Electrical & Electronics Measurement Laboratory Manual

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List of Experiments

PCEE7204 **Electrical and Electronics Measurement Lab**

Select any 8 experiments from the list of 10 experiments

1. Measurement of Low Resistance by Kelvin's Double Bridge Method.
2. Measurement of Self Inductance and Capacitance using Bridges.
3. Study of Galvanometer and Determination of Sensitivity and Galvanometer Constants.
4. Calibration of Voltmeters and Ammeters using Potentiometers.
5. Testing of Energy meters (Single phase type).
6. Measurement of Iron Loss from B-H Curve by using CRO.
7. Measurement of R, L, and C using Q-meter.
8. Measurement of Power in a single phase circuit by using CTs and PTs.
9. Measurement of Power and Power Factor in a three phase AC circuit by two-wattmeter method.
10. Study of Spectrum Analyzers.

DO'S AND DON'TS IN THE LAB

DO'S:-

1. Students should carry observation notes and records completed in all aspects.
2. Correct specifications of the equipment have to be mentioned in the circuit diagram.
3. Students should be aware of the operation of equipments.
4. Students should take care of the laboratory equipments/ Instruments.
5. After completing the connections, students should get the circuits verified by the Lab Instructor.
6. The readings/waveforms must be shown to the concerned faculty for verification.
7. Students should ensure that all switches are in the OFF position to remove the connections before leaving the laboratory.
8. All patch cords and chairs should be placed properly in their respective positions.
9. The steps for simulation of different tools should be properly known to the students for the software related laboratory.

DON'Ts:-

1. Come late to the Lab.
2. Make or remove the connections with power ON.
3. Switch ON the power supply without verification by the instructor.
4. Switch OFF the machine with load.
5. Leave the lab without the permission of the concerned faculty.

Experiment No-1

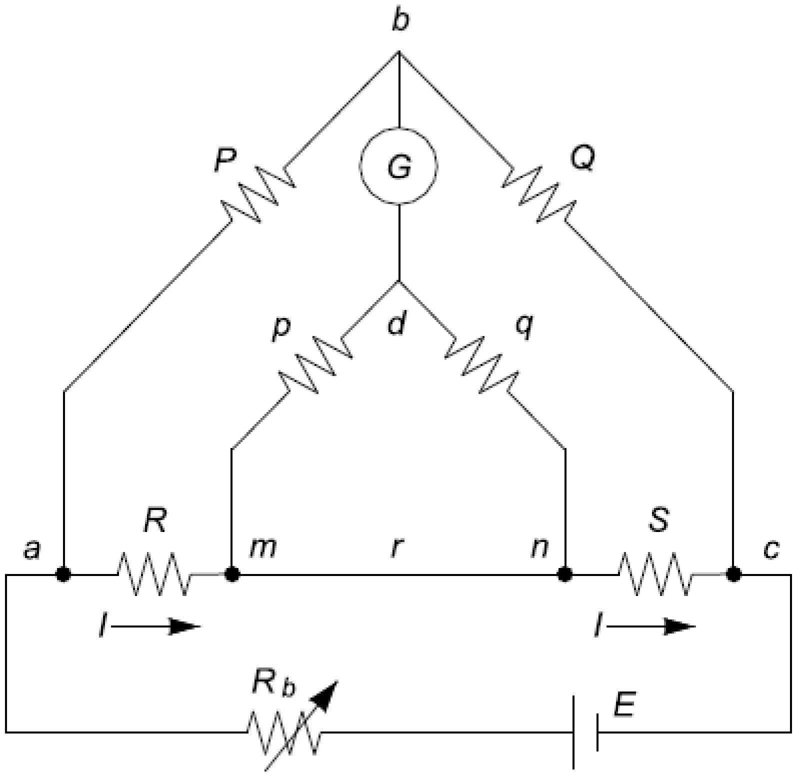
Aim of the Experiment: Measuring an unknown Resistance using Kelvin's Double Bridge.

Objective: To measure very small resistance(0.1Ω to 1.0 Ω.)

Device/Equipments Required:

i. Kelvin's Double Bridge Trainer Kit(VBK-02)
ii. Patch Cords
iii. Digital Multimeter
iv. Unknown Resistances

Circuit Diagram:



Theory:

A **Kelvin Bridge** is a measuring instrument used to measure unknown electrical resistors below 1 ohm. It is specifically designed to measure resistors that are constructed as four terminal resistors.

The operation of the Kelvin Bridge is very similar to the Wheatstone bridge except that it is complicated by the presence of two additional resistors; Resistors P and Q are connected to the outside potential terminals of the four terminal known or standard resistor S and the unknown resistor R. The resistors S, R, P and Q are essentially a Wheatstone bridge. In this arrangement, the parasitic resistance of the upper part of S and the lower part of R is outside of the potential measuring part of the bridge and therefore are not included in the measurement. However, the link ‘r’ between S and R *is* included in the potential measurement part of the circuit and therefore can affect the accuracy of the result. To overcome this, a second pair of resistors ‘p’ and ‘q’ form a second pair of arms of the bridge (hence 'double bridge') and are connected to the inner potential terminals of S and R. The detector D is connected between the junction of P and Q and the junction of p and q.

The balance equation of this bridge is given by the equation

$$\boldsymbol{R = \frac{P}{Q}S + \frac{qr}{(p+q+r)}\left[\frac{P}{Q} - \left(\frac{p}{q}\right)\right]}$$

As per the design P/Q= p/q, the value of unknown resistance is,

$$\boldsymbol{R = \frac{P}{Q}S}$$

Above equation is the usual working equation for the Kelvin double bridge. It indicates that the resistance of connecting lead ‘r’ has no effect on the measurement provided that the two sets of ratio arms have equal ratios. The above equation is useful however as it shows the error that is introduced in case the ratios are not exactly equal. It is indicated that it is desirable to keep ‘r’ as small as possible in order to minimize the errors in case there is a difference between ratios P / Q and p/q. In a typical Kelvin bridge, the range of resistance calculated is 0.1Ω to 1.0 Ω.

Procedure:

1. Connections are made as per the connection diagram
2. Connect the unknown resistance at R terminals.
3. Switch ON the unit.
4. Select the range selection switch at the point where the meter reads least possible value of voltage.
5. Vary the potentiometer (S) to obtain null balance.
6. Switch OFF the unit and find the resistance using multimeter at S.
7. Tabulate the readings and find the value of unknown resistance using the above formula.
8. Repeat the above for different values of unknown resistors.

