Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 22
Problems: 4 Terminal Resistance

Hello and welcome again. Yesterday, we were talking about 4 Terminal Resistance ok. So, I think the idea will be more clear if we solve a number of examples with 4 terminal resistances.

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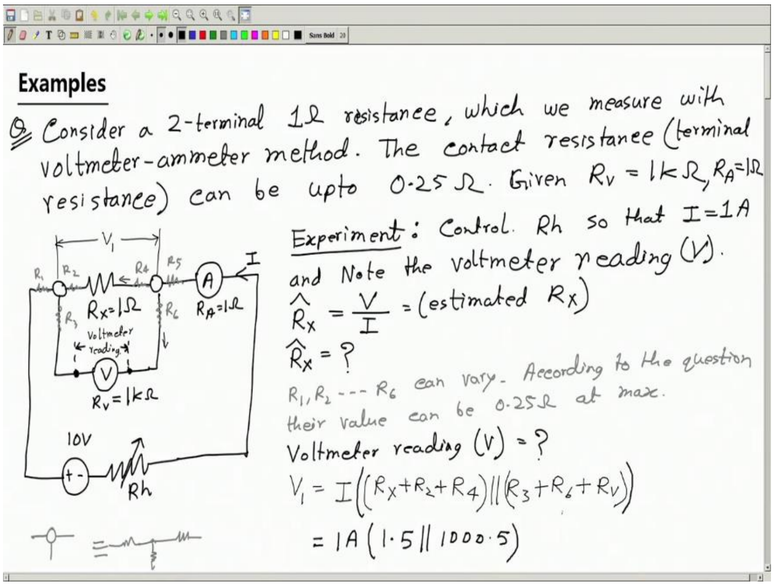

So, this video we will dedicate for solving problems, solving some problems ok. So, let us consider so, the question is considered a 2 terminal resistance, consider a 1 ohm 2 terminal resistance, 2 terminal 1 ohm resistance, which we measure with voltmeter-ammeter method. And, the contact resistance; that means, the terminal resistance can vary can be up to say 0.25 ohm; 0.25 ohm ok.

So, this is the maximum terminal resistance or contact resistance that we can have ok. Now, so, this is the data given. Now, if we measure the resistance with voltmeter ammeter method, then what can be the measured value? So, let us consider the circuit. So, this circuit is like this. So, we have this on this resistance which is R x equal to 1 ohm and it has 2 terminals ok.

So, we connect wires here we put a voltmeter and if this is the voltmeter V. And, say the voltmeter resistance that the voltmeter that we are using has a resistance of 1 kilo ohm and the ammeter resistance R A. So, that is 1 ohm ok. So, here we will connect the ammeter.

So, R A is equal to 1 ohm R v is equal to 1 kilo ohm and then we have the power supply, this is a rheostat with which we can control the total current I. So, this current will be I ok. Now, the experiment will be as follows ok. So, control this rheostat. So, that I is equal to say 1 ampere. So, this voltage has a value may be say 10 volt ok. So, control R h such that I becomes 1 ampere and note the value of the reading of the voltmeter, call that V voltmeter reading V.

So, then the estimated value of R x will be the voltmeter reading divided by the ammeter reading I. So, this is the estimated value ok. So, with this hat we mean this is the estimated value of R x not the true value, true value we know it is 1 ohm ok. So, what will be this estimated values? The question is R x hat estimated value what will be this value? So, we will control this rheostat. So, that so, we know that this circuit resistance is here around 1 ohm. So, we can have some contact resistances here which is like 0.25 ohm, then another 1 ohm.

So, this all this resistances plus this rheostat R h they together should be in such a value. So, that the I this current is 1 ampere. So, under that condition, what will be the value of V? Ok. Now, this I is 1 ampere and so, we know that the contact resistance can cause say up 2.25 ohm resistance in so, this contact. So, as we discussed yesterday any contact we will model it as like this. So, if you have a contact like this.

So, where many wires are connected through some screw or something; so, we will model it like an ideal junction with resistances cost in this individual branches ok. So, similarly here we will have get this resistances, due to this contact and this value can vary. So, this values. So, call this R 1 R 2 R 3 R 4 R 5 R 6. So, note that R 1 to up to R 6 can vary and according to the question this their value can be 0.25 ohm at max.

So, this is not a large a resisters. It is a very small resisters 0.25 ohm, but you are considering it with so, much care because this unknown resistance is also a small ok. So now, if so, what will be the voltmeter reading, voltmeter reading will be how much? So, the voltmeter reading will be. So, the voltmeter actually will measure the voltage which appears between actually it will measure the voltage which appear between these two points here and here.

So, this voltage so this is, this will be voltmeter reading. So, let us first find out this voltage, call this V 1 and then voltmeter reading will be slightly less than V 1, because some current will flow and there will be some voltage drop. So, voltmeter reading will be somewhat less than V 1 ok. So, before you find V let us find V 1 is equal to how much ok. So now, how it will be the value of V 1? V 1 is the resistance between from here to here ok. And, this current sorry V 1 is the voltage between these two points this current is I ok.

