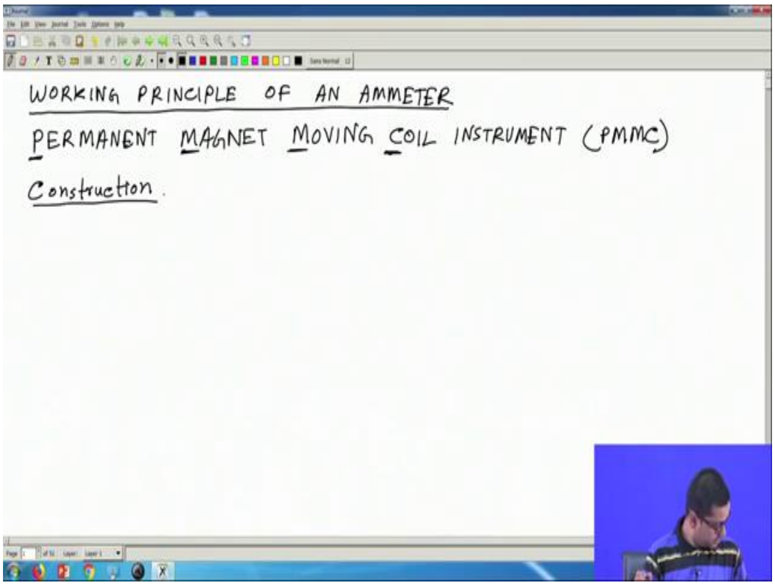
Electrical Measurement and Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 01
PMMC Instrument

Hello and welcome. So, this is our first class in Electrical Measurement and Instrumentation. In this video, we shall learn about how an ammeter works.

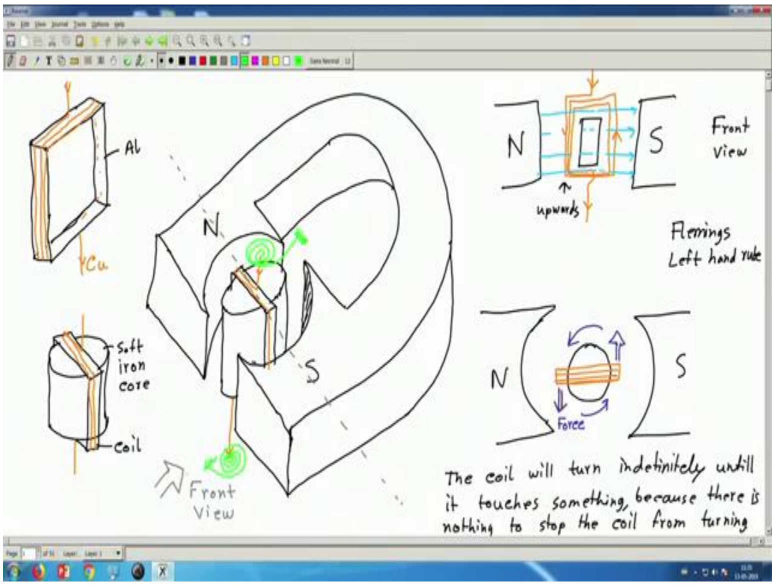
(Refer Slide Time: 00:42)



So, the topic is working principle of an ammeter. So, we will talk about a particular type of ammeter, which we also sometimes call a permanent magnet moving coil instrument and in short we call it PMMC. So, we shall see how does this emitter works? So, as you know emitters measure current. So, we will have an instrument which can measure current.

So, let us look at the constructional detail of this instrument. It is composed of mainly a permanent magnet a U shaped permanent magnet which has 2 poles.

(Refer Slide Time: 02:19)



So, the magnet looks like this, it has it is like a U. It is a U shaped magnet and it has 2 poles; one of them north, another south. The pole face is curved like this. It is like an inner surface of a cylinder. So, these are the 2 poles, and this is a permanent magnet.

And then we have a cylindrical core inside this vacant cylindrical region. So, the core which is made up of some soft iron soft magnetic material, which is like a cylinder is placed here inside this 2 poles. So, this is a cylinder inside the 2 poles. Now, we have a coil and the coil is owned on top of a rectangular frame. So, let me first draw a rectangular frame.