Tabulation:

Sl. No.	P(Ω)	Q(Ω)	S(Ω)	R(Ω)

Conclusion:

Experiment No-2(A)

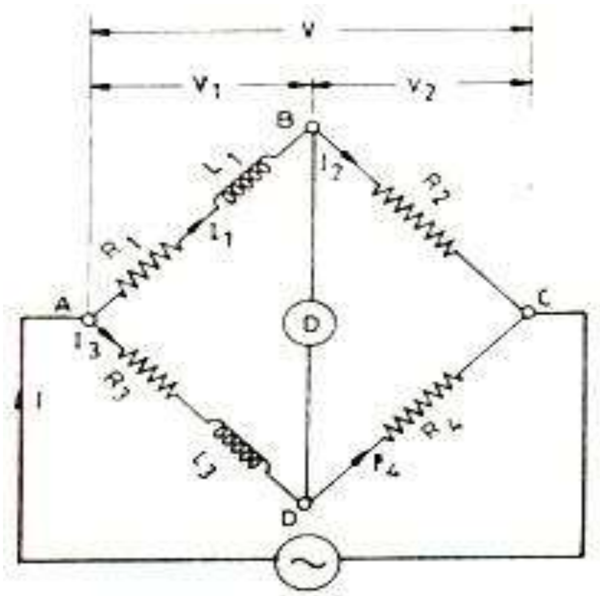
Aim of the Experiment: Measuring an unknown self-Inductance using Maxwell's Inductance Bridge.

Objective: To measure the unknown inductance of low Q value.

Device/Equipments Required:

i. Maxwell's Inductance Bridge Trainer Kit (Scientech AB59)
ii. DC Supply (+12V, -12V)
iii. Function Generator
iv. Patch Cords
v. Digital Multimeter

Circuit Diagram:



Theory: Accurate measurements of complex impedances and frequencies may be performed by using impedance-measuring AC Bridges. A **Maxwell's Bridge** is a type of Wheatstone bridge used to measure an unknown inductance (usually of low Q value) in terms of calibrated resistance and inductance.

- L_1 = Inductor whose inductance is to be determined.
- R_1 = a resistance in series the inductor L_1.
- L_3 = Fixed value inductor.

- R_3 = Fixed value resistance in series the inductor L_3.
- R_4 = a standard resistor.
- R_2 = a variable non-inductive resistance.

From the theory of ac bridges we have at balance condition,

$$z_1 z_4 = z_2 z_3$$

Substituting the values of z_1, z_2, z3 and z_4 in the above equation and equating the real and imaginary parts of it,

$$L_1 = (R_2 / R_4).\ L_3$$
$$R_1 = (R_2 / R_4).\ R_3$$

Procedure:

1. Connect +/- 12V DC power supply at their indicated position from external source.
2. Connect function generator probes between V_{IN} terminals.
3. Using patch cords connect the unknown L_1 and R_1 to the bridge circuit.
4. Switch on power supply and function generator.
5. Set the 5Vpp, 1KHz input sinusoidal signal of function generator.
6. Rotate potentiometer R_2 to find a condition for zero/minimum current.
7. Switch off the power supply and function generator.
8. Take the value of R_2 using the multimeter.
9. Calculate the value of L_1 and R_1 using their formulae.
10. The above procedure will be repeated for different values of L_1 and R_1.

Calculation:

Conclusion:

Experiment No- 2 (B)

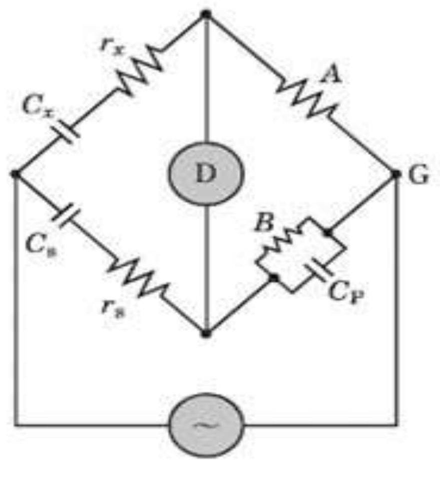
Aim of the Experiment: Measuring an unknown capacitance using Schering's Capacitance Bridge.

Objective: To measure the unknown capacitance where the balance equation is independent of frequency.

Device/Equipments Required:

i. Schering's Capacitance Bridge Trainer Kit
ii. DC Supply (+12V, -12V)
iii. Function Generator
iv. Patch Cords
v. Digital Multimeter

Circuit Diagram:



Theory: Accurate measurements of complex impedances and frequencies may be performed by using impedance-measuring AC Bridges. The **Schering Bridge** is an electrical circuit used for measuring the insulating properties of electrical cables and equipment. It is an AC bridge circuit, developed by Harald Schering. It has the advantage that the balance equation is independent of frequency.

- C_x = capacitor whose capacitance is to be determined,
- r_x = a series resistance representing the loss in the capacitor C_x,

- C_s = a standard capacitor,
- r_s = a series resistance representing the loss in the capacitor C_s, of very low value can be ignored in the equation.
- A = a variable non-inductive resistance,
- C_p = a variable capacitor,
- B = a non-inductive resistance in parallel with the capacitor C_p.

From the theory of AC bridges we have at balance condition,

$$z_1 z_4 = z_2 z_3$$

Substituting the values of z_1, z_2, z_3 and z_4 in the above equation and equating the real and imaginary parts of it,

$$R_x = (AC_p)/ C_s$$

$$C_x = (BC_s)/ A$$

The dissipation factor for the capacitor is given by the formula,

$D = (2*pi*f)\ C_x\ R_x$, where f= frequency of the input signal.

Procedure:

11. Connect +/- 12V DC power supply at their indicated position from external source.
12. Connect function generator probes between V_{IN} terminals.
13. Using patch cords connect the unknown C_x and R_x to the bridge circuit.
14. Switch on power supply and function generator.
15. Set the 5Vpp, 1KHz input sinusoidal signal of function generator.
16. Rotate potentiometer R_2(A) to find a condition for zero/minimum current.
17. Switch off the power supply and function generator.
18. Take the value of R_2(A) using the multimeter.
19. Calculate the value of C_x and R_x using their formulae.
20. The above procedure will be repeated for different values of Cx and R_x.

Calculation:

Conclusion:

Experiment No- 3

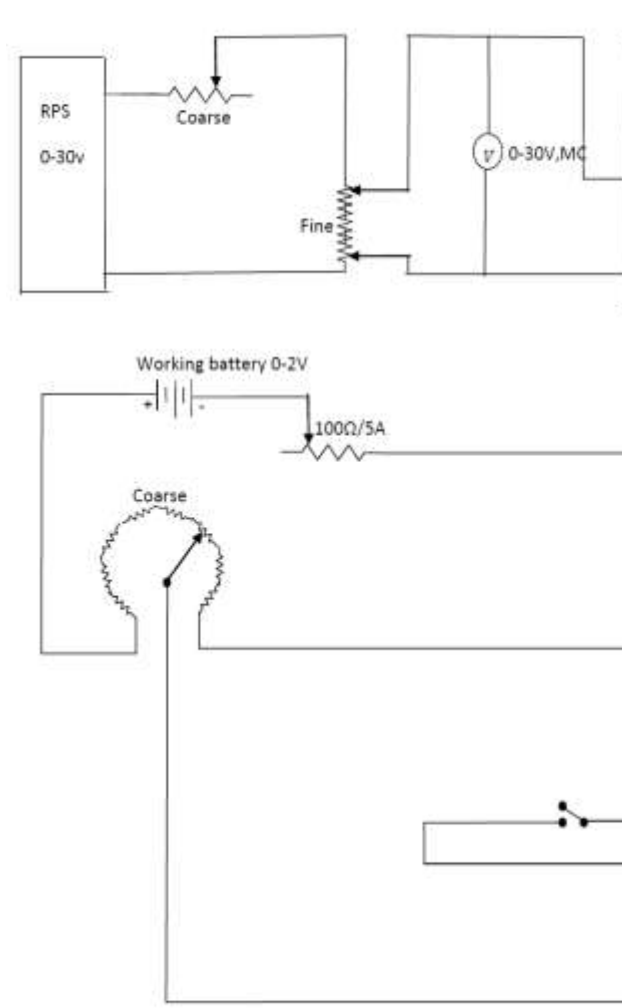
Aim of the Experiment: Standardization of the Potentiometer and use the same potentiometer for calibrating a Voltmeter and an Ammeter.

