Experimental Physics I
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Lecture - 49
Sensitivity of Blastic Galvanometer

So, for today we will discuss about the, for current Sensitivity and charge sense sensitivity of a galvanometer, basically Ballistic Galvanometer. So, let us discuss about the theory of this Experiment.

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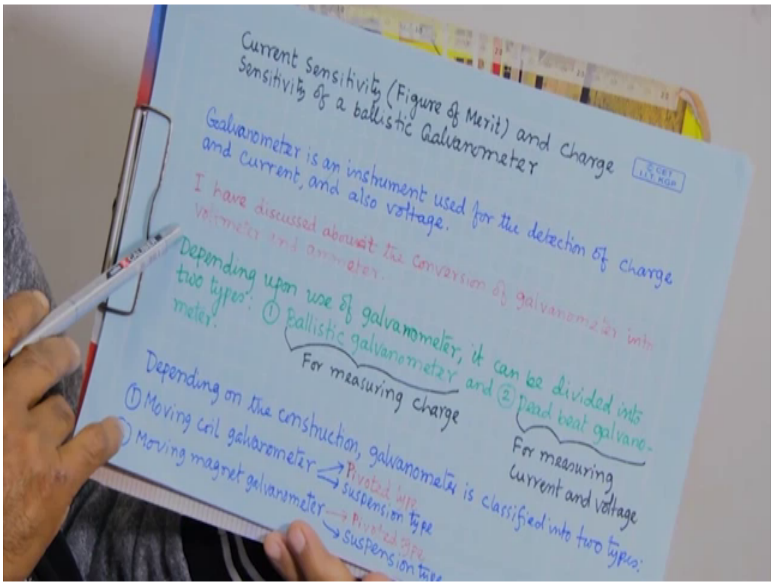

So, current sensitivity there is basically we tell figure of merit figure of merit and charge sensitivity of a ballistic galvanometer right.

So, galvanometer is an instrument used for the detection of charge current and also voltage. And, I have already discussed about the conversion of galvanometer into a voltmeter and also a an ammeter right. So, at the beginning of this course I have discussed using the using the resistance in series and resistance in parallel with this galvanometer, we can convert it to the voltmeter and ammeter right.

So, now, galvanometer basically depending upon the use of it, it can be divided into 2 types; ballistic galvanometer and dead beat galvanometer. So, ballistic galvanometer is used for measuring the charge and dead beat galvanometer is used for measuring the current and voltage ok.

So, again depending on the construction of galvanometer, it is classified into 2 types this moving coil galvanometer and moving magnet galvanometer in galvanometer. You know there are 2 parts one is permanent magnet and another is coil moving another is coil. Now, this either coil will move and this permanent magnet will be fixed or it can happen that this coil is fixed, but this permanent magnet will move.

So, these are 2 types depending on whether coil is moving or the permanent magnet is moving. Now, again for each case again this there are 2 types, one is pivoted type and another is suspension type. Pivoted type earlier whatever the galvanometer I discuss which was used to convert the voltmeter and ammeter. So, during that time or whatever the galvanometer I have shown you that is the basically pivoted type this coil.

So, now this coil again is connected with the it is rotate, it whether it will move, whether it will move with respect to an axis. So, it is basically that pivoted type ok. So, there is a axis and that axis passes through the centre of the of the coil and this axis on the plane of the coil. So, so, that is why we are telling this pivoted type and if this coil is suspended from a rope is suspended from a rope, then we tell this suspension type.

So, today we I will show you this types of suspension type of galvanometer and it is moving coil type of galvanometer ok. So, but it can be other type also this also we tell this tangent galvanometer this pivoted type this yeah we also tell this tangent type galvanometer. So, for suspension type of galvanometer especially ballistic galvanometer today we will discuss about it.