So, this is a rectangular frame often made up of aluminium and then we have copper coil owned on top of it. So, the coil starts like this. So, this is one end of the coil and then the conductor goes like this, round this frame, then like this and then it comes back. So, this is one complete turn and then it can go again, round and round. So, round and round this aluminium frame and then the other terminal comes out like this. So, this is one terminal of the coil, this is another terminal of the coil and this is owned on top of aluminium rectangular frame.

So, this is copper (Cu) for copper and this frame is made up of aluminium (Al) normally. And then we put this coil, this form mode of frame on top of this cylindrical structure. So, we put this like this may be. So, the coil is put around this core, a soft iron core. So, this is a soft iron core, and this is the coil and the coil is actually like this. So, it can have many turns and then finally, the other end comes out from the bottom of this form.

So, let me draw this coil here once again and the other end is here. So now, what will happen if we pass some current through this coil? You know that these current carrying conductors or these coils, they are in a magnetic field. And therefore, they will experience some force and therefore, some torque and then the coil will try to rotate, that is the basic principle of this instrument. Now to see it in more detail, let me take a cross section of this instrument may be like, this let me take a cross section. So, let me cut this instrument along this dashed line and see it from the front.

So, how will it look like? So, it will look like these 2 poles, like 2 rectangles; north and south and between these 2 poles, we have this coil. So, we have this coil which is like this. So, this is one turn, this is another turn, it can have many turns, 100's of turns and then it then the other end comes out from the bottom. And inside this coil we have the core. This cylindrical core which will look like a rectangle as seen from the front view.

Note that the core and the coil, they are not touching each other, they are separate; they are not attached to each other. So, the coil can move independently from this core. So, the core does not move, but the coil can move. So, this is how it looks like from the front view. Now, suppose there is a current which is flowing like this, which means it is going like, this from top to bottom on the left side and from bottom to top on the right side.

Now, what will happen? We will have magnetic lines of forces, passing from left to right; that means, from north to south like this. And these current carrying conductors, they are inside this magnetic field. So, they will experience some electromagnetic force. And the direction of the electromagnetic force can be found using the left hand rule of Fleming's.

So, let us apply Fleming's left hand rule. Now let me now apply Flemings left hand rule. So, I have 3 fingers and the first finger should point towards the flux lines, which is from left to right according to my drawing. And then this middle finger should be along the direction of the current. If I am considering this left side of the coil, then this is the direction of current.

And then my thumb points upwards. So, that means, the force acting on this side of the coil will be upwards, perpendicular to the plane of paper and it is towards us i.e., upwards.

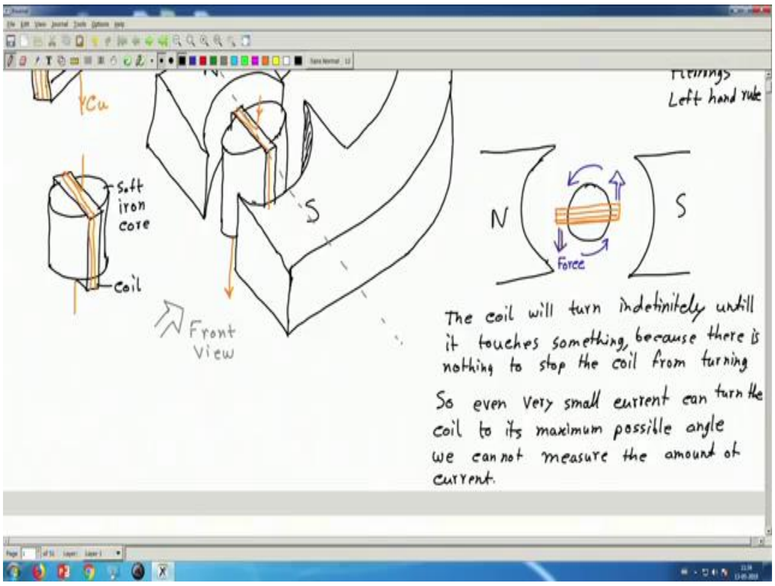
So, the force will here be upwards. So, let me also draw the top view for ease of visualization. So, this is front view. Let me draw the top view of this.

So, the top view will look like 2 poles north, south and at the center we have this cylindrical core, which looks like a circle from the top and then we have this coils which is here. These are the turns and it looks like just a line from the top ok. And as you have seen on this side the force is in this direction, this is the direction of the force.

