Industrial Instrumentation

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Lecture - 17
Problems on Temperature Sensors

Welcome to the lesson 17 of Industrial Instrumentation. In this lesson, basically we will see that we will solve some problems on the, on the, the basic temperature sensors like thermistor, thermocouple, RTD and like change in the signal conditioning circuitry, what are the different types in signal conditioning circuits are there, if they need some particular accuracy what are the things we have to do that is all those things we will discuss in details in this particular lesson.

Now contents of this as I told you, this is a problem on the temperature sensors.

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Contents - the problems and solutions on RTD, thermistor and thermocouple. So, these are the basic things which we will discuss in this particular lesson. So, let us go to the problem number 1.

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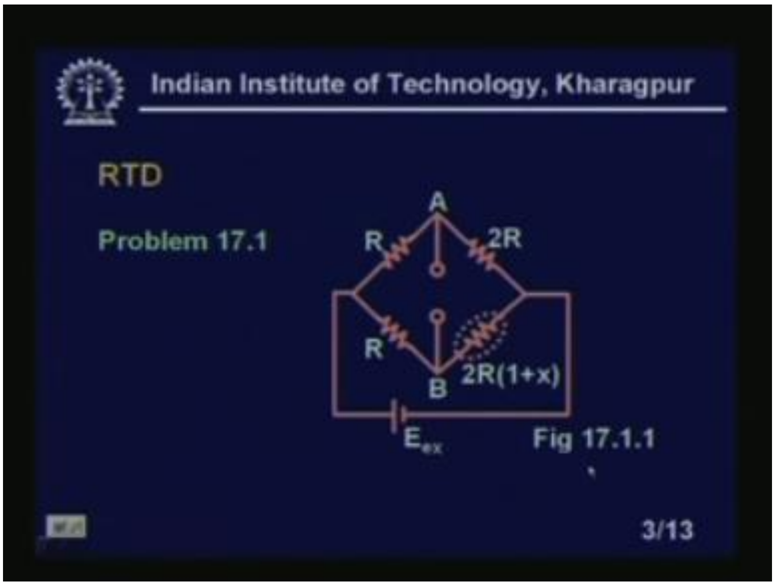

So, this is the problem number 17.1. This is basically on a RTD. You can see one Wheatstone bridge is there, so this is RTD. You can see this is RTD and there are some resistors of R, 2R; R and 2R and this is excitation voltage of this Wheatstone bridge.

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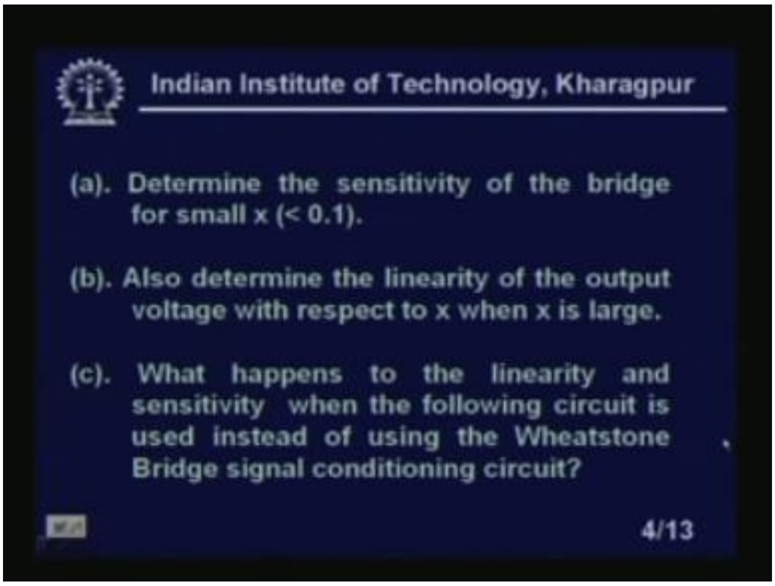

The question is, determine the sensitivity of the bridge for small value of x, right? If I go back, you can see what is x. So, this is our x. So, determine the sensitivity for small value of x when it is less than 0.1 and also determine the linearity of the output voltage with respect to x, when x is large. So, this is the part b of the problem and part c is that what happens to the linearity and sensitivity when the following circuit is used instead of using the Wheatstone bridge signal conditioning circuit? So, instead of Wheatstone signal conditioning circuits we will use one op amp based circuit and we will, we will consider the linearity, sensitivity, all these things in details.

We will find there are some advantages of using the op amp based circuits. So, we will discuss that thing in detail.

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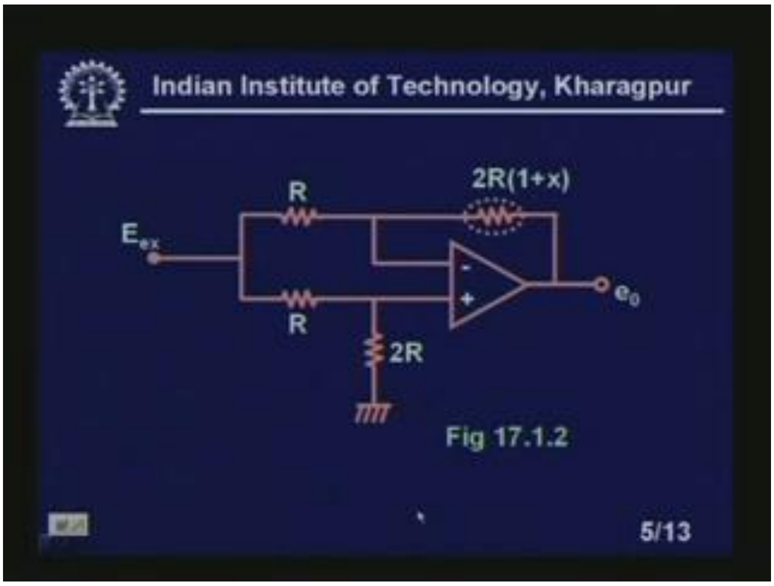

So, let us look at the circuits. This is the circuit, right? So, our solution starts here.

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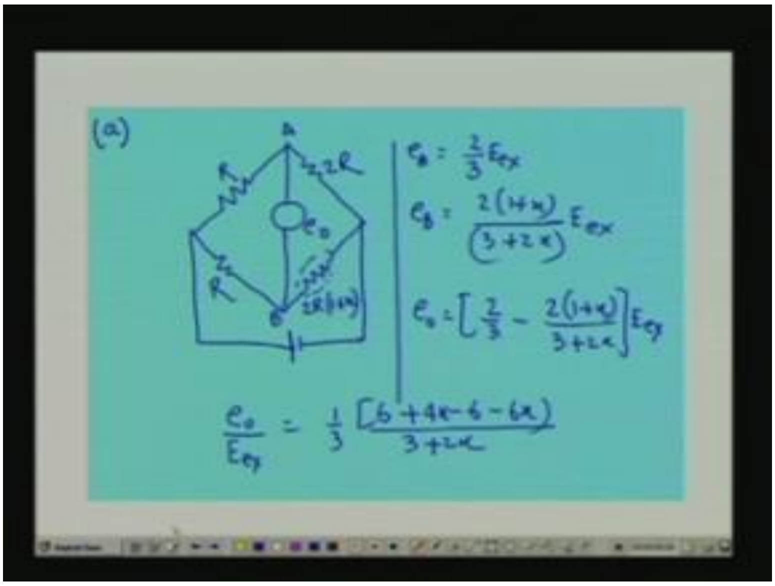

You see the, the solution of problem a. You see we have the bridge which looks like this. This we have excitation to the bridge and we are taking the output voltage. So, this is the output voltage, e o. So, this is the resistance R, this is 2R, this is R and this is our RTD. So, its resistance is 2R multiplied by 1 plus x, right? Now, solution looks like this. Now you see, in this particular case e A is equal to 2 by 3 of E ex. e B, if I take this terminal A, this a**s** B, so e B equal to, I can write 2 1 plus x upon 3 plus 2x E ex.

Therefore, the output voltage e o will be equal to 2 by 3 minus 2 1 plus x upon 3 plus 2x multiplied by the excitation E ex, right? So, I can write here that output voltage by the excitation will be given by 1 by 3 6 plus 4x minus 6 minus 6x upon 3 plus 2x, 3 plus 2x, so which will you give you, let me take a new page.

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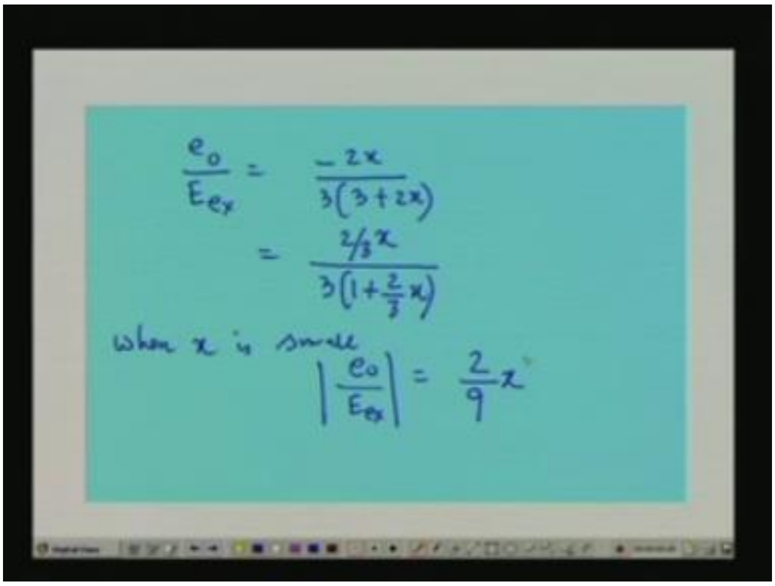

That e naught by E ex equal to minus 2x upon 3, 3 plus 2x. So, this is equal to 2 by 3x upon 3 1 plus 2 by 3x, right? Now, when x is small, x is small, this, mod of this if I take that means mod of output voltage by the excitation equal to 2 by 9. This will be all small, so I can write 2 by 9. So, this will be neglected compared to this. So, this will be only 3 in the denominator, so 2 by 9 into x.

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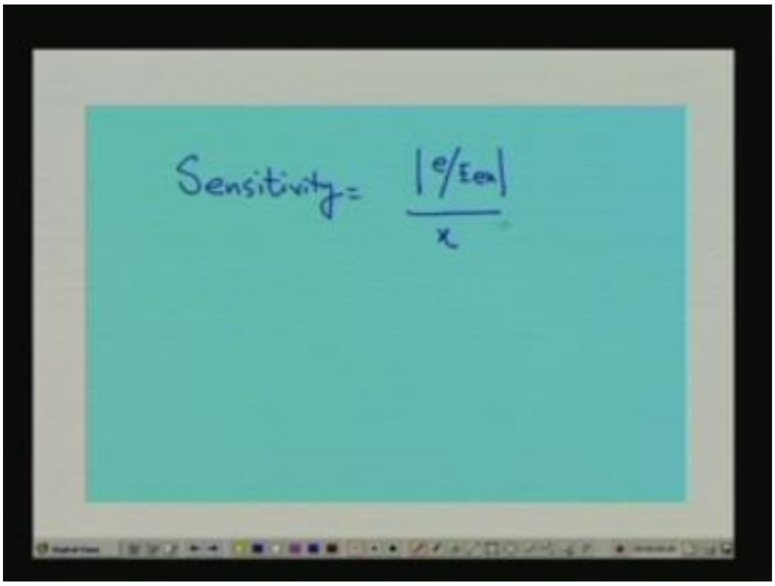

So obviously, if I take a new page, sensitivity I can write here in this particular Wheatstone bridge is e naught by E ex upon x equal to 2 by 9. It is an approximation, obviously. Fine, now let us look at when x is large.

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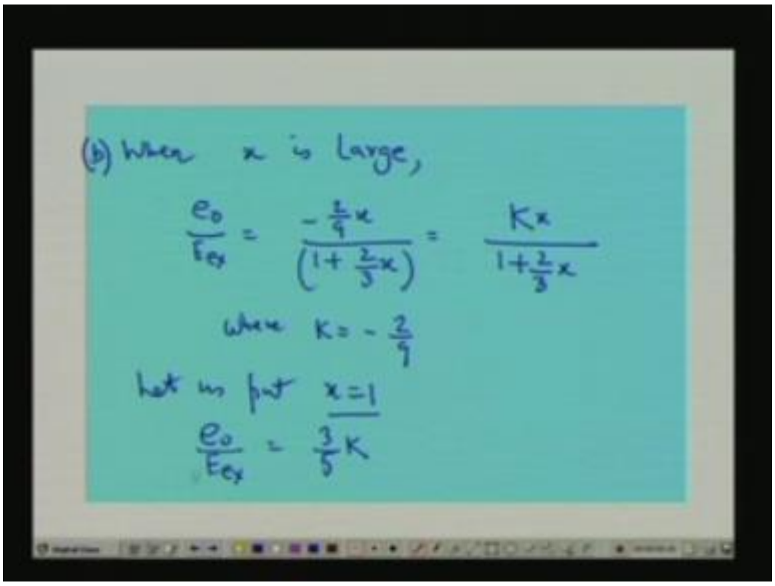

Solution b, if I take a new page, when x is large, when x is large e naught upon E ex will be equal to minus 2 by 9x upon 1 plus 2 by 3x. So, this will be equal to K x, I write upon 1 plus 2 by 3x, right where K is equal to minus 2 by 9. Now let us put, for an example let us put x equal to 1, right, which is large compared to x less than 0.1, right? So this is, usually we have taken x equal to 1. That means x is quite large compared to x less than .1. So, we will get the expression, excuse me, we will get e naught by E ex equal to 3 by, by 5 into K.

So, this is basically a straight line passing through the origin 0,0 and the point 2 by 3 K and 1, in actually the, if I plot e naught by E ex in the y-axis and x in the x-axis, right?

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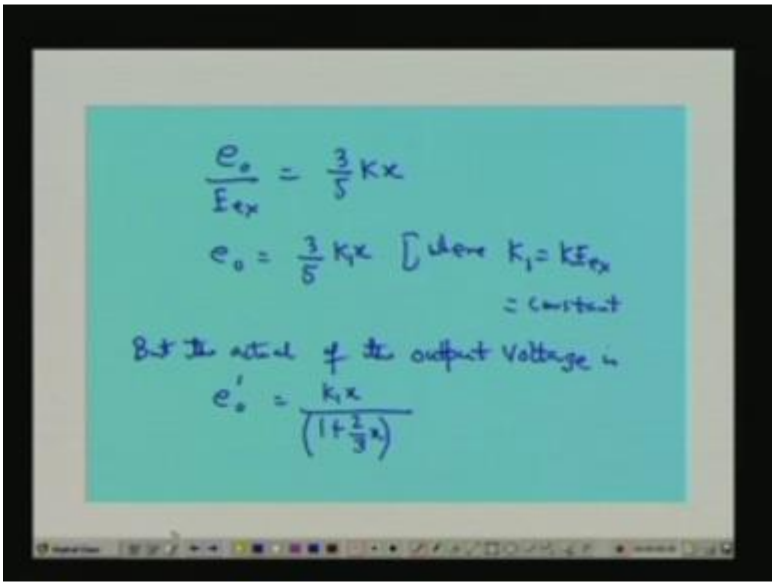

So, this will have a locus which will look like, if I take a new page, that e naught by E ex will be equal to 3 by 5 Kx, right, which I can write again e naught equal to 3 by 5 K 1 into x, where I can write K 1 is equal to K E ex and it is a constant, right? But the actual value of the output voltage, actual value of the output voltage is if I take that one as e naught dash equal to K 1 x, a very first equation 1 plus 2 by 3, this is generalized equation, is not it, because that is the actual value we have approximated in some cases as Kx less than 0.1, x less than, greater than, I mean equal to 1 like all this.

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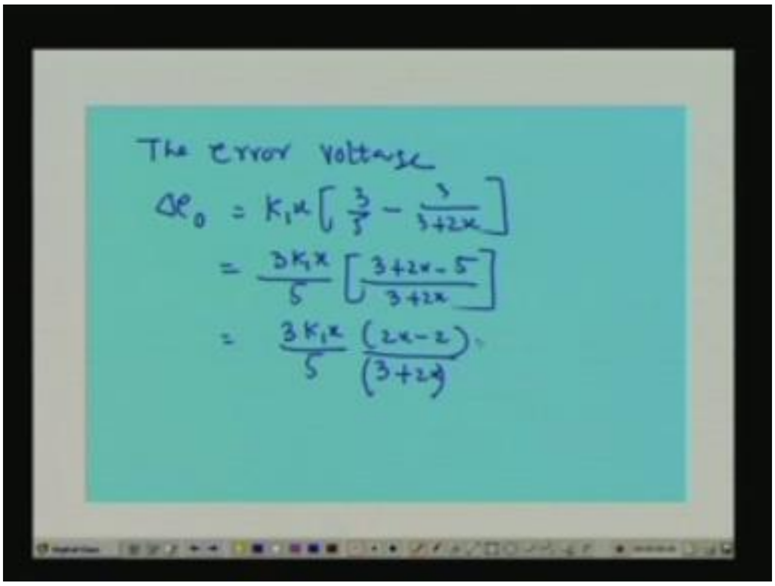

The error voltage obviously will come up as, the error voltage, so I give it name delta e naught equal to K 1 x 3 by 5 minus 3 by 3 plus 2x equal to 3K 1 x by 5. So, it is 3 plus 2x minus 5 3 plus 2x. So, it is coming 3K 1 x by 5 multiplied by 2x minus 2 upon 3 plus 2x, right? Now, let us take a new page.

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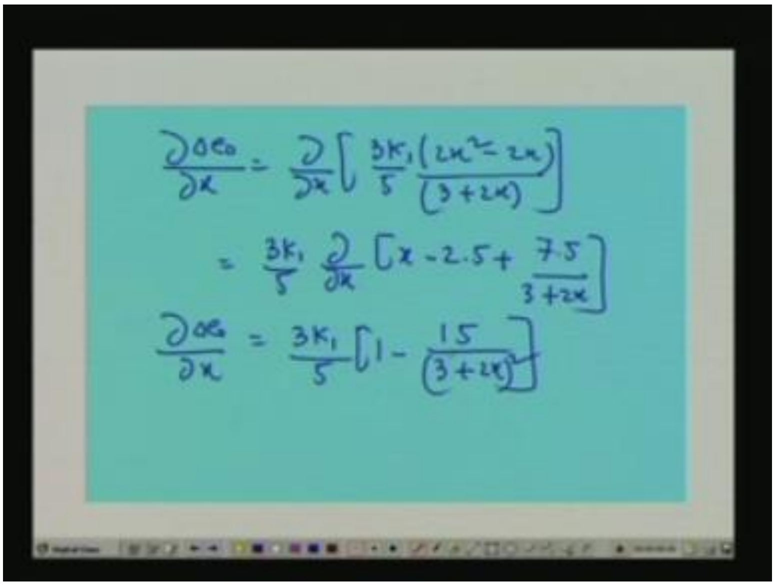

Now, to see the errors, to see whether the error is maximum with respect to x, we differentiate delta e naught, right? So we differentiate with respect to e naught, delta e naught with respect to x. So, you will get d of dx 3K 1 by 5 2x square minus 2x by 3 plus 2x, right? So, this I will give, give you the value 3K 1 by 5 del of del x x minus 2.5 plus 7.5 upon 3 plus 2x, right? So, del of delta e naught by del x will become 3K 1 by 5 1 minus 15 3 plus 2x whole square. Now that is therefore, for maximum value of delta e naught we will get 3 plus 2x whole square equal to 15.

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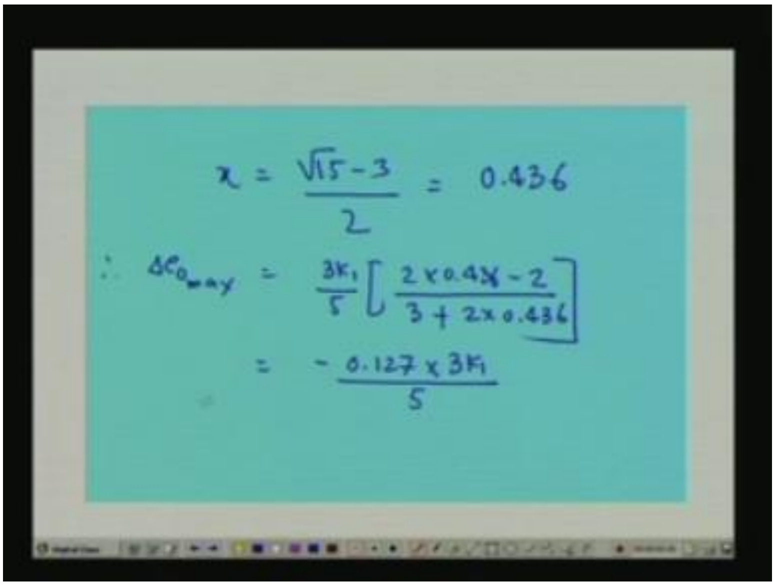

If I take a new page that means x is equal to root 15 minus 3 by 2, which is equal to 0.436, right, right? Yes, so delta e naught max equal to 3K 1 by 5 2 into 0.436 minus 2 upon 3 plus 2 into 0.436 equal to minus 0.127 into 3K 1 by 5, right?