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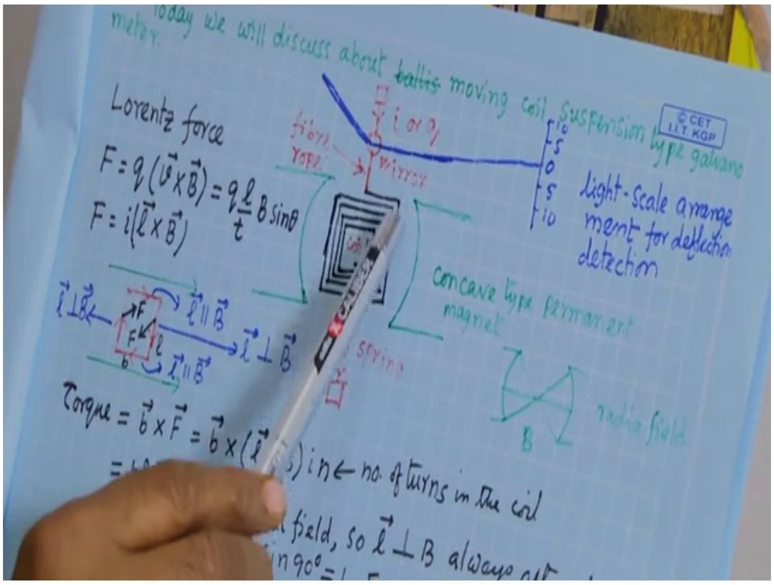

So, we will discuss about the moving coil suspension type galvanometer, moving coil suspension type galvanometer. So, this is a coil, this is a coil ok, rectangular coil. Now, this coil is suspended is hanged using a fibre rope, using a fibre rope and in between here this just we attached 1 metre.

So, why we have attached meter that I will tell you. So, now, this coil is held using this fibre rope is suspended ok. And, this other end of this other side of this coil is connected with a spring.

So, one side is coil, one side of the coil is the rope fibre rope and other side of the coil is the (Refer Time: 06:03). So, these rope has basically restore it will apply the restoring force this torsional it is the is called torsional torque torsional due to torsional torque. So, that will act as a restoring force restoring torque, because of that there will be balance between the between the restoring torque and the applied torque. So, what is applied torque that I will tell you.

So, now this coil is placed in a permanent magnet this magnet is fixed. So, this is the electromagnet this is the electromagnet not electromagnet this is a permanent magnet, but it shape it pole shape is concave type, it is pole shape is a concave type, there is a reason. For this for taking this concave type pole, if you take flat pole, then this magnetic field will be this now when coil will move. So, basically component of this magnetic field will participate in the torque. So, torque will basically vary when this coil will move will rotate, so, to avoid that one to keep the torque constant to keep the torque constant.

So, we take this concave type of pole which will produce radial field. So, radial field means this field is passing through this centre ok. So, even this coil moves. So, all the time that field will remain constant, field will remain constant means this field, on the plane of the coil field on the plane in the direction on the in the direction of the not plane direction, I should tell this field along the coil surface this will remain constant will remain constant. So, we will get basically the constant torque. So, that is the reason we take this concave type of pole pieces, to produce radial field with help us to keep the torque constant torque acting on this coil will be constant.

So, so, when coil will move; coil will move so, that that this deflection that is basically deflection of the coil. So, there will be change of angle of this coil due to this torque and due to the due to this rotation. So, that rotation that angle we have to measure. So, for that basically light scale arrangement is used. So, 1 meter is attached on the rope and if light falls on this mirror, then this will be the reflected one this the incident light and these are reflected light from the mirror.

Now, when light when this coil will rotate, so, this mirror also rotate with same angle. So, if this rotation is this angle is theta. So, this reflected one will move this spot on the scale this will move. So, because of change of this angle is 2 theta. So, that you know this if mirror rotates by theta this reflected light rotate by 2 theta. So, now, distance between mirror and scale is a capital D and the spot displacement is a small d. So, then tan 2 theta tan 2 theta will be the small d divided by this capital D.

So, since angle is small. So, tan theta we can write 2 theta, tan 2 theta we can write 2 theta. So, 2 theta will be equal to small d by capital D. So, theta will be equal to small d by cap 2 capital D 2 into capital D. So, from here will get the small d and this capital D is generally is around 1 metre. So, that also we have to measure. So, basically from this light scale arrangement with mirror. So, this will giving the angle theta ok, rotation of this coil by this angle theta or deflection of this coil that will get from this from this arrangement.