So, V 1 will be I this current which partly goes through this and partly goes through this. So, it will be voltmeter reading $V1 = I\,(Rx+R2+R4)\ ll\ (R3+R6+Rv)$

Now, let us put the values. So, I we know is 1 ampere ok. So, 1 ampere multiplied by so, R x is 1 ohm plus R 2 and R 4 maximum value of R 2 and R 4 is 0.25 ok.

$V1= 1A\ (1.5\ ll\ 1000.5)$ (considering maximum value of contact resistance)

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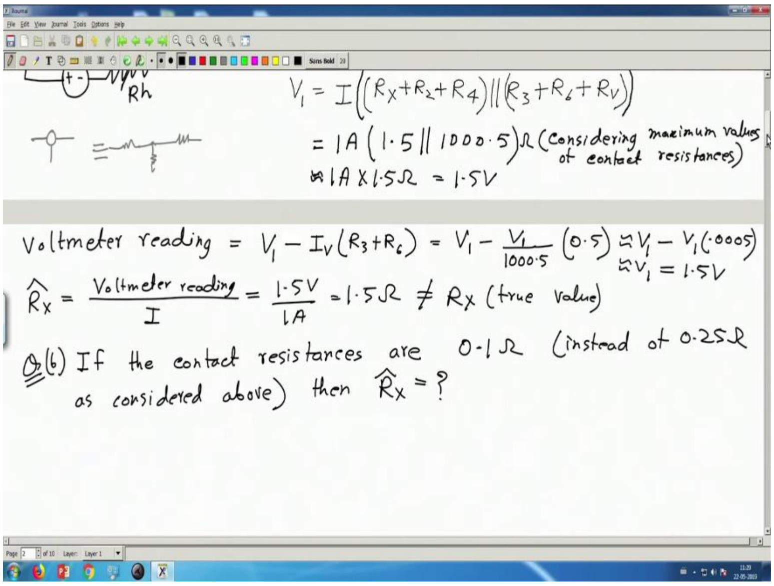

So, considering maximum values of contact resistances ok; now, this 1.5 is much smaller than this 1000.5 there is a ohm. So, the parallel combination will be approximately almost equal to 1.5. So, this will be 1.5 into 1 ampere. So, this we can write as 1 ampere into 1.5 almost equal to this which is 1.5 volt.

So, this is the value of V 1. So, this is the value of V 1. Now, the value of voltmeter reading ok, now the voltmeter reading will be V 1 minus any voltage drop here and here are across R 6 and R 3 ok. And, if I call this current is I V. So, which is a part of the total current part of the total current I, which flows through this voltmeter.

So, voltmeter reading = V1- Iv (R3+ R6) = V1- $\frac{0.5\,V1}{1000.5}$ =V1

So, this is approximately V 1 ok. So, voltmeter reading is quite close to V 1, slightly less than V 1 and V 1 is 1.5 volt. So, maybe the 2 value of the voltmeter reading will be 1.49 and very very close to 1.5, because of this slight drop and it is negligible ok.

So, this is voltmeter reading. So therefore, estimated value of R x will be how much? It will be V voltmeter reading divided by the current or ammeter reading ok. This will come out to be 1.5 volt by 1 ampere, which is 1.5 ohm, this is not same as R x true value. So, there is a huge error ok. Now, let us take another questions so, another question so, our part 2 part b ok. If the contact resistances are say 0.1 ohm instead of 0.25 ohm as considered above, then R x hat estimated value of R x hat will be how much?

So, now, so suppose this is like we are performing the experiment voltmeter ohmmeter method of voltmeter ammeter method of measuring and resistance we are doing the same experiment another day. But this day so, we connect this terminals differently therefore, this resistances come out to be 0.1 ohm instead of 0.25 ohm they can be different.

And, for simplicity we are considering all of them simple for use of calculus all of them same, but that is what is of calculation, but they need not be same. So, this can be 0.1, this can be 0.05 they can be different, but now let us say they have a different value from the previous case. So, what will be the estimated value of R x? So, we will use the same circuit.

