Electrical Measurement and Electronic Instruments

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Lecture -12
Ballistic Galvanometer

Welcome back. In our last video we were talking about the dynamics of the moving system. We have mentioned about the importance of damping the damping torque it should not be very small, because then the system will oscillate, it will take long time before it can take reading, it should not be very high, then the system will be over damped which means it will not oscillate, but it will take time to reach it's final position.

We have found the condition for critical damping that is the condition where the damping is just perfect. The system will not oscillate it will not take more than the minimum required time to reach it is final position that is the critical damping condition.

And we have also mentioned in particular where we use eddy current damping, how should we choose the value of the resistance of say the former, if we are considering the eddy current damping due to the eddy current in the former or the aluminum frame on which the conductors are owned. So, we have discussed how much should be the value of the that resistance for my resistance to get optimal based value of the damping. In this video we will talk about an interesting application of these analysis of say dynamics of the moving system.

So, we will talk about ballistic galvanometer what is a galvanometer? A galvanometer is nothing, but a PMMC instrument permanent magnet moving coil instrument galvanometer is another name of PMMA instrument.

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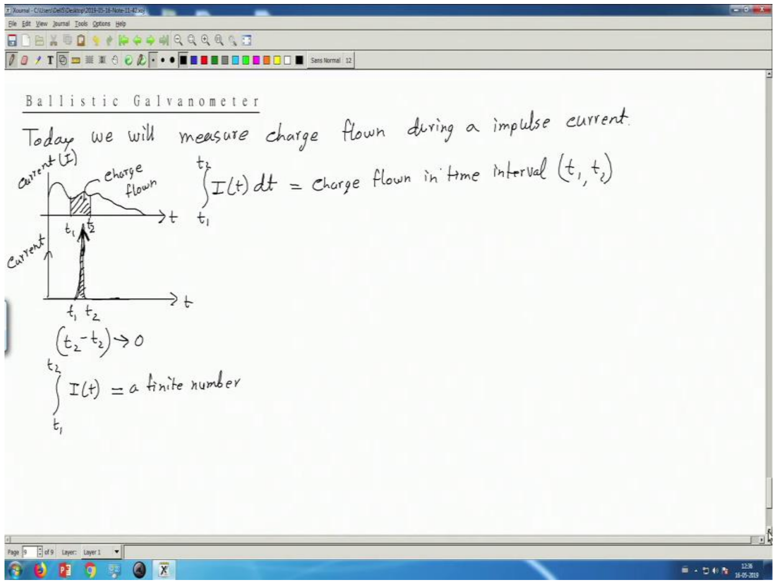

And by the word ballistic ok. Ballistic means, it is a galvanometer which has very little or almost no damping, no friction. It is almost no I mean it is a frictionless damping less galvanometer. So, the constant damping constant is ideally 0 for this galvanometer. We will talk about how we can use this fact that the damping is 0 to measure charge, flown, in a short duration, during a impulsive current using ballistic galvanometer. So, we will measure. So, today we will measure charge flown during a impulsive current impulse current.

So, what do we mean by an impulse current? Suppose, if I draw say time versus current in any I mean any conductor in any branch of a circuit. If I have if any arbitrary pattern of the current this is time this is current, then call it $\int_{t1}^{t2} I(t)dt$ this integration between two points t_1 and t_2 is nothing, but the charge that flows flown from one point of the circuit to the other between the time interval or in time interval t_1 , t_2 ok.

So, if this is t_1, this is t_2, if we perform an integration that is the area under the skull this is nothing, but the charge flown within that time. Now, an impulse current is a current which exists for a very short duration maybe it is like this. So, it is 0 here it is 0 here, but it is nonzero only for this small time interval ok. And this time interval t_1, t_2 so, the gap between t_1 and t_2 is almost 0. So, this tends to 0.

This is what happens for an impulse current, but if we perform the integration within this time the integration of this current $\int_{t1}^{t2} I(t)dt$ this should be a finite number ok; that means, the amount of charge that flows within this time that is not 0. Although, the current exists for a very short duration, but a finite amount of a nonzero amount of charge is transferred within this time, which also actually means; that the height of this should be very high. I mean study maximum the amplitude of this current should tend to yield infinity.

That is what an impulse current is the current is of very high value, it is almost infinity theoretically, but it exists for a very short duration. Therefore, a high value high very large height multiplied by a very small width that is comes out to be a finite number it is neither 0 nor infinity. So, the charge flown within this time that is the area under the curve is a finite number. And particularly if this area is equal to 1 we call that an unit impulse you may know that ok.

Now, the goal of this video is to measure this charge which has flown during an impulsive current in a circuit using a galvanometer which you called a ballistic galvanometer.

