Electrical Measurement And Electronic Instruments
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Lecture – 32
DC Potentiometer

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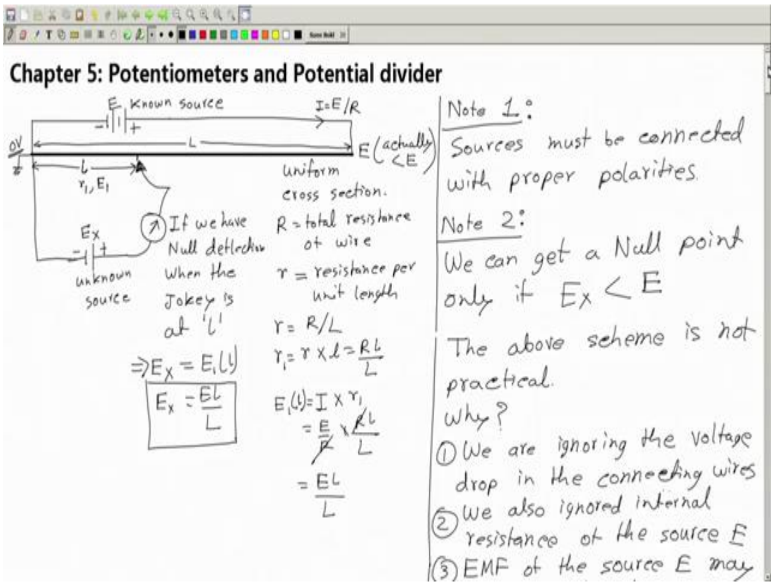

Welcome everyone. Today, we are going to start a new chapter which is on potentiometer and potential divider, ok. So, this we might have studied in school a bit, so let us recapitulate. Potentiometer is basically a long wire, so it is a long wire with uniform cross section. And then if we want to measure a unknown voltage source DC source, so what we can do? We can say apply first voltage across this wire and we have to connect this unknown source like this. So, this is a known source; so known source called the EMF equal to E. This is an unknown source we want to measure its EMF. So, we can take a galvanometer or an ammeter, we will connect it like this.

And this point is a key is a Jokey this can move along the length of this wire. So, you can move it from here to here or you can move it to another point, so likewise, so you can move this point, ok. So, you have to touch this Jokey somewhere on this wire and you have to adjust this position; position of this Jokey until and unless you see 0 current or 0 deflection in this galvanometer.

So, this is the simplest conceptually simplest notion or idea of a potentiometer, ok. And then how do we measure this unknown source? So, if this is E x, and if this total length of this wire is L ok, this is the total length of the wire with uniform cross section. So, this is with uniform cross section and say we are adjusting the position of this Jokey.

Now, we know that the total voltage from here to here is equal to E. If this is not connected, then definitely the total potential from here to here between the two ends of this long wire is equal to E. So, if I take this point as my reference that means, 0 volt then this side is at E volt or at the potential of E. And then this potential gradually increases from left to right, gradually and linearly increases, ok. So, we can estimate the current through this wire which will be equal to I= E /R, where R is the total resistance of this wire; wire, means this wire not this connecting wires, ok. So, this is a bit of recapitulation you might have studied this thing before.

And say this r is resistance per unit length ok, then; that means, r = R/ L. And therefore, the if we consider a point from, so at a distance of small l from the left up to this ok. So, if we consider a point here which is at a distance of small l from the left side, then the resistance here is, so this resistance call it r 1,

r1= r x l = $\frac{RL}{L}$

E1=Ix r1 = $\frac{E}{R}$ x $\frac{RL}{L}$ = $\frac{EL}{L}$

So, you see that the this potential at a distance L from the left. So, we can we are calling this E 1, so we can call this E 1 L because it depends on L, ok. This is a linear function of L it increases from left to right.