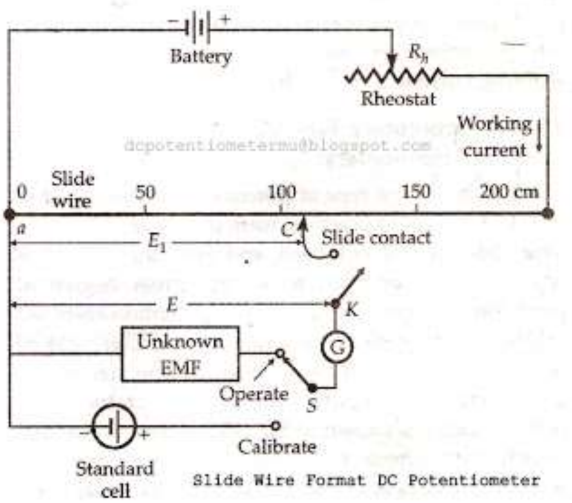
Objective: To be familiar with callibration.

Device/Equipments Required:

i. Calibration of voltmeters and ammeters by Potentiometer trainer.
ii. Calibration unit
iii. Potentiometer
iv. Sliding Jockey
v. Mains cord
vi. Patch Cords

Circuit Diagram:





Slide Wire Format DC Potentiometer

Theory:

The principle of operation of all potentiometers is based on the circuit of Fig shown beside, which shows the schematic diagram of the basic slide wire potentiometer.

With switch 'S' in the "operate" position and the galvanometer key K open, the battery supplies the "working current" through the rheostat R and the slide wire. The working current through the slide wire may be varied by changing the rheostat setting. The method of measuring the unknown voltage, E, depends upon finding a position for the sliding contact such the galvanometer shows zero deflection, i.e., indicates null condition, when the galvanometer key, K, is closed. Zero galvanometer deflection or a null means that the unknown voltage, E, is equal to the voltage drop El' across portion ac of the slide wire. Thus determination of the value of unknown voltage now becomes a matter of evaluating the voltage drop E1 along the portion ac of the slide wire. The slide wire has a uniform cross-section and hence uniform resistance along its entire length. A calibrated scale in cm and fractions of cm is placed along the slide wire so that the sliding contact can be placed accurately at any desired position along the slide wire. Since the resistance of slide wire is known accurately, the voltage drop along the slide wire can be controlled by adjusting the value of working current. The process of adjusting the working current so as to match the voltage drop across a portion of sliding wire against a standard reference source is known as "**Standardisation**".

Calibration of Ammeter using Potentiometer: The voltage across the standard resistor is measured with the help of potentiometer and current through the standard resistance can be computed. Since the resistance of the standard resistor is accurately known and the voltage across it is measured by potentiometer: this method of calibrating an ammeter is very accurate.

Calibration of Voltmeter using Potentiometer:

The voltage across the voltmeter is stepped down to a value suitable for application to a potentiometer with the help of a volt-ratio box. For accuracy measurements, it is necessary to measure voltage near the maximum range of the potentiometer, as far as possible. The potentiometer measures the true value of voltage. If the potentiometer reading doesn't agree with the voltmeter reading a –ve or +ve error is indicated.

Procedure:

Standardization of the DC Potentiometer

1. Connect the main cord to the calibration of voltmeters & ammeter by Potentiometer trainer & switch on the board.
2. Note output of DC supply V (should be 1.018V approximately).
3. Short variable resistance & ammeter i.e. connect S2 to S3 & S4 & S5.
4. Connect negative terminal of galvanometer G to positive terminal of DC supply.
5. Connect positive terminal of galvanometer G with jockey.
6. Connect S6 to positive and S7 to negative terminal of ammeterA1.
7. Connect potentiometer with X and Z terminal.
8. Now vary the variable current VR2 and set it to 35 mA.
9. Touch jokey to X terminal of potentiometer and see the reading of galvanometer.
10. Now touch jokey to Z terminal of potentiometer and see the reading of galvanometer.
11. Compare both reading of galvanometer (if terminal X gives +ve reading than terminal Z gives -ve reading).
12. Now slide the jokey on potentiometer wire & the final null point i.e., galvanometer shows zero reading.

13. Now measure distance D (in cm) moved from terminal Z to null point.
    a. Note: for odd line of wire take reading from lower scale & for even line wire take reading from upper scale.

Calibration of Voltmeter:

1. Keep switch SW in voltmeter position i.e . in downward direction.
2. Now take calibration unit & connect positive terminal 1 of DC voltmeter to SI & negative terminal 2 to S8.
3. Connect terminal 5 & 6 of voltage ratio to the terminals S11 & S13 respectively.
4. Also connect terminal 7 & 8 of voltage ratio to the terminals S12 & S14 respectively.
5. Now set voltage of DC voltmeter by variable voltage VR to 1.5V & also set voltage ratio at 15, which gives multiplication factor (M) of 10 set to 15V -1.5V.
6. Touch jokey to X terminal of potentiometer & see the reading of galvanometer.
7. Now touch jokey to Z terminal of potentiometer & see the reading of galvanometer.
8. Compare both reading of galvanometer (if terminal X gives + ve reading then terminal Z will gives - ve reading).
9. Now slide the jokey on potentiometer wire & the find NULL POINT i.e. Galvanometer shows zero reading.
10. Now measure distance D (in cm) moved from terminal Z to null point.

