ELECTRICAL MEASUREMENTS AND INSTRUMENTATION LAB MANUAL

Subject: Electrical Measurements and Instrumentation

Subject Code: ELPC 652

B.Tech VI Semester

Department of Electrical Engineering
J. C. Bose University of Science and Technology
YMCA, Faridabad-121006

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION OF THE DEPARTMENT

Electrical Engineering Department congregates the challenges of new technological advancements to provide comprehensively trained, career-focused, morally strong accomplished graduates, cutting-edge researchers by experimental learning which contribute to ever-changing global society and serve as competent engineers.

MISSION OF THE DEPARTMENT

- To commit excellence in imparting knowledge through incubation and execution of high-quality innovative educational programs.
- To develop the Research-oriented culture to build national capabilities for excellent power management.
- To inculcate and harvest the moral values and ethical behavior in the students through exposure of self -discipline and personal integrity.
- To develop a Centre of Research and Education generating knowledge and technologies which lay ground work in shaping the future in the field of electrical engineering.

PROGRAM OUTCOMES (POs)

Graduates of the Electrical Engineering program at JCBUST, YMCA will be able to:

PO1. Apply knowledge of mathematics, science, engineering fundamentals, and electrical engineering specialization to the solution of engineering problems.

PO2. Identify, formulate, review literature, and analyze electrical engineering problems to design, conduct experiments, analyze data, and interpret data.

PO3. Design solutions for electrical engineering problems and design system components of processes that meet the desired needs with appropriate consideration for public health and safety and cultural, societal, and environmental considerations.

PO4. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions in electrical engineering.

PO5. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to electrical engineering activities with an understanding of the limitations.

PO6. Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

PO7. Understand the impact of electrical engineering solutions in societal and environmental contexts, and demonstrate the knowledge and need for sustainable development.

PO8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. Communicate effectively on complex engineering activities with the engineering committee and with society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations in electrical engineering.

PO11. Demonstrate knowledge and understanding of the engineering principles and management principles and apply these to one‘s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Recognize the need for, and the preparation and ability to engage in independent research and lifelong learning in the broadest context of technological changes in electrical engineering.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. To apply state-of-the-art knowledge in analysis design and complex problem solving with effective implementation in the multidisciplinary area of Electrical Engineering with due regard to environmental and social concerns.

PSO2. To prepare graduates for continuous self-learning to apply technical knowledge and pursue research in advanced areas in the field of Electrical Engineering for a successful professional career to serve society ethically.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce competent electrical engineering graduates with a strong foundation design, analytics and problem solving skills for successful professional careers in industry, research and public service.

PEO2. To provide a stimulating research environment so as to motivate the students for higher studies and innovation in the specific and allied domains of electrical engineering.

PEO3. To encourage the graduates to practice the profession following ethical codes, social responsibility and accountability.

PEO4. To train students to communicate effectively in multidisciplinary environment.

PEO5. To imbibe an attitude in the graduates for life-long learning process.

Syllabus

Electrical Measurements and Instrumentation (ELPC-652)

L-T-P	**Internal Marks-15**
0-0-2	**ExternalMarks-35**
	Total-50

List of Experiments

1. To To determine the value of unknown resistance using Wheatstone Bridge.
2. To study and perform an experiment to measure unknown frequency using Lissajous method.
3. To measure power factor of ac load using voltage current method.
4. To determine the energy consumed by the given load.
5. To study about the potential transformer and find its transformation ratio.
6. To study about the current transformer and find its transformation ratio.
7. To measure high power using instrument transformer.
8. To measure phase and amplitude of signal using CRO.
9. To measure low resistances by Kelvin's double bridge.
10. To measure the linear displacement using LVDT Trainer kit.
11. To measure the value of unknown inductance using Maxwell's Inductance Bridge.
12. To calibrate electrical meters.

COURSE OBJECTIVES & OUTCOMES

Course objectives:

1. To determine unknown inductance, resistance, capacitance by performing experiments on D.C Bridges &A.C Bridges.
2. To determine the ratio of Instrument transformer and their application.
3. To determine power, power factor and energy consumed by the given load.
4. To examine the application of CRO.

Course outcomes:

CO1. Students will be able to determine unknown inductance, resistance, capacitance by performing experiments on D.C Bridges &A.C Bridges.

CO2. Students will be able to determine the ratio of Instrument transformer and their application

CO3. Students will be able to determine power,power factor and energy consumed by the given load.

CO4. Students will be able to examine the application of CRO.

Mapping of Course Outcomes (COs) with POs and PSOs

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	3	3	2	2	2	2	3	2	2	3	3
CO2	3	3	3	3	3	2	2	2	2	3	2	2	3	3
CO3	3	3	3	3	3	2	2	2	2	3	2	2	3	3
CO4	3	3	3	3	3	2	2	2	2	3	2	2	3	3

||General Instructions||

1. Students should come well-prepared for the experiment they will be conducting.
2. Usage of mobile phones in the laboratory is strictly prohibited.
3. In the lab, wear shoes and avoid loose-fitting clothes.
4. Read and understand the experiment manual thoroughly before starting the experiment. Know the objectives, procedures, and safety precautions.
5. Before starting the experiment, check the condition of the equipment, wiring, and connections. Report any damaged or malfunctioning equipment to the lab instructor immediately.
6. Ensure all connections are made as per the circuit diagram. Double-check all connections before powering the equipment.
7. Do not switch on the power supply until the instructor has approved your setup. Always start with the minimum voltage/current required and gradually increase as needed.
8. Do not overload machines beyond their rated capacity. Overloading can damage the equipment and pose safety risks.
9. Familiarize yourself with the lab's emergency shutdown procedures, including the location of emergency switches and fire extinguishers.
10. Do not bring food or drinks into the lab to avoid accidental spills, which can lead to electrical hazards.
11. Stay attentive during the experiment. Avoid distractions like mobile phones, and do not engage in unnecessary conversation during lab work.
12. Accurately record all measurements and observations during the experiment. Ensure that all data is properly noted in your lab report.
13. If you are unsure about any procedure or face difficulties during the experiment, do not hesitate to ask the lab instructor for guidance.
14. After completing the experiment, switch off the power supply, disconnect the setup, and return all equipment to its proper place. Ensure the workspace is clean and organized.

Electrical Measurements and Instrumentation Lab
(ELPC-652)

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Experiment No. 1

Aim : To determine the value of unknown resistance using Wheatstone Bridge .

Apparatus Required: Wheatstone bridge kit, unknown resistances, power supply

Theory: Principle and working of Wheatstone bridge

A Wheatstone Bridge works on the principle of null deflection i.e., there is no current flowing through the galvanometer, and its needle shows no deflection, hence the name null deflection. In the unbalanced state of the Wheatstone bridge i.e., when the potential across the galvanometer is different, the galvanometer shows the deflection, and as the bridge becomes balanced by changing the variable resistor, the potential difference across the galvanometer becomes zero i.e., the equilibrium state of Wheatstone bridge.