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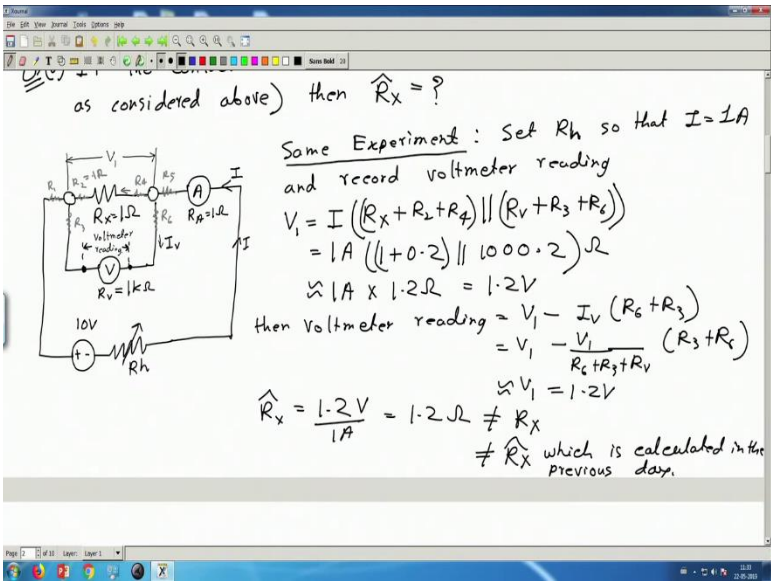

Now, this values are 0.1 ohm so, this is 0.1 ohm, this is 0.1 ohm, everything is 0.1 ohm, they all this resistances are 0.1 ohm. So, we are doing the same experiment ok. Therefore, we set r Rh; set R h so, that I is equal to 1 ampere and measure and record voltmeter reading. So, what will be the voltmeter reading? So, before we find the voltmeter reading let us find V 1. Now, V 1 will be how much? V 1 will be this current I multiplied by this parallel combination of these two resistances.

voltmeter reading $V1 = I\ (Rx+R2+R4)\ ll\ (R3+R6+Rv)$

$= 1A(1+0.2)\ ll\ (1000.2)$ ohm

$= 1A \text{ X } 1.2$ ohm$= 1.2$ V

And, then voltmeter reading $= V1- Iv\ (R3+ R6) = V1- \frac{V1}{R3+R6+Rv}\ (R3+ R6) =1.2$ V

So, therefore, R x hat will come out to be 1.2 volt by 1 ampere which is equal to 1.2 ohm ok. So, this is once again not same as R x true value or this is also not same as R x hat which is calculated, which is calculated in the previous day. So, we see that this experiment is not reliable, because every day this can give different result. Now, the next question that we will take is this.

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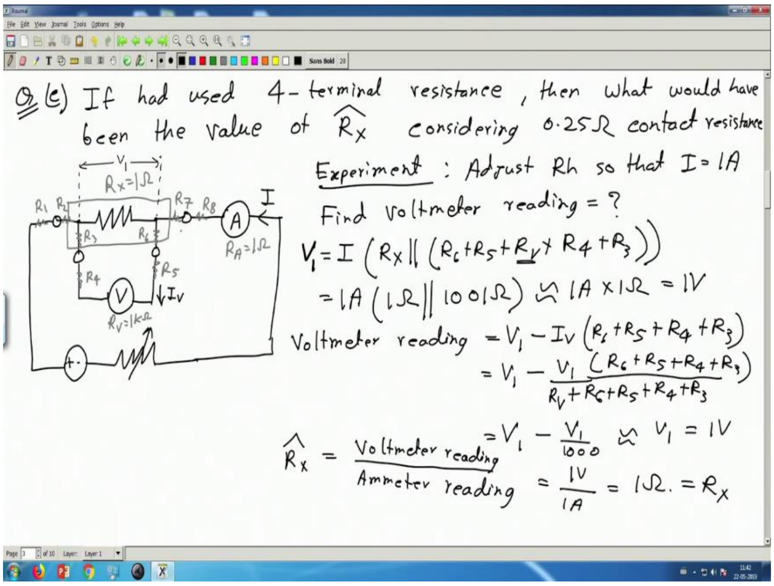

So, next question or question c, if we had used 4 terminal resistance instead of the 2 terminal 1 as above then what would have been the value of R x hat; that means, the estimated value of R x considering 0.25 ohm contact resistance ok.

So, now we are doing the same experiment with a 4 terminal resistance. So, we will have 4 terminals like this ok. Note that this is also a junction, but this junction is a permanent junction in case of a 4 terminal resistance, this junction is a permanent junction inside the box. And, therefore, whatever resistance this junction contributes this will also contribute some small resistances here, here, here similarly here, here, here, but that is a fixed value that is not going to change, that is why that is not the problem that is an important thing to understand.

Now, let us consider this problem once again. So, we have this ammeter, we have this voltmeter ok, and the power supply with a rheostat that can control the current. So, we will do the same experiment. So, once again adjust R h. So, that I is equal to 1 ampere. So, we are doing the same experiment. So, this total current is 1 ampere, now let us put all the contact resistances everywhere.

So, we will have a contact resistance here, here, here, here, here, here, here, here ok. We are considering only these contact resistances which are variable. And, the permanent contact resistances that you can assume it is already it a part of this main resistance, because that is a constant value. So, we can think of that is as a constant part of this main resistance, we need not consider that.

