Electrical Measurement And Electronic Instruments
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Lecture - 21
Four - Terminal Resistance

Welcome back. So, we are discussing our third chapter in this course which is measurement of resistance and in this video we will talk about low resistance measurement. We will start talking about low resistance measurement and in particular we will talk about Four-Terminal Resistance quite amazing isn't it a resistance which has four terminals generally we know resistance has two terminals ok. So, let us understand that. So, we are talking about low resistance measurement.

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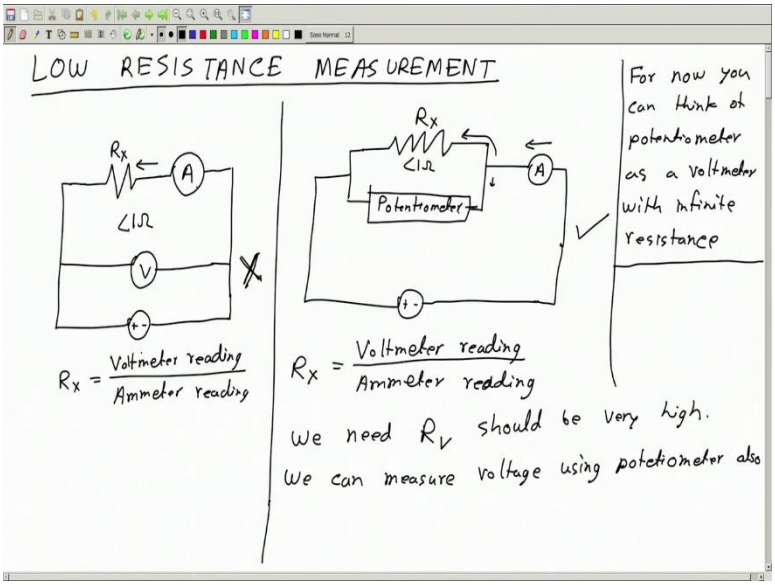

And so, let us consider of a situation and so, I particularly request you to listen to this particular topic very carefully because this is one topic which I myself had confusion or doubt for many years ok. So, this is really very and for young people I mean new students this is very confusing and there is no same if you feel that it is confusing. So, please listen to this very carefully. It is going to be interesting; it is going to be very interesting. So, let us think of very small resistance may be around 1 ohm ok.

So, this is a piece of resistance around 1 ohm or maybe even less so, maybe less than 1 ohm. So, very small resistance and I want to measure this resistance in a lab and how do I

do that. So, this is small resistance and I will use voltmeter ammeters now. So, I have to connect an ammeter and a voltmeter. Now, say I connect an ammeter to measure the current that flows through this resistance. So, I connect the ammeter in series.

And then I want to measure the voltage across it. So, I connect a voltmeter and you can connect it to a source otherwise no current will flow ok. So, this way what I can do, I can look at the reading of this voltmeter and the reading of this ammeter and then estimate the resistance R is quite R X unknown as the voltmeter reading by ammeter reading ok.

So, this is normal procedure, but I am saying that do not do this, do not use this circuit. Why? Because if you recall in our previous video we talked about that for low resistances do not connect them we should not connect the ammeter directly across these or directly besides this resister. Because, then this ammeter has also some internal resistance and that may be low ammeter resistance is low normally that is what the ammeter resistance should be low, but this resistance is also low. So, therefore, these 2 resistances are comparable.

So, if this is 1 ohm maybe this is also 1 ohms or several ohms and therefore, if I connect the voltmeter across this 2 in series I am actually measuring more voltage much more voltage than the voltage across this resistors R X. So, this is not a good circuit and therefore, we have seen there is a better circuit. So, do not use this circuit this is a bad circuit. Do not use it rather use this circuit where you can connect a voltmeter directly across this resistance R X.

So, this is again the same small resistance may be less than 1 ohm and then you then you connect the ammeter and then you connect the power supply ok. So, definitely voltmeter resistance is much higher I mean voltmeter resistance ideally is infinite practically several maybe several kilo ohms. And then of course, this circuit is therefore, better because the current through the ammeter most of it goes through this resistance and a very little amount goes through this voltmeter ok.

So, this circuit is better ok. So, this circuit is better and then once again you can measure R X as the voltmeter reading whatever the voltmeter source divided by the ammeter reading. So, this is actually a recapitulation of what we have done in the previous video ok. So, this is a better circuit and we need R V voltmeter resistance ok. Now, I guess it is clear when I write R V it means voltmeter resistance should be very high infinite I theoretically that is what you want. But it is never infinite, but if you recall from your high

school physics we can measure voltage also using potentiometers. So, we can measure voltage using potentiometers as well ok.