Similarly, if we find the direction of force on this side of the coil. So, let me use my hand once again. So, here the flux lines are once again from left to right. The current is from bottom to up. So, like this and then my thumb points downwards, perpendicular to the plane of paper, but inwards or away from me. So, here the force will be like this. Now, this two forces together form a couple, or they apply a torque which tries to turn the coil in this anti-clockwise direction. So, what we have seen, we have seen that if there is a current flowing through this conductor, then we will have two forces acting on two sides of this coil which will try to turn this coil.

Now, the coil can get turned by indefinite amount. So, the coil will turn indefinitely until it touches something or hit something, because there is nothing to stop the coil from turning. So, therefore, what will happen?

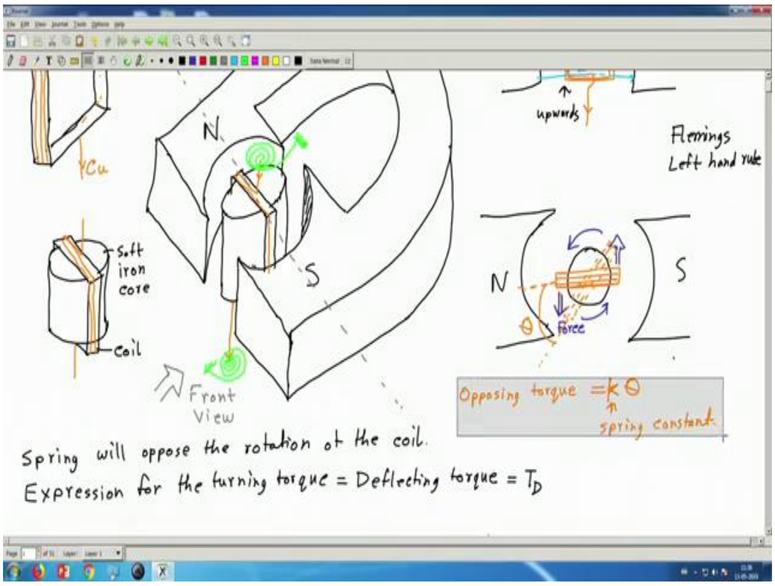
(Refer Slide Time: 16:05)



No matter I mean whether the current is small or large, the coil will turn to it is maximum possible angle. So, if so, even very small current can turn the coil to its maximum possible angle. So, essentially we cannot distinguish between small and large current or in other words we cannot measure the amount of current, in this configuration. Now to be able to measure the amount of current, we need another component in this construction which is a spring. So, we will take a spring and we will connect it here. This is a spiral spring and the other end of this spring is connected to the frame of the instrument. So, this end cannot move and this end is connected to the coil.

Similarly, we will have another spring here, one end is connected to the body or the frame of the instrument and the other end to the coil. So, now, what happens, as soon as the coil tries to move, the spring will oppose the motion.

(Refer Slide Time: 18:35)

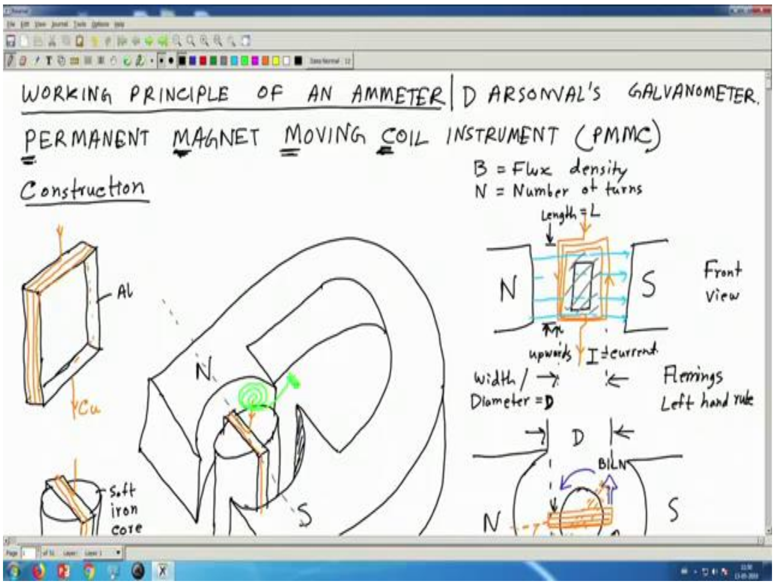


Now, the spring will oppose the rotation or motion of the coil. So, if the coil is turned by an angle of theta, say this coil is turned by an angle of theta and has come here say it's here. So, this is the new position of the coil and this angle, call this angle as theta. So, if the coil is turned by an angle of theta then these springs are twisted and according to Hooke's law, it will give an opposing torque. So, with the opposing torque according to Hooke's law is given by