So, now so, when current will flow through this coil through this coil ok. So, then what will happen? This coil will rotate why coil will rotate while coil will rotate. So, this coil will rotate with respect to this axis. So, with respect to this with respect to this suspension of this coil. So, this will be taken as a axis. So, this rope this fibre rope that will be taken as a axis of rotation and with respect to this, this will rotate ok. So, by angle some theta.

So; that means, some torque will work on this coil, when current will flow through this or charge will flow through this. So, what is a relation of this current flow through this and the and the rotation that we should find out. So, you know the Lorentz force ok. So, this is Lorentz force F equal to q charge v cross B v is the velocity of the charge and charge is in a magnetic field B. So, these cycle ride the charge find this q this v I can write this length by time.

So, that is the v velocity length by time into B and this cross product is sin theta ok. So, now, these capital B is basically this magnetic field, this magnetic field from the permanent magnet and this charge moving in this charge, moving in this coil, because of this current, because of this current i.

So, from here I can write q by t into l. So, q by t is basically current i. So, this force I can write force equal to i l cross B. So, in our case in our case this charge is flowing through this coil. So, length of the coil is l, length of the coil is l and cross b now you look at it. So, there are 4 direction, there are 4 direction of the l, one is this direction another is this other one is this and other one is this. So, 4 arms so, 4 length 4 direction.

Now, this i so, current flowing this i l direction is i l basically. So, direction of the length in which direction this current is flowing so, current is coming this way and then moving this way ok. So, let us say this one. So, this the for this arm current is moving down and this current this i l this l this direction is perpendicular is perpendicular to the magnetic field direction is this ok. So, B is in this direction and this current is in this direction.

So, l cross B. So, that will be the force this force direction will be this force direction will be the C C force direction will be this. Now, when we will consider these arm so, these so, this is the l direction current direction, this is the l direction or current direction cross v B is also in this direction. So, l and B are in the same direction. So, this theta is 0. So, these this force is 0.

So, there will not be any force on these are as well as on this arm which is parallel to the magnetic field. So, only force will act on this arm this vertical arm and this other one, but direction of the current is in opposite direction. So, this force will be in opposite direction. So, the same force are acting on this 2 arm that this distance is B right. So, then there will be couple and this corresponding torque corresponding torque will be b cross F, b cross F and b is we have taken as l this length we have taken as l ok.

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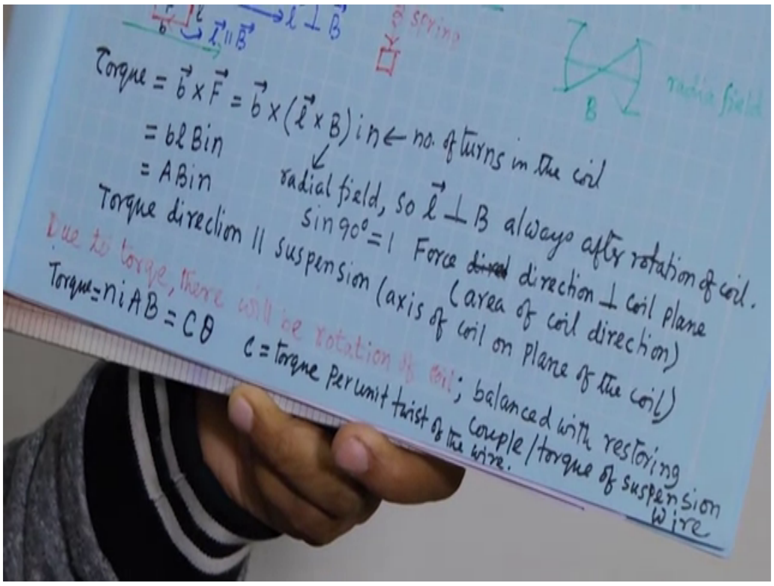

So, now F is l cross B into i into i is there. And, now I have multiplied with n multiplied with n. So, if number of turns in the coil is n number of turns in the coil this is n ok. So, that will be the torque, that will be the torque. Now, this since this B we have taken radial field ok. So, all the time so, all the time so, this sin theta this theta on the time 90 degree, theta will be 90 degree, because as I told this, this is the l direction and this is the B direction, when it will move when it will move.