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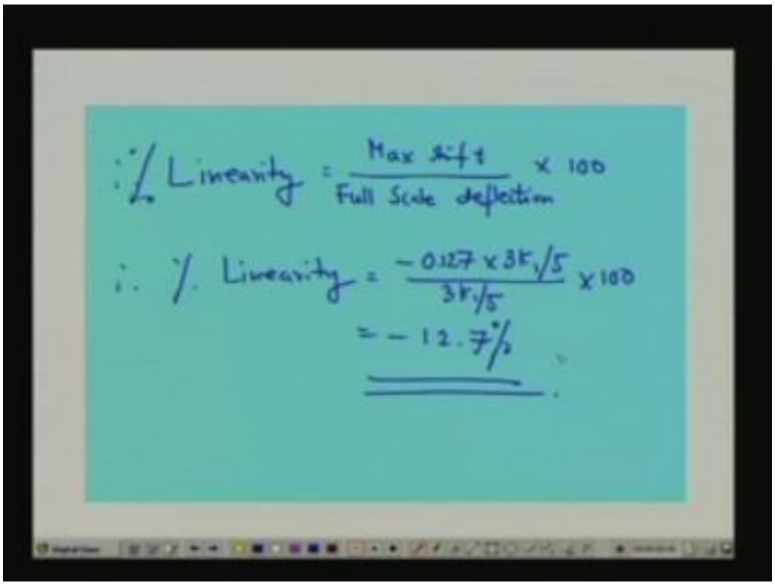

Now, linearity we will define. So, the percentage linearity is defined as, I should say, percentage linearity equal to maximum drift shift divided by full scale deflection into 100. So, we will get the linearity. So the percentage linearity in this case, in this case is equal to minus 0.127 3K 1 by 5 by 3K 1 by 5 into 100. So, this is coming as minus 12.7%. So, this is the answer, right?

Now let us solve the third, I mean c. In c we are saying that instead of Wheatstone bridge we are connecting one op amp. The circuits already we have shown, so for that circuit how the sensitivity will change or the linearity will change, let us look at that. Let us take a blank page again.

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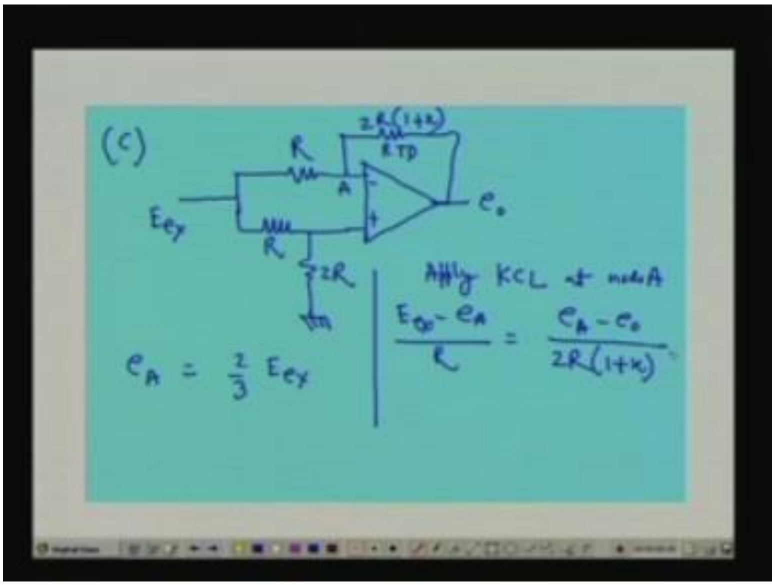

So, this is the solution to the problem 17.1c. So problem, solution now let us redraw the circuit again. The circuit looks like this. This is an op amp here, 2R, R, R. This is A point and this is, all the four resistances are as usual as before, but we have taken 1 plus x, right? So, this is our RTD, so this is our RTD. So, this is 2R, now we are connecting the excitation and taking the output from this terminal, right? So, voltage at the point A which if, if I define as e A will be equal to 2 by 3 of excitation, is not it?

Now, if I apply the KCL, apply the KCL at node A I will get E ex minus e A by R equal to e A minus e naught by 2R 1 plus x or quite obviously it will be, if I take a new page …

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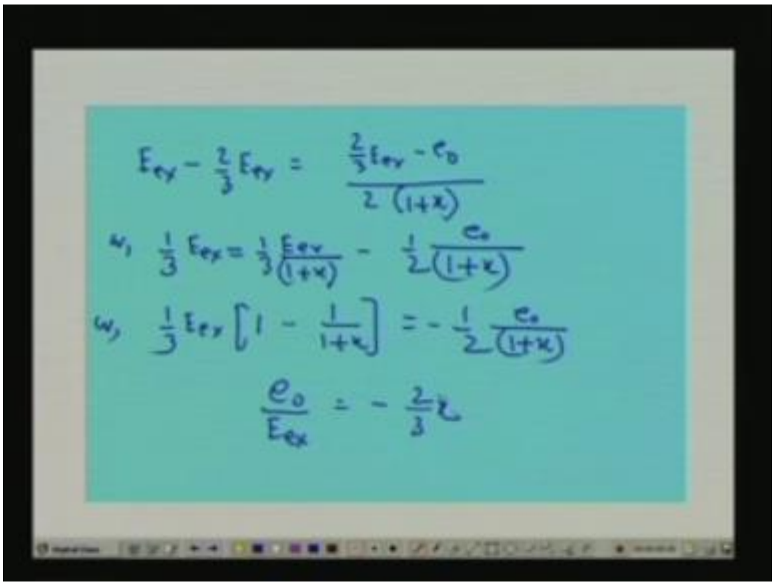

I will write again, E ex minus 2 by 3 excitation equal to 2 by 3 E ex minus e naught upon 2 1 plus x or 1 by 3 E ex minus sorry, equal to 1 by 3 E ex 1 plus x half of e naught 1 plus x or I can, if I take 1 by 3 E ex common, so it will be 1 upon1 plus x equal to half of e naught upon 1 plus x, right? So, this will, I mean lead to an expression e naught by E ex equal to minus 2 by 3x, right?

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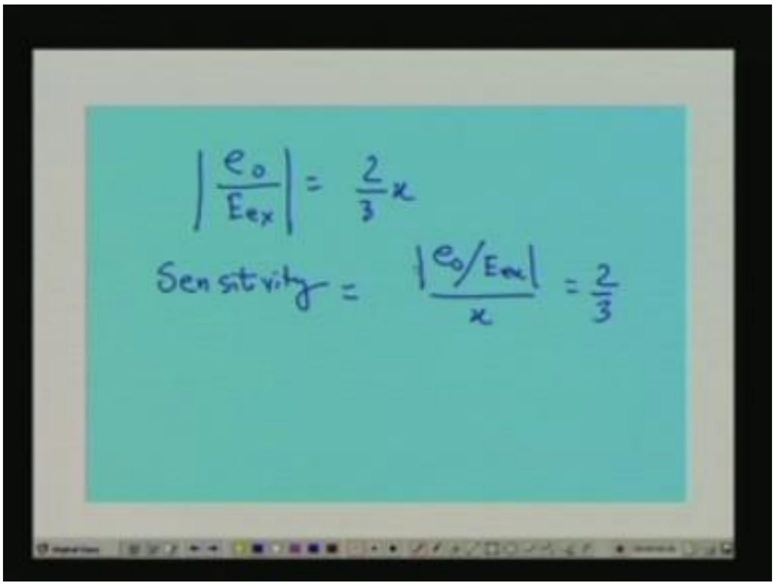

If take the mod, so it will look like, if I take a new page, so if I take mod of this E ex the excitation equal to 2 by 3x, right? So, sensitivity in this case I can write that e naught upon E ex by x equal to 2 by 3. We have seen that the sensitivity has been improved in this case and also it is perfectly linear. That is most import…. In first case it is, we have, the final output also becomes very much linear. So, this is the improvement over the previous case, right?

So, now let us go to the problem number 2, 17.2.

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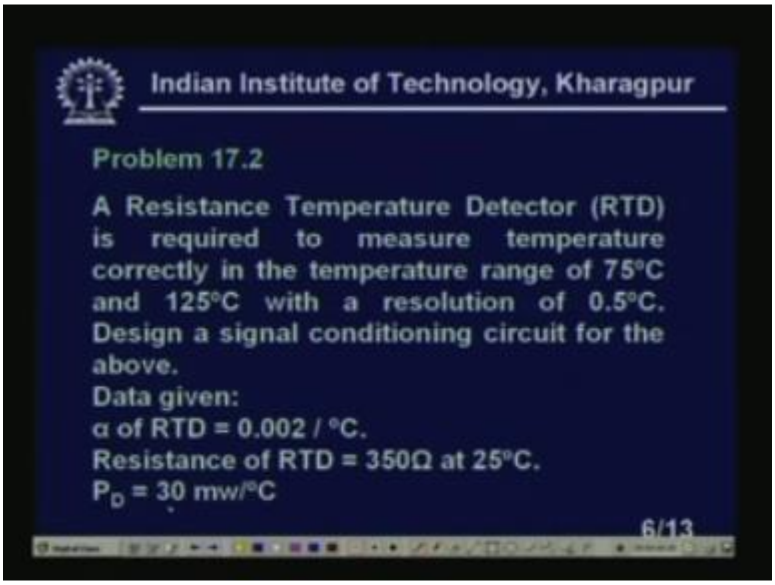

So if I, problem number 17.2 is telling that the resistance temperature detector RTD, this is also an RTD, a resistance temperature detector is required to measure the temperature correctly in the temperature range of 75 degree centigrade and 125 degree centigrade with a resolution of 0.5 degree centigrade, right? This is the range. I will not measure below 75. This is very common in industrial problem. That is we are, not always necessary we will measure from zero degree centigrade or 30 degree centigrade.

There is a particular range, so within that range how will be my, what will be my signal conditioning circuitry that we will look at. So, it is 75 degree centigrade and 125 degree centigrade with resolution of 0.5 degree centigrade. Design a signal conditioning circuit for the above, for this above requirements and some data are given, so they are that alpha that is temperature coefficient of resistance of RTD is 0.002 per degree centigrade and resistance of RTD is 350 ohm at 25 degree centigrade and PD, power dissipation factors we are using 30 milliwatt per degree centigrade, right? So, this is the problem. Now, let us look at the solution, right? So, let me take a blank page.