Now, if we get a null deflection when this Jokey is at a length L, ok. So, if we have null here, if we have null deflection when the Jokey that means, this arrowhead when the Jokey is at distance L; that means, the potential difference or the voltage of this unknown source is same as the voltage here. So, this two voltages are same that is why no current is flowing in the circuit or through the galvanometer. So, we can write then that

E x = E1 L =$\frac{EL}{L}$

So, therefore, we can measure this unknown Ex using this equation, ok. So, this is the principle of a potentiometer.

And now some small points that you must note. So, note 1, is that if I have plus on the right side and minus on the left side of this battery, then the unknown source must also connect must be also connected in the same way, plus on the right side minus on the left side. If you connect it in the opposite way then you can never get a balance, because if, so this side is minus this side is plus, so this is my reference point. So, from here to here potential increases.

If I by mistake connect it like this plus and minus then this is at 0, then with respect to this point this is at a negative potential and with respect to this point this is at a positive potential. So, this is at negative potential, this is a positive potential. So, there will be a current, always will be a current, so you can never get a balance, ok.

So, this is very important that you connect the polarity of this batteries properly correctly, ok. They should have the positive side in the same direction and the negative side in the same direction, ok. So, the batteries or the cells or the sources must be connected with proper polarity, ok. So, by this I mean what I already have said, ok. So, if you are taking minus on the left side here; here also the minus should come on the left side, similar, ok.

Then another note, important point is that. So, we can measure Ex only if this E is much higher than this x, ok. So, we can get a null point only if $Ex < E$, ok. So, I mean because if E is smaller, ok; that means, say if E is 2 volt and this is say 5 volt if that is the case, then from here I have 0 volt this is at 2 volt. And now, if I move this Jokey from left to right, so then I am travelling through a potential of 0 up to 2 volt, ok. So, I will never ditch the potential of 5 volt which is the value of this E x. So, this potential will never be equal to the potential at any point on this wire. So, we can never get a balance, ok. So, this is also point.

Now, the diagram that I have drawn is only for our understanding. This is not the practical way to use a potentiometer, ok. So, this scheme is only for our understanding. So, the above scheme is not practical, it is not completely practical. Why? Because see we are assuming that this potential E is present across the length of this wire, ok. So, we are ignoring any drop in these wires which may be there, ok. So, we are firstly ignoring the voltage drop, in the connecting wires; connecting wires and leads etcetera, ok. So, there will be some drop here, there will be some drop here. Depending on the amount of current that flows, so there will be some drop. So, this will not be, this will be actually less than E, ok. So, this is one problem.

Then next; so practically all batteries, all cells, also have some internal resistance, ok. So, there will be also some drop in the internal resistance, ok. So, that therefore, also the voltage here will be less than E. As some current flows there will be some drop in the internal resistance and therefore, we will have a voltage here which is less than E, ok. So, we also ignored the internal impedance or resistance of the source; source E, ok.

Then, also normally I mean even if we ignore these two points, there is another factor, the factor is that all cells, all practical cells, they discharge slowly as we draw more and more current and therefore, they are EMF slightly decreases with time, ok, it decreases more or less with time, it is not a constant EMF. So, as we are drawing current constantly through this battery, so the EMF, E will also decrease, ok. So, all batteries discharges with time. So, EMF of the source E may also decrease with may also drop with time.