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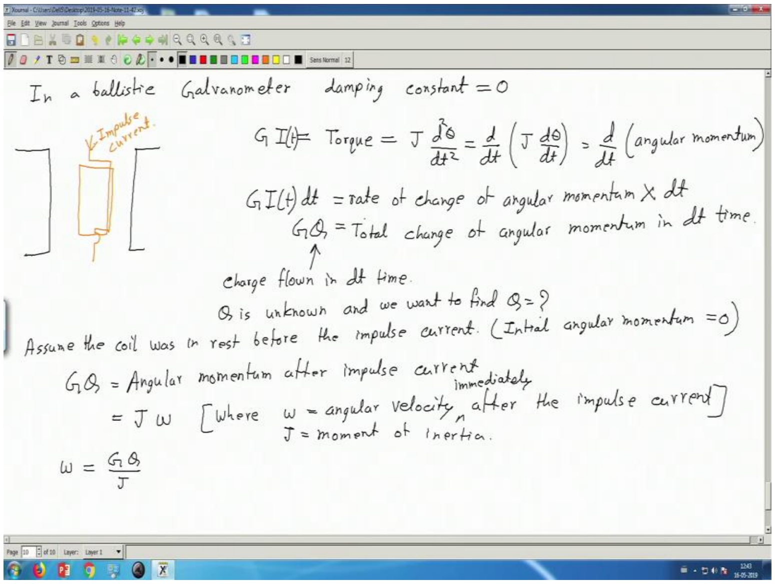

So, in a ballistic galvanometer the damping constant is 0 ideally ok. So, there is no damping force no damping torque. Now, say impulse current flows through the coil of the instrument for a very short duration ok.

So, impulse current flows ok. Now, if we call this current as I ok, then we know that I G, G is what the galvanometer constant which is BAN; that means, torque per unit current. This is equal to the torque ok. And therefore, this should be equal to the moment of inertia multiplied by the angular acceleration ok. So, this is the or we can say that this is the rate of change of the angular momentum ok. So, this is.

$$\text{GI=Torque=J}\frac{d^2\theta}{dt^2}= \frac{d}{dt}(\text{J}\frac{d\theta}{dt})= \frac{d}{dt}\,(angular\ momentum)$$

Now, we know that this I which is a function of t is impulsive, so, it flows for a very short duration say dt. Therefore,

GI(t) dt= rate of change of angular momentum x dt

GQ= total change of angular momentum in dt time

Q=charge flown in dt time

And this is what we want to find out, we want to find out the value of Q. Q is unknown and we want to find Q ok. So, Now, assume the coil was in rest before the impulse current ok. So, therefore, the initial angular momentum was equal to 0 and the total change of angular momentum we have found that this is equal to G Q ok.

So, the total change of angular momentum is G Q, now total change of angular momentum is nothing, but the angular momentum after the impulse current minus the initial angular momentum which was 0. Therefore, we can write this is not same as the angular momentum after impulse current. So,

GQ= angular momentum after impulse current

=J w (where w=angular velocity immediately after impulse current, J=moment of inertia)

So, therefore, we can find the velocity omega immediately after this current has flown as $\frac{GQ}{J}$. So, if this is the angular velocity then how much kinetic energy do we have immediately after this charge has flown this current has flown?

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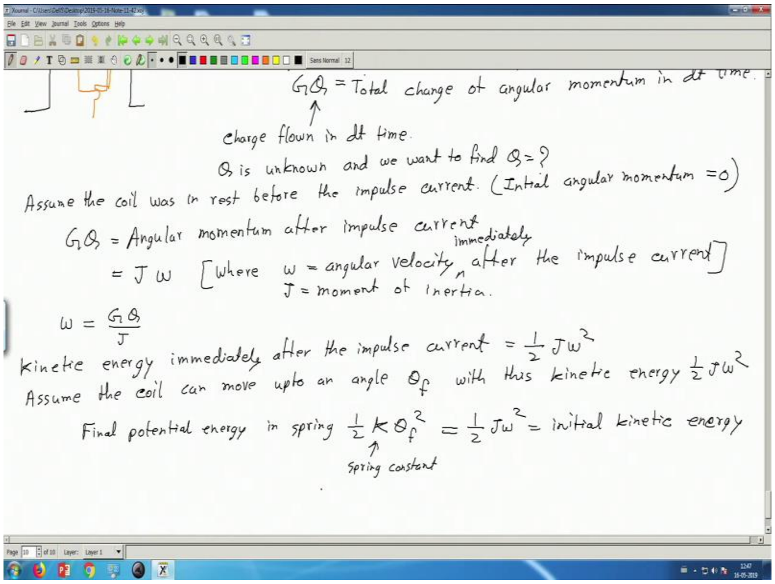

So, that will be given by so,

the kinetic energy immediately after the current impulse current=$\frac{1}{2}JW^2$

So, this is the kinetic energy immediately after the charge has flown. Now, what will happen the charge has stopped the current has stopped, but this current has set the coil into motion the current has stopped, but within that short time the coil has already started to move the coil has already gained some velocity, gained some kinetic energy. And then when the current has stopped due to inertia the coil will continue to move. And as the coil moves the angle theta increases therefore, the spring tries to stop it. So, springs now wants to stop this coil but, due to inertia the coil will go up to some distance.