Construction of Wheatstone Bridge requires four resistors P, Q, R, and S that are placed in the form of four sides AB, BC, AD, and DC of a quadrilateral ABCD. A cell E and key K1 are placed between the A and C ends of this quadrilateral, and a sensitive galvanometer G and key K2 is placed between the B and D ends. Clearly, the potential of point A will be equal to the potential of the positive plate of the cell and the potential of point C will be equal to the potential of the negative plate of the cell.

It is clear from the figure that the resistances P and Q are in series when the key K2 is open. Similarly, resistances R and S are in series, but P and Q together (arm ABC) and R and S together (arm ADC) are connected in parallel to each other. Since the side BD of the galvanometer is placed like a bridge over the sides ABC and ADC of the quadrilateral, this circuit is called a bridge.

When the bridge is in an equilibrium state, that is, there is no deflection in the galvanometer. That is, in the equilibrium state of the bridge, the ratio of the resistances of any two adjacent arms is equal to the ratio of the remaining two adjacent sides.

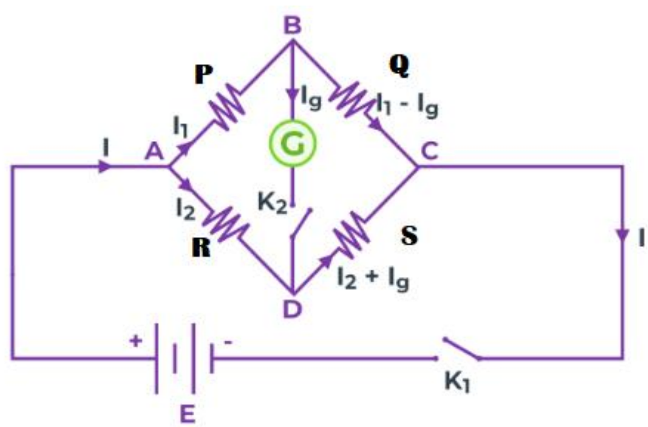

Figure1.1 Wheatstone Bridge Circuit

The Wheatstone Bridge Formula for the calculation of the unknown resistor is as follows:

$$R = PS/Q$$

where,
***P** and **Q** is the resistance of ratio arm*
***S** is the known resistance of the standard arm*
***R** is the unknown resistance*

Advantages of Wheatstone's Bridge

Various advantages of the Wheatstone's Bridge are

- With the help of Wheatstone's Bridge, we can build a Meter bridge.
- The biggest advantage of Wheatstone's Bridge is to accurately measure the electric resistance instead of using costly instruments.
- We can measure minute changes in the bridge, even in m ohm.
- It is very easy to find out the unknown resistance as the rest of the three are easily known.
- We can measure strain and pressure using a Wheatstone bridge.

Disadvantages of Wheatstone's Bridge

Various disadvantages of the Wheatstone's Bridge are:

- The result of Wheatstone's Bridge can be easily affected by temperature and EMF cells.
- Wheatstone bridge may also get affected if the galvanometer is not of good quality.
- Wheatstone Bridge fails if it is not in a balanced condition.
- We can't measure large resistance with the help of Wheatstone's Bridge.

Procedure:

1. Take 5 resistance and measure their resistance value by color coding.
2. Measure the value of these resistances using multimeter.
3. Determine the value of each resistance by changing various knobs to obtain wheatstone bridge for zero deflection in galvanometer.
4. Note down the resistance when zero deflection takes place.
5. Calculate error in percentage

Observations:

Sr. no.	Resistance by color code	Resistance by Wheatstone bridge	Difference	Percentage error
1.				
2.				
3.				
4.				

Result: The value of the % error can be found out by finding the arithmetic mean of the values obtained.

Precautions:

1. Measurement should be done accurately using colour coding.
2. There should be no error in multimeter.
3. Reading should be done carefully.

Experiment No. 2

Aim: To study and perform an experiment to measure unknown frequency using Lissajous method.

Requirements: C. R. O, Function generators, Patch cords, CRO probes

Theory: The oscilloscope is a sensitive indicator for frequency and phase measurements. The techniques used are simple and dependable, and measurement may be made at any frequency in the response range of the oscilloscope.

When Sinusoidal voltages are simultaneously applied to horizontal and vertical plates, then a pattern of closed figure is obtained which is known as Lissajous figure or pattern. Two sinusoidal inputs are applied to the oscilloscope in X-Y mode and the relationship between the signals is obtained as a Lissajous figure. To generate a Lissajous pattern two different signals are applied to the vertical and horizontal inputs of the CRO. A signal generally sine wave of unknown frequency was applied to horizontal input and a frequency whose value is known applied to the vertical input of CRO. The pattern observed was depend on the ratio of the two frequencies applied to the vertical and horizontal inputs. Figure 2.1 below shows the Lissajous pattern with equal frequency voltages and zero phase shift.

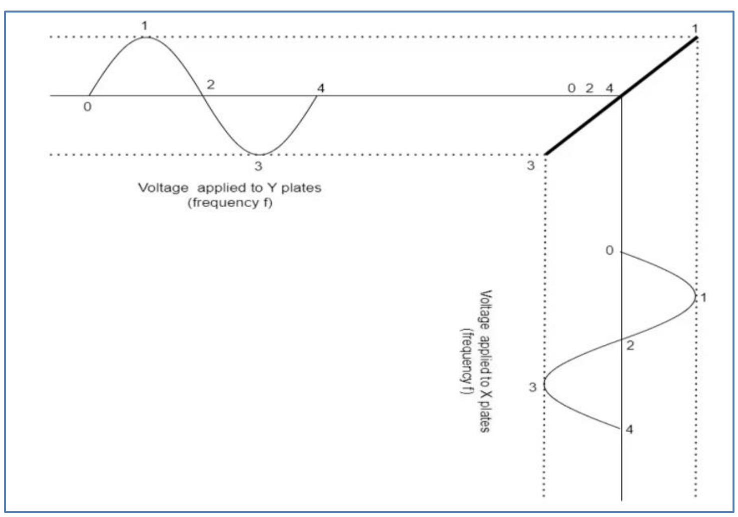

Figure 2.1 Lissajous Pattern with Equal Frequency Voltages and Zero Phase Shift.