Calibration of Ammeter:

1. Connect terminals of potentiometer to X & Z terminal.
2. Keep switch SW in ammeter position i.e. in upward direction.
3. Disconnect terminal S2 & S3 of variable resistance.
4. Now take calibration unit & connect terminal 9 & 10 of variable resistance to S2 & S3 resp. .
5. Disconnect terminals S4 & S5 of ammeter A.
6. Connect + ve terminal 3 of DC ammeter to S4 & - ve terminal 4 to S5.
7. Connect terminal 5 & 6 of voltage ratio to the terminals to S11 & S13 resp. .
8. Also connect terminal 7 & 8 of voltage ratio to the terminals S12 & S14 resp. .
9. Now set current of DC ammeter by variable voltage VR 1 at 0.1A & also set voltage ratio at 15.
10. Touch jokey to X terminal of potentiometer & see the reading of galvanometer.
11. Now touch jokey to Z terminal of potentiometer & see the reading of galvanometer.
12. Compare both reading of galvanometer (if terminal X gives +ve reading then terminal Z will gives – ve reading).
13. Now vary the variable resistance knob & set it any arbitrary value like 10E.
14. Now slide the jokey on potentiometer wire & the find null point i.e. galvanometer shows zero reading.
15. Now measure distance D (in cm) moved from terminal Z to null point.
    a. Note; for odd line of wire take reading from lower scale & for even line wire take reading from upper scale.
16. Measure the resistance of variable resistance of calibration unit.

17. For measurement of current use OHM'S LAW
    i. i.e . I=V/R
    b. where V=C*d*M
    c. R=value of variable resistance.
    ii. Thus measured current from DC potentiometer is calculated.
18. This is calibrated current across DC ammeter put this value in observation table below.
19. Again set current of DC ammeter by variable voltage VR 1 at the interval of 1 & find corresponding null reading of galvanometer by sliding jokey on potentiometer wire .(Remember value of variable resistance R should not be change).
20. Tabulated all the retrieved data in below table & calculated other factors.
21. Repeat above procedure for different value of variable resistance R.

Observation Table :

SL. NOS.	DC Ammter Reading I(amplifier)	Distance D (in Cm)	Voltage across potentiometer V=C*D*M	Calibrated current Ic=V/R	Percentage error I-Ic/I*100

Conclusion:

Experiment No- 4

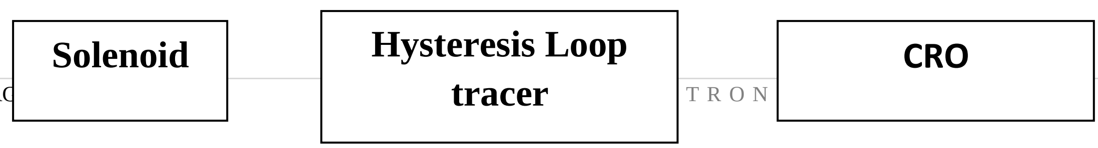
Aim of the Experiment: Measurement of Iron Loss from B-H Curve using CRO.

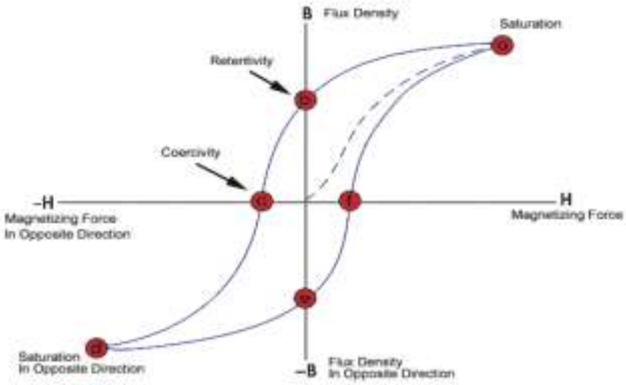
Objective: To study the characteristic of magnetic hysteresis loop.

Device/Equipments Required:

i. Hysteresis Loop tracer(NV 6108)
ii. Solenoid
iii. Ferromagnetic Specimen
iv. CRO
v. CRO Probes

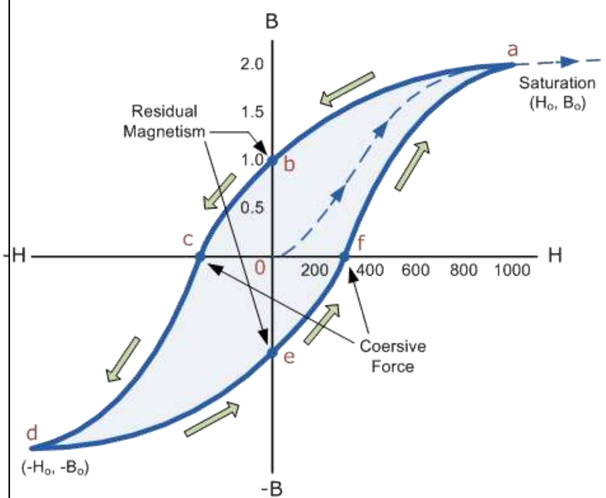
Circuit Diagram:





Theory:

The lag or delay of a magnetic material known commonly as **Magnetic Hysteresis**, relates to the magnetisation properties of a material by which it firstly becomes magnetised and then de-magnetised. We know that the magnetic flux generated by an electromagnetic coil is the amount of magnetic field or lines of force produced within a given area and that it is more commonly called "Flux Density", given the symbol B with the unit of flux density being the Tesla, T. the Magnetic Strength of an electromagnet depends upon the number of turns of the coil, the current flowing through the coil or the type of core material being used, and if we increase either the current or the number of turns we can increase the magnetic field strength, symbol H. The relative permeability, symbol μ_r was defined as the product of the absolute permeability μ and the permeability of free space μ_o (a vacuum) and this was given as a constant. However, the relationship between the flux density, B and the magnetic field strength, H can be defined by the fact that the relative permeability, μ_r is not a constant but a function of the magnetic field intensity thereby giving magnetic flux density as: $B = \mu H$.



Lets assume that we have an electromagnetic coil with a high field strength due to the current flowing through it, and that the ferromagnetic core material has reached its saturation point, maximum flux density. If we now open a switch and remove the magnetising current flowing through the coil we would expect the magnetic field around the coil to disappear as the magnetic flux reduced to zero. However, the magnetic flux does not completely disappear as the electromagnetic core material still retains some of its magnetism even when the current has stopped flowing in the coil. This ability for a coil to retain some of its magnetism within the core after the magnetisation process has stopped is called **Retentivity** or remanence, while the amount of flux density still remaining in the core is called **Residual Magnetism**, B_R .Some ferromagnetic materials have a high retentivity (magnetically hard) making them excellent for producing permanent magnets. While other ferromagnetic materials have low retentivity(magnetically soft) making them ideal for use in electromagnets, solenoids or relays. One way to reduce this residual flux density to zero is by reversing the direction of the current flowing through the coil, thereby making the value of H, the magnetic field strength negative. This effect is called a **Coercive Force**, H_C. If this reverse current is increased further the flux density will also increase in the reverse direction until the ferromagnetic core reaches saturation again but in the reverse direction from before. Reducing the magnetising current, i once again to zero will produce a similar amount of residual magnetism but in the reverse direction. Then by constantly changing the direction of the magnetising current through the coil from a positive direction to a negative direction, as would be the case in an AC supply, a **Magnetic Hysteresis** loop of the ferromagnetic core can be produced.

