Electrical Measurement and Electronic Instruments
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Lecture – 05
Moving Iron Instruments

Hello and welcome back to our next tutorial on Electrical Measurements and Electronic Instruments.

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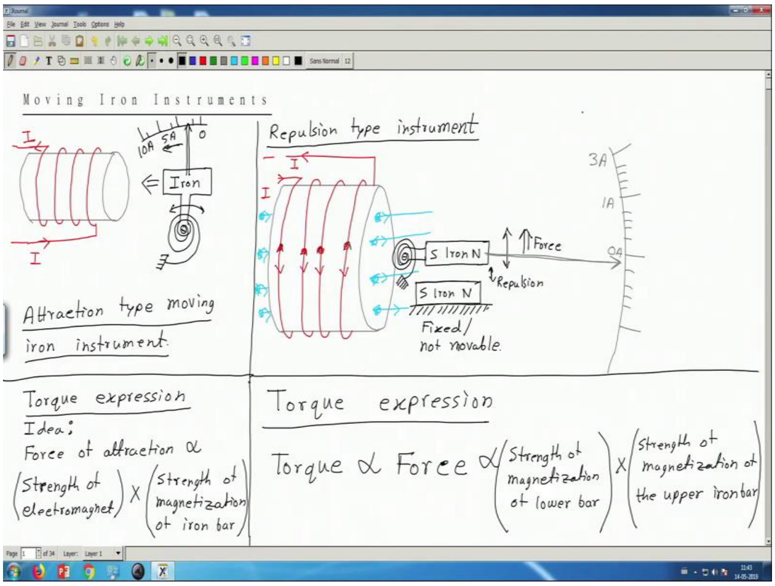

In this video, we are going to learn about another type of instruments ammeters which we call moving iron instruments. These are very simple instruments. This is made up of mainly a coil and this coil will have turns and this coil can carry some current. Let me call this current as I. So, this is the current, the unknown current that we want to measure.

Now, we will have a piece of iron in front of this coil. Now, when any current flows through this coil, the coil acts like an electromagnet like a solenoid and therefore, it is magnetized, and it will attract this iron bar this piece of iron. So, this piece of iron will try to move closer to this electromagnet or solenoid. Now, what I will do, I will attach this iron bar to some pivot and so that this iron bar can rotate around this pivot and I will attach a spring. The spring will try to hold this piece of iron at it is normal position. It will not allow the iron piece to move towards this electromagnet.

And then what I will do? I will connect a long pointer to this iron piece so that when any current flows through this coil this iron bar will get attracted towards the electromagnet and the spring will try to hold it back in its original position, but due to attraction iron bar will move towards this magnet by some amount, which will cause this pointer to also move towards the left according to my diagram and I can have a scale, with markings like this, so that these markings will indicate the value of the current. The higher the value of this current, this iron bar will be attracted more towards this electromagnet and this pointer will move more towards the left. Therefore, by observing the position of this pointer along this scale, we can measure the amount of current.

So, according to my diagram here I may have higher current values towards the left maybe 10 ampere here, maybe somewhere here 5 ampere, maybe 0 ampere here etcetera or maybe 0 ampere here are depending on or I may erase part of this gap. So, this way we can measure this unknown current by observing the position of this pointer along this scale. This instrument is called an attraction type moving iron instrument, because this instrument acts based on the attraction between this iron bar and this electromagnet.

We can have another type of moving iron instrument which is more common in practice and that is called a repulsion type instrument. So, let us see how that works? Once again, I will have a coil which will carry the current unknown current. So, let me draw the coil and this is the conductor carrying the current. Let this current be I, the unknown current and now I will have two pieces of iron bars instead of one. So, let me draw then here, this is one iron bar and let this be another iron bar.

Now, suppose if I have current flowing in this direction. So, it is like this. Then it will generate flux, may be in this direction depending on the direction of the current. Therefore, both these pieces of ions will get magnetized and maybe this side will be north, and this side will be the south pole of this induced magnet. If this side is north for this induced magnet, this side should also be north, and this side should also be south because they are in same magnetic field they are placed side by side. So, they should have same polarity if this side is north then this side should also be north, if this is south then this should also be south or vice versa.

So, anyway the like polarity, similar poles will be nearby. So, this South Pole and this South Pole will repel each, other similarly these two North Poles will repel each other.

Now, what I will do among these two bars of iron, I will fix one of them to the frame of the instrument. So, this is fixed. So, this is not movable and this one I can connect once again say with a pivot. So, then this iron bar can move up or down. I will connect a spring once again, so that the spring holds this iron bar at a normal position when there is no current, but as soon as this current flow, the repulsion starts, and the iron bar will move upwards.

So, now I can connect again a long pointer to this, and I can draw a scale here. So, as current flows the pointer moves upwards in an if the current is more this repulsion force will be more and the pointer will move further up and indicating higher value of current. So, now, I can possibly mark, say this position by 0 ampere, this position by say maybe 1 ampere this position by I do not know maybe some higher value maybe 3 ampere or so on.