And, the nice thing about potentiometer is that we will talk about potentiometers in more detail later, but from your high school physics we can recall that potentiometers also can measure voltage. But, and the nice thing is that at the null condition of the potentiometer no current goes through the potentiometer.

So, if I have a potentiometer instead of voltmeter that will be even better. So, let me instead of having a voltmeter let me use a potentiometer ok. So, right now I am drawing it as a black box put in what is there inside potentiometer, how it is connected that we are not going to discuss. So, potentiometer right now you think of a potentiometer. So, for now you can think of potentiometer as a voltmeter with infinite resistance it is equivalent to an ideal voltmeter with infinite resistance.

So, for now it is enough that. So, I mean we will talk about potentiometer in more detail later, but for to focus our attention on this topic low resistance measurement you think of potentiometer as an ideal voltmeter. So, there exists something like a ideal voltmeter with infinite resistance. So, for now let us think in that way. So, the circuit we should use to measure a low resistance is this.

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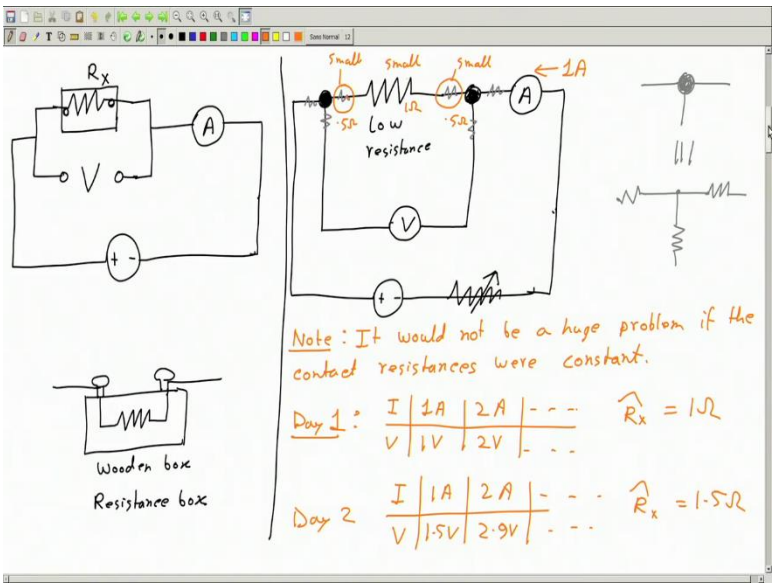

This is the low resistance we should have the potentiometer or voltmeter with infinite resistance ok; so, the here directly across it. So, this is where we will measure the voltage this can be a potentiometer or a very good voltmeter and then we will have the ammeter and here we will have the power supply. So, this is the circuit. Now, we know the you might have seen that we have resistance boxes you might have seen resistance boxes in lab.

So, those are like wooden boxes with terminals. So, so we have a wooden box with leads or terminals and inside it we have the resistance inside the box and then we can connect wires to these terminals. So, this is a resistance box and this resistance R X which is a small resistance low resistance can also come in a box with 2 terminals.

So, therefore, in this experiment we can connect the wires to these terminals. Now if we do so let us see what will actually happen. So, note that this terminals also have some resistance everything has some resistance. The wires have some resistance, terminals have some resistance and these resistance of this terminal will also depend on how say tightly you connect this wire how much pressure you applied.

So, this resistance will depend on I mean they did on a lot of things ok. So, if I draw this resistance simply like this. So, this is a low resistance, small resistance, low resistance with 2 terminals which I am drawing as 2 knobs 2 circles.

So, these are these 2 lids and wires are connected here. Now this lid will also have some resistance ok. Now let us consider this circuit once again. So, we have the voltmeter connected here an ideal voltmeter or a potentiometer ok. It is connected here. So, the terminals of the potentiometer or voltmeter is connected to this lid and this lid then the ammeter terminals are also connected to this lid and this supply is here. Now this will have some resistance this lid will have some resistance.

Now this is very important. So, these lids will have some resistance for ease of understanding. So, let us think that the lid resistance will cause some small resistance added in all these 3 branches which are connected to it. So, this will cause some small resistance being equivalent to some small resistance here and some small resistance here and some small resistance here.

So, this is like if I have lid wired 2 3 terminals are connected ok. So, these are wires and this is equivalent of saying that I have some small resistance some small resistance and some small resistance being contributed in all these 3 branches because of this lid similarly here also will have some small resistance some small resistance and some small resistance here ok. Now, do you see a problem? The problem is that this part of the small resistance contributed by the connection it is getting added to this low resistance. Although this is small so, this is small, this is definitely small this is small, but this is also small.

So, therefore, these are comparable maybe this is just maybe I do not know half ohm also maybe this is quarter ohm, but this is also a small resistance maybe this is just 1 ohm or less. So, this 2 are coming in series with this resistance. So, we have a significant amount of error. If this is like say half ohm is this is like half a ohm and this small resistance is like 1 ohm then actually between these 2 terminals I have total of 2 ohm resistance.

So, this is a large error, but it would not have been a problem actually if this 0.5 ohm and this 0.5 ohm was constant. So, let me now note that it would not be a huge problem if the contact resistances were constant. But it is not constant; so, for example, when I measured this resistance using this voltmeter ammeter method.

So, I apply some voltage source some current is flowing through this through this ammeter, I record the ammeter reading and the voltmeter reading and I get some voltmeter reading. Next day I come and do the same experiment, but the next day I do not make these terminals; that means, this lids as tight as it was on the previous day.

So, the first day say I made this terminal very tight and the next day I was doing it differently and I did not make it so tight it has loose. So, then maybe these resistance says this contact resistances which will come in picture in series with this resistance that will be different. Say that then for day in day 1 when this current I was say 1 ampere ok.

So, say I have a resistance rheostat. So, I was varying this and I was. So, therefore, this current was varying. So, in day 1 I had this table voltage versus current voltage or current versus voltage maybe. So, current and voltage and then for 1 ampere current I got some reading maybe the reading was 1 volt 2 for 2 ampere I got the reading 2 volt and so on.

In day 1 or in day 2 when I was doing the same experiment and same current was flowing 1 ampere then 2 ampere. The voltage reading which I was getting here was not same it was

coming say 1.5 volt 2.9 volt and so on. Why? Because maybe the next day I did not make these terminals as tight as it was on the first day. So, this small resistances which are coming in picture they were different. So, therefore, and you see the volt the volt this voltmeter this is an ideal voltmeter and the voltage that it is measuring is the voltage across this small resistance plus this series contact resistances.

So, therefore, if these contact resistances are varying then for same amount of current the voltmeter reading will be different. So, here for first day my estimated value of R X was like. So, V by I it was like 1 ohm, but on the second day my estimate is like up almost like 1.5 ohm.

So, that is the problem with this setup ok. So, I hope the problem with this setup is clear. The problem is due to the fact that the contacts these contacts have some resistances they are small they are small and generally we do not bothered about them, but when these resistance which you are measuring itself is small then anything small compared to this resistance is significantly large this is small this is also small.

So, they are comparable and more crucial problem is that these contact resistances are not constant. So, if I do this experiment 3 days 4 days every day I will get different reading. So, this way I cannot say what is I mean the value of this resistance. Now I will give you the solution to this problem ok.

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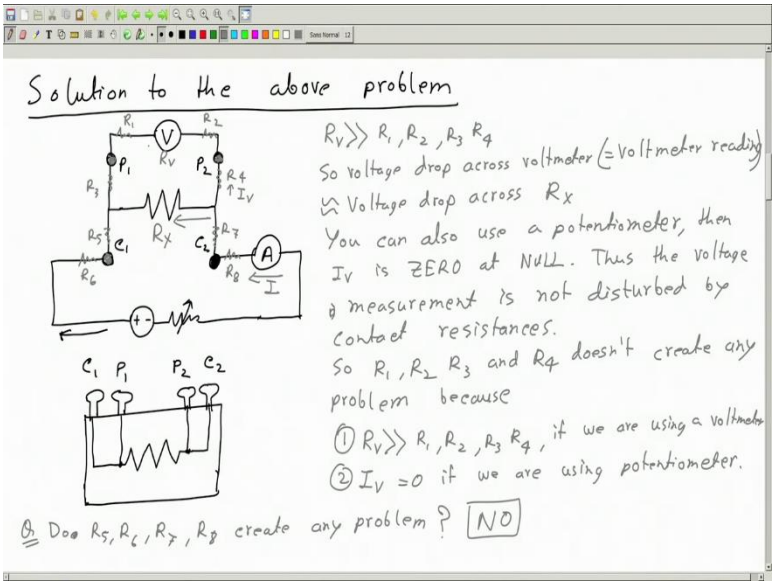

So, the solution to this problem is as follows; so, solution to the above problem ok. Solution is if this is the small resistance then attach 4 lids to it 2 on either side ok. So, you have 4 lids 2 on this side 2 on this side. So, maybe if I draw it in a box. So, I can draw it like this. So, if this is a wooden box a resistance box ok.

So, where this is the small resistance inside, from this here you connect 1 terminal here you connect another terminal another lid and this is soldered inside. So, this is a permanent joint. So, this joint is not going to change or alter anyway. Similarly, connect another terminal here again, this is soldered another terminal here, again this is soldered.

So, this way I have 4 terminals ok. Let me call them as like P 1 P 2 C 1 C 2. These are just some names I am giving right now do not bothered about my pc anything. So, this is what is there inside the box ok. So, here let me similarly call this as; so, 2 of them as P 1 P 2 C 1 C 2 ok.

So, one P on one side another P on another side, one C on one side, another C on another side. Now what I will do I will connect the source of current ok. So, what I want I want to measure this resistance using Ohm's law using a voltmeter and then ammeter. So, I need a power source. So, which I connect across this ok so, now, current can flow through this resistance and I have to measure this current.

So, I connect the ammeter in series with this resistance and I have to measure the voltage across this voltmeter. So, I need a voltmeter or a potentiometer which is a near perfect volt meter I mean it is act with infinite resistance you can think of that I will connect here across these 2 terminals ok.

So, now what happens? Now it can think that all these terminals they will contribute some small resistance here and some small resistance here. Similarly this will contribute some small resistance here and some small resistance here similarly some small resistance will come here and here also some small resistance here and here ok.

Now, now the what is this voltmeter is measuring. This voltmeter is measuring the voltage across itself and we know that that the current through the voltmeter should be small. Why it should be small? Because, this resistance is much higher than this resistance so, most of the current goes through this resistance; so, if this current is I then most of it will go through this and very little amount of go amount will go through this.

So, the voltage drop across this lid. You can ignore because this current is small and also compared to this resistance this resistance is much higher. So, R V. So, R V is much much higher than. So, let me give this resistances some names like let me call this R 1 R 2 R 3 R 4 R 5 R 6 R 7 R 8 ok.

Now, R V is much much higher than R 1 R 2 R 3 and R 4. Therefore, the voltage drop across the voltmeter is almost same as the voltage drop across this resistance ok. So, voltage drop across voltmeter which is same as voltmeter reading is almost same as the voltage drop across the unknown resistance call it R X this is the small unknown resistance ok. You can also think you can also use a potentiometer then this current at null condition will be 0.

So, this current this small current call it I V through this branch then these this current then I V is 0 at null ok. Therefore, this voltmeter or this potentiometer actually is measuring the right voltage. Thus the potentiometer or let me write it thus the voltage measurement is perfect. Thus the voltage measurement is not disturbed it is it is perfect almost disturbed it is not disturbed by contact resistance ok.

Now, even if I do this same experiment for 2 3 days when I have different amount of pieces and I mean tightness. So, that these R 2 R 4 their values here R 1 R 3 they are values change when I do this experiment in different days. Even then this voltage reading is you can think of a potentiometer or a high internal resistance of voltmeter. So, that these resistances are so small and also if this current is 0 for potentiometer.

So, therefore, the voltage measurement is perfect and it is no way disturbed by the value of this contact resistances. So, so R 1 R 2 R 3 and R 4 does not create any problem. Why? Because so observe that. Firstly, this if we are using if we are using a voltmeter ok.

And I V is equal to 0 if we are using potentiometer ok. So, you may revisit this video after study potentiometer. So, therefore, the voltage reading is not disturbed by these contact resistances. Anyway these contact resistances are very small compared to R V. Now the next question I will ask I will ask this question to you does or do R 5 R 6 R 7 and R 8 create any problem; these R 5 R 6 R 7 and R 8.

So, do they create any problem? Think of a bit. The answer is no why because you can think all these resistances as a part of this I mean this is a supply circuit part of the maybe

it is you can think of this as the part of these rheostat or part of this internal resistance of this voltage source. So, or the ammeter so, all these resistances I mean they do not I can think of they are part of this supply circuit and this does not create any problem ok.

Because what we measure we measure the value of this voltage for a particular amount of current through this ammeter. So, you measure this voltage for say 1 ampere current through this ammeter and that will give this resistance R X ok. Now whatever resistance I have in this circuit they do not create any problem. You can think that this is or they all together are serious resistance which is a part of this rheostat which you are changing to vary this current.

So, these resistances they do not come into picture at all. So, no so, they do not create any problem. So, they are not in the picture at all. So, these contact resistances do not matter and these two contact resistances which affect which affect this voltage within, but the effect is small because these resistances are much smaller than the R V ok.

So, think of this very carefully and think of considering the fact that how your result might get changed if you do repeat this experiment and the previous experiment many a times when your contact resistance is changing how much error you may you may get. So, think in this term in this way. In our next video we will take some concrete examples some concrete numeric examples to make this more prominent more clear.

Thank you.