$$Opposing\ Torque = K\theta$$

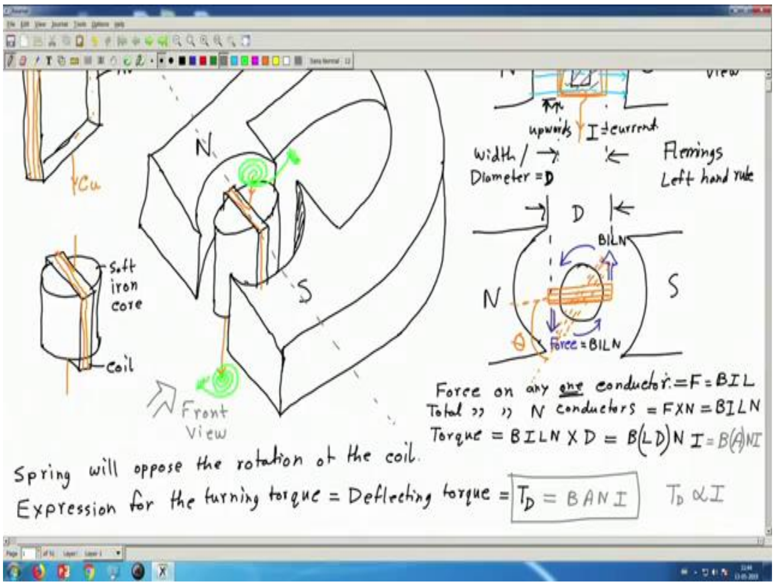
And then the coil will settle down at some position where the opposing torque is equal as the turning torque. So, this is the mechanism. Now, let us try to find out the expression for the turning torque. The torque due to this current which tries to turn this coil. Now, this is also called the deflecting torque, because it tries to deflect or turn the coil and we generally denote this as T_D; D for deflecting torque. Now, let us find the expression.

(Refer Slide Time: 21:45)



So, see that this flux density is B and say the length of this coil inside the magnetic field, Call this length as L. And then this current, call this current as I which is flowing through this coil and say this coil has N number of turns. So, let N be the number of turns in this coil. Now, consider, say only one conductor.

(Refer Slide Time: 23:03)



So, the force on any one conductor on this side. So, consider just one conductor, one particular conductor.

$$F = B\ I\ L$$

So, this is from our knowledge of physics, high school physics, we know that this force is given by BIL, B is the flux density, I is the current through the conductor and L is the length of this coil. Now, there are N turns. So, the total force on N conductors,

$$F_{total} = B\ I\ L\ N$$

Now, what will be the torque, the torque will be given by this forces multiplied by the distance between the lines of actions of these forces and that distance, So, this is the distance which is same as this distance.

So, this is basically the width of the coil. We also call it the diameter of the coil and we can call it as D but note that this is actually not the diameter of the coil. So, this is not I mean because the coil is not circular at all. So, strictly speaking this is not the diameter of the coil, but you can say this is the diameter of the core approximately, but we generally call it the diameter of the coil often and let us call this distance as D. So, D is this distance, between the 2 forces.