So, let us considered this experiment and all this resistances let me give their names for is of reference R 1, R 2, R 3, R 4, then R 5, R 6, R 7, R 8 ok. You have so, many contact resistances this is R v equal to 1 kilo ohm and R A is not required, but still this is 1 ohm and this R x this resistances 1 ohm ok. So, adjust R h so, that the current is 1 ampere and now we have to find voltmeter reading.

So, voltmeter reading is how much. So, voltmeter reading will be we can write it as this current I multiplied by ok. So, before we find voltmeter reading let us find the value of the voltage which is between these 2 points V 1 call that V 1. So, considered these 2 points here this and this and the voltage between this is V 1 ok. So, let us find V 1 first then we can find voltmeter reading.

V1= I (Rx ll (R6+R5+Rv+R4+R3))

= 1A (1 ohm ll 1001 ohm) = 1V

Voltmeter reading = V1- Iv (R3+R4+R5+R6)

$$= V1- \frac{V1(R3+R4+R5+R6)}{(Rv+R3+R4+R5+R6)}$$

$$= V1- \frac{V1}{1000} = V1$$

Therefore, R x hat will come out to be voltmeter reading divided by ammeter reading voltmeter reading by ammeter reading which is I ok. So, this will be 1 volt by 1 ampere is equal to 1 ohm. So, you see that this is same as R x, where R x means all the resistances starting from this point to this point including these and even this everything from here to here is R x ok.

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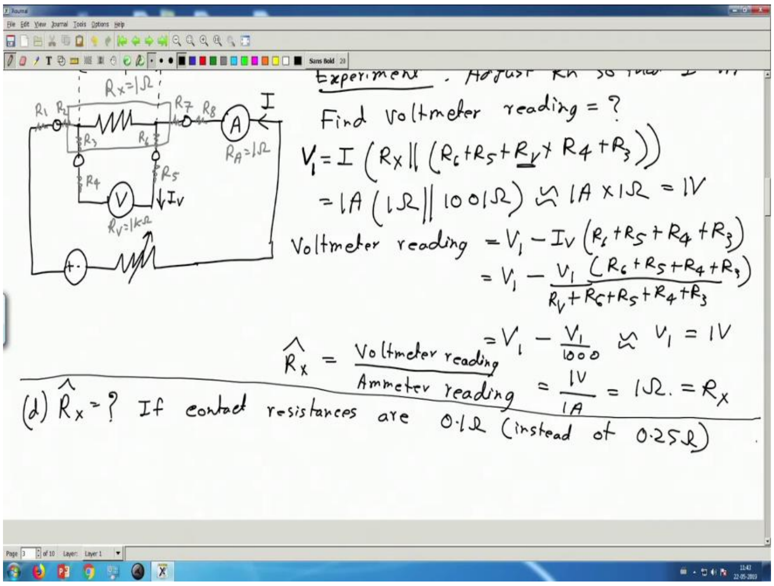

But most important thing to observe is that, so let us take another question what if what happens if. So, let me write it this way. So, R x hat will be equal to how much if contact resistances are 0.1 ohm instead of 0.25 ohm as before. So, what will be that value ok? So, this is next thing to consider ok. So now, we can basically do the same calculation so, what we will do, we will since we can do the same calculation we will copied and now we will change the values here ok.

So, now let us put the actual values. So, in this experiment once again when you start will be adjusted. So, that I is equal to 1 ampere now we have to find the voltmeter reading, but before that we have to find this V 1 and V 1 will be again just like this same expression will hold, but now R x R 5 this will be 0.1 ohm. So, the denominator will become instated of 1000 and 1 this will become 1000.4.

Because, this is 0.1 ohm this is 0.1 ohm all these are now 0.1 ohm ok. So, this becomes 0.1000.4 what this is again approximately same as 1 1 volt, because this is much lower than 1000. And, then V 1 will be this same expression is true. And, now this factor will change, this factor will become the numerator will be 0.4 and this will denominator will be this, but still this is a very small number.

So, we will ignore it. So, this is a once again approximately equal to 0. So, V 1 is still same and therefore, R x will still be same as 1 ohm it is not changing. So, observe this is the beauty of our 4 terminal resistance measurement is so, reliable we can repeat the same experiment every time my contact resistance will change, but my reading or the value of estimated value of this R x will come out to be same. So, this is the beauty of this 4 terminal resistance. Now, we will take another problem in this video, which will be the last problem in this video.

