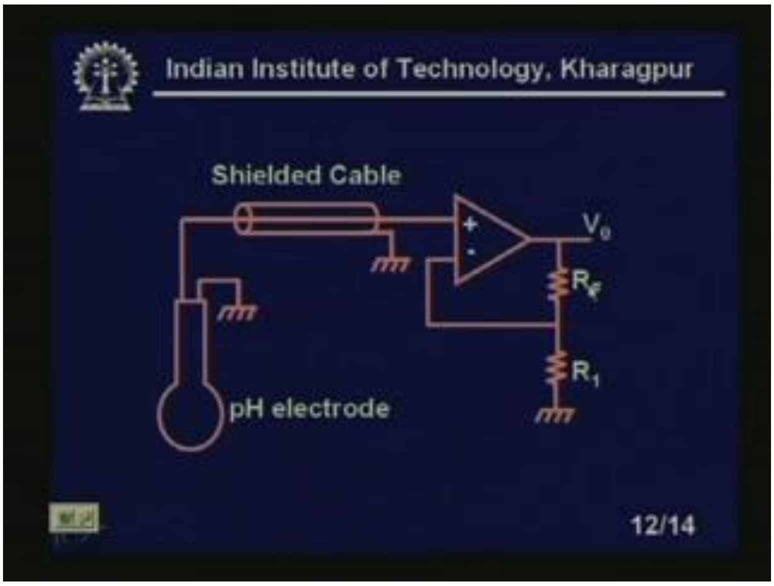

Shielded cable is, looks like this pH electrode and this looks like this way. So you see, this is buffer amplifiers we have used, supposed to be very high input impedance, so we have used shielded cable.

Now, data given, let me see whether we have, yes; find the output voltage V naught of the following circuit when 22.5 millivolt signal generated at the electrode, right, very small signal were generated.

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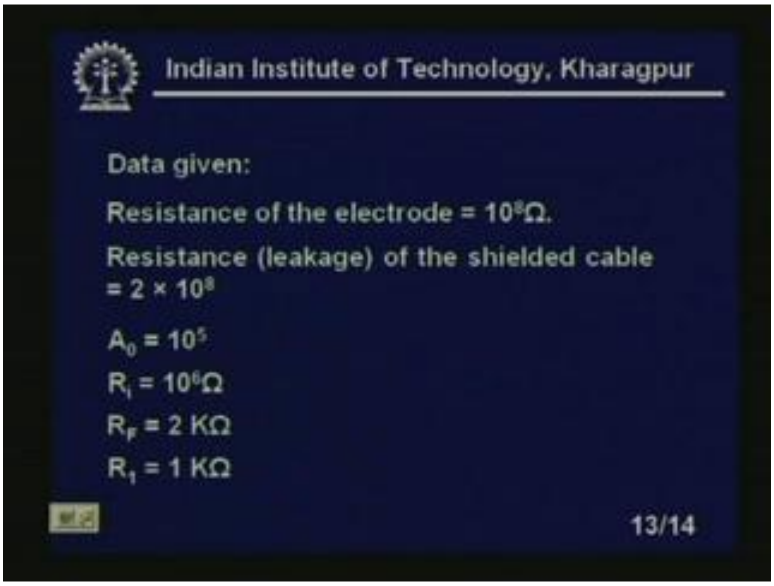

The data given are: the resistance of the electrode is 10 to the power 8 ohm, right? The resistance leakage of the shielded cable is 2 into 10 to the power 8 ohm, right? A naught, open loop gain of the amplifier is 10 to the power 5, R i is, the input impedance is 10 to the power 6 ohm and R f is 2 kilo ohm and R 1 is 1kilo ohm. So, this is our… Now, let us look at the solution.