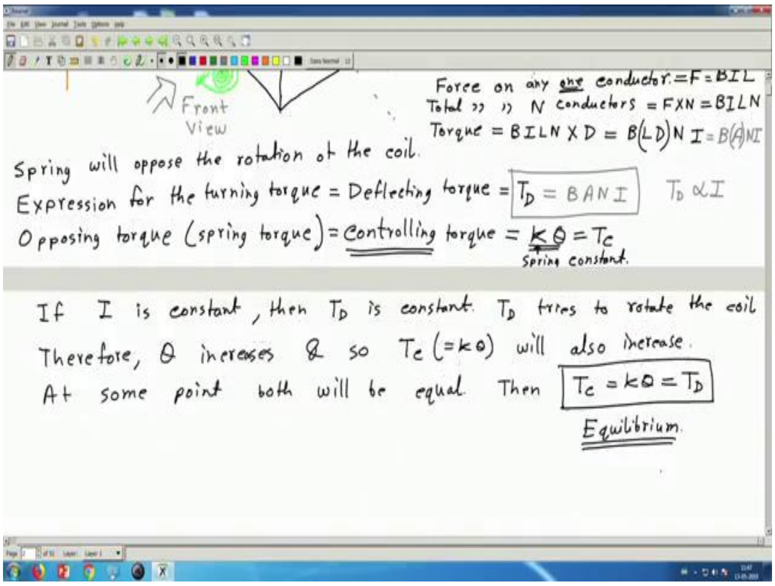
$$Torque = B\ I\ L\ N \times D$$

$$Torque = B \times (L\ D)\ N\ I = B(A)NI$$

So, this is the expression for the deflecting torque. So, it is observed that T_D is proportional to the current flowing through the coil. So, more the current is the higher will be the torque which is trying to deflect or turn this coil.

So, this is the turning torque or deflecting torque. Now, as we have already seen that there are springs which tries to oppose the movement of this coil and it gives some opposing torque, which we can write as opposing torque, that is spring torque, we also call it the controlling torque.

(Refer Slide Time: 27:34)

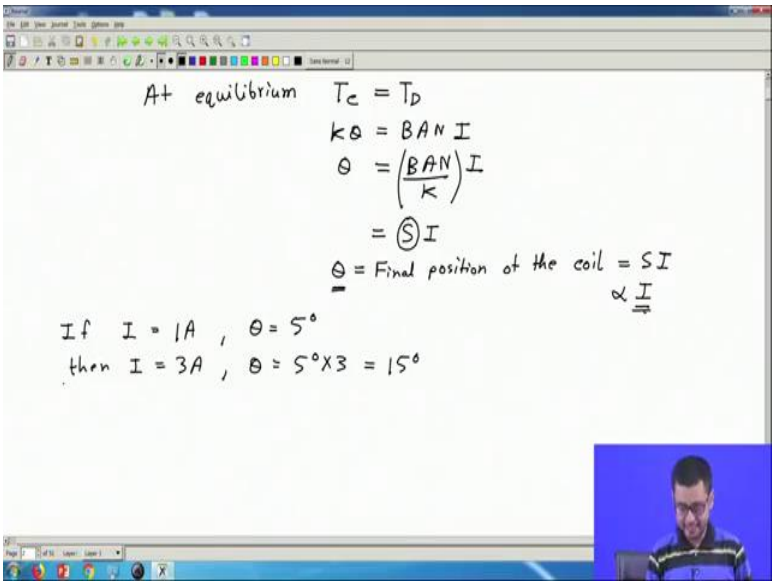


So, these are all the names of the same thing, this is given by Hooke's law,

$$T_c = K\theta = T_D$$

So, the 2 opposing torques are equal in magnitude, but opposite in direction. So, then there will be no resultant torque and the coil need not move further. So, this condition is called the equilibrium.

(Refer Slide Time: 31:11)



$$At\ equilibrium, T_c = T_D$$

$$K\theta = B\ A\ N\ I$$

$$\theta = \left(\frac{B\ A\ N}{K}\right)\ I$$

Because, the area of the coil is constant, number of turns is a constant. Once the instrument is manufactured, they are not going to change, flux density not going to change, spring constant is not going to change.

$$\theta = S\ I$$

$$\theta\ \alpha\ I$$

So, more the current is, the position or the angle theta of the coil will be higher. So, for example, if current is say 1 ampere, then if theta is equal to say 5 degrees, then it for I equals say 3 amperes, theta will be 5 degree multiplied by 3 or 15 degree.

So, this is the working principle of this instrument, which we call a PMMC instrument or Permanent Magnet Moving Coil Instrument in short PMMC. This is also called D Arsonval's Galvanometer. So, this is how we can measure current, because when there is a current flowing through this through the coil, it will get deflected by an angle theta, we can observe the value of theta and if we know the value of S,

$$S = \left(\frac{B\ A\ N}{K}\right)$$

So, we observed the angle theta and therefore, we can measure the current. So, this is the working principle of this instrument. Let us meet in our next lecture.

Thank You!