So, we can mark these positions so that these pointers can indicate the value of the current. So, this is called a repulsion type instrument. Now the next thing that we should do as usual is find out the expression of torque. So, let us consider first this attraction type instrument. The idea that you should understand is that the force of attraction depends on two factors. It is proportional to two factors. First factor is how strong this electromagnet is. So, let me write strength of electromagnet, this is one factor and another factor is the strength of magnetization of this iron bar. So, these are the two factors on which the force of attraction depends.

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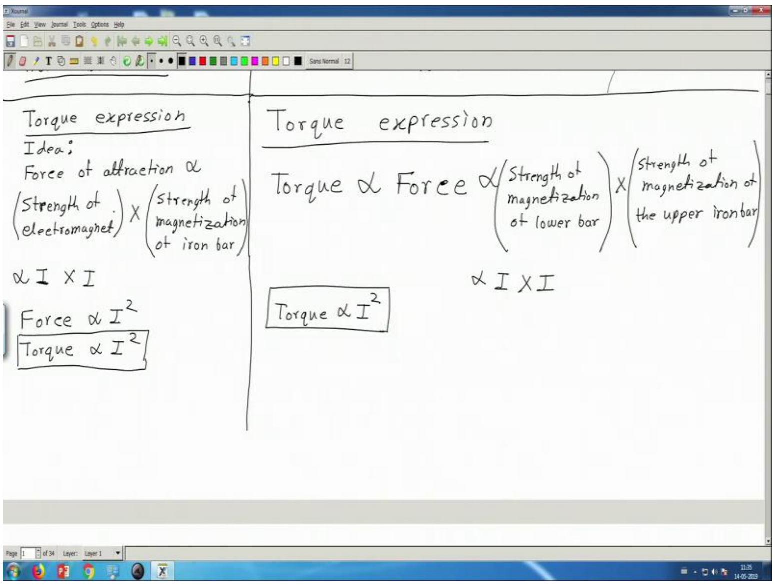

Torque expression

Idea:

Force of attraction $\propto$ $\left(\text{Strength of electromagnet}\right) \times \left(\text{Strength of magnetization of iron bar}\right)$

$\propto I \times I$

Force $\propto I^2$

$\boxed{\text{Torque} \propto I^2}$

Torque expression

Torque $\propto$ Force $\propto \left(\text{Strength of magnetization of lower bar}\right) \times \left(\text{Strength of magnetization of the upper iron bar}\right)$

$\propto I \times I$

$\boxed{\text{Torque} \propto I^2}$

$$Force\ of\ attraction\ \alpha\ (Stength\ of\ electomagnet) \\ \times\ (Strength\ of\ magnetization\ of\ iron\ bar)$$

So, this is one important result about the attraction type instrument.

$$Force\ \alpha\ I^2$$

Now, let us see what happens for a repulsion type instrument.

$$Force\ of\ attraction\ \alpha\ (Stength\ of\ magnetization\ of\ lower\ bar) \\ \times\ (Strength\ of\ magnetization\ of\ upper\ bar)$$

$$Torque\ \alpha\ I^2$$

So, this is an important result about moving iron instruments that the torque deflecting torque is proportional to the square of the current. Now, let us consider the equilibrium condition.

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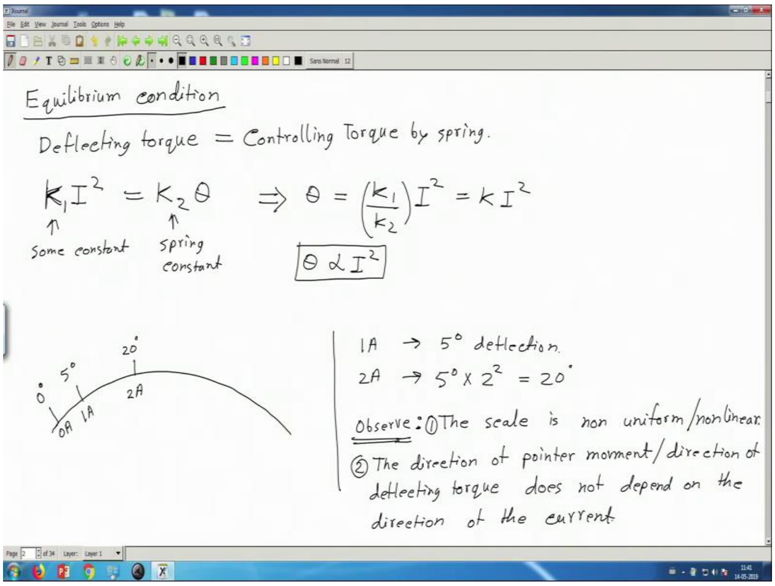

Equilibrium condition

Deflecting torque = Controlling Torque by spring.

$$K_1 I^2 = K_2 \theta \Rightarrow \theta = \left(\frac{K_1}{K_2}\right) I^2 = K I^2$$

Some constant

spring constant

$$\boxed{\theta \propto I^2}$$

1A → 5° deflection.