So, this direction in that direction this field will be available same field will be available. So, that is why l and B will be all the time perpendicular theta will be remain 90 degree and then basically we are getting l B that sin theta sin 90 degree that will be 1 ok. So, from here you are getting basically b, l capital B, i n, b l, b l, b l. So, that is nothing, but the area of the coil. So, that I have written A, that A is area of the coil, B is the magnetic field permanent magnetic field, i is the current flowing to this coil i and n is number of terns.

So, torque acting on this coil will depend on the area of the coil, then magnetic field permanent magnetic field B radial field B and this current I and the number of turn. So, for a particulars galvanometer so, l is also fixed B is also fixed and area of the coil also fixed. So, here torque is basically you can vary just varying the current i right. So, and then what will be the reaction of the torque what will be because these are all cross product. So, direction of the torque; direction of the torque will you can find out. So, direction of the force is this direction of the force is this is perpendicular to the on the on the on the on the plane of this paper.

So, from here direction of the force is this now cross b; b is b is this direction. So, b is this direction and force direction is this. So, then torque direction will be third direction then torque direction will be third direction right, torque direction will be third direction. So, which one is third direction? Third direction is this one right third direction because force is this direction b is this direction. So, third direction is these. So, this is the direction of the coil rotation this torque so; that means, that will be the axis of rotation, that will the axis of rotation.

So, this is nothing, but this direction is along the direction of the fibre rope or direction of the suspension ok. So, that is why this coil rotate about this axis of suspension ok, which is passing through the centre of the coil as well as it is on the plane of this coil ok, this axis is on the plane of the coil not perpendicular of the coil passing through the centre, it is passing through the centre, but it is on the plane of the coil. So, this the rotation of the coil will be basically with respect to the axis of these or with respect to the suspension of the coil.

So, this finds. So, due to this torque there will be rotation of coils. Now when it will rotate so, there will be balance between this torque and the restoring torque. So, this restoring torque or coupled of the suspension wire. So, that is basically one can write C theta, where C is the torque per restoring torque per unit twist of the wire ok. So, then for theta 2 angle so, this for unit angle so, for theta angle so, torque restoring torque will be C theta.

So, now, when this 2 will balance this torque this torque due to this current will be equal to this restoring torque. So, then I will give this steady deflection. So, that is why the our final relation has come between current at angle. So, n i A B is equal to C theta.

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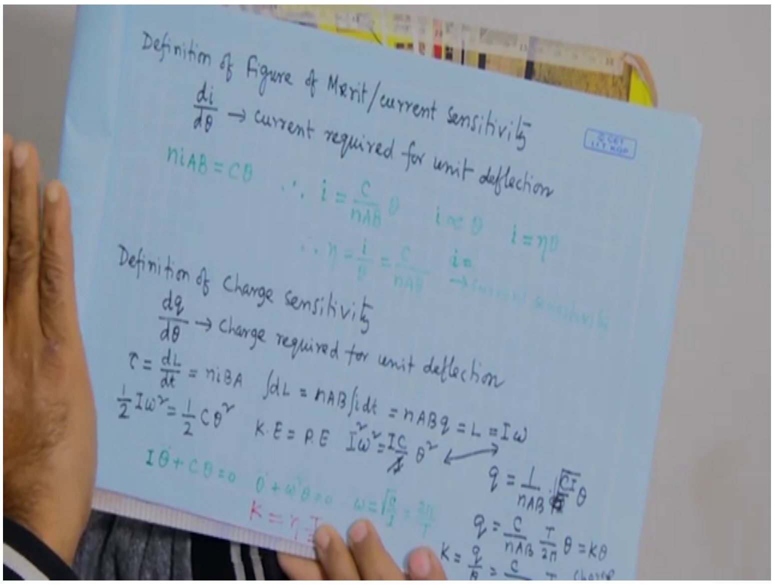

Sonow what is a definition of figure of merit or current sensitivity, that is d i by d theta, this is d i by d theta. So, means for so, what amount of current is required for unit rotation, for unit rotation how much current is required. So, if small current is required. So, this will be this will be smaller. So, smaller value of figure of merit is better means current sensitive will be it is very current sensitive, then it will be very current sensitive. So, we need very small current to rotate by unit angle.