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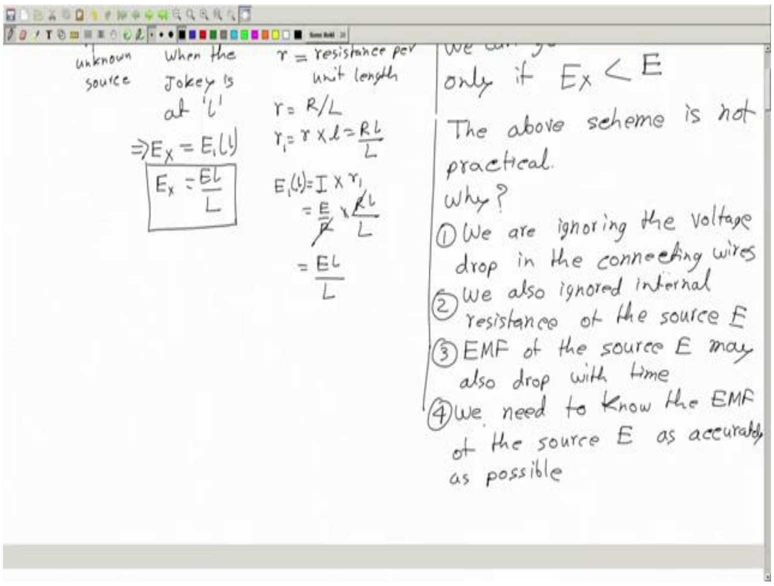

And finally, another thing that we require is that. So, if we want a precise measurement of this unknown EMF, then definitely we need to know the EMF of this cell very precisely, ok. So, we need a cell or a battery for which the EMF is known very precisely, as precisely as possible. So, we also need to know the EMF of the source E as accurately as possible, as precisely as possible. So, we need a source for which the EMF does not change much with time as it discharges, it does not depend on any other factor, maybe environmental factor, temperature etcetera I mean it should not depend on any other factor or it should depend as minimally as possible. So, we need such a good source, such a reliable source.

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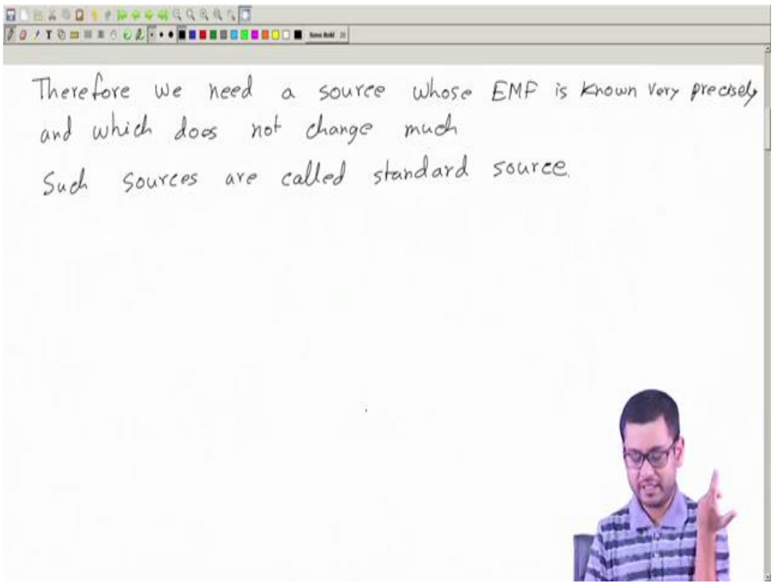

So, therefore, we need a source whose EMF is known very precisely and which does not change much due to discharge, I mean due to any other factor environmental factor it should not change much, ok. So, such cells are called, such sources are called standard source. And in laboratory we use the standard source which is a which could be made up of some mercury sulfate based thing, I do not remember the exact chemical composition of the source very well. You may studied this from the book or any other source this is not that interesting, you may just study what is the chemical composition. But from the perspective of electrical engineering, the chemistry of the source is not that important, we are not going to talk about that here if you are interested you can read it from the book ok.

And so, the important fact for us is to understand that this is a source, this is the source of EMF for which the value of EMF does not change with any other factor temperature whatever you can think of and its value its known very precisely ok. So, a standard source, such a standard source often has a EMF of something around 1.083 something.