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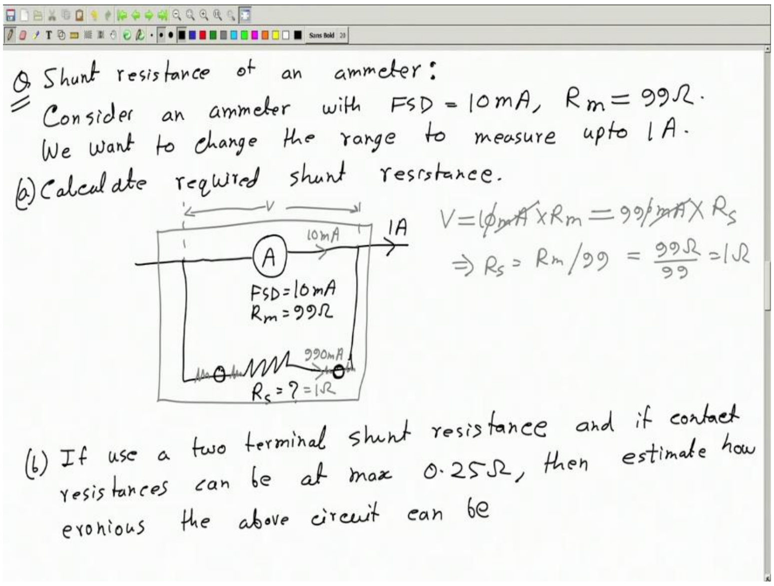

So, the next question is as follows so, the question now is regarding the shunt resistance of an ammeter ok. So, this is related to the shunt resistance of an ammeter. So, consider an ammeter with full scale deflection current is equal to say 10 milliampere this is my favorite number I always use this number because calculation become so, so, easy.

So, consider an ammeter with full scale deflection current as 10 milli ampere and the meter resistance R m; that means, the call resistance may be is say 99 ohm. So, we were to change the range, we want to change the range to measure up to 1 ampere. So, first calculate so, calculate required shunt resistance. So, this is part a; this is part a. So, we will have more parts, but let us do this part first this is the easiest. So, we have a ammeter full scale deflection current is how much 10 milliampere we want to put a shunt.

And, shunt resistance is how much that we have to find out meter resistance is 99 ohm and we want to measure a current which is 1 ampere. So, when 1 ampere current flows through this circuit ok. If, 1 ampere current is flowing through this circuit, then the meter should show full scale deflection current; that means, when this current is 1 ampere this current should be 10 milliampere and if so, then the remaining current must flow here.

So, this will be how much this will be 1 ampere means 1000 minus 10; so, 99 milliampere. Now so, what will be the value of R s. Now, we can write that this voltage from here to here. So, this voltage consider this voltage, this voltage from here to here this we can write as V is equal to this current 10 milliampere multiplied by meter resistance R m. We can also write it as this current 99 milliampere multiplied by this resistance R s ok. So, then from this two we can write, that now can cancel this milliampere, milliampere 00.

So, here we see that R m is 99 R s or R s is R m by 99, which will be 99 9 ohm by 99 ohm sorry by 99 just 1 ohm. So, this should be 1 ohm this is simplest. Now, part b next part is if we connect if we use a two terminal, if we use a two terminal resist shunt resistance ok, if we use a two terminal shunt resistance in the above scenario in the above problem. And, if contact resistances can be at max contact resistances can be at max 0.25 ohm, then in this ammeter circuit, then this ammeter circuit will be erroneous because of the contact resistances.

So, if we use a two terminal resistance, which will have two terminals like this and we will connect wires like this, and this two terminals will cause some resistances some variable resistance unknown resistance here, here and here and here. Their maximum value can be 0.25 ohm here, here, here, here etcetera ok. Now, the question is now this resistances this variable contact resistances will chase the calibration of this meter.

And therefore, this meter this circuit will be erroneous. How erroneous that can be ok. So, let us estimate that. So, then estimate how erroneous the above circuit can be? So, have this let me draw once again.

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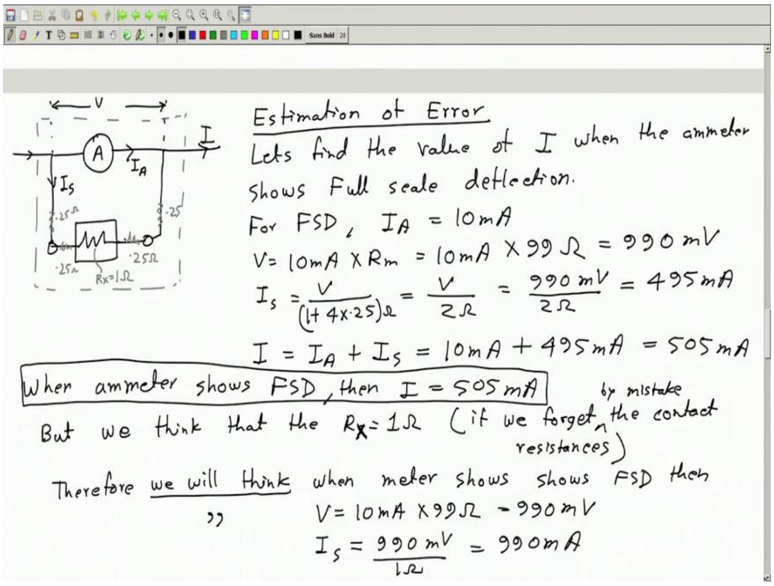

We have this ammeter and we are connecting this with R two terminal resistance yes this is inside a box. And we have joining this with wires and the current will enter through this and live through this. So, this will be the I mean ammeter total ammeter I mean ammeter circuit.