The **Magnetic Hysteresis** loop above shows the behaviour of a ferromagnetic core graphically as the relationship between B and H is non-linear. Starting with an unmagnetised core both B and H will be at zero, point 0 on the magnetisation curve.

if the magnetisation current, i is increased in a positive direction to some value the magnetic field strength H increases linearly with i and the flux density B will also increase as shown by the curve from point 0 to point a as it heads towards saturation.

Now if the magnetising current in the coil is reduced to zero, the magnetic field circulating around the core also reduces to zero. However, the coils magnetic flux will not reach zero due to the residual magnetism present within the core and this is shown on the curve from point a to point b.

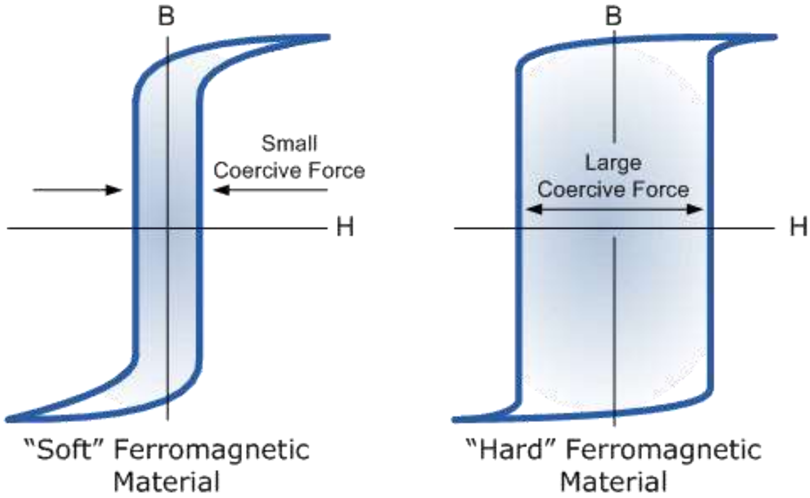
To reduce the flux density at point b to zero we need to reverse the current flowing through the coil. The magnetising force which must be applied to null the residual flux density is called a “Coercive Force”. This coercive force reverses the magnetic field re-arranging the molecular magnets until the core becomes unmagnetised at point c.

An increase in this reverse current causes the core to be magnetised in the opposite direction and increasing this magnetisation current further will cause the core to reach its saturation point but in the opposite direction, point d on the curve.

This point is symmetrical to point b. If the magnetising current is reduced again to zero the residual magnetism present in the core will be equal to the previous value but in reverse at point e.

Again reversing the magnetising current flowing through the coil this time into a positive direction will cause the magnetic flux to reach zero, point f on the curve and as before increasing the magnetisation current further in a positive direction will cause the core to reach saturation at point a.

Then the B-H curve follows the path of a-b-c-d-e-f-a as the magnetising current flowing through the coil alternates between a positive and negative value such as the cycle of an AC voltage. This path is called a **Magnetic Hysteresis Loop**.



Procedure:

1. Take the sample holder and insert a ferromagnetic specimen in the lower side hole of the holder.
2. Insert this sample holder in the solenoid.
3. Before switch ON the Hysteresis Loop Tracer, connect din connector cable of solenoid to the input of the tracer.
4. Connect the solenoid three pin connector to the tracer solenoid socket.
5. Connect Y terminal of the Hysteresis Loop Tracer to CRO Y terminal with the help of crocodile cable and the other terminal of cable to the E terminal of the Hysteresis Loop Tracer.
6. Similarly connect terminal of the Hysteresis Loop Tracer to CRO X terminal with the help of crocodile cable and the other terminal of cable to the E terminal of the Hysteresis Loop Tracer.
7. Keep CRO in 'XY' mode.
8. Rotate H-balance, phase and DC balance knobs of Hysteresis Loop Tracer fully anticlockwise.
9. Keep B, $\dot{B}$ knob of Hysteresis Loop Tracer always in $\dot{B}$.
10. Switch on the Hysteresis Loop Tracer and CRO.
11. By the Area ratios and demagnetizer knob of Hysteresis Loop Tracer, we can adjust the shape of the curve.
12. Adjust the magnetic field intensity with the help of the Magnetic field knob of the Tracer.
13. Now the Hysteresis Loop of the sample will display on CRO.
14. Plot the Hysteresis Loop from CRO and tabulate the magnetic field reading from display.
15. Here magnetic field in Gauss, will display on LCD in accordance to the intensity of magnetic field.

Tabulation:

Sl. No.	Ferromagnetic materials	Magnetic field (Gauss)	Loop Width(mm)	Tip to tip Height(mv)	Intercept(mm)	
					X	Y

Calculation:

Diameter of the pick-up coil = 3.26 mm ($2r_2$) .
Gx = 100.
Gy = 1
Sample Used: Thin cylindrical rod made of Commercial Nickel.
Length of the sample = 37 mm
Diameter of sample = 1.17mm ($2r_1$).
Area Ratio [As/ Ac] = 0.135
Demagnetization factor β= N= 0.0029.

(a) Coercivity:

$$H_c = [G_0\, e_x]/[\frac{A_s}{A_c} - N]$$

Where, e_x = ½ (loop width)

(b) Saturation magnetisation:

$$\mu_s = G_0 \mu_0 G_x\, (\frac{1}{2} e_y)/4\pi G_y [\frac{A_s}{A_c} - N]$$

Where, e_y = tip to tip height.

(c) Retentivity:

$$\mu_r = G_0 G_x\, \mu_0 e_y / G_y [\frac{A_s}{A_c} - N]$$

Conclusion:

Experiment No-5

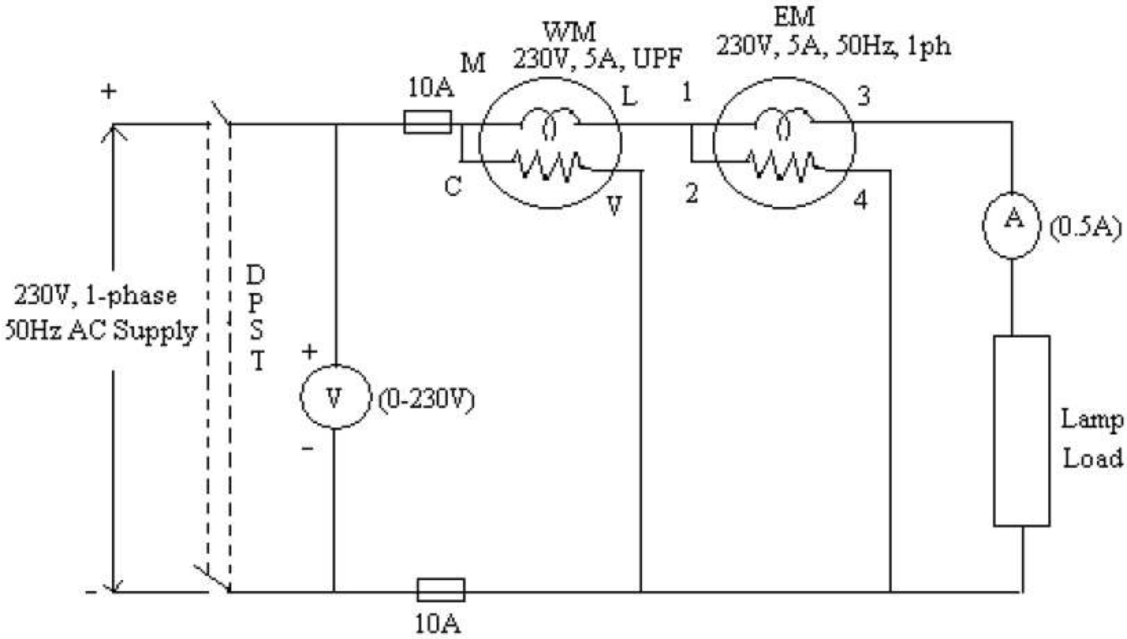
Aim of the Experiment: To calibrate and test the Single-phase Energy Meter for different Loads.