Circuit Diagram:

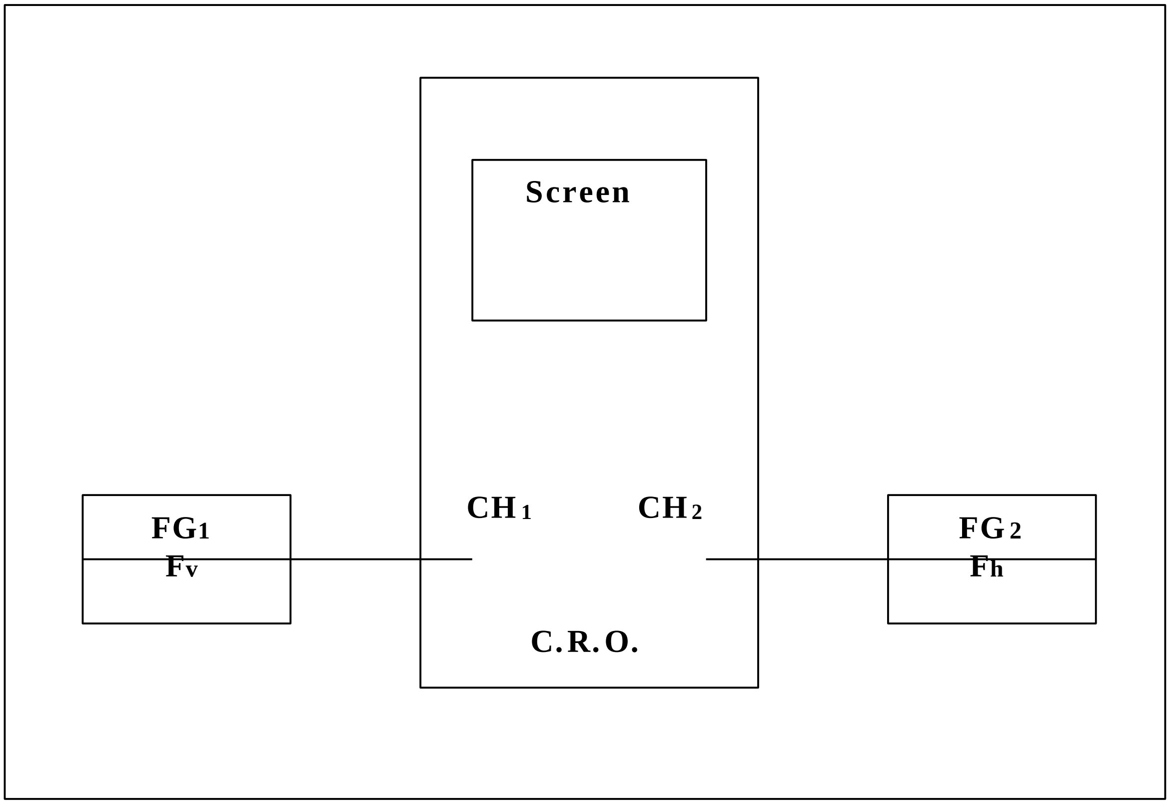

Figure 2.2 Set- up for Frequency Measurement by Lissajous Method.

Formula:

$$f_v/f_h = \frac{\text{No.o f horizontal tangentices}}{\text{No.of vertical tangentices}}$$

Where f_v = Unknown Frequency

f_h = Known frequency

Procedure :

1. Connect two Function Generators to the channel 1 and 2 as shown in Fig.
2. Consider channel -1 as unknown frequency channel and channel - 2 as known frequency channel.
3. Press XY mode switch of C. R. O, so that channel - 1 signal is connected to the vertical plate and channel - 1 signal is connected to horizontal plate.
4. Set the frequency as given in observation table and very the unknown frequency as given pattern.

Observations:

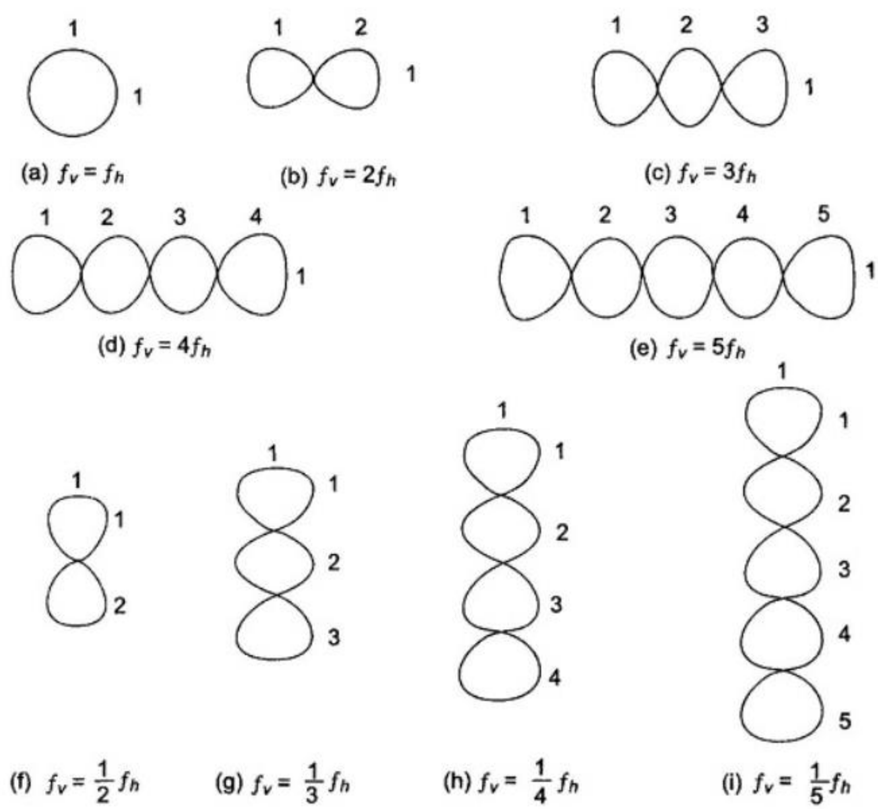

Figure 2.3 Lissajous Patterns for Integral Frequencies

Experiment No. 3

Aim: To measure power factor of ac load using voltage current method.

Apparatus Required: Single phase power supply (240 V), Ammeter (0-5A), Voltmeter (0-300V),Wattmeter (250V,5A), connecting wires, load (Resistive/inductive), Single phase Variac.

Theory: In an AC circuit, power consists of two components: real power (P) and reactive power (Q). Real power represents the actual energy transfer and performs useful work in the circuit. Reactive power represents the energy stored and released by the inductive or capacitive elements in the circuit, without performing useful work

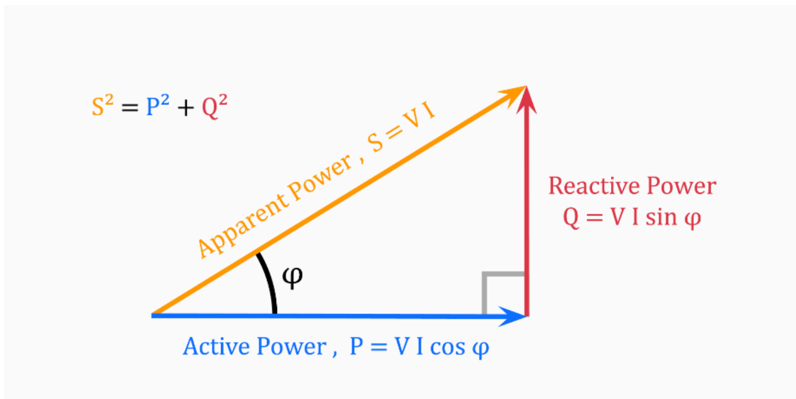

Figure 3.1 Power Triangle

Mathematically, $S^2=P^2+Q^2$

Formula for Real Power (P):

Real power (P) in an AC circuit can be calculated using the formula:

$$P=V_{rms}\times I_{rms}\times \cos(\phi)$$

Where,

V_{rms} is the RMS (Root Mean Square) voltage across the circuit

I_{rms} is the RMS current flowing through the circuit,

$\cos(\phi)$is the power factor cosine of the phase angle-φ between voltage and current.