And, now so, how erroneous this ammeter is considering that this resistances are 0.25 ohm. So, 0.25 ohm 0.25 ohm so, this is the maximum value that we can have ok. So, how erroneous can and this resistance so, we have chosen this resistance as computed in part A this should be 1 ohm ok. Now, let us estimate the error ok.

So, consider when say consider when 1 ampere current is flowing through this, what will be the reading of this ammeter ok. We can calculate that or we can calculate in the opposite way say, when this ammeter is showing 1 ohm full scale deflection, then what is this current ok.

So, considered or let us find. So, the let us find the value of I this is I the total current, when the ammeter shows full scale deflection full scale deflection ok. So, note that since we have connected a shunt resistance with nominal value 1 ohm, we will think that when this ammeter is showing full scale deflection this current is actually 1 ampere. So, note that ok so, before that ok.

So, let us first solve this let us find the value of I when the ammeter shows full scale deflection ok. So, for full scale deflection ammeter current I A call this I A this will be 10 milliampere according to the specification of the ammeter ok. So, this current is 10 milliampere. So, what is this voltage? So,

For FSD I_A = 10mA

V=10mA X Rm =10mA X 99 ohm= 990 mV

$$Is = \frac{V}{(1+4\ X\ 0.25)} = \frac{V}{2} = \frac{990}{2} = 495mA$$

I = I_A + Is = 10mA + 495mA = 505mA

So, note this, but we if we, but we think that this shunt resistance is equal to R x according to that notation is 1 ohm. So, if we forget about if we forget by mistake the contact resistances ok. So, if we forget by mistake the contact resistances, then we will think that the R x is 1 ohm.

And, therefore, we will think we will think when meter shows FSD meter shows full scale deflection, then so, this is important we will think this is not true, then

V = 10mA X 99ohm= 990 mV

And therefore, we will think that I s shunt current is 990 millivolt by 1 ohm, so, this is 990 milliampere. And therefore, we will again think that

I= I_A + Is= 990 +10 = 1A

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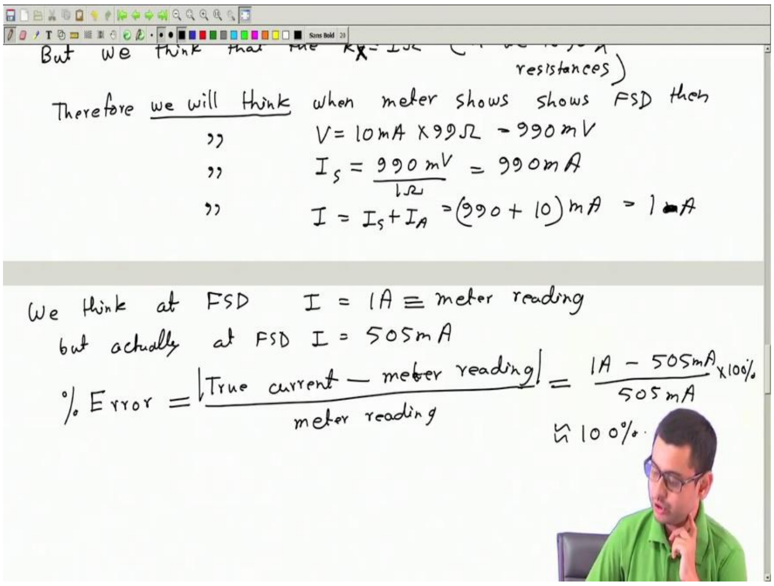

So, we will think that the current I is 1 milliampere, but because of the contact resistances this current is actually 505 milliampere. So, we will make a error of almost 50 percent. So, we think so, we believe, the current is 1 milliampere sorry this is 1 ampere. The current is 1 ampere, but the actual current is 505. So, we think at FSD I is equal to 1 ampere, but actually at FSD I is only 505 milliampere half of this.

So, there is a huge error ok. So, there is a huge error. So, and now if we define an error say a percentage error. So, now this time we can define the first percentage error as say

$$\% \text{ Error} = \frac{true\ current - meter\ reading}{meter\ reading} = \frac{1A - 505mA}{505mA} = 100\%$$

true current minus the meter reading. Basically, meter reading means what we think the current actual current is so; this is this you can call as meter reading. I mean this is what we believe the value is and then let us divide it by meter reading.

So, this is percentage error so, error as a percent as a fraction of the meter reading ok. So, you have not I mean you could have also divided this by true current that is also I mean both a both estimates are used in practice. So, then we can take a mod sign if you do not need; what you do not want the plus minus sign?