So, now if it is a definition of the figure of merit or current sensitivity, and relation we have for this suspension coil in a permanent magnet, the relation we got n i A B equal to C theta. So; that means, i equal to C by n i A B theta. So, basically i is proportional to theta. So, then I can write i equal to n the eta theta eta is a proportionality constant. And, if I compare this 2 if I compare this 2 then eta equal to I can write i by theta. So, this equal to d i by d theta. So, i by theta equal to C n A B ok.

So, this eta is nothing, but is called the current sensitivity or figure of merit. So, current sensitive or figure of merit is equal to this C by n A B. So, it completely depends on this on this galvanometer, it depends on the torsional torque C of the suspension rope and it depends on the coil and permanent magnet amount of permanent magnet. So, this is the definition according to definition and from our relation we could find out this current sensitivity eta equal to C by n A B right.

So, then next definition of charge sensitivity so, this is d q by d theta this is similar d i by d theta this is d q by d theta right. So, then again this how much charge is required for unit deflection. So, that is the charge sensitivity if small charge is required. So, it is better it sensitivity better although this magnitude wise is. So, when magnitude will be lower and lower. So, the sensitivity will be better and better right.

So, to find out the relation of these charge sensitivity. So, what I have to do? So, we have to go few steps. So, now, you see this force, force is so, linear force ok. What is the relation between the force and the momentum? So, change of d p by d t d p by d t. So, that is the force linear force.

Similarly, this torque it is a reason for the rotation force f is a reason for the translational motion. So, this torque is basically change of angular momentum with time. So, d L by d t L is angular momentum, change of angular momentum with time that is the torque, change of linear momentum with time that is the force. So, one is responsible for the linear motion another is responsible for the rotational motion.

So, now this torque tau is n i B A that we have seen n i B A ok, now from here these we can so, d L equal to n i B A into d t i is there so, i d t. So, if we integrate. So, you will get integration over this i into d t so, that will give you charge q.

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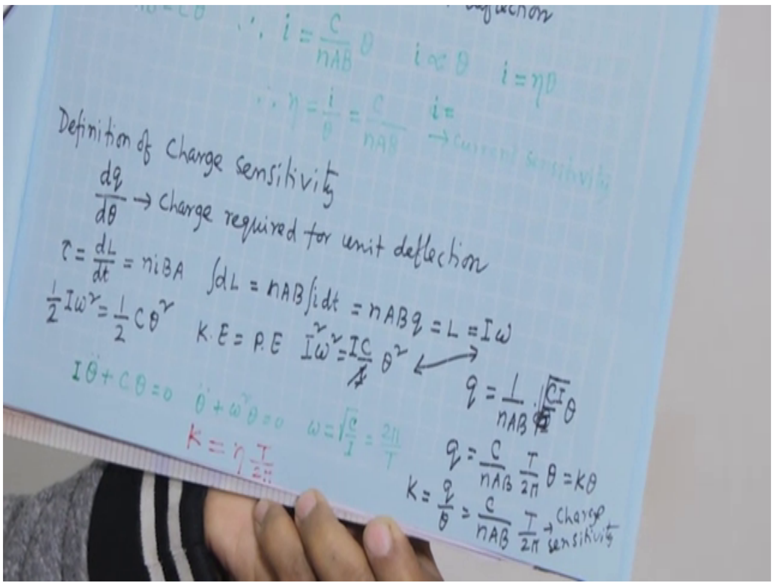

So, this part is this and this, this one is basically L, now L for linear momentum linear momentum that is p equal to L A L is the mass and a is the acceleration right similarly for angular momentum L.

So, there is the L is replaced by the moment of inertia I and v is replaced by the angular velocity omega so, I omega linear momentum equal to I omega right. So, here I go to on relation I omega equal to this I omega equal to n A B q fine. Now, when this coil will rotate and then to due to restoring force it will come at a particular position at a particular deflection angle of deflection. So, due to restoring force so, it will remain there it will stop there.

So, basically what happens in that position so, this it will have only potential energy due to the restoring force restoring torque ok. And, initially at the starting point there is no restoring force. So, that time this coil start to move with maximum velocity ok, then it is velocity will angular velocity will decrease and come to at a stop position, where that restoring force will be maximum because is twisted now, and then basically then we can tell this it is a now at stop position.

So, this system will have the completely potential energy. At the beginning the system will have the completely it will have the completely kinetic energy. So, basically due to this deflection kinetic energy is converted into potential energy right. So, these 2 energy will be same kinetic energy will be equal to the potential energy. So, kinetic energy half m b square so, half m is replaced by I B is replaced by omega, half I omega square. And, you know this you are familiar with this spring mass system right, if spring constant is K.

So, it is potential energy become half K x square. So, similarly here half C theta square. So, these will be the potential energy and these will be the kinetic energy and they are same and from here, you can get this I square, omega square equal to I multiplied with I basically I multiplied in I both side. So, is equal to I C theta square.

Now, if you equate these 2 I omega equal to this and I square omega square is equal to this. So, you can eliminate this I omega and equating these 2, equating these 2, square of this I think square root of this these will be become the square root of this. So, q will be equal to 1 by n A B and square root of this. So, square root of C I into it was theta square. So, it is theta outside of the square root thus theta.

So, these I can just rearrange. So, I just take multiplied with square root of C and divided by with square root of C. So, basically then I will get the square root of C into square of C. So, it will be C and inside the square root I will get I by C I by C. Now, square root of I by C, what it is? I can tell you this you know this is the simple harmonic motion, simple harmonic motion ok. So, equation I can write it theta double dot plus C theta equal to 0 right.

So, theta double dot equal to C by I theta. So, this is written as a omega square. So, this omega is square root of C by I and omega is 2 pi by T. So, then square root of C by I. Here, what we are getting I by C just reverse. So, it will be see the 1 by omega, 1 by omega, 1 by omega. So, that is T by 2 pi. So, here this T by 2 pi has come. So, q equal to we are getting this term right. So, this now q equal to I can write K theta earlier I was writing eta theta eta theta I equal to eta theta.

So, similarly q equal to K theta ok. So, q is basically is proportional to theta. So, this k is proportion proportionality constant and then this k will be equal to k will be equal to basically q by theta q by theta equal to this C by n A B T by 2 pi. So, this is nothing, but call it is called the charges occur q by theta means d q it is a equivalent to d q by d theta. So, that is what we have define as a charge sensitivity. So, this K is charge sensitivity and it is relation in this.

Now, C by n A B C by n A B is nothing, but eta is nothing, but eta. So, this K is equal to basically eta T by 2 pi. So; that means, so; that means, if I know if I know the charge current sensitivity eta, then only I have to find out the time period of this oscillation time period of the oscillation of this coil. So, if I find out this time period of this oscillation of the coil and if I know the current sensitivity eta, then I will know the charge sensitivity.

So, if I calculate the current sensitivity, then only I have to additionally I have to find out the time period of the oscillation of the coils, then we will know the charge sensitivity along with the current sensitivity right.

So, this is the basically theory. So, now, here you see eta. So, this working formula for charge sensitivity and current sensitivity is basically, this K equal to e equal to eta into T by 2 pi and for current sensitivity is a eta equal to this. Now, now we see this, this all are not known to us you know. At this all are either one has to supply all this or we have to measure all this, but this we cannot we cannot because is the close system either it has to be given to you or you have to find out another way how to measure this eta.

So in this experiment basically we have to design the experiment in such a way, that we can measure the current sensitivity, we can measure the current sensitivity. So, here so, how to design that experiment for measuring the current sensitivity and after that after that just measuring the time period we can get the charge sensitivity. So, for that we have to design the experiment and that is what I will discuss in next class, when we will do the experiment ok. So, I will stop here and in next class we will start our experiment.

Thank you.