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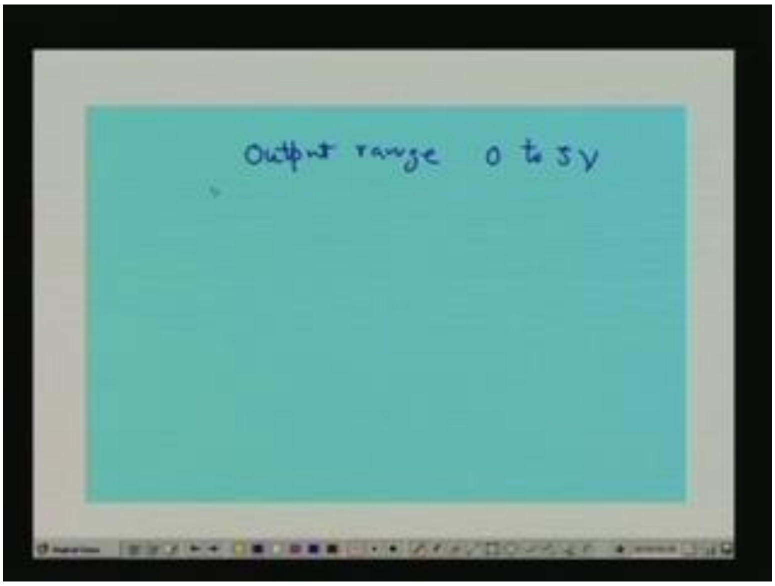

See, the signal conditioning circuit should give a zero volt at 75 degree centigrade and 5 volt at 125 degree centigrade. That means we define our output range is 0 to 5 volt, 0 to 5 volt, right and we need this, you see basically one Wheatstone bridge along with the instrumentation amplifier. The Wheatstone bridge is necessary to give an output of zero volt at 75 degree centigrade and output of the Wheatstone bridge will be very small and hence an instrumentation amplifier is necessary.

Now we have proposed the following circuits, right? Let us look at the circuit, let us look at the circuit. The circuit looks like this. Let me take a blank page again.

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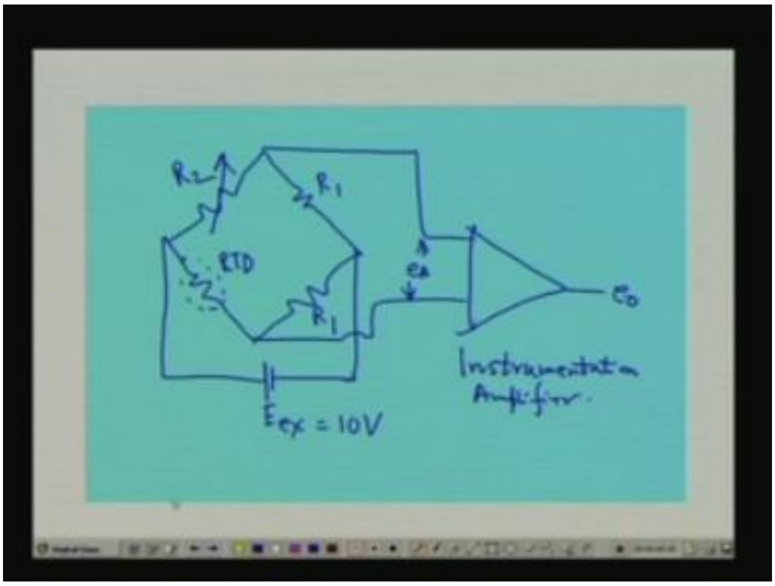

So I have a, I have an instrumentation amplifier here and this resistance we have taken variable, so this RTD is connected here, clear? We have this excitation, this is E ex, so this is our RTD. This is R 2 and this is R 1. This is also R 1. This is our RTD sensor, right? Now, instrumentation amplifier is necessary, because the output voltage is very small, right? So, this is our e A, I should rather name it e A. This is our output and this is the instrumentation, instrumentation amplifier, right?

So, variable resistance R 2 is necessary, so that the bridge remains balanced at 75 degree centigrade. We take that E ex equal to suppose 10 volt, right? Let us take a blank page again.

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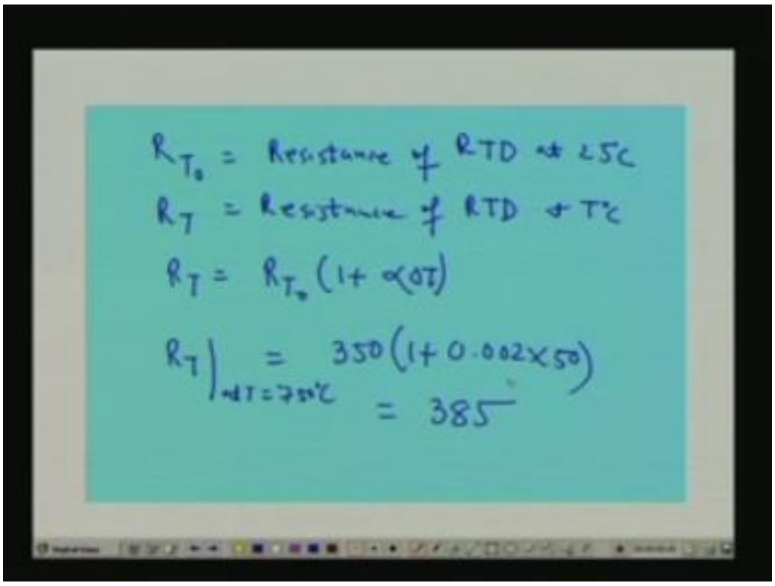

So, if it is there, so you see now resistance of the, our RTD will look like this. R To, resistance of the RTD at 25 degree centigrade, R T is the resistance of the RTD and it, at temperature of T degree centigrade, RTD at T degree centigrade and R T obviously we know, this R To at zero degree centigrade plus alpha we have taken the first order approximation, so it will look like this. So, quite obviously that means R T at T equal to 75 degree centigrade will be 350 is already given, 350, right it is given multiplied by 1 plus 0.002 into 50. So, this will give you 385 ohm, right?

Now, to keep the bridge balanced at 75 degree centigrade, RTD is to be adjusted to 385 ohm, right? So, in that case bridge will be balanced. Now, the question is we need a resolution of 0.5 degree centigrade, right?

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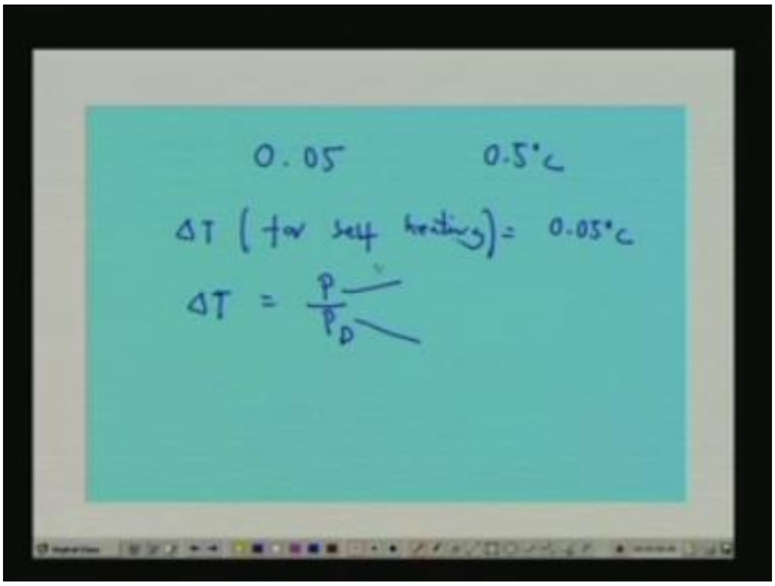

So, if you have a resolution of 0.5 degree centigrade, the output should change by 0.05 volt for every change of 0.5 degree centigrade in temperature. Now, the error may be introduced due to self heating of the RTD. To ensure that this is not, so we choose the temperature change due to self heating to be 10% of the given resolutions. So, we have taken the delta T for self heating or self heating equal to 0.05 degree centigrade. Now, delta T we know equal to P by P D, right, where P is the power dissipations in the RTD, right, in watt. It is a power dissipation in the RTD in watt and P D is the dissipation constant of RTD. It is in watt per degree centigrade, right? So, this is the, all the unit of now maximum, maximum allowable, let me take a blank page.

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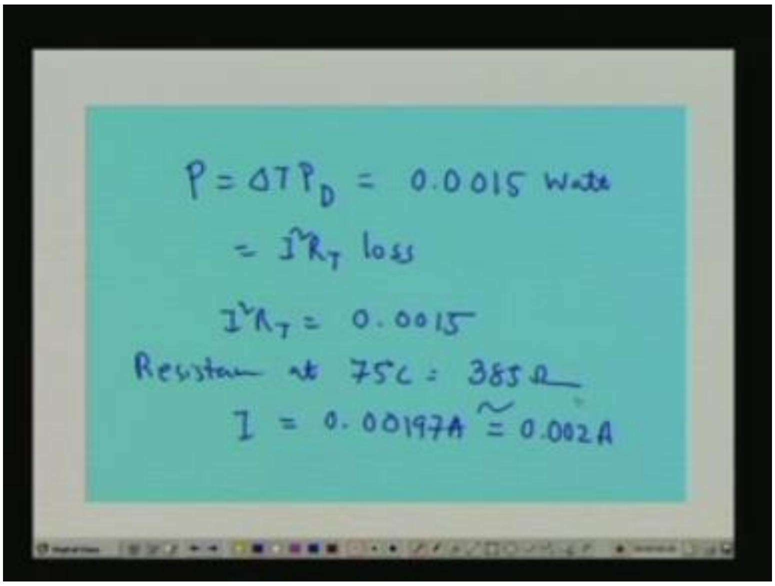

Maximum allowable power dissipation in the RTD is equal to P equal to delta T into P D. This is the maximum allowable power dissipation in the RTD. So, this will be equal to, quite obviously 0.0015 watt, right which is equal to, obviously this will be equal to I square and R T, right, I square R T loss. So, I can equate these things. So, if I write I square R T equal to 0.0015, so the resistance at 75 degree centigrade will be, as you know, it is 385 ohm. So, current I which is flowing through RTD at 75 degree centigrade is equal to 0.00197 ampere or equal to, almost equal to 0. 002 ampere. This is the current which is flowing through the RTD.