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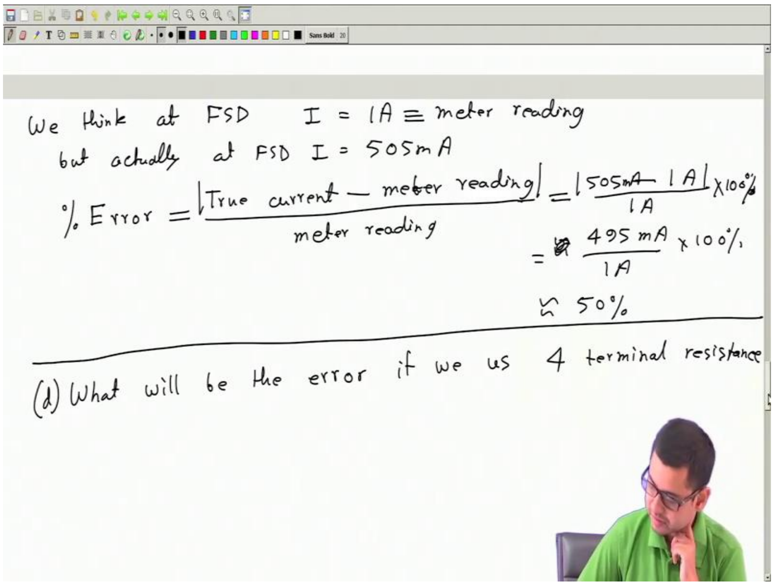

Sorry there is a mistake. So, this is not 505 this is a there is a mistake let me corrected. So, this true value,

$$\% \text{ Error} = \frac{true\ current - meter\ reading}{meter\ reading} = \frac{|505mA - 1A|}{1A} = 50\%$$

Now, last part what will be the error if we use 4 terminal resistances ok. So, this is the final part ok. So, here we will now use a 4 terminal resistance.

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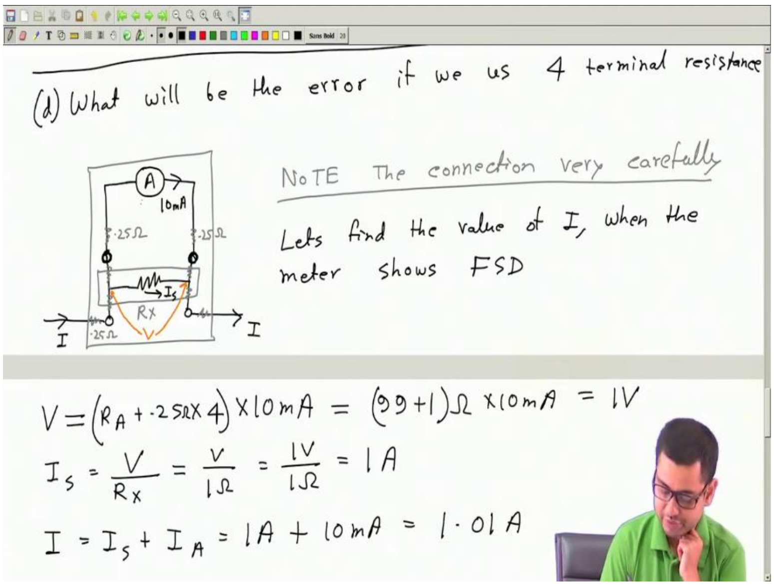

So, this is my ammeter and I have a resistance which has 4 terminals ok. And, this thing is in a box and the 4 terminals are outside. Now, it is important to know how to connect this 4 terminal resistance as a shunt to this ammeter.

What we should do is this we should. So, carefully note this connection very carefully note this connection. If you make any mistake then you will have a huge error. The way we should connected is the like this connect the ammeter to two terminals and make the other two terminals as the inlet outlet of the unknown current. So, current I will enter through this and will live through this and this is my entire ammeter ok. This is how we should connected. So, note the connection very careful ok.

So, now what will be the error? So, we note this resistance is R x ok. So, let us find the value of I, when the meter shows Full Scale Deflection ok. So, when the meter shows full scale deflection; that means, this current must be 10 milliampere which is this specification of this ammeter, then the question is what is this value of this current I. So, before we define that and we may have this contact resistances here, here, here, here, here and here and here.

And, let us consider all of them to be the maximum contact resistance which is 0.25 ohm, point here is everywhere 0.25 ohm, point everywhere 0.25 ohm. So, all this contact resistances are 0.25 ohm under that situation what will be the value of I. Now, before we can find the value of I we need the value of the voltage between this point and this point.

So, we need the voltage between this 2 points ok. So, now, this voltage V how much will be this voltage V, this voltage will be same as this current multiplied by this total resist this total resistance ok. And, this total resistance is R A plus 0.25 plus 0.25. So, this is the total resistance ok, this is and then sorry there are 4 1 2 3 4.