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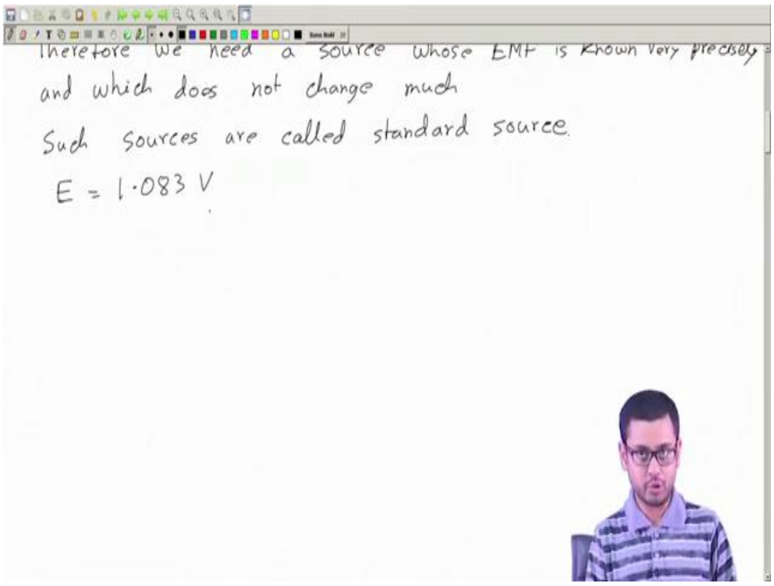

Once again, this value exact value you can study from volt, exact value you can study from the book, the exact I mean this is this you need not memorize. So, the point is this value is quite constant. In a also in the sense that, if we manufacture, if we prepared such cells 10 times then this value is going to be very close to this value. It is not going to be like 1.09 or 1.07, it is not going to change much. So, it is such a reliable source which we can rely on ok.

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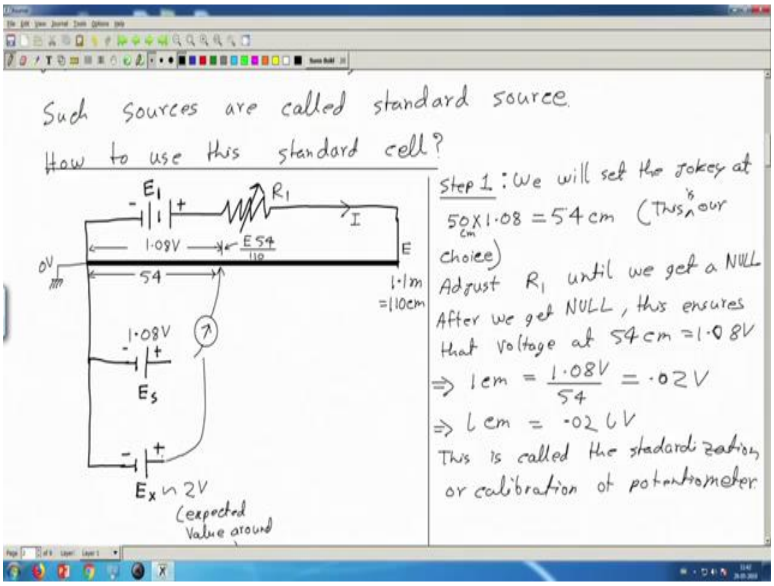

So, now how to use this standard cell? So, we cannot use this standard cell like we have used here. So, we cannot put this standard cell here directly. Then what will be the problem? The problem is that definitely standard cell means its EMF is constant, but there will still be some internal resistance, there will be still be some wire resistance and as some current flows there will be still some voltage drop. So, this will not be equal to the EMF of the standard cell, so we cannot use it like this. Because if we use it like this there will be voltage drop due to internal resistance, due to wire resistance etcetera.

So, how do we use it? We use it as follows. So, let this be the wire of the potentiometer with uniform cross section; that means, uniform resistance per unit length, then we take a battery a normal battery not a standard cell. We can connect it like this. This is minus side; this is plus side, we can take a rheostat, and then here we connect it like this. Now, this is a call this E, E 1 or E s, ok. So, this is not, not s, this is not standard cell; so, call this E 1, ok. So, this is an this is not the standard cell.