Formula for Power Factor (PF):

Power factor (PF) is the ratio of real power (P) to apparent power (S). This factor ($-1 < \cos\varphi < 1$) represents the fraction of total power that is used to do the useful work. It indicates how effectively electrical power is being converted into useful work output.

Mathematically: Power Factor (PF)=$\frac{P}{S}$

Where, P is the real power, S is the apparent power which is the product of RMS voltage and RMS current without considering phase difference.
In power factor calculation, we measure the source voltage and current drawn using a voltmeter and ammeter respectively. A wattmeter is used to get the active power. Now we know that $P=VI\cos\varphi$ watt

Circuit Diagram:

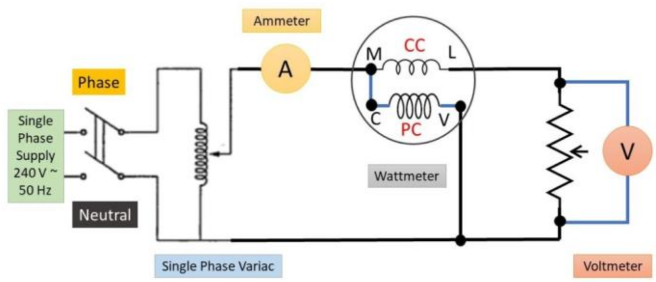

Figure 3.2 Circuit Diagram to Measure Power Factor

Procedure:

1. Connect input supply to M point of wattmeter
2. Connect V to the neutral.
3. Connect a voltmeter parallel to wattmeter.
4. External L point of wattmeter is connected to load with an ammeter in series.
5. Connect point C with M and V point of wattmeter.
6. Calculate power with wattmeter, voltage with voltmeter and current with ammeter.
7. Repeat the experiment and find average power factor.

Observations:

S.No.	Power (watt)	Voltage (volts)	Current (Ampere)	Power Factor
1.				
2.				
3.				
4.				
5.				

Result: The value of the power factor can be found out by finding the arithmetic mean of the values obtained.

Precautions:

1. All connection should be neat and tight.
2. Multiplying power sector should be chosen wisely.
3. Circuit should be correct and cross check with the circuit diagram before switching the power supply.

Experiment No. 4

Aim: To determine the energy consumed by the given load.

Apparatus Required: Single phase power supply (240 V), Ammeter (0-5A), Voltmeter (0-300V), Wattmeter (250V,5A), connecting wires, load (Resistive/inductive), Single phase Variac.

Theory: Induction type of energy meters are universally used for measurement of energy in domestic and industrial a.c. circuits. Induction type of meters possesses lower friction and higher torque/weight ratio. Also they are inexpensive and accurate, and retain their accuracy over a wide range of loads and temperature conditions. There are four main parts of the operating mechanism are:

Driving System: The driving system of the meter consists of two electro-magnets. The core of these electromagnets is made up of silicon steel laminations. The coil of one of the electromagnets is excited by the load current. This coil is called the 'current coil'. The coil of second electromagnet is connected across the supply and, therefore, carries a current proportional to the supply voltage. This coil is called the 'pressure coil'. Consequently, the two electromagnets are known as series and shunt magnets respectively. Copper shading bands are provided on the central limb. The function of these adjustable bands is to bring the flux produced by the shunt magnet exactly in quadrature with the applied voltage.

Moving System: This consists of an aluminum disc mounted on a light alloy shaft. This disc is positioned in the air gap between series and shunt magnets.

Braking System: A permanent magnet positioned near the edge of the aluminum disc forms the braking system. Thus aluminum disc provides a braking torque. The position of the permanent magnet is adjustable, and therefore, braking torque can be adjusted by shifting the permanent magent to different radial positions.

Registering (counting) Mechanism: The function of a registering or counting mechanism is to record continuously a number which is proportional to the revolutions made by the moving system. In all induction instruments we have two fluxes produced by currents flowing in the windings of the instrument. These fluxes are alternating in nature and so they produce emfs in a metallic disc or a drum provided for the purpose. These emfs in turn circulate eddy currents in the metallic disc or the drum. The breaking torque is produced by the interaction of eddy current and the field of permanent magnet. This torque is directly proportional to the product of flux of the magnet, magnitude of eddy current and effective radius 'R' from axis of disc. The moving system attains a steady speed when the driving torque equals braking torque.

Circuit Diagram:

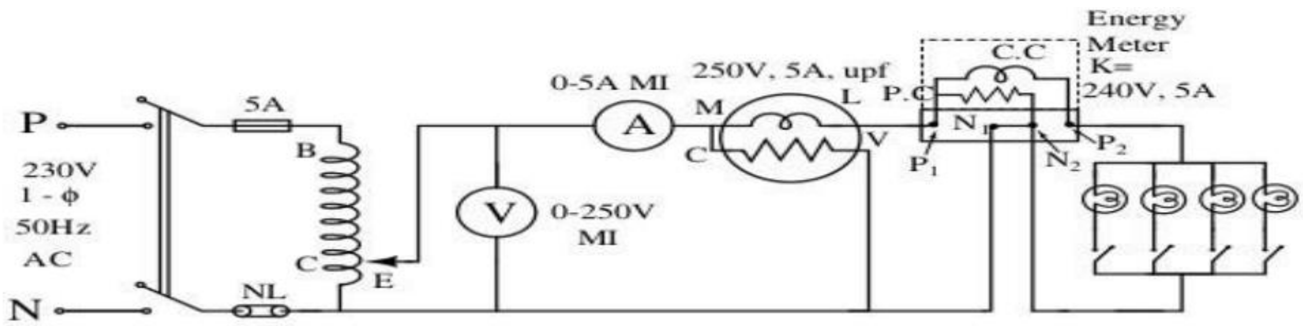

Figure 4.1 Circuit diagram to calculate energy of given load

Procedure:

1. Connect the circuit as per the circuit diagram.
2. Keep the single phase variac at zero volt position.
3. Now switch on the power supply.
4. Gradually vary the variac to apply the rated voltage (230 volts).
5. For different values of load, note down the readings of the ammeter, voltmeter, wattmeter and time taken for 10 revolutions of the disc.
6. Gradually vary the variac to minimum or zero volt position.
7. Switch off the power supply.
8. Calculate observed reading, actual reading, %error, %correction

Observations:

S.No.	Voltmeter (Volts)	Ammeter (Amps)	Wattmeter (Watts)	Time for 10 rev(sec)	Theoretical E1	Practical E2=W*t	% Error= (E1-E2)/E2 *100

Result: The value of the % error can be found out by finding the arithmetic mean of the values obtained.