$V = (R_A + 0.25 \times 4) \times 10mA = 1\ V$

$Is = \frac{V}{Rx} = 1A$

$I = Is + I_A = 1A + 10mA = 1.01A$

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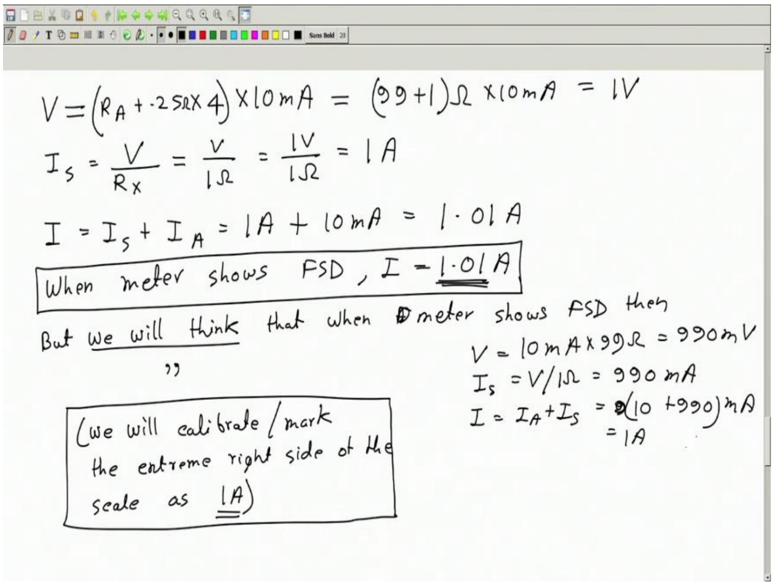

So, when meter shows FSD I is equal then I is equal to 1.01 ampere, but we will think, but if we hat calibrated the meter ignoring this contact resistances because we do not know the value of the contact resistance. So, if we so, we will think so, we will think ok, that when meter shows FSD then this voltage V between these 2 points will be how much that will be

V= 10mAX99 ohm= 990 mV

Is = V/1ohm = 990mA

I = Is + I_A = 10+990 = 1A

that means, this; that means, that we will calibrate or we will mark or mark the full extreme right side of the meter extreme right side of the scale will mark, the extreme right side of scale of the scale as 1 ampere. So, we will mark the full scale deflection as 1 ampere, but actually full scale deflection means 1.01 ampere. So, what is the error?

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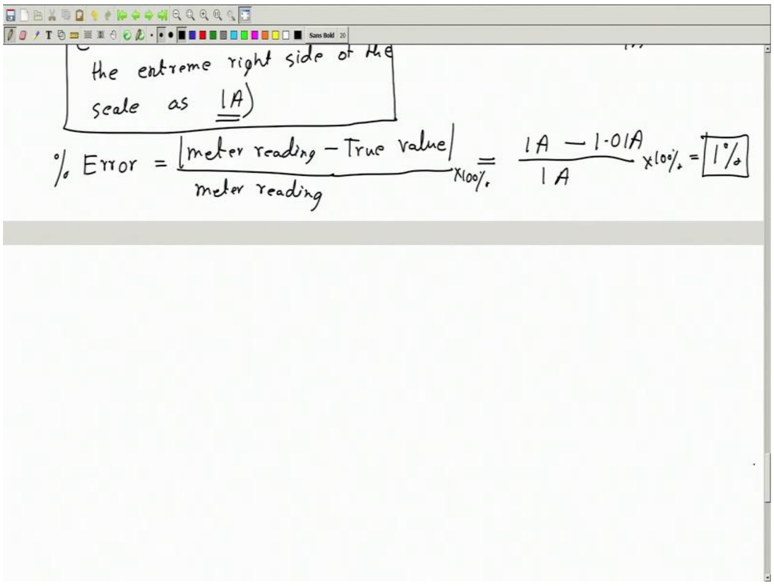

So, the error therefore, the percentage error so, you are calculating it has meter reading and here meter reading minus true value you can take a mod ok.

% Error = $\frac{true\ current - meter\ reading}{meter\ reading} = \frac{|1.01A - 1A|}{1A}$ X 100% = 1%

so, small only 1 percent whereas, if you had used the two terminal resistance, which is here the error was 50 percent ok. So, this is the beauty of a 4 terminal resistance. So, I guess I have spent long long enough time in conveying you why 4 terminal resistances are useful so, useful ok.

I have a tried to give you numeric demonstrations in different scenarios 1 practical scenario is use of shunt resistance to change the scale of an ammeter, where 4 terminal resistances are very useful. Otherwise if you use two terminal resistances we can have huge error. So, I have a tried a to give you a lot of examples and I ask you request you to think thoroughly over this topic because, you will be using 4 terminal resistances again and again in your lab I guess I believe.

But, maybe you always thought, why should had resistance should have 4 terminals resistance means always it has two terminals theoretically. What this 4 terminals mean, why do we call them as a two of them as put in shear terminals, current terminals, etcetera why 4 terminals. So, I have tried to give you enough examples why is it so, useful.

Thanks for watching let us meet again.