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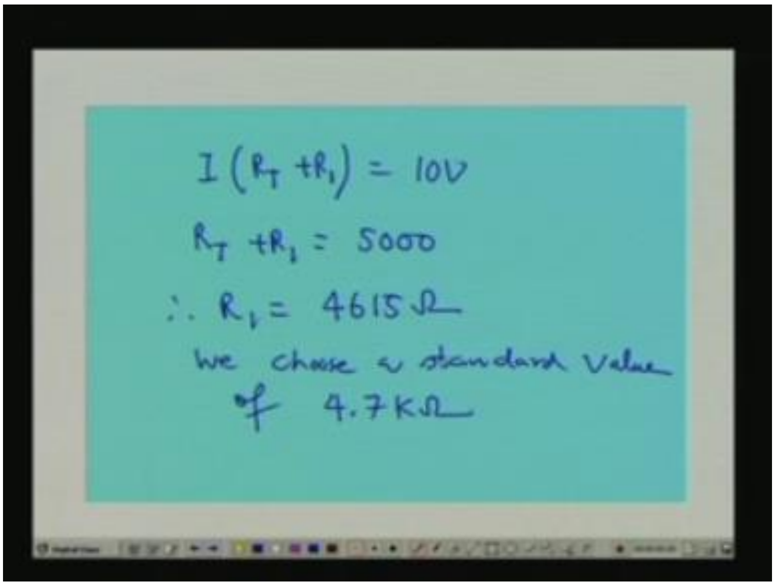

Now, from the Wheatstone bridge circuits quite obviously I can write, from Wheatstone bridge circuit I can write I equal to R T plus R 1 equal to 10 volt, quite obviously. So, this will give you that R T plus R 1 equal to 5000. So, R T we already know it is 385 ohm. So, therefore R 1 will be equal to 4615 ohm, right? We choose a standard value, because this resistance will not be available, so we choose a, some standard value. We choose a standard value, value of, excuse me, value of 4.7 kilo ohm, right?

Now, as temperature increases the value of the resistance increases, but still that does not introduce much of error, I mean this resistance may also increase, but it is not that error is temperature sensitive. Now again from the Wheatstone bridge circuit we see that, let me take a blank page.

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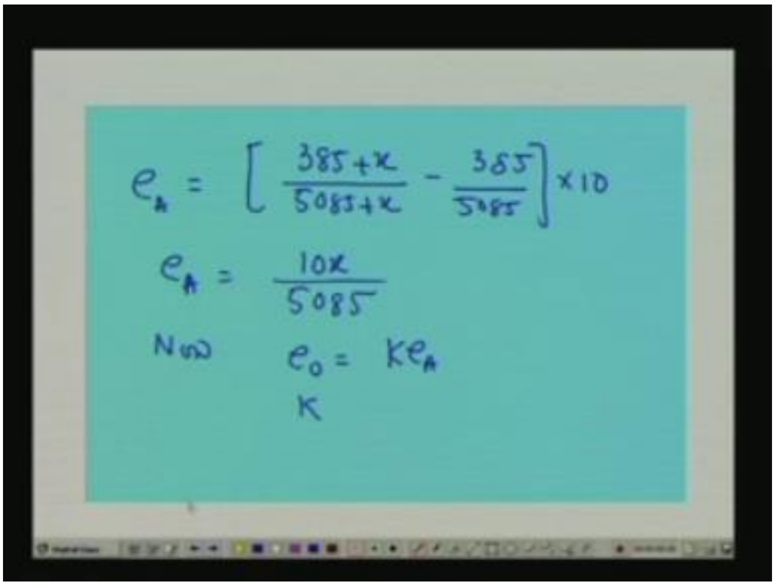

That output voltage e A equal to 385 plus x upon 5085 plus x minus 385 by 5085 into 10, right? So, x is the change in the resistance of the RTD. As x is very small compared to 5085, so we can write, approximate e A equal to 10x upon 5085, right? Now, what will be the gain of the instrumentation amplifier? Now, you see that output of the instrumentation amplifier we can write e o equal to K into e A, so where K is the gain of the instrumentation amplifier.

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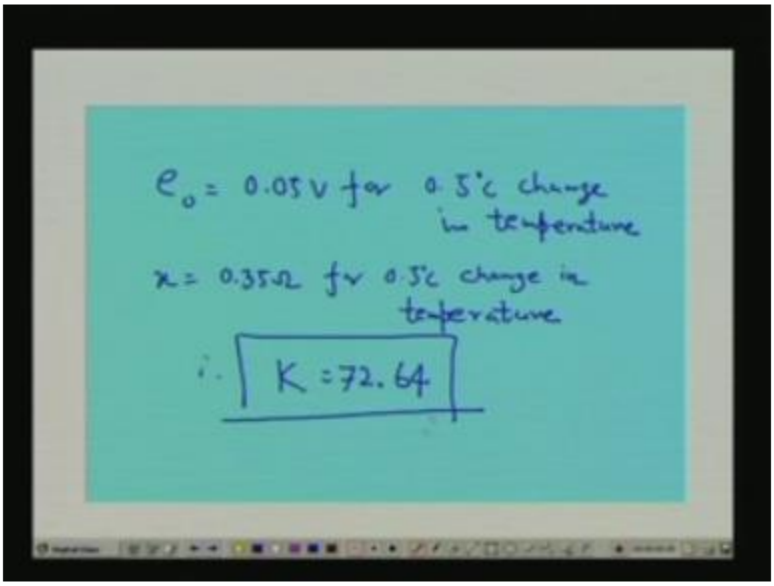

Now, e naught equal to 0.05 volt for 0.05 degree centigrade change of temperature, change in temperature and x equal to 0.35 ohm for a gain 0.5 degree centigrade change in temperature. So, K equal to, we can find K equal to 72.64, right? So, the gain of the amplifier, instrumentation amplifier should be like this. So, this completes our design of the problem number 17.2. The next problem will be on thermistor. Let us solve the problem.

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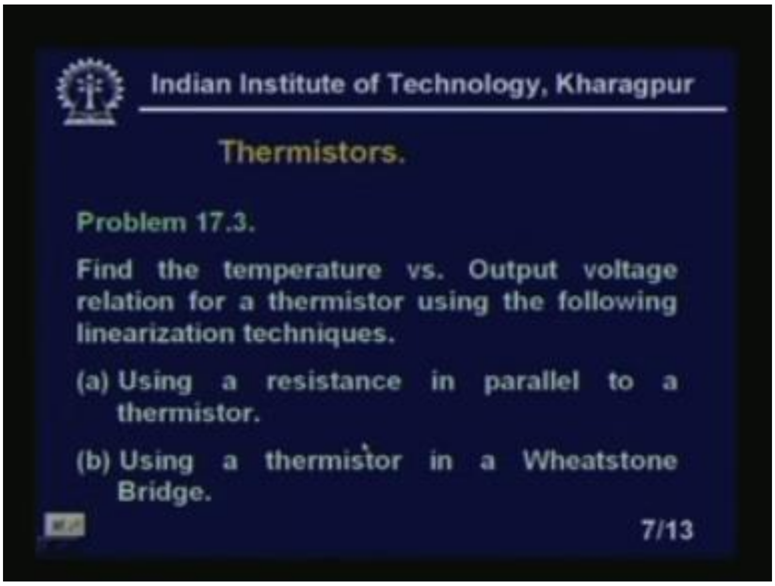

This thermistor problem, it is telling that find the temperature versus output voltage relation for a thermistor using the following linearization techniques: Number a, using a resistance in parallel to a thermistor, right, resistance in parallel to a thermistor and b, using a thermistor in a Wheatstone bridge, right? So, this is the two problem, two I mean thermistor with two different problems we have given. So, let us take a digital ……, we will take a board, right?

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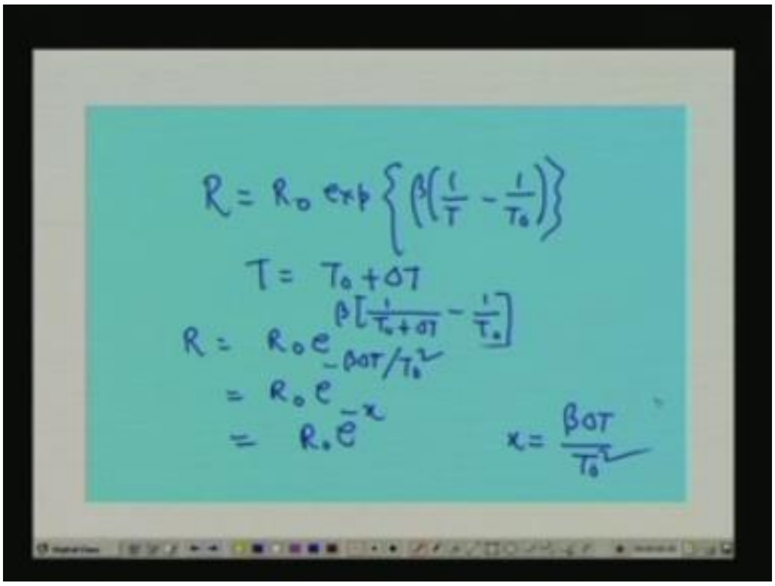

So, this is our problem. Now, we know that in the case of thermistor that you all know the thermistor will have a relationship R equal to R naught exponential beta 1 by T minus 1 by T naught, right? Now, suppose T is equal to T naught plus delta T. So, we can write R equal to R naught e to the power beta 1 upon T naught plus delta T minus 1 by T naught. So, R naught e to the power minus beta delta T by T naught square, so this I can write R naught into e to the power minus x, where x equal to beta delta T by T naught square, is not it? Let us take a new page.

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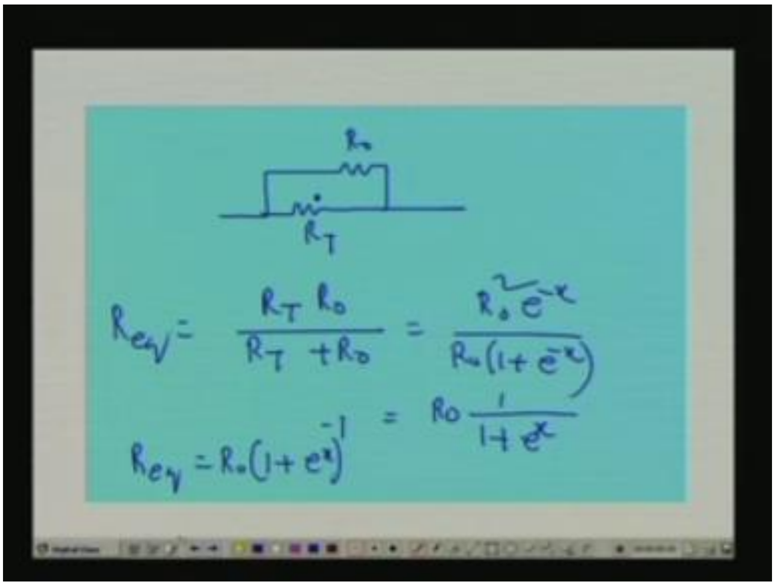

Using a parallel resistance, so if I take a parallel resistance, so this is our thermistor, R T, I am using with a parallel resistance, so this is our thermistor, thermistor symbol typical. We are assuming that in this case that parallel resistance has a same resistance as the thermistor at the temperature of the t zero. So, we will get the equivalent resistance of the, in this case R equivalent is equal to R T R naught upon R T plus R naught equal to R naught square e to the power minus x upon R naught 1 plus e to the power minus x, excuse me.

This I can write R naught 1 plus e to the power x, right, clear? So, R equivalent I can write equivalent equal to R naught 1 plus e to the power x to the power minus 1, right?

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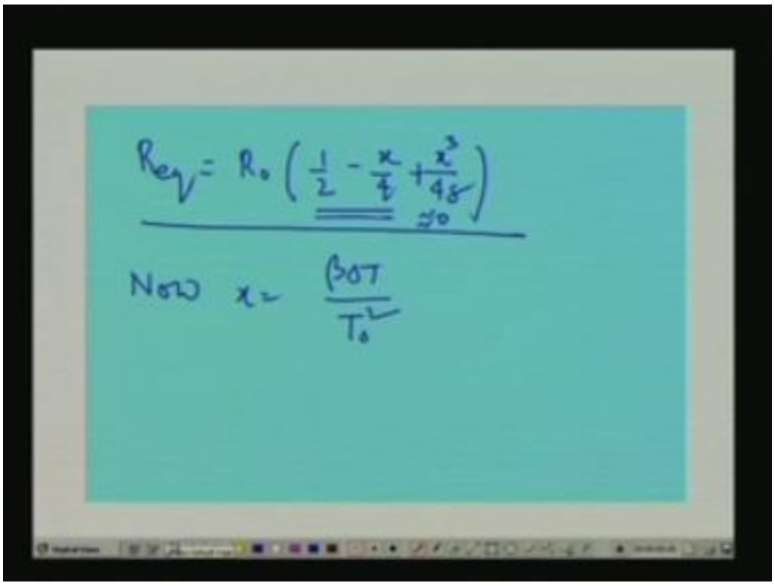

So, quite obviously this I can expand and tell that, sorry, so this R equivalent becoming R naught 1 plus half minus x by 4 plus x cube by 48 like this one, right, clear? Fine; now we see that x equal to beta delta T by T naught square which is very small value. Therefore, x to the power cube, 48 and higher order terms become negligible. So, this becomes very negligible. Therefore, we see that more or less a linear relationship between the resistance and R equivalents and temperature change, delta T, right? So, this will be almost equal to zero. So, these two terms will predominate, right? Because this is very small, therefore we can predict that R more or less linear relationship between the resistance R equivalent and temperature change delta T, right? If you put delta T here, so it will be that means this thing here, so it will get this.

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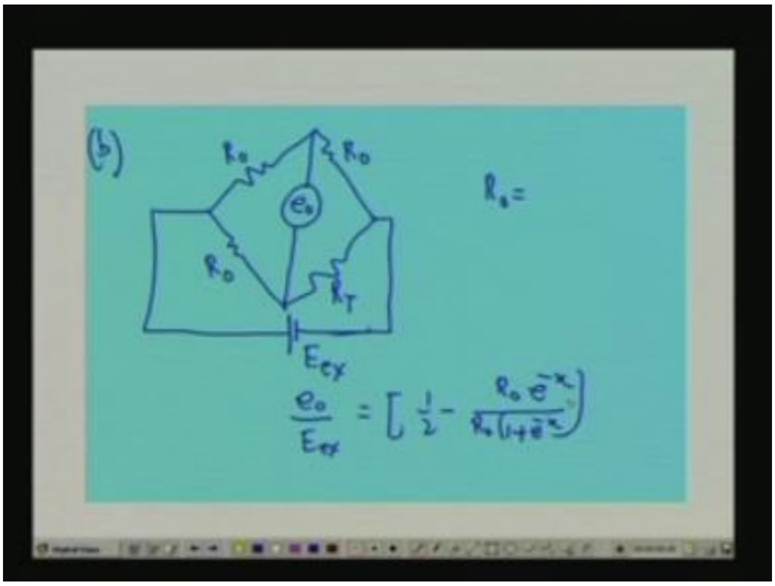

Now, part b is, again let me draw the, so it is, I put the thermistor now in the Wheatstone bridge, right and look at linearity business. So, I have the output e naught, so I have a power supply. Now, in this scheme, all the resistances are made equal to the thermistor resistance R 0 at temperature T 0, right? So, I assume that the R 0 plus if all the resistances are equal, this is equal to the thermistor resistance at temperature T 0. From the circuit we can write obviously, so there we can write that e naught by E ex equal to half minus R naught e to the power minus x upon R naught 1 plus e to the power minus x, right?

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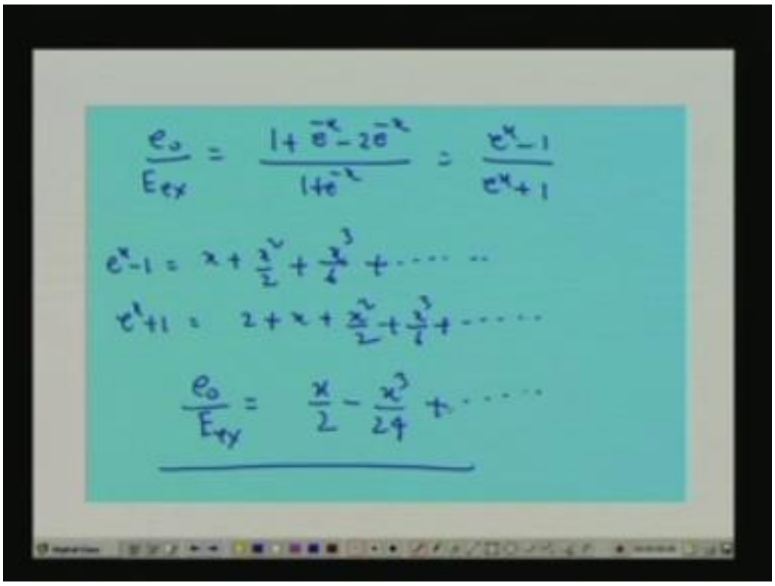

So, so now if I take a blank page, e naught by E ex equal to 1 plus e to the power minus x minus 2 e to the power minus x upon 1 plus minus x. So, this will give you e to the power x minus 1 and e to the power x plus 1, is not it? So, this is e to the minus x. Now, e to the power x minus 1 we know; x plus x square by 2 plus x cube by 6 plus so on and e to the power x plus 1 is equal to 2 plus x plus x square by 2. So, I can write here that e naught by E ex it will become x by 2. If we make a long division, if we make a long division of this, it will become x by 2 minus x cube by 24 plus so on.

So, we can see that the, using the Wheatstone bridge also the relation between the output voltage and the temperature change is almost linear, right? This proves this part. Now, let us go the problem number 17.4. This is on the thermocouple, right, so this is on the thermocouple.

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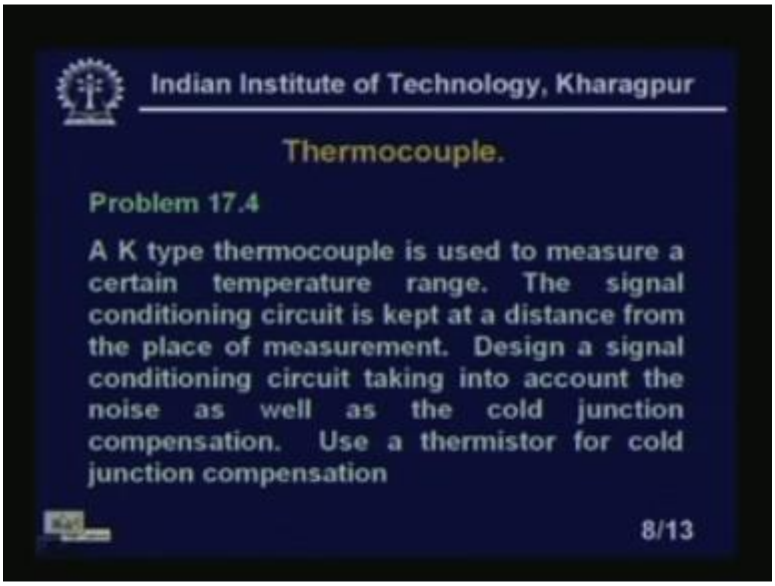

It is telling a K type thermocouple is used to measure a certain temperature change, range and the signal conditioning circuitry is kept at a distance from the place of the measurement. That means I need a cold junction compensation, because in the point of measurement and the, and the, and the, the, the and the point of actual, the installation of the sensor and the point of the voltmeter is far away, I need some phase, I mean compensating cable, right or lead wires sometimes we call it. So, you know actually from, when we studied the thermocouple that for K type of thermocouple which is basically Chromel Alumel thermocouple, what should be the lead wires, right?

Now, the question is design a signal conditioning circuitry taking into account the noise as well as the cold junction compensation and use a thermistor for cold junction compensation, right? So, instead of using, I mean 8590 and all these things, use the thermistor. Because, we have seen that by using 8590 we can make cold junction compensation. But here we are asking you that use the, make the cold junction compensation using a thermistor, right? So, this is your problem, fine. If this is the problem, so let us look at the solution.

Now, since the signal conditioning circuitry is placed at a distance from the place of measurements, we need some lead wires for compensating cables. Here we are using

K type of thermocouple, so it is a Chromel Alumel thermocouple. So I, the lead wires or compensating cables we will use is a copper constantan, right? There are two types of, I mean lead wires. So, we are choosing copper constantan here. Now, the thermocouple is an active transducer. It gives very few millivolts as the output voltage. As they are highly prone to noise and environment, noisy environments, so noise can, can also be introduced by the signal conditioning circuitry from the power line and all these things.

To remove this we, we use a capacitance between the power supply and the circuit. Noise is also introduced by the capacitive coupling and the magnetic coupling, so I have introduced in the circuit, right? Now, to measure this we may use a shielded pair of twisted cables with the shield grounded. It is then passed through the low pass filter before feeding to an amplifier. Then we can see the circuit looks like this.

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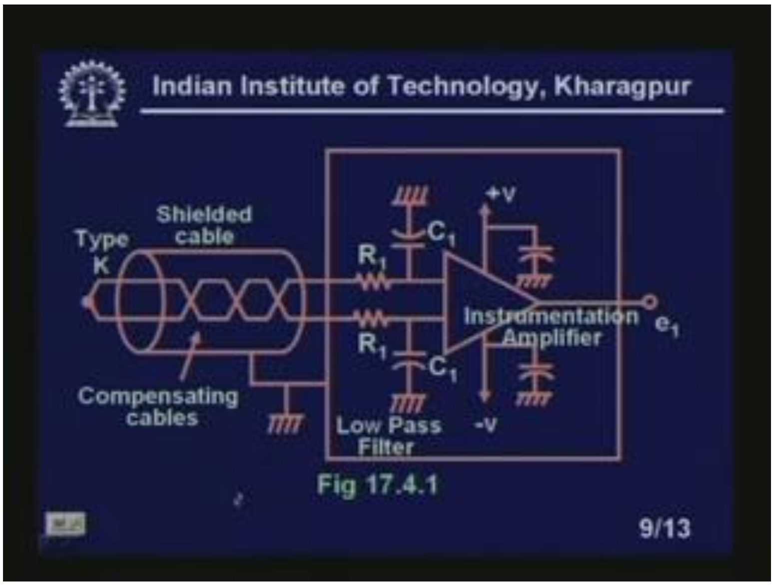

This is the circuit. You see this is the shielded cable, a type K thermocouple. There is a compensating. This is the shielded, this is the shield and this is the twisted pair compensating cable, because thermocouple will end here. So, after that it will go, so it is going to a low pass filters. Ultimately it is fed into the instrumentation amplifier, so we are using some capacitor. We will introduce, I mean eliminate the power supply noises and all those things. So, this is our complete circuit, right?

An instrumentation amplifier with high CMRR needs to be used, so that any common mode noise signal will be attenuated. So, this is our …. Now, see that for cold junction compensation we use the thermistor, fine. Thermistor being a nonlinear device, we need to use a linearization technique. This is then passed through an amplifier to make the sensitivities of these two circuits identical, so that it will take care of ambient temperature fluctuations or variation, right, right? So, the circuit will look like this. Let me go down, yes.

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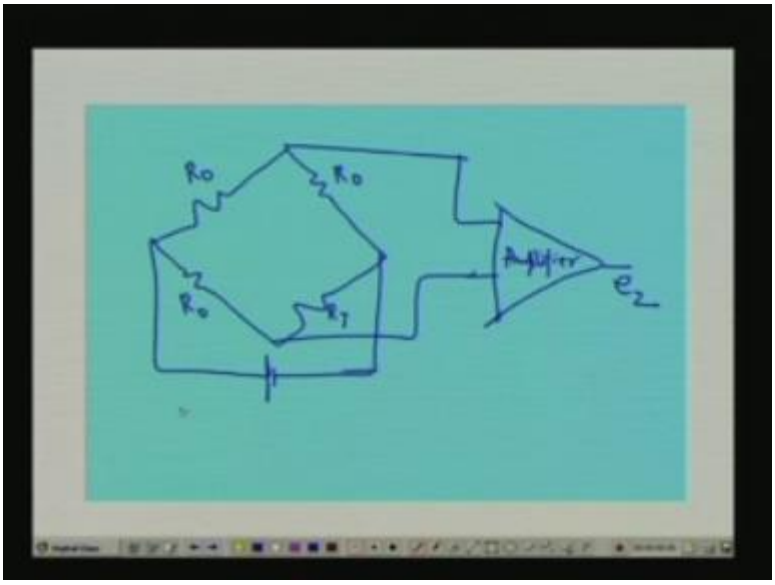

So we have, it is a cold junction compensation circuit, right? This circuit will be used along with the thermocouple circuit through some signal conditioning circuit, so that to avoid any change in the ambient temperature. This is an amplifier. This is the output voltage e 2. First case output voltage is e 1. We have chosen R o, this is R o. This is R o and this is R T. Now, this cold junction compensation circuit, as it happened in the case of 8590 also, should be placed close to the different junction temperature, so that any fluctuations in temperature of the environment will be nullified, right, so that, in that, in that case it will since the, the temperature of the cold junction actually, right? Ideally they should be within the isothermal block and the total circuit is shown in the next slide.

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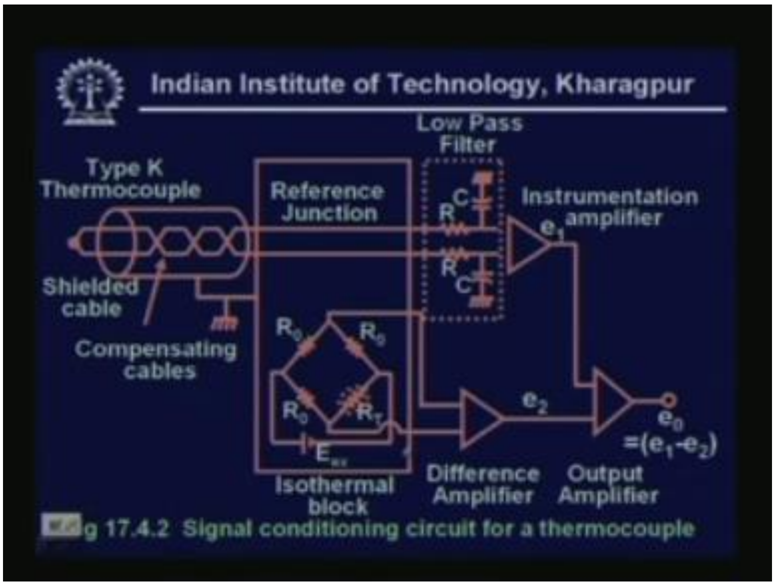

So, let us look at; so, this is our complete circuit diagram you see, right? You can see here, this is the type K thermocouple, this already we have shown. These are figure, the circuit 1, circuit 2. This is e 1, this is output voltage. It is not cold junction compensated. We have a reference junction. Now, this we put on a, on a isothermal block. You see here and this is our circuit which I have used, is not it? Just now we have used this circuit, yes; so, this is our thermistor, this is our thermocouple. I need cold junction compensation, so this is isothermal block. Then this is a, you see this output is coming down here.

So, any change will be, obviously what will happen? It will be subtracted, so the output voltage is e naught equal to e 1 minus e 2. So, the difference amplifier is coming, because this will give you high input impedance. This is output to the, this is coming to the instrumentation amplifier, right? So, this output is coming down here, so difference I am getting output here, right? So, this way also I can make the cold junction compensation, right? Fine.

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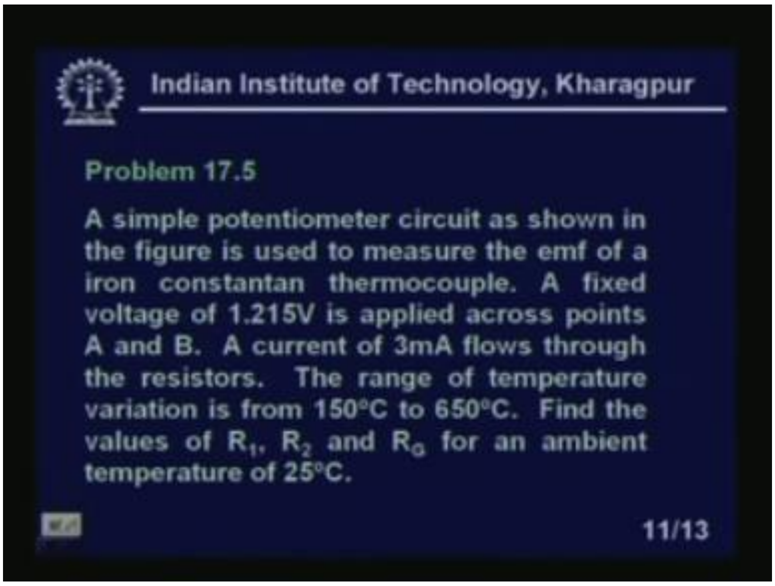

So, we can now come to the problem number 5 or 17.5. It is telling that a simple potentiometer circuit as shown in the figure is used to measure the, to measure the emf of an iron constantan thermocouple. A fixed voltage of 1.215 volt is applied across the points A and B. A current of 3 milliampere flows through the resistors and the range of temperature variation is from 150 degree centigrade to 650 degree centigrade. Find the values of R 1, R 2 and R G for an ambient temperature of 25 degree centigrade. Let us look at the circuit diagram.

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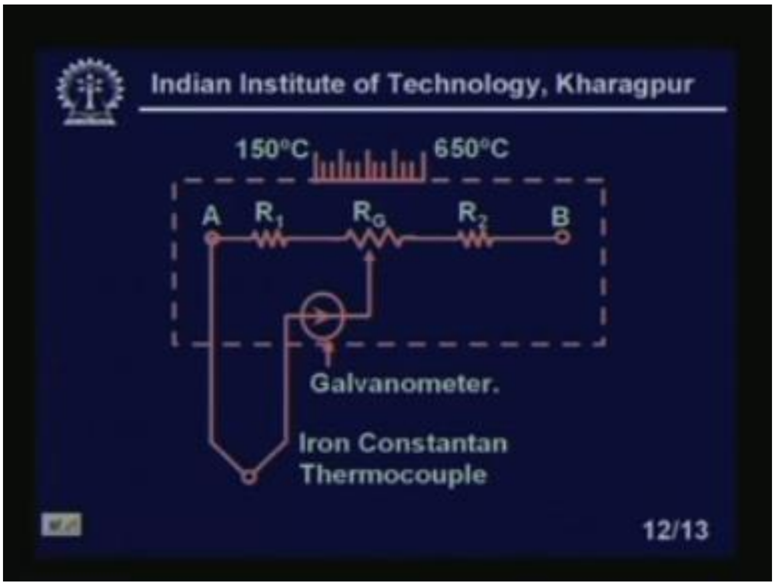

So, this is our circuit, right? It is telling that the, we have to find the values of R 1, R 2 and R G for an ambient temperature of 25 degree centigrade. So, this is our iron constantan thermocouple, right? So, the fixed voltage is 1.215 volt, standard voltage which will not vary, applied across the points A and B, right and we have a galvanometer to know the current. Now we have given also some data.