Precautions

1. Connection should be proper and terminals insulated.
2. Revolution should be stopped exactly on completing revolutions.
3. Readings should be carefully noted.

Experiment No. 5

Aim: To study about the potential transformer and find its transformation ratio.

Apparatus Required: Single Phase Potential Transformer (5VA), Single Phase Supply.

Theory: Potential transformers are instrument transformers used to feed the potential coils of indicating and metering relays. These transformers make the ordinary low voltage instruments suitable for the measurement of high voltages and isolate them for high voltage.

The primary winding of the transformer is directly connected to the high voltage power circuits between two phases or between a phase and ground depending on the transformer rating and its application. The secondary of the potential transformer is connected various measuring devices and relays. The primary winding has a large number of turns and the secondary winding has lesser number of turns than the primary winding. These two windings are magnetically coupled. The number of secondary turns depends upon the purpose for which the potential transformer is used.

The primary of the potential transformers are rated from 400 V to several thousand volts. Most of the potential transformers have the secondary rating of 110 V. The ratio of the rated primary voltage to the rated secondary voltage is known as turn or transformation ratio.

Potential Transformers used to operate voltmeter, potential coins of wattmeter and delay from high voltage lines. The primary winding of the transformer is connected across the bine carrying the voltage circuit

Circuit Diagram:

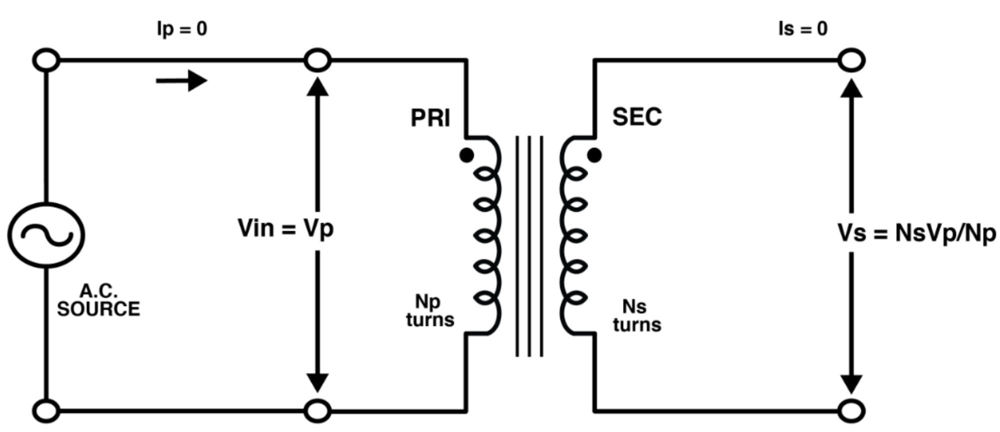

Figure 5.1 Circuit Diagram to Find the Transformation Ratio of Potential Transformer

Procedure:

1. Connect circuit as shown in diagram.
2. Note down the secondary voltage.
3. Calculate the transformation ratio and plot the graph.

Observations:

Sr.No.	Vp	Vs	Vp/Vs	Remarks
1.				
2.				
3.				
4.				

Result: The value of the unknown ratio can be found out by finding the arithmetic mean of the values obtained.

Precautions:

1. Auto transformer should be kept at zero when the starting of experiment.
2. Connection should be tight.
3. Multimeter should be kept off when not in use.

Experiment No. 6

Aim: To study about the current transformer and find its transformation ratio.

Apparatus Required: Single Phase Current Transformer (10VA), Single Phase Supply, Lamp Load, Connecting wires.

Theory: A current transformer is an electric device that produces an alternating current (AC) in its secondary which is proportional to the AC in its primary. Current transformers, together with voltage transformers or potential transformers, which are designed for measurement, are known as Instrument Transformers.

When a current is too high to measure directly or the voltage of the circuit is too high, a current transformer can be used to provide an isolated lower current in its secondary which is proportional to the current in the primary circuit. The induced secondary current is then suitable for measuring instruments or processing in electronic equipment. Current transformers also have little effect on the primary circuit. Often, in electronic equipment, the isolation between the primary and secondary circuit is the important characteristic.

Circuit Diagram:

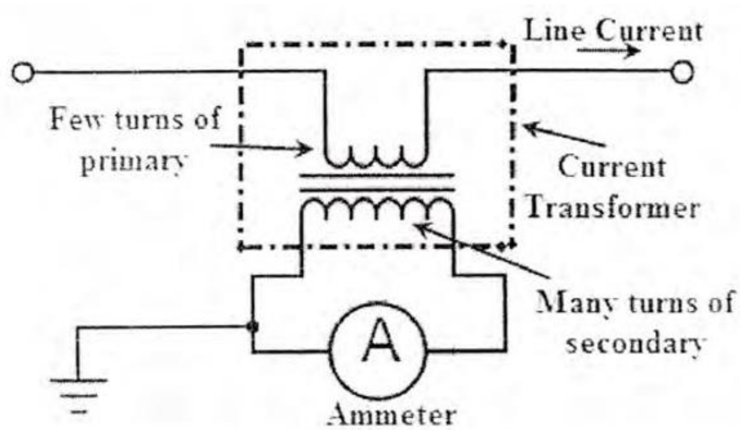

Figure 6.1 Circuit Diagram to Find the Transformation Ratio of Current Transformer

Procedure:

1. Connect the circuit as shown in the Figure 6.1.
2. Now increase the voltage from auto transformer.
3. Note the reading of current in primary and secondary winding
4. Calculate the nominal ratio and Transformer ratio.

Observations:

Sr.No.	Ip	Is	Ip/Is	Remarks
1.				
2.				
3.				
4.				
5.				

Result: The value of the unknown ratio can be found out by finding the arithmetic mean of the values obtained.

Precautions:

1. Primary and secondary winding should be properly insulated.
2. Multimeter should be kept off and not in use.
3. Auto transformer should be kept on zero before starting the experiment.

Experiment No. 7

Aim: To measure high power using instrument transformer.

Apparatus Required: Single Phase Potential Transformer(5VA), Single Phase Current Transformer (10VA), Single Phase Supply, Lamp Load, Connecting wires.

Theory: Instrument transformers are high accuracy class electrical devices used to isolate or transform voltage or current levels. The most common usage of instrument transformers is to operate instruments or metering from high voltage or high current circuits, safely isolating secondary control circuitry from the high voltages or currents. The primary winding of the transformer is connected to the high voltage or high current circuit, and the meter or relay is connected to the secondary circuit.