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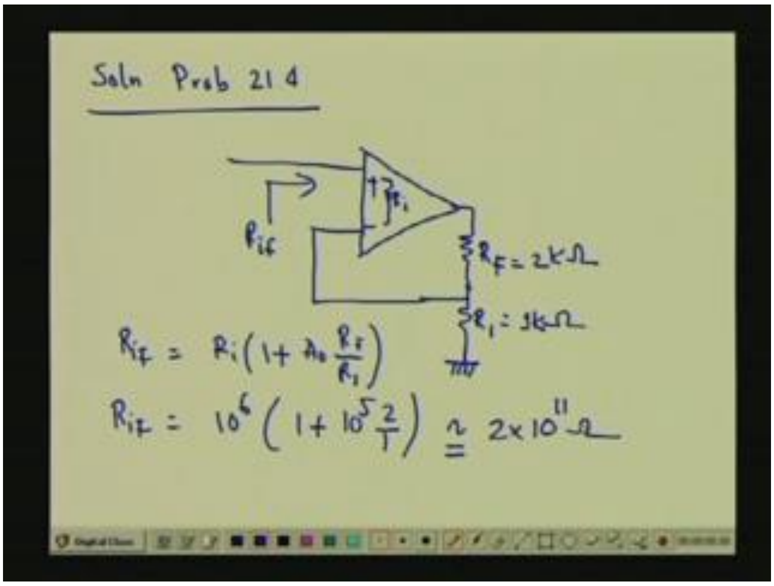

The solution looks like this, solution to problem 21.4, right? The op-amp given in the problem can be represented like below. You see that is we can, we can draw it like this. So, plus minus, so it has a very high input resistance. This is R i, right, R i and this signal is coming here and this signal is coming here, connected here, connected here this is R f, this is R 1 1 kilo ohm and this is 2 kilo ohm, right? Now, obviously I can write you see that R if, R if is looking from this terminal, R if. R if equal to R i 1 plus A naught R f by R 1 and so, R if equal to 10 to the power 6 1 plus 10 to the power 5 by 1. So, this will give you almost 2 into it is 10 to the power 11 ohm, quite high input impedance, right?

So, now if draw the equivalent circuit for, for measurement systems it will look like this.

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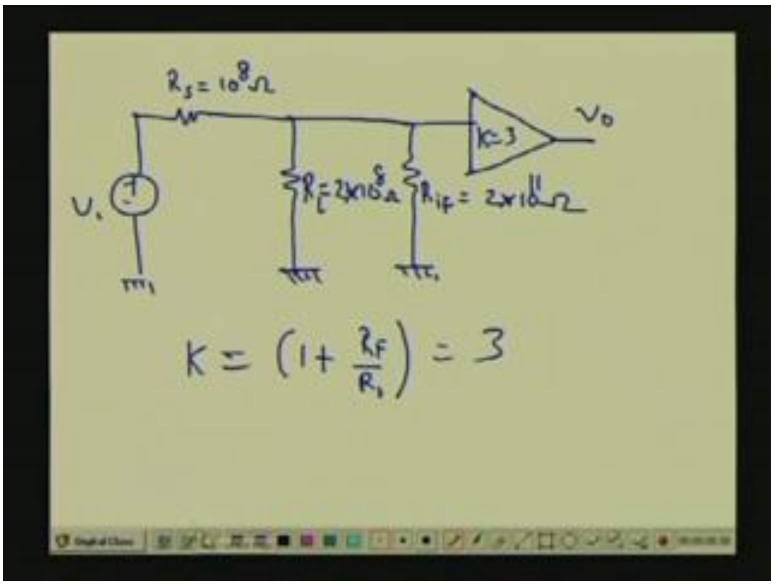

Let me draw the first equivalent circuit of the entire system. This is the pH voltage which we are getting, source impedance, then resistance, this is the impedance of the meter, then we have an amplifier, amplifier has a gain of 3, because if you look at the …. value of R f and R 3, you will find the gain as, is of 3. So, this is the output voltage, so this looks like this, right? So, this R s 10 to the power 8 ohm, source impedance, this is our pH voltage and this is a length R L actually the, the cable resistance, right? So, this cable resistance or leakage resistance of the cable, leakage resistance of the cable is 2 into 10 to the power 8 ohm; cable resistance to the 8 ohm and R if, input impedance becomes 2 into 10 to the power 11 ohm that we have just computed, right?

So, that leakage resistance 2 into 10 to the power 8 ohm, I mean input impedance 2 into 10 to the power 11 ohm, please note it is 11 if I take, so it is 11 ohm. So, this is 11 ohm. Then, the source impedance is 10 to the power 8 ohm and gain of the amplifier is 10, 3 that is we can find because the closed loop gain is 3. So, the R s is the resistance of the probe or the resistance of the sensor and R L, R L is the leakage resistance. Now, the closed loop gain, obviously what is the closed loop gain of the circuit? That is I already put it, it looks like this - 1 plus R f by R 1.