$2A \rightarrow 5^\circ \times 2^2 = 20^\circ$

Observe: ① The scale is non uniform/nonlinear.

② The direction of pointer movment/direction of deflecting torque does not depend on the direction of the current

So, by equilibrium we mean the situation when the deflecting torque is same as equal to the opposing torque given by the spring. So, that at the position the two torques cancel each other and the pointer can stay at that position without moving further. So, at equilibrium we can write the deflecting torque is same as the controlling torque or opposing torque given by the spring. This is true for both type of instruments no matter attractions type or repulsion type.

$$K_1 I^2 = K_2 \theta$$

$$\theta = \left(\frac{K_1}{K_2}\right) I^2 = K I^2$$

$$\theta \; \alpha \; I^2$$

Therefore, on the scale if I have 0 ampere here and if I call this as my 0 degree position or 0-degree angle, say for 1 ampere current, I get 5 degree deflection. So, somewhere here at 5 degree or maybe this is more than 5 degree. So, I will have 1 ampere, but now 2 ampere current will indicate will cause the pointer to move by an amount 5 degree multiplied by 2 square, equal to 20 degree. So, it will be somewhere here maybe. So, observe the scale is non-uniform or we say non-linear.

Now, another important fact, another important observation is that the direction of pointer movement, that is theta or the direction of the torque, this does not depend on the direction of the current. So, let us go back to our schematic diagram. Suppose, if I reverse the direction of the current from like this. So, if I even reverse the direction of the current, but if the magnitude of current remains same, then also this iron bar will get attracted because magnet can always attract an iron bar a magnet never repels an iron bar.

So, the direction of the torque will always remain same unchanged in this situation. Once again here if I change the direction of the current, then maybe all these currents will also be reversed and so, therefore, these flux lines will also be reversed and this north and south will be altered. So, this will become south and north, but still you see the similar poles are close by, they are side by side. So, once again these force will be still repulsive. We will never have attractive force between these two. So, the direction of the current does not matter. The pointer will always move in the same direction.

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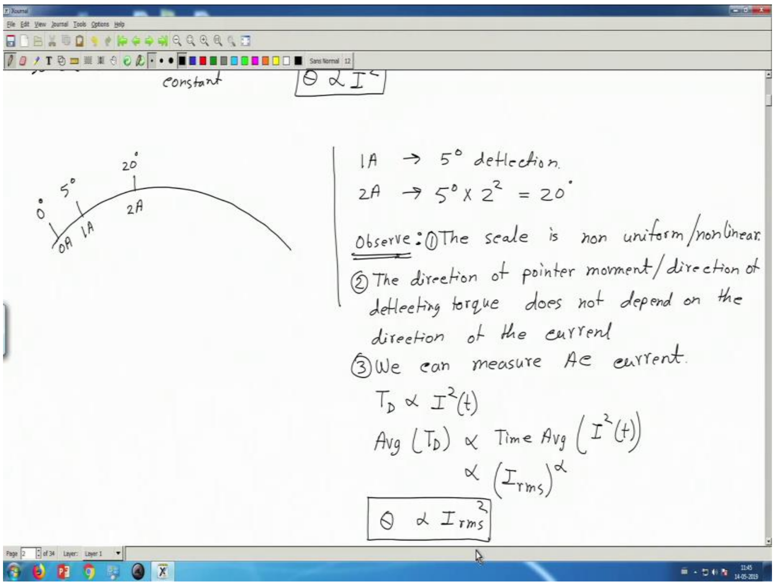

constant $\boxed{\theta \propto I^2}$

1A → 5° deflection.

2A → $5^\circ \times 2^2 = 20^\circ$

Observe: ① The scale is non uniform/nonlinear.

② The direction of pointer morment/direction of deflecting torque does not depend on the direction of the current

③ We can measure AC current.

$T_D \propto I^2(t)$

$Avg\,(T_D) \propto Time\ Avg\,(I^2(t))$

$\propto (I_{rms})^\alpha$

$\boxed{\theta \propto I_{rms}^2}$

So, therefore, we can measure AC current with this instrument and the deflecting torque will be T_D.

$$T_D\ \alpha\ I^2(t)$$

$$Avg.(\,T_D)\ \alpha\ Time\ Avg.\ \left(\,I^2(t)\right)$$

$$\theta\ \alpha\ I_{rms}^2$$

So, that is it in this video. In our next video we will demonstrate you we will show you a real instrument a real moving iron instrument and we will talk in more detail about subtle aspects of the construction and different things of a real instrument in our next video.

Thank you.