Objective: To calculate the energy stored over a period of time for various loads.

Device/Equipments Required:

i. Single phase energy Meter
ii. Lamp loads
iii. Connecting wires

Circuit Diagram:



Theory:

An instrument that is used to measure either quantity of electricity or energy, over a period of time is known as energy meter or watt-hour meter.In other words, energy is the total power delivered or consumed over an interval of time t may be expressed as:

$$W = \int_0^t v(t)i(t)dt$$

If *v(t)* is expressed in volts, *i(t)* in amperes and *t* in seconds, the unit of energy is joule or watt second. The commercial unit of electrical energy is kilowatt hour (KWh). For measurement of energy in A.C. circuit, the meter used is based on "electro-magnetic induction" principle. They are known as induction type instruments. The measurement of energy is based on the induction principle is particularly suitable for industrial or domestic meters on the account of lightness and robustness of the rotating element. Moreover, because of smallness of the variations of voltage and frequency in supply voltage, the accuracy of the induction meter is unaffected by such variations. If the waveform of the supply is badly distorted, the accuracy, however, is affected. Basically, the induction energy meter may be derived from the induction watt-meter by substituting for the spring control and pointer an eddy current brake and a counting train, respectively. For the meter to read correctly, the speed of the moving system must be proportional to the power in the circuit in which the meter is connected.

Procedure:
For calibration of the Energy Meter:

1. First of all make sure that the power of trainer is at 'OFF' position.

2. Now connect a suitable load of 1kw to the socket provided on the trainer (Any other load can also be connected and calculations can be performed correspondingly).
3. Set the SCF, S1 and S0 at 0,1,0 position with the toggle switch.
4. Rotate the potentiometer, connected to the voltage channel, fully anticlockwise.
5. Connect mains cord to the trainer and switch 'ON' the main supply as well as the power of the trainer.
6. Now note the time at which 0.01kwh (1 unit) is shown on the display. Time required for 0.01 unit=………………
7. Now switch 'OFF' the trainer.
8. Now slightly rotate the potentiometer, connected to the voltage channel, in clockwise direction.
9. Switch 'ON' trainer every time & note the time required for 0.01kwh for different positions of the potentiometer.
10. The time shown on display is then the calibrated position of energy meter.

Study of the Single Phase Energy meter for different load conditions

1. Observed and calculated in how much time the reading will be 1.00 (1unit).It must be 1 hour if 1kw load is connected. Hence the reading shown on the display is KWh or the units of consumption.
2. Connect load of other value and can observe the change in time interval of load indicator as well as the timing of data refresh on display.
3. Record the time and KWh reading in the following table & study the collected data.

S.NO.	Load	Time required for first refresh on display	kWh Reading
		4.	5.
		6.	7.
		8.	9.
		10.	11.
		12.	13.

Conclusion :

Experiment No- 6

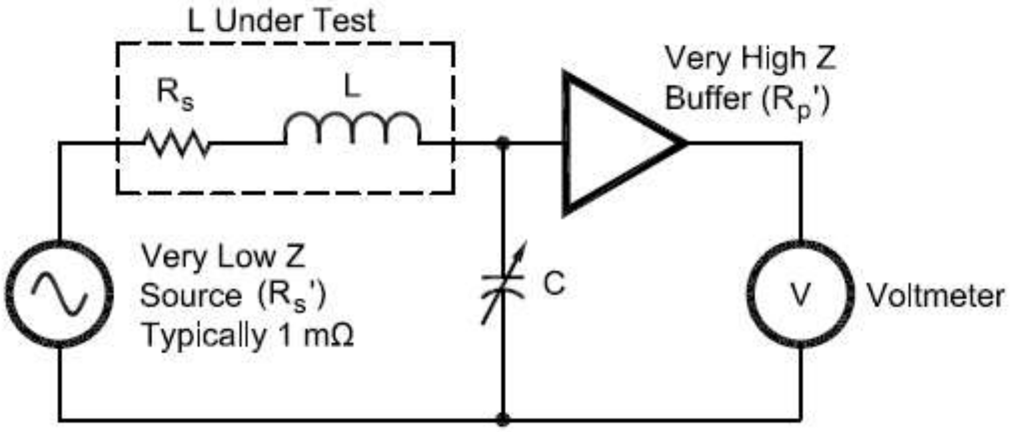
Aim of the Experiment: Measurement of R, L, and C using **APLAB MT 4090** Q-meter.

Objective: To measure the Quality factor(Q).

Device/Equipments Required:

i. **APLAB MT 4090** Q-meter
ii. Bread Board
iii. Resistor, Capacitor, Inductor of different Values.

Block Diagram:

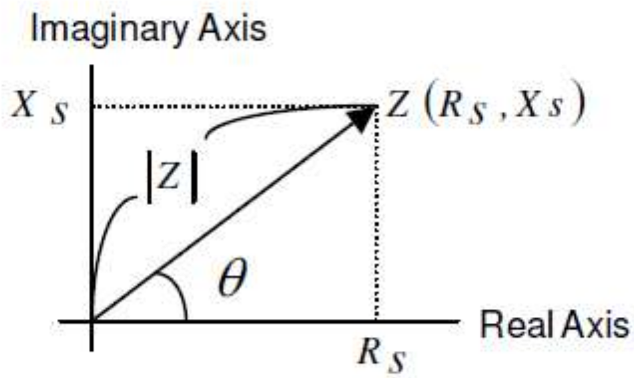


Theory:

The *Q* factor gives a figure of merit for inductors and capacitors. It is the ratio of reactance to resistance. For filters, it relates directly to the circuit selectivity: The higher the *Q*, the better the selectivity and the lower the insertion loss of the filter. For oscillators, higher *Q* also means that lower phase noise is produced. In the case of antennas, a lower *Q* is generally preferred, giving a larger SWR bandwidth.