How far will it go, it depends on the initial energy it has immediately after the current has stopped. And that in that energy as we have written right now is half J omega square. So, we have to find out with this energy how much can this coil move. And let us assume the coil can move up to an angle say θ_f for final. So, assume the coil can move up to an angle θ_f means final angle when the coil stop.

So, as in the coil can move up to an angle θ_f with this kinetic energy ok. So, as the coil is moving, as the θ is increasing, this kinetic energy will be used and that will get converted into the potential energy of this spring.

$$\frac{1}{2}k{\theta_f}^2=\frac{1}{2}Jw^2$$

So, at it is final position when the pointer stops the kinetic energy will become 0, potential energy will become same as the initial kinetic energy, because the entire kinetic energy will be converted into potential energy. which is the initial kinetic energy this is conservation of energy ok.

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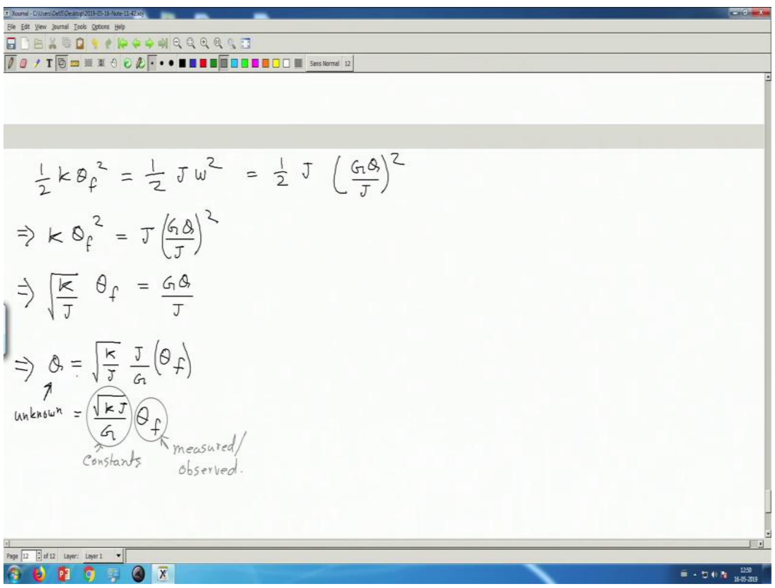

previously we have seen that the value of omega that is the angular velocity immediately after the current is given by $\frac{GQ}{J}$. So, let us put it. So, let us put the value ok.

$$\frac{1}{2}k{\theta_f}^2=\frac{1}{2}Jw^2=\frac{1}{2}J(\frac{GQ}{J})^2$$

So, now we can cancel this half from both sides and so, we can write

$$k{\theta_f}^2=J(\frac{GQ}{J})^2$$

$$\sqrt{\frac{k}{j}}\theta_f = \frac{GQ}{J}$$

$$Q=\sqrt{\frac{k}{J}}\ \frac{J}{G}\ \theta_f$$

$$Q=\frac{\sqrt{kJ}}{G}\ \theta_f$$

So, we can measure this we can observe this. So, this is measured or observed and then if we know these constants if we measure θ_f we can find the value of Q. So, that was our target. So, we have achieved it how to find the value of Q. So, how to do it very quickly that summarize how we how will we do it experimentally, we will let the impulse current flow through the coil and then the pointer will start to move and will start to oscillate.

So, if the pointer is here initially at it is 0 position and if then the impulse current flows, it will set the pointer in motion, it will give it some kind of energy. So, it will start to oscillate it will go to some extreme it will go to some extreme position and then it will oscillate ok. As the impulse current flows it will start to oscillate and we have to measure this amplitude of oscillation; that means, how much it is going, how much what is the maximum angle this pointer is reaching, that is the value of theta f maximum angle that the pointer is reaching. This theta f we know if we observe this amplitude ok.

This is the amplitude theta f we will put it here in this expression and we can find the value of Q. So, this is how we can find the value of unknown charge using ballistic galvanometer and this will be important later on when we talk about magnetic measurements, we will see that with this we can with this mechanism we can measure flux density in some coil in some toroid, then this mechanism will be useful. So, right now you just understand how to measure some charge during an impulsive current, we will make it more useful later on in our course.

Thank you.