Electrical Measurement And Electronic Instruments
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Lecture - 20
Resistance measurement with a Voltmeter and an Ammeter

Hello and welcome back. So, today we are going to start a new chapter 3 which is on a measurement of resistances ok.

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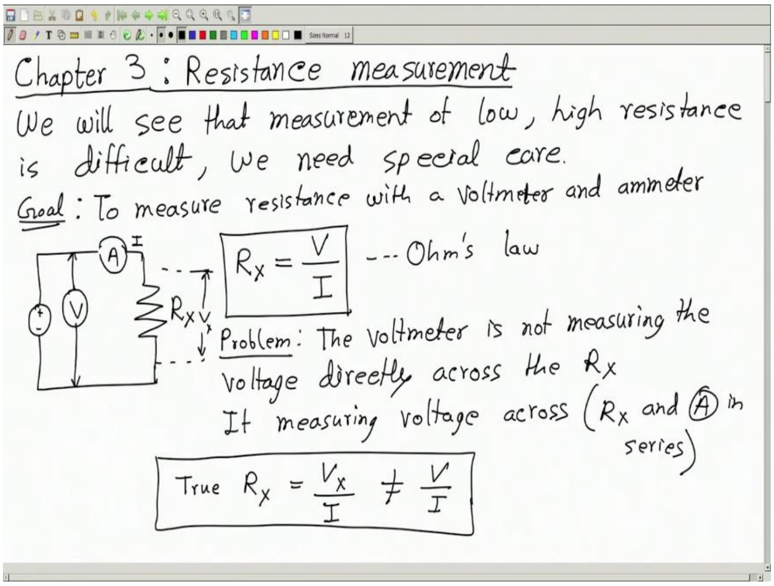

So Chapter 3 resistance measurement and particularly we will talk about low and high resistance measurement in detail because. So, we will see that measurement of low I mean low may be something like about 1 ohm more or less ok. So, need not remember the values like what is called low resistance. So, we will understand it in more detail soon.

So, we will see that the measurement of low and similarly high maybe several mega ohms, high resistances resistance is a bit difficult is difficult. There are some issues and we need special care about that ok. So, this is what we will learn in this chapter. So, this chapter is on measurement of resistance. So, let us begin with very simple idea. Suppose I have a resistance and let us call it R X, X once again stands for unknown and the idea is to measure the value of R X. How do we measure? So, we have a say voltmeter and then ohm and then ammeter.

There is no ohmmeter right now. So, we have a voltmeter and then ammeter we want to measure this R X. So, the goal is to measure resistance with a voltmeter and ammeter and then an ammeter ok. Now how do we do that? So, we need to apply Ohms law. So, what we will do? We will connect some voltage source across this resistance and then we will measure this voltage across this resistance with the voltmeter.

So, this is the symbol of a voltmeter V inside a circle. So, this will give me the voltage across this resistance and then I will measure the current through this resistance. So, what I have to do? I need an ammeter I have to insert it in series. So, we know that ammeters are connected in series. So, let us connect an ammeter, the symbol is like this, A inside and circle.

So, this ammeter will measure this current I and this voltmeter will measure this voltage call it V ok. So, and then we can estimate R X as using Ohm's law the voltage divided by the current. So, if this voltage as given by this voltmeter is equal to V and if the current is I as shown by this ammeter then we can say that $R_X = V / I$.

So, this is from Ohm's law. So, simple, but there is a catch. What is that? Observe the moment I have inserted this ammeter in this circuit this voltmeter is not measuring the voltage across this resistance. It is actually measuring the voltage across the series combination of this ammeter and this resistance R X ok. So, note or the problem: the voltmeter is not measuring the voltage directly across the unknown resistance R X. It is measuring voltage across R X and ammeter in series. So, it is measuring the voltage across these two the across the series combination of these two ok.

So, this voltage is not the voltage across this resistance. So, there is an error because according to Ohm's law R X is I mean this is true only if this voltage is the voltage here across this; call it V x ok. So, true R X is V x by I and this not equal to V that is the voltmeter reading by I. So, there is a problem. Now can we solve it? So, the problem is due to the fact that the ammeter is after this voltmeter.

So, can we instead connect the ammeter maybe say here ok? Can we connect it here so that the voltmeter is not affected by the voltage drop across the ammeter? So, let us try that. So, let us make a make another circuit ok. So, the previous circuit was like this.

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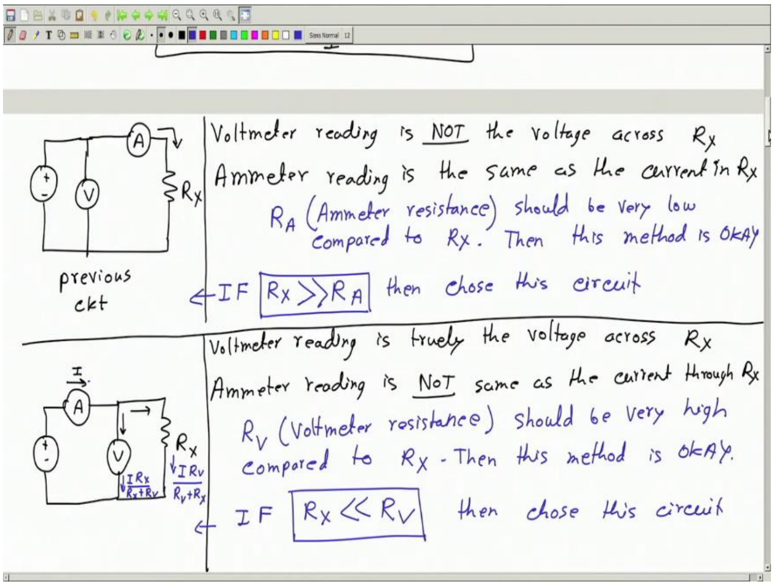

This is the previous circuit ok. Let us try another circuit. Let me put the ammeter before the voltmeter like this ok. Now it is fine. The voltmeter reading is truly the voltage across this resistance because the voltmeter is directly connected across this resistance. So, this circuit is seems like it is better ok. So, for this circuit voltmeter reading is truly the voltage across the resistance, but for this circuit it was not so.

Voltmeter reading is not the voltage across R X ok. So, this circuit seems better good, but there is a problem. The problem is that now the ammeter the current through the ammeter if this current is I is not the current which flows through R X because part of this current I goes through this voltmeter and part of it goes through these resistance R X ok.

So, this circuit has a problem. So, this circuit in this circuit ammeter reading is not same as the current through R X but let us see through the previous circuit. In the previous circuit the ammeter was fine because whatever current goes through the ammeter the same current must go through R X. So, here ammeter reading was fine is the same as the current through R X current in R X ok. So, in this circuit the ammeter reading is fine it is ok.

It is exactly what we want, but the voltmeter reading is not what we want. In this circuit the voltmeter reading is exactly what we want, but the ammeter reading is not so. So neither of this circuit is a good is perfect, but ideally now let us think of an ideal situation ok. So, ideally an ammeter should have very low resistance. So, ammeter resistance should be very low ok. Therefore, the voltage drop across the ammeter should be negligible compared to this R X then this voltmeter reading is fine. So, it is measuring almost the same voltage as R X.

So, ammeter resistance should be very low compare to R X ok. So, let me write this ammeter resistance as R A, A for ammeter ok. So, R A ammeter resistance should be very low compared to R X and then this method is not perfect though, but it is this method is acceptable because then the voltage drop across the this ammeter will be much lower compared to the voltage drop across R X. So, voltmeter reading will be almost same as this voltage drop across R X.

Similarly, if I have a near perfect or very much ideal voltmeter in this circuit ok, so, for ideal voltmeter what we have? The resistance of a voltmeter call it R V. So, this is voltmeter resistance and this should be very high. We have seen this before when talking about ammeters and voltmeters. Voltmeter resistance is very high ammeter resistance is very low. So, R V should be very high compared to R X ok. So, why compared to R X because if this R V is very high compared to R X then most of this current I will flow through R X and very little amount of current will go through this voltmeter.

Because according to the current divider rule this current we can write as $\frac{IR_x}{R_v+R_x}$ Now if R V is very high then this current will be almost equal to 0 and this current according to current divider rule this is $\frac{IR_v}{R_v+R_x}$. Now if Rv is very high compared to R X then we can ignore this R X and therefore, this will be almost same as I.

So, almost the entire current goes through R X very little amount of current goes through voltmeter. So, then the ammeter reading will be almost same as the current through the resistance. So, then again then this method is ok. So, that means, it depends. So, if I have to use a voltmeter and then ammeter to measure the resistance an unknown resistance.

Then which circuit I will choose that will depend on the comparative value between the R X and R A R X and R V. So, if let me write if R X is much higher than R A ok. If R X is much higher than R A then choose this circuit. This means this circuit ok. So, because then the voltage drop across the ammeter is much lower compared to the voltage drop across this resistance. Similarly, if I have R X much less than R V then choose this circuit this means a once again this circuit. If this resistance R V is much higher than R X then most of the current will go through R X and this method is acceptable ok. So, depending on the a value of the resistance we may decide which circuit to choose.

So, to make it more clear maybe with should taken example.

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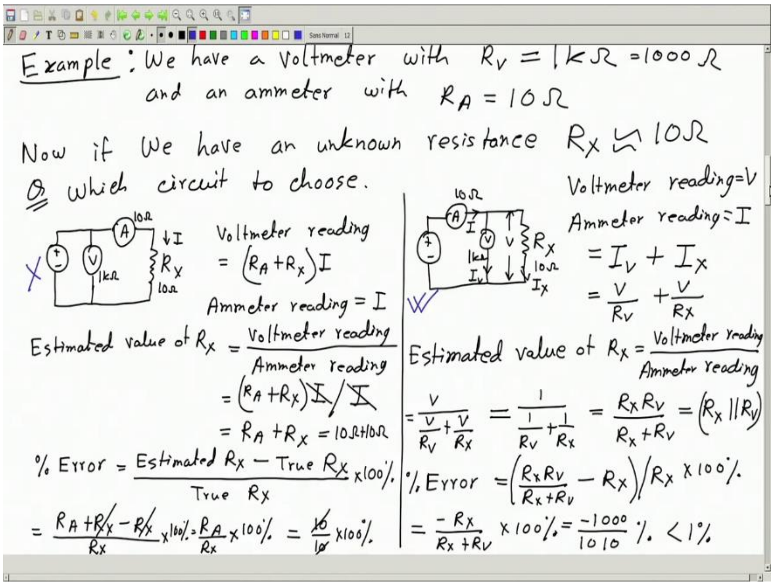

So let us take an example ok. Suppose I have a voltmeter with say R V internal resistance of the voltmeter equal to. So, let us take it 1 kilo ohm and an ammeter with ammeter resistance R A equals say it should be small let us take 10 ohm ok. So, obtaining a small value for ammeter resistance and a large value for the voltmeter resistance this is 1 kilo ohm 1,000 ohm and this is 10 ohm. Now if we have an unknown resistance R X whose value is we know it is around say 10 say 10 ohm ok. So, if you take a I mean resistance whose value is approximately 10 ohm then which circuit. So, we chose then the question is which circuit to choose ok.

So, let us try 2 circuits side by side. So, 1 circuit is like this voltage source then let us take a voltmeter sorry ammeter resistance R X. So, this is one circuit ammeter resistance is 10 ohm this is 1 kilo ohm and this is say 10 ohm and let us choose the other circuit which for which we will have the ammeter before the voltmeter. So, that the voltmeter reads the correct voltage, but the ammeter will read erroneous current. So, this is around 10 ohm this is 1 kilo ohm this is 10 ohm.

Now, so let us find out what will be the measured value of R X in this circuit ok. So, if we call this current as I which is flowing through this resistance ok. If this current is I then the voltmeter reading this will be equal to the total voltage drop from here to here; that means ammeter and resistances in series. So, this will be this (R A + R X) x I ok.

So, this will be the voltmeter reading and the ammeter reading is the current is same as the current that was through the ammeter. So, that will be I ok. So, therefore, estimated or calculated value of R X this will be same as the voltmeter reading divided by the ammeter reading ok. So, this then we can write it as.

So, voltmeter reading is same as = (R A + R X) x I

Ammeter reading = I

Estimated value of Rx= $\frac{voltmeter\ reading}{ammeter\ reading}$ = (RA+RX)

$$\%Error = \frac{estimated\ Rx - True\ Rx}{True\ Rx} \text{ X } 100 = \frac{RA+RX-RX}{RX} = \frac{RA}{RX}$$

So, in 200 percent this will be equal to into 100 percent ok. Now if we put the values R A is given as 10 ohm and R X is also 10 ohm. So, these will the error will be 100 percent. So, 10 by 10 into 100 percent; so, this will be 100 percent; so, huge error 100 percent error.

So, estimated value will be actually R A plus R X. So, this will be actually 10 ohm plus 10 ohm 20 ohm double of the true value. So, we add what we add actually measuring in this circuit is not R X, but the series combination of R A plus R X see this is the series combination of R A plus R X. So, the error is huge. So, this circuit is not good. So, this circuit is not good cancel the circuit we will not use it.

Now, let us see what will be the error in this circuit ok. So, for this circuit say now the it is easier if you to start our calculation as you mean the voltage across the resistance to be V ok. So, if this voltage is V then the voltmeter reading will be will be how much. So, this will be definitely V because it is deductly across this voltage. So, this is the V and what will be the ammeter reading ammeter reading. So, this will be same as the current that flows here through the ammeter call it I ok.

So, this will be same as I whatever this current is and what will be the value of this current I. So, this I will be same as this current call it I V voltmeter current I V; so, the current that goes through the voltmeter plus I X which goes through this call this current as I X ok. So, this current I; so, it is it has 2 components I V and I X. So, I is this.

Ammeter reading = I = $\text{Iv} + \text{Ix} = \frac{V}{R_v} + \frac{V}{R_x}$

estimated value of Rx = $\frac{voltmeter\ reading}{ammeter\ reading} = \frac{V}{\frac{V}{R_v}+\frac{V}{R_x}} = \frac{Rx\ Rv}{Rx+Rv}$

which is nothing, but the parallel combination of R X and R V ok. So, what we are actually measuring is not R X, but the parallel combination of R X and R V. This will be same as R X only if R V is much higher than R X then the parallel branch can be ignored. Now so this is the estimated value and the error how much will be the error.

$$\%\ Error = \frac{\frac{Rx\ Rv}{Rx+Rv} - Rx}{Rx} \text{ x } 100 = \frac{-Rx}{Rx+Rv} \text{ x } 100$$

This minus sign you can ignored because we are interested about the at the magnitude of the error whether it is a positive or negative error that is right now not so important ok.

So, this will be $\frac{Rx}{Rx+Rv}$ and this will be close to 0 only if R V is much higher than R X and now if we put the values from here. So, R X is 10 R V is 1,000 then this will come out to be how much. So, this will come out to be. So, let me let me make some space by erasing one step and ok. So, now, let us put the values. So, R X is 10 by. So, this is 10 plus 1,000. So, 1 0 1 0 I am ignoring the minus sign or you can put it. So, this is this much into 100 percent hm. So, let us put 2 more 0's I for 100 and percent. So, this is like 1,000 by 1,010. So, this is less than 1 percent ok. So, this is a better circuit for this particular value of R X ok.

So, observe we have chosen R X to be similar as R A. So, this circuit is not good, but R X is much less than R V. So, this circuit is good. So, this circuit can be used. Similarly, so I will just make.

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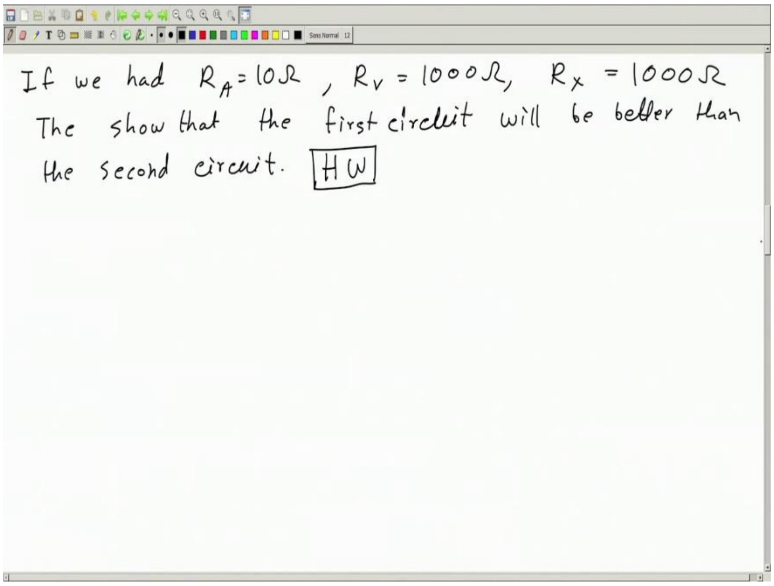

I will give you a small home work may be. So, if we had say R A equals 10 ohm as before R V equals 1,000 ohm as before, but R X equals say around 1,000 ohm. Sorry this is not volt this is the ohm then you can. So, then, so, that the second circuit. So, the first circuit will be better than the first circuit ok so, that the first circuit will be better than the first circuit sorry second circuit ok.

So, and that case this circuit will be better than this circuit. So, that is a homework and I will be very happy if you do this homework you can share your result your calculation in the forum will be happy to check that and correct that if required. So, please do this homework.

Thank you will meet in the next video.