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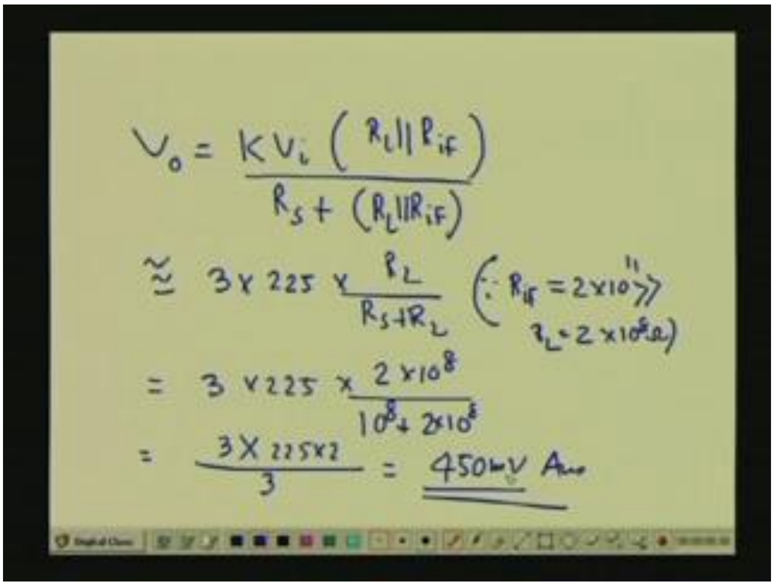

So, this will give you 3 and analyzing the above circuit we can write, analyzing the above circuit we can write that V o will be equal to K V i R L parallel R if upon R s plus leakage resistance R L parallel R if, right, so which becomes, almost equal to 3 into 225, because this is voltage generated by the pH probe into R L upon R s plus R L. Please note this is almost equal to …, right, like this. Why? Because you see that R if is equal to 2 into 10 to the power 11 ohm, right, which is much, much greater than 2 into that means R L which is equal to 2 into 10 to the power 8 ohm, right, quite obviously. So, this we can write ultimately, this can we can write 3 into 225 into 2 into 10 to the power 8 upon 10 to the power 8 plus 2 into 10 to the power 8, right? So, this will give you 3 into 225 into 2 upon, let me take eraser, upon 3. So, it is coming up as, since this is in millivolt, 225, so this also will be in millivolt, 450 millivolt. This is the answer, clear?

Now, let us one solve, let us solve one problem on the McLeod gauge. In low pressure measurements we have seen that there is a, McLeod gauge has a, it is typically used for measurements of the low pressure. Now, McLeod gauge has non-linearity. So, if you discard that nonlinearities we can sense as a, the linear sensor, but nonlinearity introduce some amount of error. So, let us look at that. The problem will be on that, let us look at that, right?

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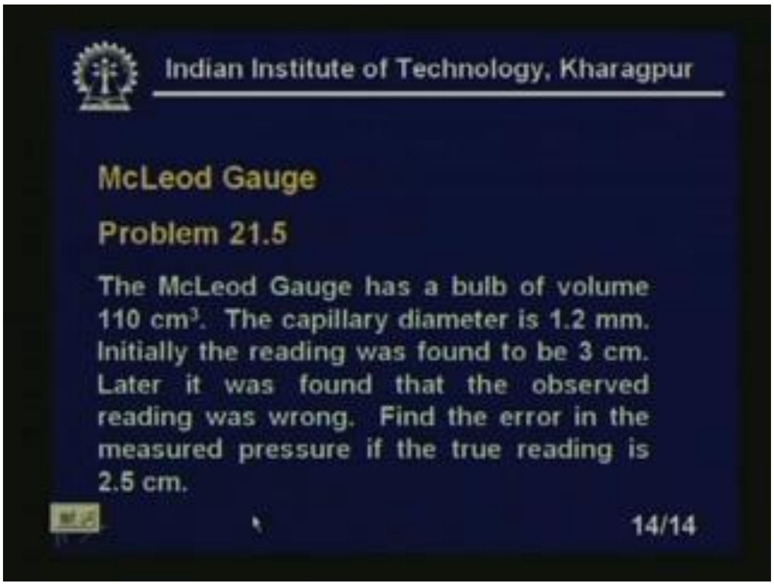

This is problem on the McLeod gauge. This is 21.5 I think, yes, 21.5. The McLeod gauge has a bulb of volume, you must refer to the lectures or to the video lectures of the low pressure measurements of the McLeod gauge, right? The McLeod gauge has a bulb volume of 110 centimeter cube, right? The capillary diameter is 1.2 millimeter. Initially the reading was found to be 3 centimeter. Later it was found that the observed reading was wrong and find the error in the, find the error in the measured pressure if the true reading is 2.5 centimeter. So, there some error has been introduced, let us look at that, right?

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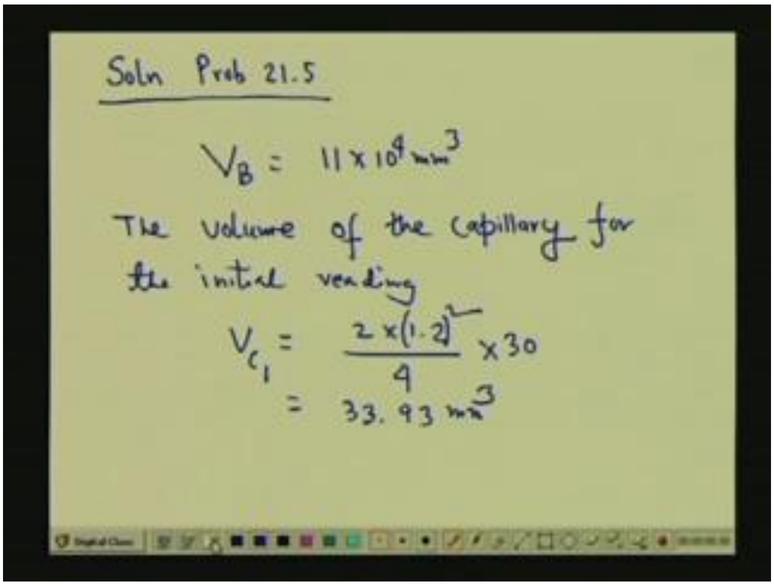

So, solution to problem 21.5, right? The volume of the bulb is given by, volume of the bulb will be given by 11 into 10 to the power 4 millimeter cube, right? The volume of the capillary, of the capillary for the initial reading is given by V c1, let us take that volume, 2 into 1.2 to the power square upon 4 into 30, so which is giving you 33.93 millimeter cube. So, the pressure p 1 in that case, I will take a new page.

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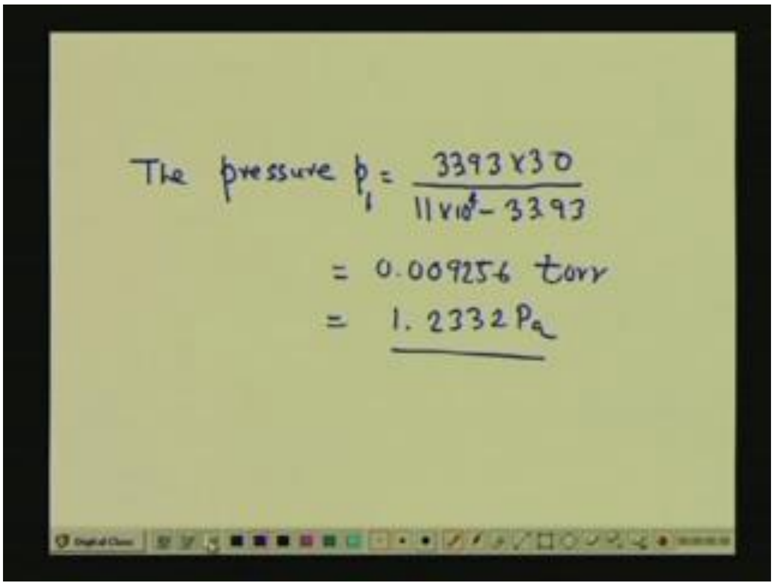

The pressure p 1 is equal to 33.93 into 30 upon 11 10 to the power 4 minus 33.93, which is coming up as 009256 torr, right? So, it is coming up as 1.2332 Pascal, clear? However the exact capillary volume is, what is the exact capillary volume?

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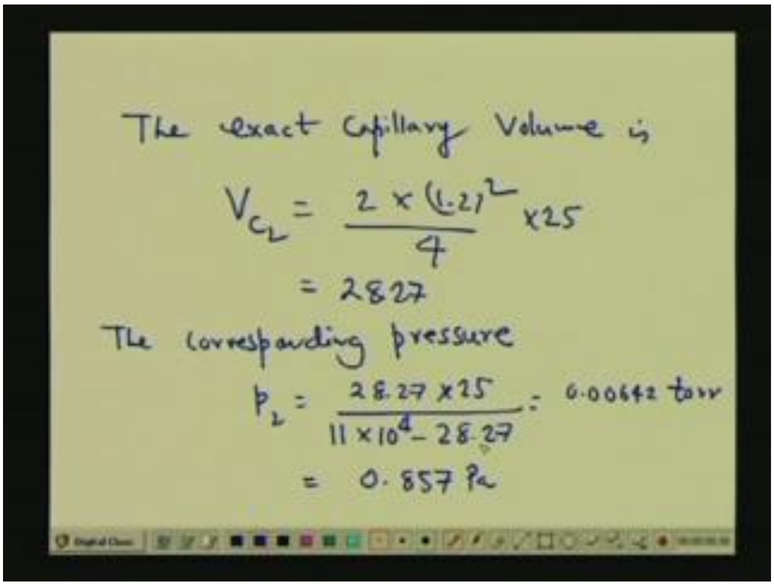

The exact capillary volume is V c2 equal to 2 into 1.2 whole square by 4 into 25. So, this will give you 28.27 millimeter cube, right? So, the corresponding pressure, corresponding pressure will be p 2 if I take that is 28.27 into 25 upon 11 point10 to the power 4 minus 28.27 is equal to 0. 00642 torr, right? So, it is coming up as 0.857 Pascal. So, this is the true pressure.

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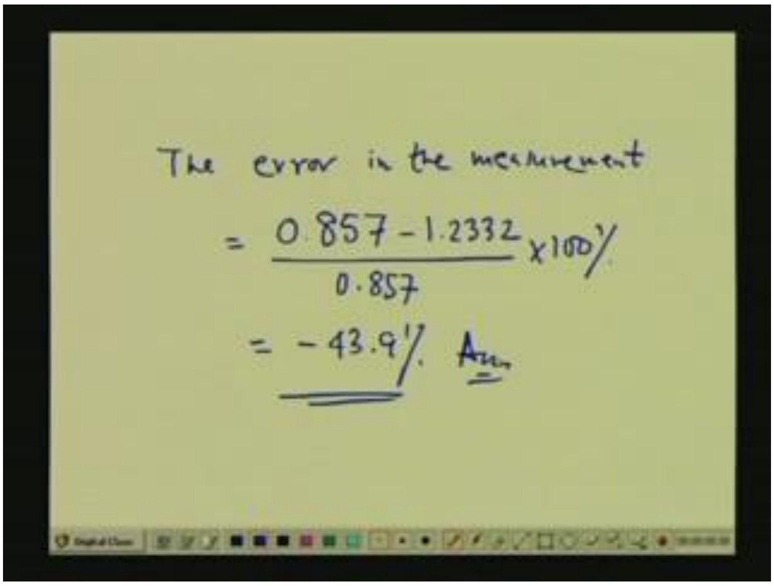

So, therefore the error is, so error in the measurement is 857. Let me take, it is 857 minus 1.2332 upon .857 into 100%, which is giving a error of 43.9%, right? So, this is the answer to the system, right? So, with this I come to the end of lesson 21, where we have solved all the problems.

Preview of next lecture

Welcome to the lesson 22 of Industrial Instrumentation. Actually in this lesson and subsequent lesson, we will find that, we will discuss some of the basic signal conditioning circuits. As you know, the signal conditioning circuits are very much necessary in various phases of the sensors, because we need the, whenever the signals are electrical, we need, we need to process, we have to process that about signals and we need some signal conditioning circuits. So, in this lesson and the next lesson we will discuss some of the signal conditioning circuits commonly used in instrumentations. This is lesson 22. Now, this is the signal conditioning circuits I.

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Contents of this lesson - positive and negative feedback topology we will discuss, we will discuss the active filters, we will single amplifier structure.

So, it does not matter if the sensitivity parameters are high, because I have exactly designed the resistance value and the capacitance value. So, in that case even though sensitivities are high, I will get the desired value of the, desired value of the filter parameters, omega p, Q p, omega z, Q z and capital K, right? So, it is very cheap. It is very small, noises also, because if you increase the number of amplifiers your noise problem will also, I mean will be predominant. So, these are the typical problem in the higher amplifier structures. However, we will see that, we will in a subsequent, I mean lessons that the, we will go for three amplifier structures where we can achieve this orthogonal tuning. Also, the sensitivity figures will also, will be less.

With this I come to the end of the lesson 22.Thank you!