Impedance Parameters:

Due to the different testing signals on the impedance measurement instrument, there are DC and AC impedances. The common digital multi-meter can only measure the DC impedance, but the MT4090 can do both. It is very important to understand the impedance parameters of the electronic components. When we analysis the impedance by the impedance measurement plane (Figure 1), it can be visualized by the real element on the X-axis and the imaginary element on the y-axis. This impedance measurement plane can also be seen as the polar coordinates. The Z is the magnitude and θ is the phase of the impedance.



$$Z = R_s + jX_s = |Z|\angle\theta \ (\Omega)$$

$$R_s = |Z| \ Cos\ \theta$$

$$X_s = |Z| \ Sin\ \theta$$

$$|Z| = \sqrt{R_s^2 + X_s^2}$$

$$\theta = Tan^{-1}\left(\frac{X_s}{R_s}\right)$$

Z = (Impedance)

Rs = (Resistance)
Xs = (Reactance)
Ω= (Ohm)

There are two different types of reactance: Inductive (X_L) and Capacitive (X_C). It can be defined as follows:

L = Inductance (H)
C = Capacitance (F)
f = Frequency (Hz)

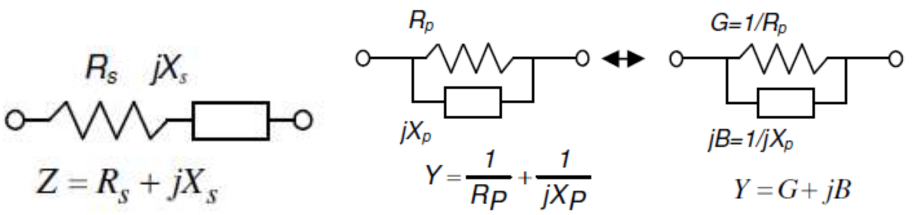
Also, there are Quality factor (Q) and the Dissipation factor (D) that need to be discussed. For component, the Quality factor serves as a measurement of the reactance purity. In the real world, there is always some associated resistance that dissipates power, decreasing the amount of energy that can be recovered. The Quality factor can be defined as the ratio of the stored energy (reactance) and the dissipated energy (resistance). Q is generally used for inductors and D for capacitors.

$$X_L = \omega L = 2\pi f L$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$\begin{aligned} Q &= \frac{1}{D} = \frac{1}{\tan\delta} \\ &= \frac{|X_s|}{R_s} = \frac{\omega L_s}{R_s} = \frac{1}{\omega C_s R_s} \\ &= \frac{|B|}{G} \\ &= \frac{R_p}{|X_p|} = \frac{R_p}{\omega L_p} = \omega C_p R_p \end{aligned}$$

There are two types of the circuit mode, the series mode and the parallel mode. See Figure below to find out the relationship of the series and parallel modes.



Procedure:

1. Connect the Resistor, Capacitor, and Inductor on the bread board in parallel or series.
2. Connect the Q meter to the circuit and switch on the supply.
3. Observe the parameters like Q, D, DCR, Cp, Cs, R, Z.

Observation:

Conclusion:

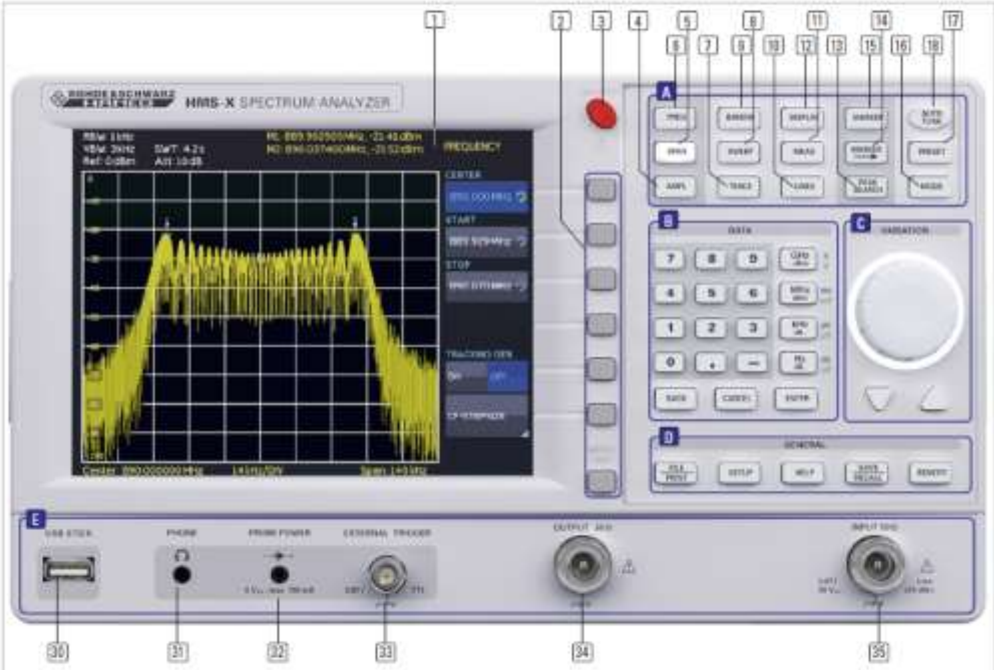
Experiment No- 7

Aim of Experiment: Study of Spectrum Analyzer.

Device/Equipments Required:

i. 1.6 GHz/3GHz Spectrum Analyzer HMS-X
ii. Function Generator

Spectrum Analyzer HMS-X



Theory:

A **spectrum analyzer** measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. The input signal that a spectrum analyzer measures is electrical, however, spectral compositions of other signals, such as acoustic pressure waves and optical light waves, can be considered through the use of an appropriate transducer.

Analyzingthe spectra of electrical signals,dominant frequency, power, distortion, harmonics, bandwidth, and other spectral components of a signal can be observed that are not easily detectable in time domain waveforms. These parameters are useful in the characterization of electronic devices, such as wireless transmitters.

For any function f(x) with period 2π (f(x) = f(2π +x)), we can describe the f(x) in terms of an infinite sum of sines and cosines,

$$\begin{aligned} s_N(x) &= \frac{a_0}{2} + \sum_{n=1}^{N} \left(\overbrace{a_n}^{A_n \sin(\phi_n)} \cos\left(\tfrac{2\pi n x}{P}\right) + \overbrace{b_n}^{A_n \cos(\phi_n)} \sin\left(\tfrac{2\pi n x}{P}\right) \right) \\ &= \sum_{n=-N}^{N} c_n \cdot e^{i\frac{2\pi n x}{P}}, \end{aligned}$$

Where,

$$a_n = \frac{2}{P} \int_{x_0}^{x_0+P} s(x) \cdot \cos(\tfrac{2\pi nx}{P}) \; dx$$

$$b_n = \frac{2}{P} \int_{x_0}^{x_0+P} s(x) \cdot \sin(\tfrac{2\pi nx}{P}) \; dx$$

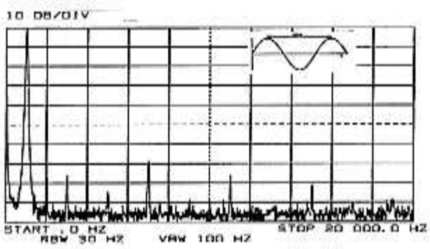
$$c_n = \frac{1}{P} \int_{x_0}^{x_0+P} s(x) \cdot e^{-i\frac{2\pi nx}{P}} \; dx,$$

Procedure:

1. Connect the function Generator to Spectrum analyzer.
2. Set the frequency of the function generator around 1MHz and choose a sine function.
3. Set the centre frequency of spectrum analyzer at 1MHz.
4. Span of the spectrum analyzer at 10MHz.
5. Adjust the other parameters to visualize harmonics of the signal.
6. Note the amplitude of the spectrum of fundamental frequency signal, and also of it's harmonics.
7. Repeat the above procedure for square wave and triangular wave.