Now, what we will do? So, we will use the standard cell, call this Es and we will also have an unknown source which you want to measure call this Ex, ok. We will connect the minus side of all this together on the left side. So, this is the potentiometer wire and all the minus sides are connected to the left side. Now, what we will do? We will connect first say our galvanometer to the standard cell and there will be a Jokey on the other side, we will move this Jokey to a suitable position, ok. So, let me also write these steps how to use it.

So, the steps; step 1, see if the length of this wire is say around 1.1 meter. So, this is 1.1 meter. And say if we know that the unknown source has a value of around maybe 2 volt, ok. So, we expect the, so this is the expected value; expected value around 2 volt. It can be 2.1, it may be can be 1.8 ok, but it is not going to be far from 2 volt ok.

So, therefore, when, so when we will measure this E x, ok. So, before that; so before that what we will do say we will set this Jokey say at a length say if this is 1.08 volt, ok. Exact value I do not remember, say for example, this is the value 1.08 volt, this is 1.1 meter or which is same as 110 centimeters, ok. So, we will put sake this at a length say 50 into 1.08, ok. So, how much is this? Do you have a calculator? So, 1.08 star 50, this is 54, ok. So, 54 centimeter. So, what we will do? So, we will set the Jokey at this length 54 centimeter, ok. So, this is a chosen value. So, this is this is our choice, ok. So, this is 54 centimeter we where we have kept this Jokey.

And then we will adjust this rheostat call this R1, ok. Then we will adjust R 1 until we get a null; null here, ok. So, when we will get the null? We will get the null if the potential from here to here is 1.08 volt because this is 1.08 volt. So, if we adjust this, then different amount of current will flow this I will also change, ok. So, we can decrease this resistance therefore, I will increase, therefore this potential will increase which will also cause this potential to increase, ok, if this potential is call it E, then this potential is at this point it is E multiplied by this 1 point this 54/ 110. So, this is the potential at this point.

So, if we increase this current, this will increase, this will also increase. If we decrease this current, this will decrease, this will also decrease. So, by this we can adjust the potential at this point and therefore, when this potential is same as 1.08 volt, we will get a null, ok. And when get a null, so after we get the null this ensures that the voltage at 54 centimeter is equal to 1.08 volt, ok. So, once you do this after that 54 centimeter is same as 1.08 volt,

1 cm =1.08/54 = 0.02 V

So, this step is called the calibration or standardization of the potentiometer.

So, this is this step 1; this is called the standardization or calibration of potentiometer, ok. So, now once this calibration is done then what we will do? We will disconnect this standard cell. So, we will disconnect it here, ok, and we will connect this galvanometer to this unknown source, ok.

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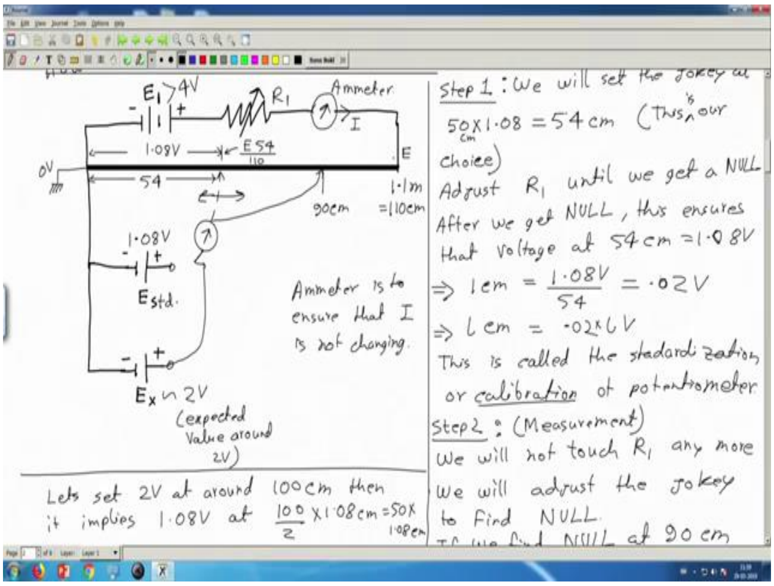

So, now the galvanometer is connected to the unknown source and this is open. So, we can have a key, with which we can switch between the standard and the unknown source. So, now, step 2. So, this is the actual measurement step. The previous was the calibration a standardization. Now, measurement, what we will do?

Now, we will not touch this R 1 anymore, ok. So, we will not touch R 1, we will not change R 1 anymore. So, which ensures the potential here is same as before because the current is same as before, so that means, now 1 centimeter of the wire is same as 0.02 volt and L centimeter is same as 0.02 into L volt, ok. So, this calibration is now same as what is whatever we have done in the previous step.

So, now we will not change the calibration, we will not change this R 1 we will instead adjust the Jokey, we will adjust the position of this Jokey to find null. Now, if we find say for example null at a position say here which is say this point, if this point is 90 centimeter for example, ok.

So, if we find the null at 90 centimeter, then E x that is the unknown source, unknown value of this EMF must be same as the potential drop from here to here within this 90 centimeter which is equal to 90 centimeter multiplied by 0.2 volt per centimeter, ok, because here we have this relationship, 1 centimeter is equivalent to 0.2 volt, so 90 centimeter is this. So, this will come out to be 1.8 volt, ok. So, the unknown source E x will come out to be 1.8 volt.

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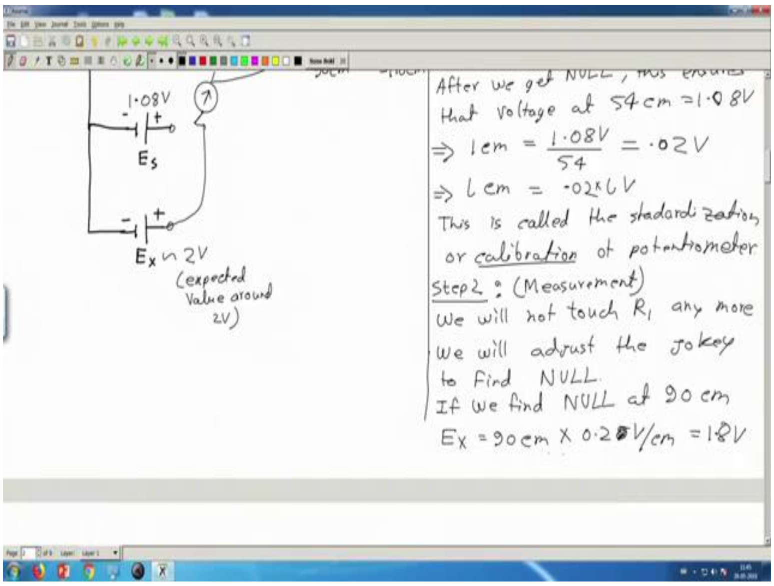

Now, some important points to observe are, ok.

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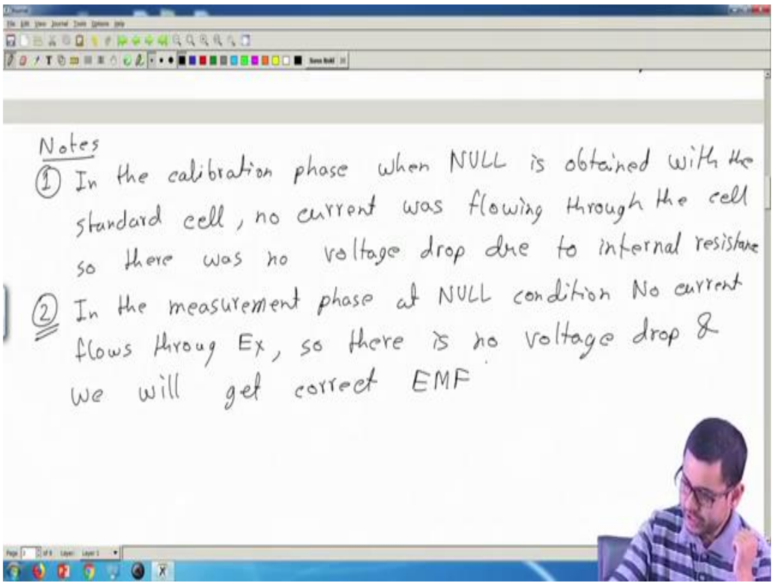

So, notes; note 1. In the calibration phase in the first step or the standardization phase when we got the null with this standard cell at some length which is 54 centimeter that is what we have chosen. So, at the null condition no current was flowing through this cell. Yes. So, there was no drop due to the internal resistance or the connecting wires, because no current was flowing, ok; so this is the important point. In the calibration phase when null is obtained with the standard cell no current was flowing through the cell. So, there was no voltage drop due to internal resistance, ok.

So, unlike the previous scheme, if we had used the standard cell here, then the standard cell is delivering some current always, so there is always some voltage drop. But in this practical scheme, so when we caught the null at that point no volt, no current was flowing through this cell. So, there was no voltage drop, ok, let me call this E standard, ok. So, there was no voltage drop, so this potential 1.08 is a perfect value is a correct value, there was no job.

Now, next thing also during the measurement of this unknown Ex, ok. So, at the null condition there is no current which is flowing through Ex. So, there will be no voltage drop in the x and the EMF that we will measure is the correct EMF, ok. So, which was actually true in this circuit also even in this circuit there was no voltage drop during the measurement in because there was no current at the null condition. So, that is the beauty of potentiometer, ok. So, this is more important that is that when; so, in the measurement phase; in the measurement phase at null condition no current flows through E x. So, there is no voltage drop and we will get correct EMF.

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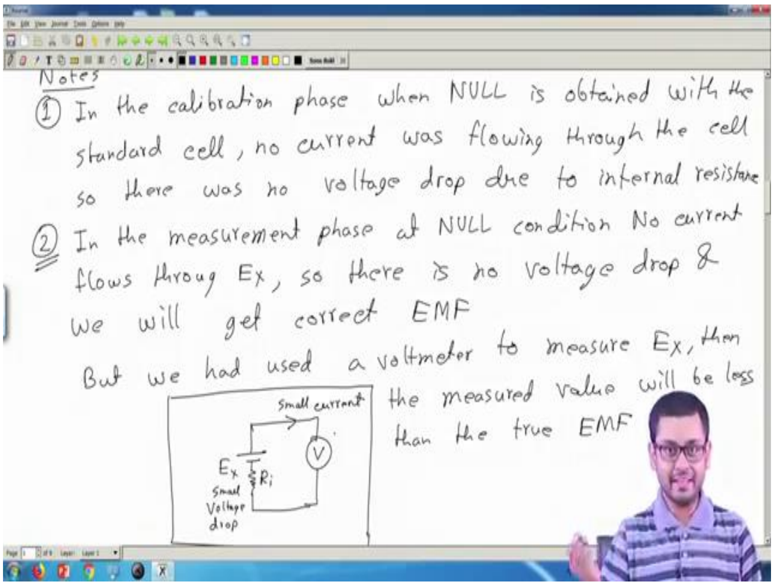

But if we had used; but if we had used a voltmeter to measure E x like this. So, this is the unknown E x, if we connect this E x to a voltmeter and E x has some internal resistance R i then all voltmeters practically draw some current. No matter how high is the internal resistance, this is not infinite. So, practically we always have some small current, ok. So, therefore, we will always have some small drop and the measured value by this voltmeter will there before be less than E x, it will be E x minus this drop, ok. So, if we had used a voltmeter to measure E x, then the measured value will be less than the true EMF or open circuit EMF, ok. So, this is the duty of or the main property of a potentiometer; why one should use potentiometer, ok.

So, if you recall in a previous class, we have mentioned that you can think that potentiometers are like ideal voltmeters whose internal resistance is infinite, so it draws no current and no voltage drop occurs due to internal resistance ok,. But then, you may ask why do we not then use potentiometer always instead of using voltmeter. This the practical reason is that, to measure a voltage with potentiometer you have to adjust the null and then only we will get the reading, but volt meters give you live reading. Even if the voltage in unknown voltage is changing you will have a live reading indicated by the pointer. With a potentiometer you cannot get life online reading always, so that is that is not easy to use, ok.

Now, , ok; so this point one is important because sorry because the unknown sorry because the standard cell does not suffer any voltage drop due to internal resistance because at the null condition no current flows. And ok, and in the another important small important fact is that. So, I have chosen this 54 centimeter, to find to add to say it the null. Why 54 centimeter? Why did I not choose 58 or 50 or 59 or anything else? Ok. So, choice was a bit of cleverness, a bit of common sense that I have applied because I knew that I have the unknown source which is around 2 volt that means; so when I will measure this 2 volt source I would like this potential this wire to have more than 2 volt, ok. So, only if this in this potentiometer has more than 2 volt then only we can get a null.

So, I decided that, let us have a 2 volt at 100 centimeter, ok. So, I actually decided, I actually mentally calculated that. So, let us set 2 volt at around 100 centimeter, ok. And so, then it implies this 1.08 volt it will be at. So, 100 divided by 2 in to 1.08 centimeter which is same as 50 into 1.08 centimeter, so that is what I did here, ok. So, I did this calculation mentally because I knew what I am going to do.

So, I wanted this point to be around 100 centimeter. Also, because then this value that volt per centimeter ok, so this volt per centimeter this comes out to be a nice number like 0.02. It is not a fraction like 0.0257, 0.193, it is not a random fraction. It is a nice fraction, easy to calculate, so that is how I did it, ok. So, in the lab also if you do an experiment with the potentiometer you have to intelligently cleverly set your calibration length, like this with the knowledge of the unknown source the value of unknown source, is it around 2 volt, is it around 5 volt accordingly you have to do the charged, ok and ok.

So, therefore, one more thing; one more small thing is that now we will lead this E 1 to be greater than definitely greater than 2 volt, maybe we will choose this great some somewhat around 4 volt, ok. So, that or maybe 3 volt that is also, ok. Otherwise we will never get more than 2 volt here, if we do not get more than 2 volt then we cannot find the null, we cannot find the balance.

Another last small practical fact is, what we can do what we should do is we may put an ammeter here or any meter any galvanometer, ok. This an ammeter that is the (Refer Time: 44:56) ammeter, ok. This ammeter is to ensure that the current in this wire I is not changing, ok. So, this ammeter is to ensure that current I is not changing. Otherwise, what may happen? Say that in the calibration step I set 1 centimeter equal to 2, 0.02 volt by at finding the null and by adjusting R 1. But in the measurement step, when I come in the measurement step by then say this battery discharges and this current drops, then this 1 centimeter equal to 0.02 volt is no longer true. Therefore, the measurement will be wrong.

So, we need an ammeter, so that we look at the reading of this ammeter after the calibration and then once again we take that reading after the measurement and if we see the current is changing, then there is something wrong, we have to do the experiment again, maybe we have to change this battery. But if you see this current is not changing, then our experiment is fine.

So, this ammeter is to ensure that this current is not changing, but this is not to measure this current, ok. I mean not we will never read the value of this current and then multiply the resistance with this current to get the voltage here, no, that is not the way to; that is not why we have this ammeter because this is mainly to ensure that this current is not changing, ok, ok.

So, thank you. In our next class we will talk about AC potentiometers. So, by then when you come back please make sure you understand the necessity of these two steps calibration; that means, standardization, and the measurement very well, ok. And we will meet again in our next class.

Thank you.