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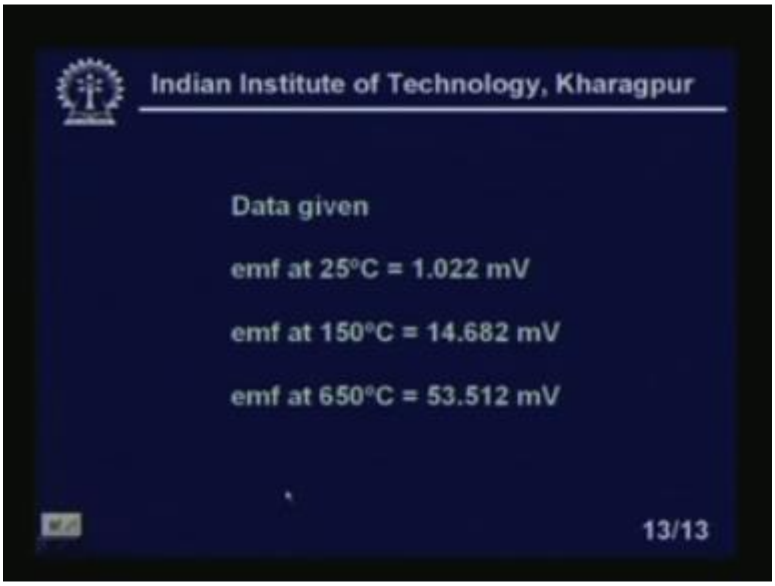

So, data are emf at 25 degree centigrade is 1.00, 1.022 millivolt emf at 150 degree centigrade is 14.682 millivolt and emf at 650 degree centigrade is 53.512 millivolt, right? That is emf at 150 degree centigrade, emf at 53, I mean 650 degree centigrade fifty three point one, 53.512 millivolt. Now, let us look at the solution. Solution looks like this. Now you see the current is 3 milliampere, is not it? Sorry, current is 3 milliampere. Now, I should go to the, now see what will happen here? Let me draw the circuit again, so that will be more clear.

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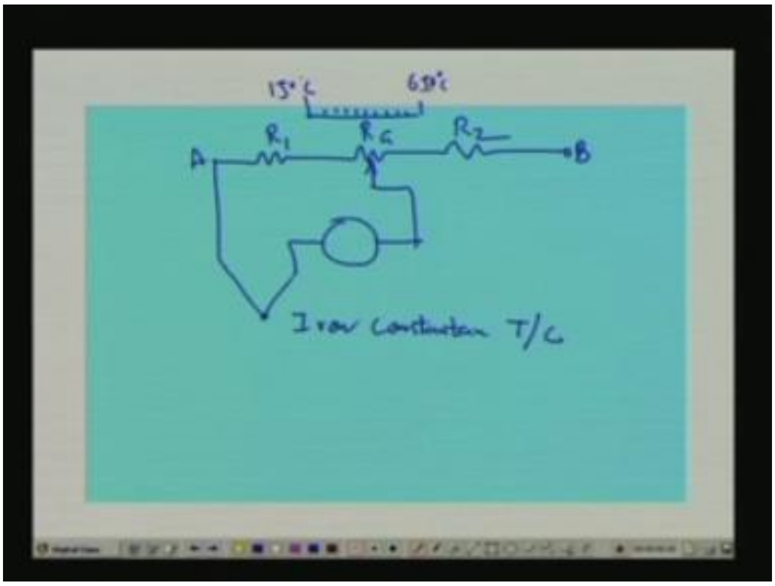

So, we have R 1, R G, R 2, it is connected to a thermocouple. It is galvanometer, so I have point here. So, this is R 1, this is R G and this is R 2. This is A, this is B, right? So, this is our iron constantan thermocouple, constantan thermocouple, right? So, it is our range. So, we are saying it is 150 degree centigrade to 650 degree centigrade, right? So, the current is of 3 milliampere, is not it, it is given. So, let me now make the solution.

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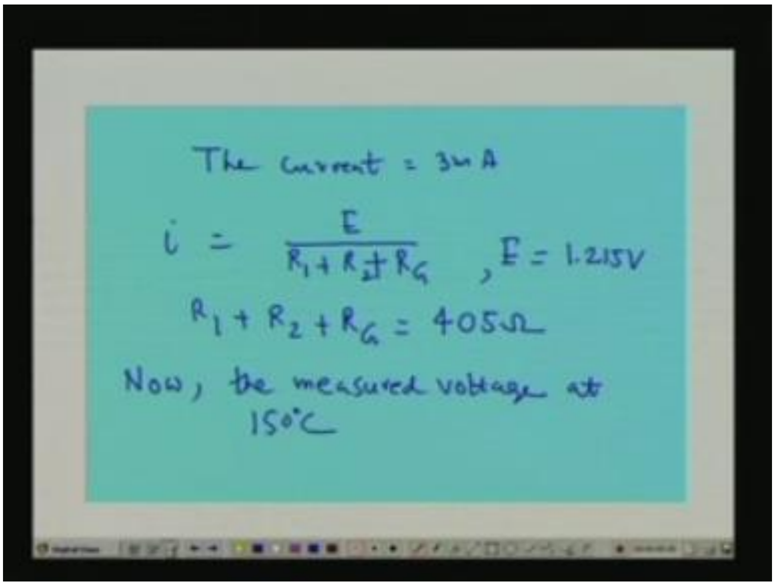

So, the current is 3 milliampere. So, I equal to the voltage E divided by R 1 plus R 2 plus R G. So, I will get that R 1, because this, I am sorry, so this should, you see, this is plus R G. Now, E is given, E is equal to 1.215 volt. So, R 1 plus R 2 plus R G equal to 405 ohm.

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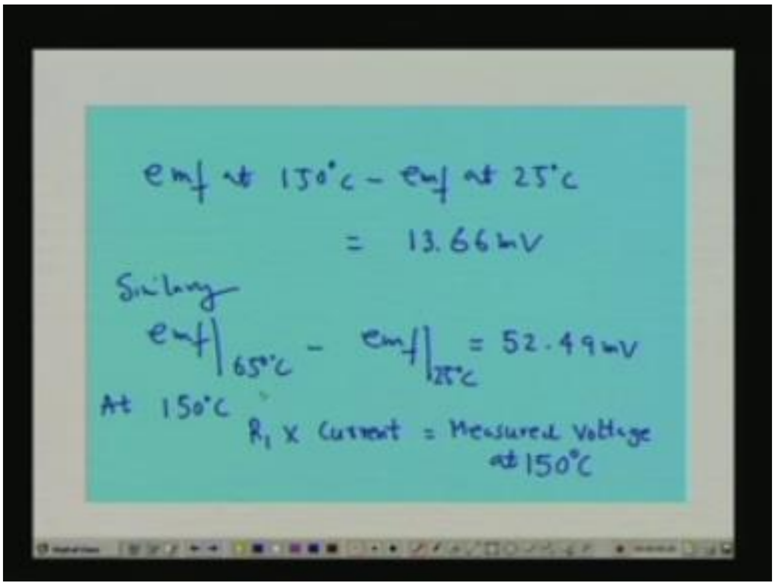

Now, the measured voltage, voltage at 150 centigrade is emf at 150 degree centigrade minus emf at 25 degree centigrade. So, this will give you 13.66 millivolt. Similarly, thermistor voltage at 650 degree centigrade, …… emf at 650 degree centigrade minus emf at 25 degree centigrade. So, this will give you the value 52.49 millivolt. Now, at 150 degree centigrade, from the circuit we can see that R 1 into current is equal to the measured voltage, voltage at 150 degree centigrade, right? It is not very good, I should delete it. So, take the pen again, 150 degree centigrade, right?

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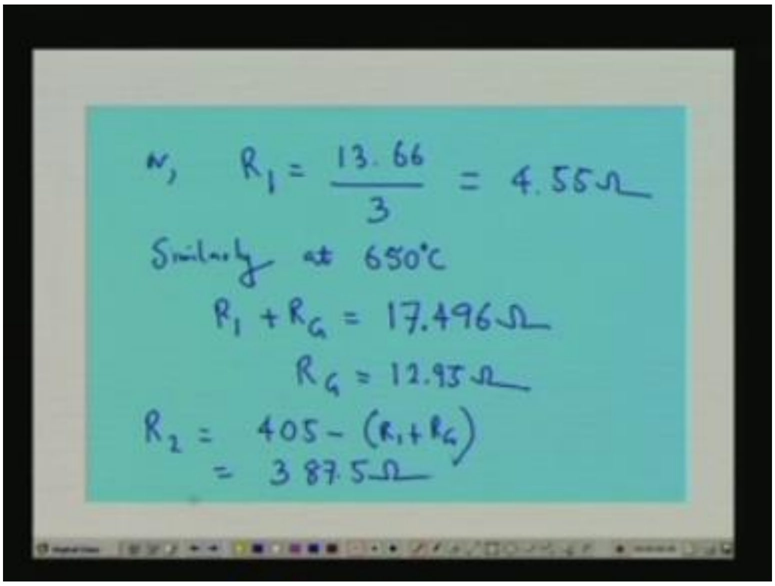

So the or I can write R 1 equal to 13.66 by 3 equal to 4.55 ohm. Similarly, similarly at 650 degree centigrade, R 1 plus R G equal to 17.496 ohm. So, R G will become 12.95 ohm. So, R 2 will become 405 ohm minus R 1 plus R G equal to three hundred eight seven five, 387.5 ohm.

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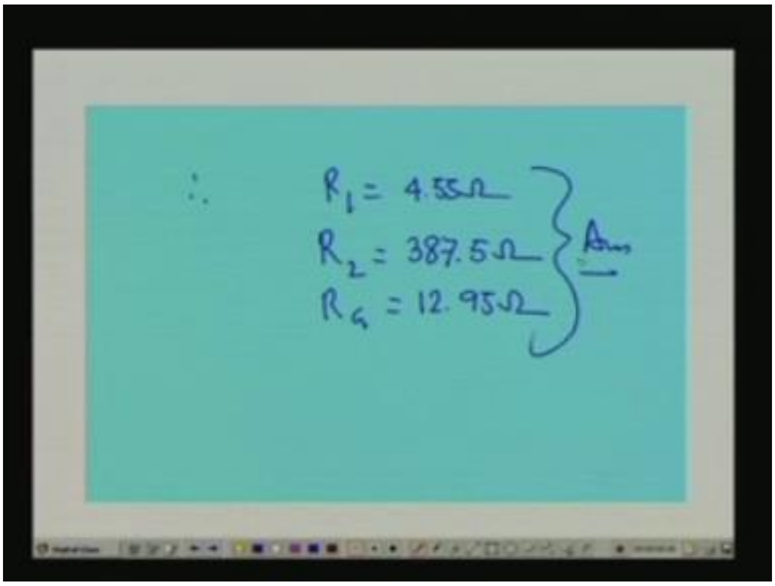

So, if I write all the answers at one point, it will be R 1 equal to 4.55 ohm. R 2 equal to 387.5 ohm and R G is equal to 12.95 ohm. So, this is our answer to the problem number 17.5.

So, in this lesson we have seen that we have solved several problems on the temperature sensors. When we discussed the thermocouple we have solved one problem, while the, if, if the, the compensating cables terminals change, then what will be the effect on the output? But these are the, we have solved several problems in this particular lessons on the, only on the problems on the temperature sensor. This ends the lesson 17 of Industrial Instrumentation.