Observation:

A typical spectrum analyzer output for a sine wave :



Conclusion:

Experiment No- 8

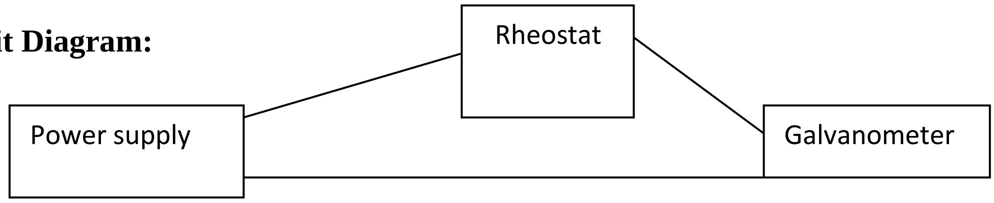
Aim of the Experiment: To study a D'Arsonval galvanometer.

Device/Equipments Required:

i. D'Arsonval galvanometer

ii. Rheostat.
iii. Power Supply

Circuit Diagram:



Theory:
The meter movement of a D'Arsonval galvanometer is a rectangular coil of wire suspended in a horizontal radial magnetic field (Figure). The current to be measured flows through the coil via the suspension wire above and a light metal spiral below. When the coil rotates from its equilibrium position, the upper suspension exerts a restoring torque on the coil. The rotation is measured by means of an optical lever, which consists of a light source, a mirror attached to the coil, and a scale. Rotation of the coil is induced by magnetic forces exerting a torque on the coil proportional to the current flowing through it. Under steady state conditions, the angular deflection of the coil and light spot is proportional to the DC current flowing in the instrument. The galvanometer is ingeniously made.

Equation of Motion of the Galvanometer Coil:
The coil (in the Figure 1) is a rectangular coil of *N* turns of wire with vertical sides of length ***l*** and horizontal sides of length ***x***. The coil is immersed in a radial magnetic field **B** produced by an internal permanent magnet. This means that when a current ***i*** flows in the coil a torque $\boldsymbol{\tau_i}$ is exerted on the coil given by

$$\tau_i = NlxBi = NABi, \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

where ***A*** is the area of the coil. When the coil twists by an angle **θ** (radians) from equilibrium the suspension wire exerts a restoring torque on the coil given by the angular version of Hooke's law:

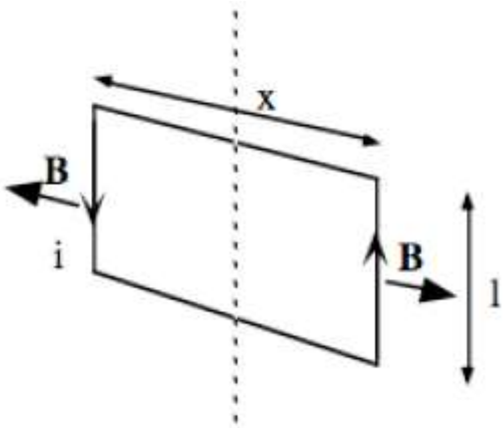
$$\tau_S = -k\theta, \qquad \ldots\ldots\ldots\ldots (2)$$

where ***k*** is the torsion constant of the elastic suspension. There is also a torque, proportional to the angular velocity of the coil, which is mainly due to air resistance when the coil is moving. This damping torque can be expressed as:

$$\tau_m = -\alpha \frac{d\theta}{dt}. \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

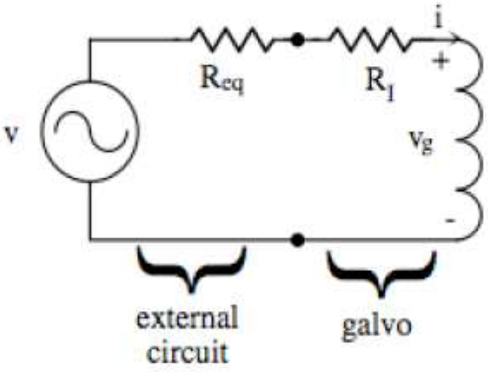
If the coil has a moment of inertia **I**, then the coil's equation of motion is:

$$I\frac{d^2\theta}{dt^2} = NABi - k\theta - \alpha\frac{d\theta}{dt}. \qquad \ldots\ldots\ldots\ldots$$



Galvo coil in a radial magnetic field **B**.

(4)



To eliminate **i** from eq[4] we must find a second equation linking the mechanical variable **θ** and the electric current **i**. The current i that flows is supplied by an external circuit, which can always be denoted by its Thevenin equivalent. Neglecting the normally tiny effects of the self inductance and capacitance of the coil, the equivalent circuit of the external circuit and coil can be indicated as shown in Figure 2. $\mathbf{R_{eq}}$ is the source resistance and $\mathbf{R_I}$ is the resistance of the coil.

When the coil moves in a field **B** an emf v_g is induced in the coil given by

$$v_g = NAB\frac{d\theta}{dt} .$$

….. (5)

Writing $\boldsymbol{R_{eq}} + \boldsymbol{R_I} \equiv \boldsymbol{R}$ the deflection **θ** is related to the current ***i*** by

$$v = Ri + v_g = Ri + NAB\frac{d\theta}{dt} .$$

…….. (6)

Substituting *i* from eq [6] into [4], eq [4] becomes

$$I\frac{d^2\theta}{dt^2} + \left(\alpha + \frac{(NAB)^2}{R}\right)\frac{d\theta}{dt} + k\theta = \frac{NABv}{R}.$$

……………..(7)

This is an equation in θ. It is somewhat more convenient to express it in terms of the scale deflection ***s***, which for small deflections is related to **θ** by $s \approx 2L\,\theta$ The result is,

$$I\frac{d^2 s}{dt^2} + \left(\alpha + \frac{(NAB)^2}{R}\right)\frac{ds}{dt} + ks = \frac{2LNABv}{R}$$

……….. (8)

Procedure:

1. Connect the +ve terminal of power supply to rheostat, and the other side of rheostat to +ve terminal of Galvanometer.
2. Connect the -ve terminal of Galvanometer to -ve terminal of power supply.
3. Change the rheostat value to see the deflection in the Galvanometer.

Observation

Conclusion: