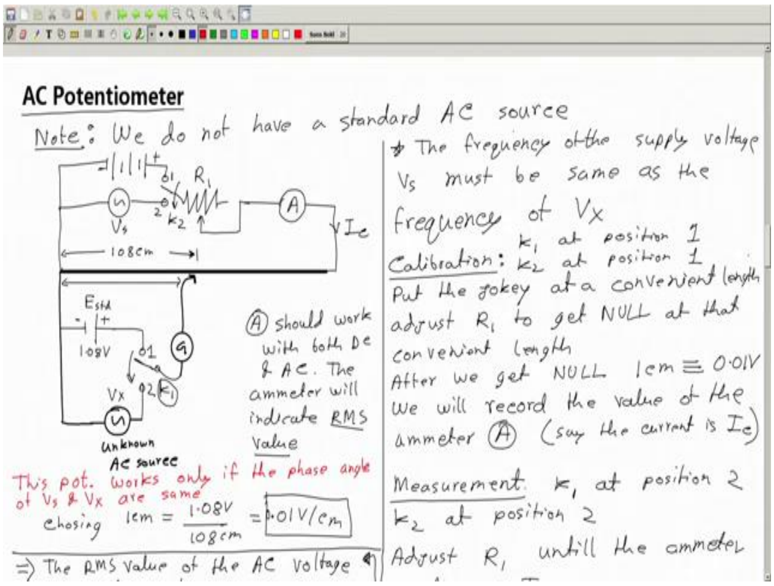
Electrical Measurement and Electronic Instruments

Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 34
Polar potentiometer and phase shifter

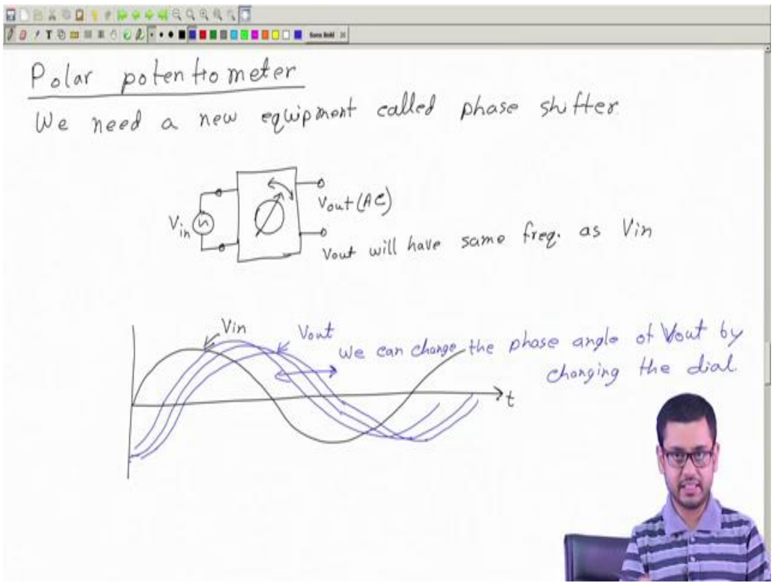
Hello again. So, in our last class, we were talking about AC potentiometers. What we have learned in that class mainly is how to use a DC standard cell to calibrate AC potentiometer, because there is no AC standard cell that is one important thing we have learned. But then we have ended our class with a question that if the supply to the potentiometer does not have same phase angle with the unknown source, then we cannot get the null at all. So, we cannot use AC potentiometers in that way.

(Refer Slide Time: 01:26)



So, in this class ok, so there that means, the potentiometer that we have discussed in the previous class this potentiometer, this will work only if the phase angle of V s and V X are same. So, this potentiometer works only if the phase angle of V X and V s; V s and V X source I mean supply and unknown are same, else it will not work. Today we are going to look at two schemes with which we can measure an unknown AC source with arbitrary phase angle ok. So, these two solutions, these two potentiometers are called coordinate potentiometer and polar potentiometer ok.

(Refer Slide Time: 02:45)

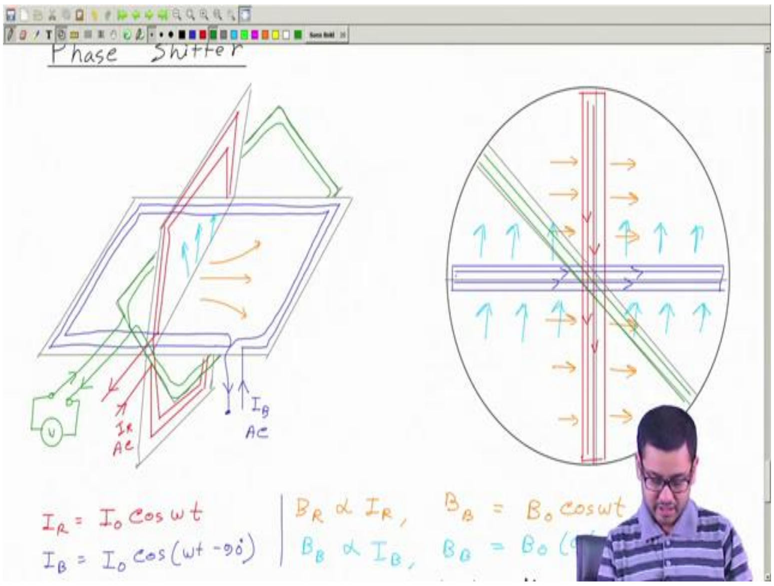


So, let us first talk about polar potentiometer. So, in this potentiometer, we will need a new instrument a new equipment which is called a phase shifter. What is a phase shifter? Let us first understand what a phase shifter is ok. So, a phase shifter functionally is a black box which has a input and a output. So, you can give input voltage V in AC of course, and so we will get a voltage V out once again AC ok, and the frequency of this two will be definitely same. So, whatever frequency you give at the input, output will have same frequency ok. So, V out will have same frequency.

And we will have an like a knob or a dial or something so which we can turn ok. So, this is a control ok, so this you can turn. What happens if we turn it? The phase angle of V out with respect to V in changes ok. So, if I drop say this is time, if this is V in ok, so this is V in, V out will of course have same frequency, but need not have same phase as V in. So, V out can have a delay like this, so this is V out. And we can change the position I mean the phase angle of this V out with respect to V in by moving this knob or dial. So, we can shift this V out maybe here or towards the left maybe if you want so that is also possible ok. So, you can shift, so we can change the phase angle of V out by controlling this knob changing the dial ok.

So, we can move this say if we move towards the right, maybe it will go it will have a it will have more delay; if we move it towards left, if it may have smaller delay. So, this is the, this is what a phase shifter does functionally this is the functionality of a phase shifter what it does. Now, there are two things that we have to learn, number 1 how the phase shifter is made or what is there inside the phase shifter; and secondly, how to use this phase shifter to measure unknown AC source using potentiometer.

(Refer Slide Time: 07:52)



So, let us now understand a phase shifter. So, you may have studied this in any other course like electrical machines ok. So, but here also we will discuss it and we will discuss a simplified scheme. And it is not act not the actual I mean the actual at the actual device may constructional, a bit different, but the principle is same, theory is same.

So, what we will do, so what we need is 3 coils, we need 3 coils. And the coils are to be placed in a particular manner ok. So, let us first assume that there is a plane like this which is horizontal. So, this is a horizontal plane. Now, imagine another plane which is vertical ok, which is perpendicular to this, these are some fictitious or imaginary planes ok. So, we have two planes; one horizontal, one vertical.

And now let me place two coils in these two planes like this. So, let me draw say one coil with rate which I was which I will put on this vertical plane like this. So, let me start from here, then let me go like this; like this, then like this, then I will go like this, and then here; here; here. So, this is one complete turn of this coil ok. So, if you want, we can have more turns ok. So, now, we have two turns ok. So, this is the start of the coil, and the coil rotates like this in the vertical plane and then it comes out ok.

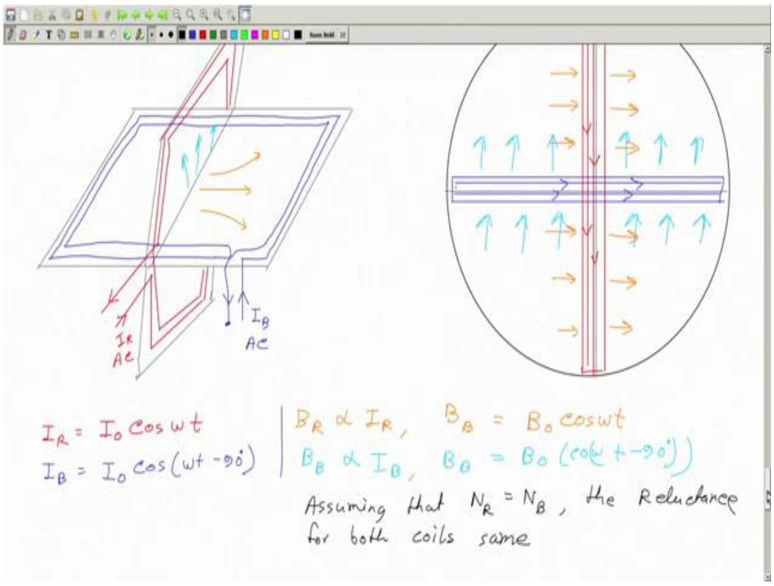
So, if I pass any current, it will flow like this ok. And if this current I call this I R; R for rate is in this direction, then it will create a flux; it will create flux lines which will be in horizontal plane. So, the flux due to this will be from left to right like this right ok. So, this is this, these are the flux created by this coil.

Now, let me take another coil which I will put on this horizontal plane like this. So, let me start from here, and then go around and like this ok. So, this is one complete turn, let me have another turning. So, I can have many turns like this and then this is the end of the coil ok. So, this is the start, this is the end of the coil called the current that may flow through this as I B. And if any current flows then it will create some flux which will be in vertical direction, so the flux due to this will be like this ok. So, it will be in the vertical direction ok. So, I may I may also draw the front view of this arrangement ok. Another view, so that you have a better visualization what I am doing.

So, the front view, so in the front view I will see this horizontal plane just like a line ok. So, this horizontal plane will be seen like a line, and this vertical plane will be seen like a line again. And then this is this blue coil we will see it like this ok. So, and these are the turns ok; from left to right these are the turns ok. And similarly, we have this red one which we will see like this and the turns or the coil sides are like this. And in the front side we have the current flowing downwards like this ok.

And this creates flux lines, rate flux lines are in this direction; and blue flux lines are upwards. So, they are perpendicular to each other. So, they are actually closed curves, but I am not drawing them as close, because I do not want to make it clumsy ok. Now, if I pass AC currents say this I R is AC, this I C is all I B is also AC, and say this two are at a at 90 degree phase.

(Refer Slide Time: 15:29)



Say let me write that $I_R = I_0 \cos \omega t$

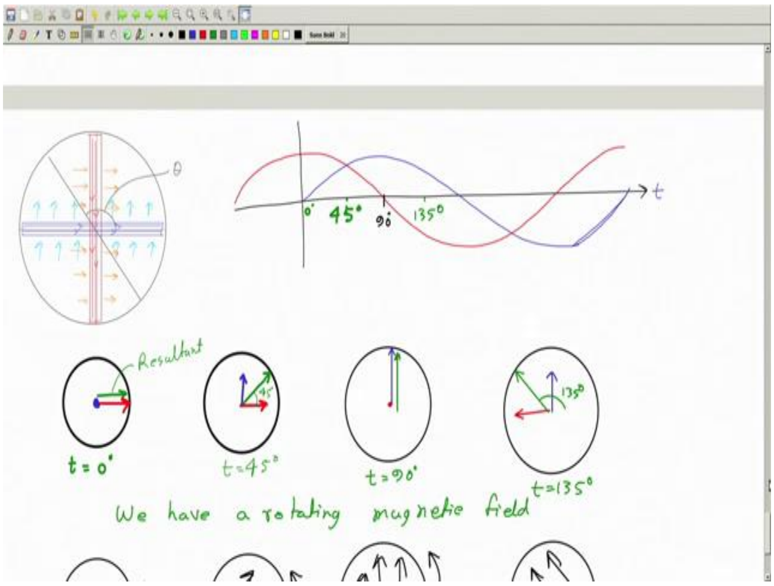
$I_B = I_0 \cos(\omega t\text{-}90)$

$B_R \alpha I_R$ $B_B = B_0 \cos \omega t$

$B_B = B_0 \cos(\omega t - 90)$

And so as we are assuming that the number of turns in the red coil is same as the number of turns in the blue coil, then the reluctance for both because etcetera reluctance for both coils same. So, under this assumption, if I_0 is same as I mean if the magnitude of I_R and magnitude of I_B are same I_0, then their magnitude will also be same B_R and B_B will have same magnitude, B_0; B_0, but they will be out of phase by 90 degree ok. So far so good.

(Refer Slide Time: 18:32)



Now, let us see how these two flux lines add up together ok. So, for that; so let me first draw the two currents I_R and I_B ok. So, I have chosen it to be cause, so this is the origin. And then I_B is 90 degree lagging, so we will have the I_B here ok. And now let us see how these flux lines look like at different time instants. Say at t = 0, so , then this red current is maximum, so this red flux will be maximum ok. So, we will have a maximum red flux from left to right. So, this is the miniature version of this diagram ok. So, red flux flows from left to right and the blue flux is 0, because the blue current is 0. So, the blue current is just 0.

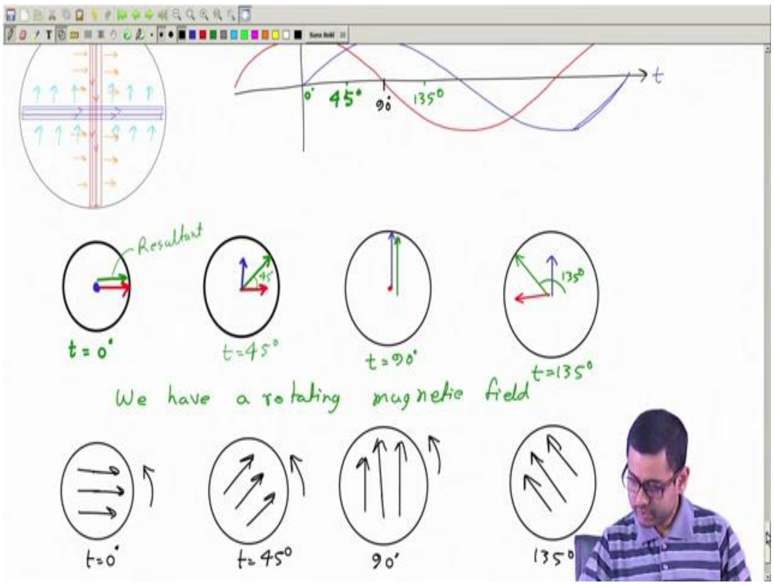
Now, if we add this, these two fluxes the resultant will be same as the vector sum of these two fluxes, so the resultant will be same as this one. So, this is the resultant; this is from left to right ok. So, this is at t equals or this angle at the angle of 0-degree, t equal to 0 degree, so this is 0 degree.

Now, for let us now let us consider at this point this is 45 degree ok. So, at 45 degree what do we have? These red fluxes are positive red current is positive. So, red flux will be from left to right and its value is not as much as before, it is somewhat lower. If it is I_0, it will be I_0 by root 2, 45 degree. So, the red flux we can draw like this with a smaller length and the blue flux we can draw like this, it is again upwards, because this current is now positive ok. And it is this, its length is as same as the length of this their magnitudes are same. So, the resultant flux will be this ok, so the green is the resultant flux. So, this green will be from it is at an angle of 45 degree, this is 45 degree ok, because these two are same, so this is at t = 45 degree.

Now, similarly let us consider what happens at t = 90 degree. Now, red flux is 0 blue flux is maximum and positive. So, the resultant will be same as the blue flux upwards ok. So, this is at t equals 90 degree. Now, similarly say at here saying this is 135 degree. So, what do we have? So, we have the red flux negative, that means, now it will be towards the left side, but it is not the peak it is smaller than the maximum value. Blue is positive, but not the peak, so the resultant will be this. So, this angle is 135 degree. So, this is at t equals 135 degree.

So, if you see how the resultant flux looks like as time progresses, you see actually the resultant flux is rotating. With the same speed same angular speed as the angular frequency of these two currents ok, and it is rotating ok. So, we have so the conclusion is that we have a rotating magnetic field ok.

(Refer Slide Time: 24:16)



So, we may also draw the same thing like this, so at t = 0, flux lines are from left to right; at t = 45, flux lines are like this, resultant flux lines, then like this; then like this. So, the flux lines are rotating, see this is rotating. Now, so we have created a rotating magnetic field with two coils like this, which are carrying currents 90 degree out of phase, and they are placed in two perpendicular planes, they are spatially also displaced by 90 degree.

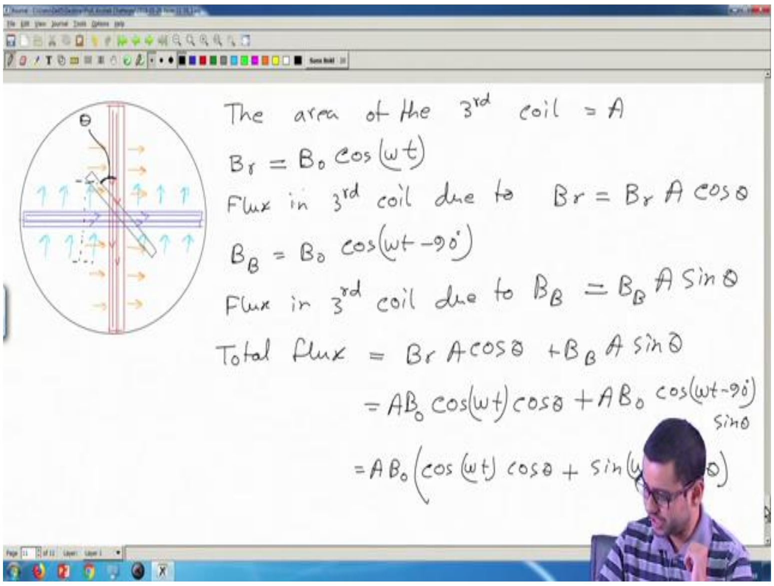
Now, let me take a 3rd coil ok. So, let me take a third coil, which I will put neither on this horizontal plane nor on this vertical plane, but on a third plane which is say, so let me draw that with a different color. So, a third plane let me draw that here ok. So, this is at an angle like, it is neither vertical nor horizontal this is like this ok. And I can so this will go like this behind, this will also go like this behind and like, so this is the plane. I am not possibly very good at this drawing, let me show that here ok. So, this third plane is like this.

In the front view, this is like, this is the third plane. And it has another coil, so let me draw that coil with green which says goes like this. So, starting from here, it goes like this, comes like this, and then we can have more turns ok, we can have more turns. And this is the out and in; in and out of this coil ok. So, the coil is here, this coil is here, from the front view, the coil is here ok.

Now, if I put a voltmeter across this coil or an oscilloscope, what do we expect, will there be any voltage? Yes, of course. Why? Because this coil is here and the magnetic field is rotating, we have a rotating magnetic field ok. So, the flux linkage of this coil is changing with time ok; so the flux linkage of this coil is changing with time. And therefore, we will have some according to Faraday’s law some voltage induced across this ok.

Let us do some math if you like. Say if we have the 3rd coil at an angle theta. So, this is the 3rd coil ok. So, let me draw it in the same way as I did before. So, control z yeah, so let me draw it in the same way as I did before. So, this is the 3rd coil ok, which is at an angle say theta. Now, how much is the flux linkage of this coil at any particular time. So, let us calculate that.

(Refer Slide Time: 29:40)



So, the 3rd coil is here ok. So, let me take this length of this coil to be much smaller like this ok. I do it on, so this is the third coil. And say the cross-section area of this coil is A. So, cross section means which area? In this diagram, this area; this area. So, that area or let me just write the area of the coil, 3rd coil is equal to A, the and it is at an angle of theta ok.

$Br = B_0 \cos \omega t$

So, the flux due to flux in 3rd coil due to B r that means red current is equal

$B_r = B_r A \cos \theta$

$B_B = B_0 \cos (\omega t\text{-}90)$

$B_B = B_B \sin \theta$

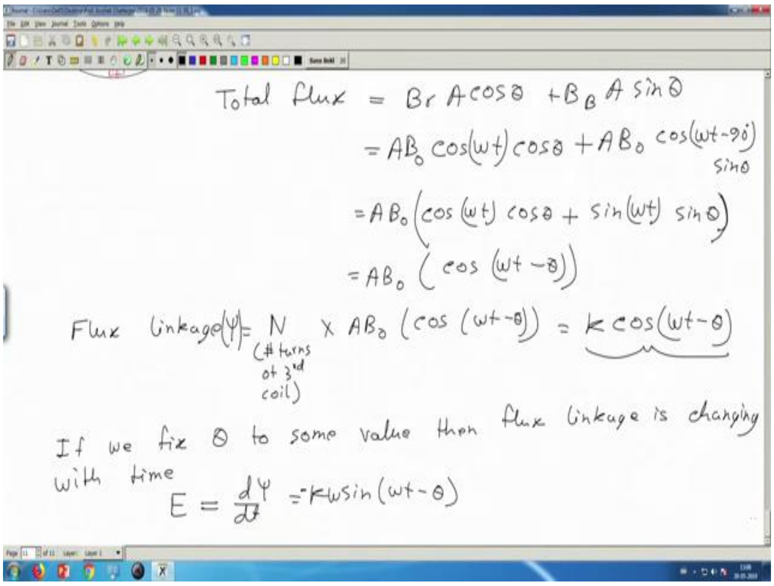
Total flux = $B_r A \cos \theta + B_B \sin \theta$

$= A B_0 \cos \omega t \quad \cos \theta + A B_0 \cos (\omega t\text{-}90) \sin \theta$

$= A B_0 [\cos \omega t \quad \cos \theta + \sin \omega t \quad \sin \theta]$

$= A B_0 \quad \cos (\omega t - \theta)$

(Refer Slide Time: 34:53)

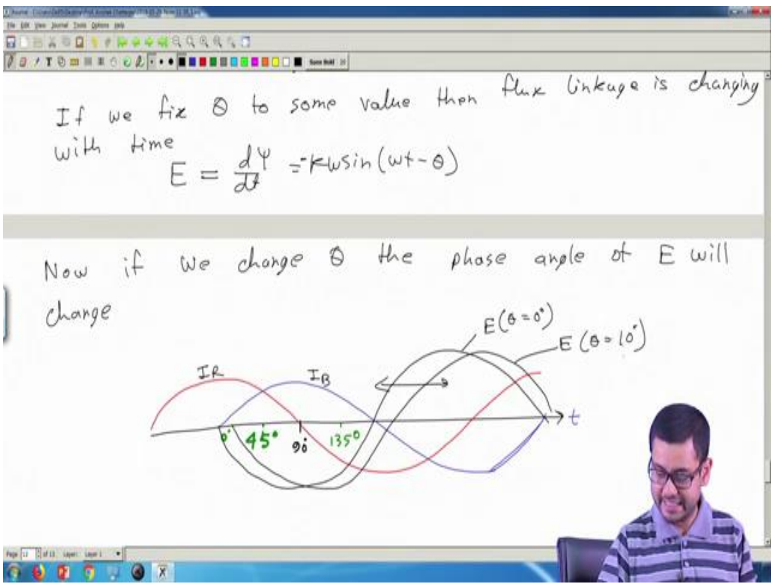


Flux linkage φ = N x AB_0 cos (ω t – θ) = K cos (ω t – θ)

Now, if theta is constant, what is theta, theta is the position of this coil. And I can keep it constant, I can put this coil at a particular angle. So, if we fix theta; fix theta to some value, then the flux linkage is changing ok, then flux linkage is changing with time and the induced EMF will be equal to rate of change of flux linkage.

E = $\frac{d\varphi}{dt} = -K\omega \sin{(\omega t - \theta)}$

(Refer Slide Time: 37:50)



So, now if we change theta the phase angle of E will change ok. So, for example, let me where is the yeah. So, let me; so if this is the timing diagram for the two currents I_R and I_B in the two primary coils, then the secondary or the third which I am calling the 3rd coil which you can call the secondary because it is like a second in a transform secondary coil of a transformer where some EMF is induced, so that E; so this E can change. If I consider say theta to be 0, if I keep it at an angle 0, then E will be minus sin omega t. So, E will be like this. So, this is E for theta equals 0 degree

So, that means, if I keep this coil here, so I can move this coil ok. So, this coil is movable; this coil is movable, I can keep this coil here and lock it, so that it does not move by any chance, I can keep this coil here and lock it, so that it does not move. So, I can change theta and now if I change theta, so for 0 degree theta, that means, when the coil is vertical you see that this will be the form of the EMF ok.

And now if I change theta to be something else, so if I take theta to be something like 10 degree or so, then I will have a delay of 10 degree maybe like this. So, this is E for theta equal to may be 10 degree and so on. So, we can change this position of this EMF by changing this position of theta the angle of the third coil.

Therefore, you see that this arrangement is actually a phase shifter if we give two currents 90 degree out of phase to supplies in these two coils, then we will get an EMF which we can change its angle by changing the position of this third coil, that means, this angle ok. So, this is how our phase shifter works.

So, in our next class we will start our discussion from this point. We will talk once again about how to use this phase shifter in a AC potentiometer and then we will talk about another potentiometer which is coordinate potentiometer with which also we can measure AC voltage with arbitrary phase.

Thank you.