Instrument transformers may also be used as an isolation transformer so that secondary quantities may be used in phase shifting without affecting other primary connected devices.

There are three primary types of potential transformers (PT)- electromagnetic, capacitor, and optical. The electromagnetic potential transformer is a wire-wound transformer. The capacitor voltage transformer (CVT) uses a capacitance potential divider and is used at higher voltages due to a lower cost than an electromagnetic PT An optical voltage transformer exploits the electrical properties of optical materials.

The CT is typically described by its current ratio from primary to secondary. A 10005 CT will provide an output current of 5 amperes when 1000 amperes are flowing through its primary winding. Standard secondary current ratings are 5 amperes or 1 ampere compatible with standard measuring instruments.

Circuit Diagram:

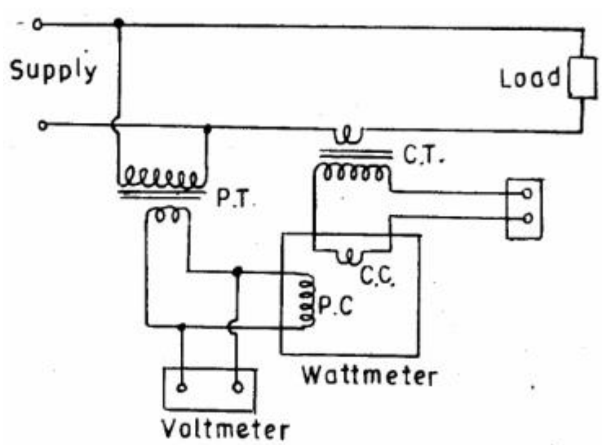

Figure 7.1 Circuit Diagram to Measure High Power

Procedure:

1. Connect the circuit as shown in Figure 7.1
2. Switch on the power supply.
3. Connect the load and note down all the readings of wattmeter voltmeter and ammeter.

Observations

Sr. no.	PT Reading	CT Reading	Wattmeter Reading	Error	% Error
1.					
2.					
3.					
4.					

Result: The value of the unknown power can be found out by finding the arithmetic mean of the values obtained.

Precautions:

1. Ammeter should be connected in series and voltmeter should be connected in parallel.
2. Connection should be neat and tight.

Experiment No. 8

Aim: To measure phase and amplitude of signal using CRO.

Apparatus Required: CRO, Function generator, Digital Voltmeter, Connecting Wires.

Theory: A Cathode Ray Oscilloscope, abbreviated as CRO and referred to as oscilloscope, in short, is now a basic, important and versatile instrument in every electronics and electrical engineering laboratory. In the previous experiment, you got opportunities to measure voltages of a dc-source and an ac-source using a voltmeter and a multimeter. If you study time variation of these voltages, you will observe that the dc voltage remains constant with time (the curve is a straight line parallel to the x-axis in a voltage versus time graph), whereas ac voltage varies sinusoidally with time. While an ac-voltmeter or multimeter can give us information about the magnitudes of the voltages, details on the nature of waveform (of an ac or dc signal) remain hidden. To display a signal or a waveform of any type, we have to use an oscilloscope. This characteristic of CRO makes it a vital tool in medical diagnostics and care.

On a CRO, you can measure important characteristic parameters of a signal like voltage amplitude, frequency, period and shape of the waveform. On a CRO screen, a luminous spot enables us to study the instantaneous value of input voltage. For this reason, an oscilloscope can also be viewed as a plotter or a recorder.

To provide a more stable trace, an additional feature in the form of a trigger is provided in present day oscilloscopes. While using a trigger, the CRO pauses in each cycle when the sweep reaches extreme right side of the screen and retraces back to the left hand side of the screen. Then it waits for a specified event before starting the next trace. The trigger event is usually the input waveform reaching some user-specified threshold voltage in a specified direction (going positive or negative).

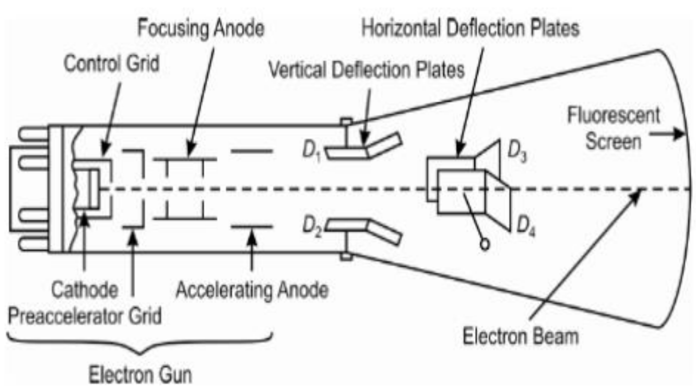

Figure 8.1 Block Diagram of CRT

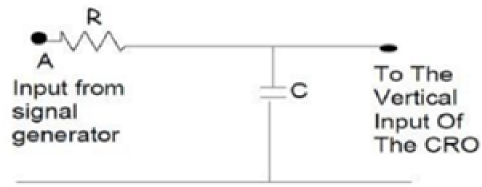

Figure 8.2 Connection diagram of CRO

Procedure :

1. To Measure the phase difference of two sine waves their frequencies must be equal.
2. Connect a 1Volt peak-peak, 1KHz sine wave signal from the function generator to the horizontal input of the CRO.
3. Connect the output of phase shift network to the vertical input as shown in Figure 8.2.
4. Adjust the vertical and horizontal gains properly for good display. Observe Lissajous Patterns for different combinations of R and C values.

Formula:

Suppose the graph obtained on CRO is as shown in the Figure 8.3

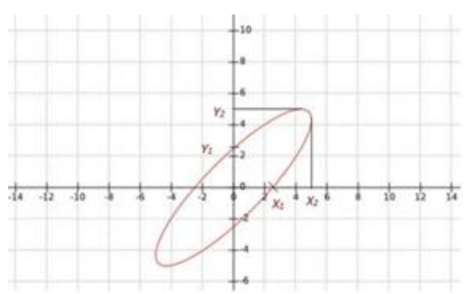

Figure 8.3 Graph on CRO

In this condition the phase difference will be

$$\emptyset = sin^{-1}\left(\frac{x_1}{x_2}\right) = sin^{-1}\left(\frac{y_1}{y_2}\right)$$

Observations:

Sr. No.	Frequency	R(ohm)	C(μF)	x_1	x_2	φ

Result: The value of the phase difference can be found out by varying the frequency of unknown signal.

Precautions:

1. Connection should be neat and tight.
2. Observe the curves carefully.
3. Wire should be properly insulated.

Experiment No. 9

Aim: To measure low resistances by Kelvin's double bridge.

Apparatus Used: Power Supply, Resistance Box, Kelvin Double bridge set up, Galvanometer etc.

Theory: Kelvin's double bridge is used to measure a small resistance. Small resistance falls in the category of resistance less than 1 Ω. The Wheatstone bridge does not take into account the contact or the lead resistance and hence error is considerable. Four terminal resistors have two current lead-in terminals and two potential terminals across which the resistance equals the marked nominal value. This because, the current must enter and leave the resistor in a fashion that there is same or equivalent distribution of current density between the particular equipotent surfaces used to define the resistance. The additional points also eliminate any contact resistance at the current lead-in terminals. Kelvin's double bridge possess two set of ratio arms. The ratio P/Q and p/q must be equal so that the contact resistance can be avoided. For a particular value of P/Q (0.01,0.1, 1, 10) multiplier the value of standard resistance S is adjusted such that the galvanometer gives no deflection.

The kelvin double bridge incorporates the idea of a second set of ratio arms , hence the name double bridge- and the use of four terminal resistors for the low resistance arms. Fig.1. shows the schematic diagram of kelvin bridge. The first ratio arms are P and Q. The second set of ratio arms p and q is used to connect the galvanometer to a point d at the appropriate potential between points m and n to eliminate the effect of connecting lead resistance *r* between the unknown resistance R and the standard resistance S.

The ratio p/q is made equal to P/Q. Under balance conditions there is no current through the galvanometer which means that the voltage drop between a and b, E_{ab} is equal to voltage drops E_{amd} between a and c.

$$E_{ab} = \frac{P}{P+Q} E_{ac} \ \text{and} \ E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right]$$

$$\text{and} \ E_{amd} = I[R + \frac{p}{p+q}\left\{\frac{(p+q)r}{p+q+r}\right\}] = I[R + \frac{pr}{p+q+r}]$$

for zero galvanometer deflection, $E_{ab}=E_{amd}$

$$\frac{PI}{P+Q}[R+S+\frac{(p+q)r}{p+q+r}]=I[R+\frac{pr}{p+q+r}]$$

$$or\ R=\frac{P}{Q}S\ +\frac{qr}{p+q+r}[\frac{P}{Q}-\frac{p}{q}]\ -------------(1)$$

$$\frac{P}{Q}=\frac{p}{q}\ Eq\ (1)\ becomes,\ R=\frac{P}{Q}S\ ---------(2)$$

If, eq (2) is the usual working equation for the kelvin 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.

Circuit Diagram:

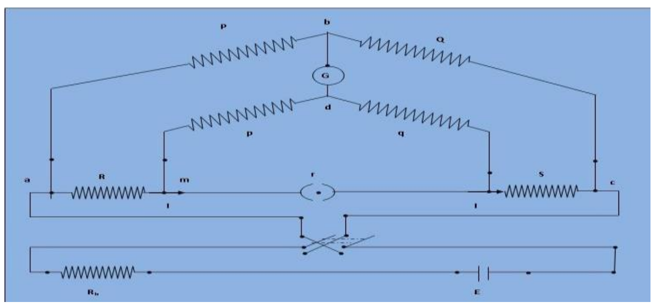

Figure 9.1 Circuit diagram for Kelvin Double Bridge

Features of the Bridge:

a) The source of the bridge is 4V, 2A.

b) The bridge has a main dial. There are 10 coils of 0.1 Ω each.

c) The bridge is provided with a slide wire. The resistance of the slide wire is 0.1Ω. Each main division is equal to 0.001Ω and each sub-division is equal to 0.0005Ω. The reading of the left of zero is to be subtracted and that to the right of the zero is to be added to main dial reading.

d) In this bridge a range multiplier switch is there which furnishes five ranges of X0.01, X0.1, X1, X10 and X100.

e) The value of the unknown resistance R is found out by sum of main dial and slide wire reading, multiplied by range used.

f) The range of resistance that can be measured with the help of the bridge is 0.00001Ω to 110Ω.

Procedure:

1. Connect the four terminal resistance to the respective points in the kelvin's bridge setup.
2. Internal galvanometer is already present in the setup. Connect an external galvanometer for greater sensitivity.
3. Keep the multiplier (P/Q) at a particular ratio and vary the standard resistance S so that the galvanometer gives zero deflection.
4. For balance use the internal galvanometer. The push button in the setup enables to complete the path of the galvanometer and hence current flows through it.

5. When the bridge is balanced find out the unknown resistance by using the expression,

$$R = PQ \times S$$

6. If balance is not obtained then change the multiplier and try to achieve the balance.

Observations:

Sr. No.	Multiplier (P/Q)	S	R=(P/Q)*S
1.			
2.			
3.			
4.			
5.			

Result: The value of the unknown resistance can be found out by finding the arithmetic mean of the R for different multipliers.

Precautions:

1. Connection should be neat and tight.
2. Observe the curves carefully.
3. Wire should be properly insulated.
4. Don’t push the push button for prolonged state. The push button must be pressed momentarily to check if the pointer of the galvanometer is deflecting or not.

Experiment No. 10

Aim: To measure the linear displacement using LVDT Trainer kit.

Apparatus Required: LVDT Trainer Kit, connecting wires.

Theory: An LVDT is non self-generating type inductive transducer often used to measure force, pressure, or position. It consists of three wires wound coils on same former with a movable iron core. An ac excitation signal of 1 to 20 KHz is applied to the primary. The two secondary's connected in phase opposite usually positioned on either side of primary gives a zero output voltage if movable core has been positioned in middle. If the core is centered then the induced voltages in secondary are equal and they cancel, so there is no output voltage. If the core is moved off center, coupling will be stronger to one secondary coil so that coil will produce a greater output voltage. The result will be a output voltage. The phase relationship between the output signal and input signal is an indication of the direction. of the core movement from center position. The amplitude of the output is linearly proportional to the core displacement from the center or zero position.

An LVDT can be used directly in this form to measure displacement and position. If a spring is added ,so that a force is required to move the core, then the voltage output of the LVDT is proportional to the force applied to the core. In this form LVDT can be used in load cell for an electronic scale. Likewise, if a spring and core is attached to a diaphragm in a threaded housing, the output from LVDT will be proportional to the pressure exerted on the diaphragm.

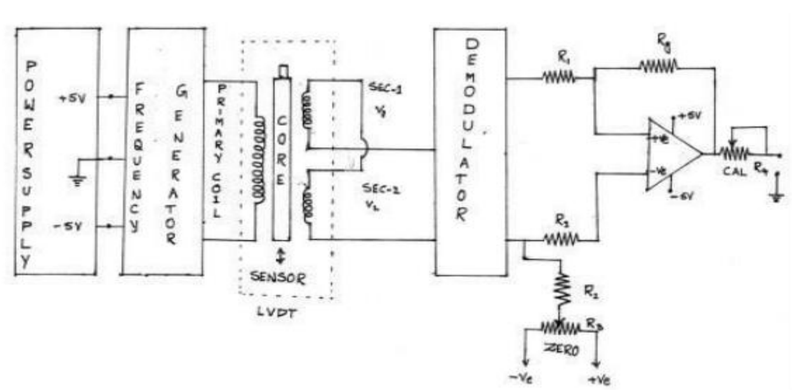

Figure 10.1 Circuit Diagram of LVDT

Procedure:

1. Connections are made as per the circuit diagram.
2. Switch on the supply keep the instrument in ON position for 10 minutes for initial warm up.
3. Rotate the micrometer core till it reads 20.0 mm and adjust the CAL potentiometer to display 10.0 mm on the LVDT trainer kit.
4. Rotate the micrometer core till it reads 10.0 mm and adjust the zero potentiometer to display 20.0 mm on the LVDT trainer kit.
5. Rotate back the micrometer core to read 20.0 mm and adjust once again the CAL potentiometer till the LVDT trainer kit display reads 10.0 mm. Now the instrument is calibrated for 10mm range.
6. Rotate the core of micrometer in steps of 2 mm and tabulate the readings of micrometer, LVDT trainer kit and multimeter reading.

Observations:

Sr. No.	**Micrometer reading in mm**	**Output Voltage**
1.		
2.		
3.		
4.		
5.		

Model Graph:

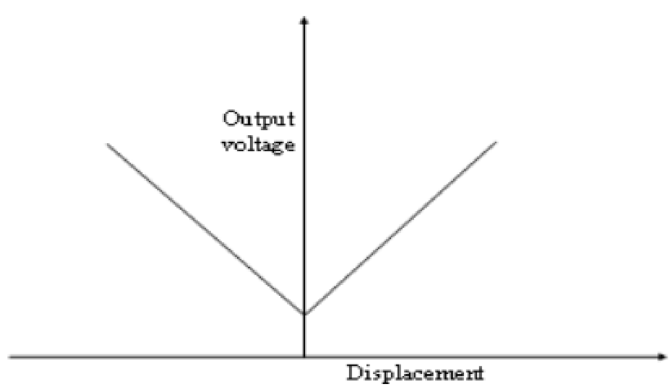

Figure 10.2 Expected Graph of Displacement Vs Output Voltage

Result: A linear graph is obtained between displacement and output voltage.

Precautions:

1. Connection should be neat and tight.
2. Observe the readings carefully.
3. Wire should be properly insulated.

Experiment No. 11

Aim: To measure the value of unknown inductance using Maxwell's Inductance Bridge.

Apparatus Required: Maxwell's Inductance Bridge Trainer Kit ,DC Supply (+12V, -12V) ,Function Generator ,Patch Cords, Digital Multimeter.

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.

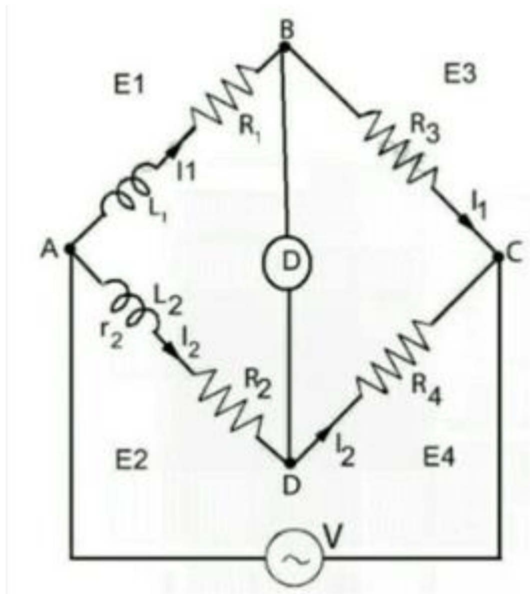

Figure 11.1 Circuit diagram of Maxwell's Inductance Bridge

L1 = Inductor whose inductance is to be determined.
R1 = a resistance in series the inductor L1.
L3 = Fixed value inductor
R3 = Fixed value resistance in series the inductor L3
R4 = a standard resistor
R2 = a variable non-inductive resistance

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

$$z_1z_4=z_2z_3$$

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,

$$L1 = (R2/ R4) .L3$$

$$R1= (R2/R4). R3$$

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 L1 and R1 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 R2 to find a condition for zero/minimum current.
7. Switch off the power supply and function generator.
8. Take the value of R2 using the multimeter.
9. Calculate the value of L1 and R1 using their formulae.
10. The above procedure will be repeated for different values of L1 and R1.

Calculations:

Calculate the values of L1 and R1 using the following formulae

$$L1 = (R2/ R4) .L3$$

$$R1= (R2/R4). R3$$

Result: The value of unknown inductance has been measured as …...

Precautions:

1. Connection should be neat and tight.
2. Observe the readings carefully.
3. Wire should be properly insulated.

Experiment No. 12

Aim : To calibrate electrical meters.

Apparatus Required : Fluke 5502A Electrical Calibrator, Digital Multimeter, voltmeter, ammeter, Connecting Wires and Probes –

Theory: Calibration is the process of adjusting an instrument to match a known standard. Electrical meters such as voltmeters, ammeters, and wattmeters need to be calibrated to ensure their measurements are accurate. Precision electrical calibrators like the Fluke 5502A provide known and stable outputs of voltage, current, and power. By comparing these known values with the meter readings, adjustments can be made to correct any discrepancies.

- **Voltmeter Calibration:** Ensures that the voltmeter accurately measures the voltage applied to it.
- **Ammeter Calibration:** Ensures that the ammeter accurately measures the current flowing through it.
- **Wattmeter Calibration:** Ensures that the wattmeter accurately measures the power being consumed by a load.

Figure 12.1 Fluke 5502a Multi Product Calibrator

Procedure:

Calibrating the Voltmeter

1. Set up the Fluke 5502A and ensure it is warmed up and stable.
2. Connect the Fluke 5502A to the voltmeter under test using appropriate cables.
3. Set the Fluke 5502A to output a known voltage (e.g., 10.000 V).
4. Set the voltmeter to the appropriate range.
5. Measure the applied voltage and record the reading.
6. Compare the voltmeter reading with the reference voltage from the Fluke 5502A.
7. If necessary, adjust the voltmeter calibration according to the manufacturer's instructions.
8. Repeat the process at different voltage levels (e.g., 1 V, 5 V, 100 V) to ensure accuracy across the range.

Calibrating the Ammeter

1. Set up the Fluke 5502A and ensure it is warmed up and stable.
2. Connect the Fluke 5502A to the ammeter under test using appropriate cables.
3. Set the Fluke 5502A to output a known current (e.g., 1.000 A).
4. Set the ammeter to the appropriate range.
5. Measure the applied current and record the reading.
6. Compare the ammeter reading with the reference current from the Fluke 5502A.
7. If necessary, adjust the ammeter calibration according to the manufacturer's instructions.
8. Repeat the process at different current levels (e.g., 0.1 A, 5 A, 10 A) to ensure accuracy across the range.

Calibrating the Wattmeter

1. Set up the Fluke 5502A and ensure it is warmed up and stable.
2. Connect the Fluke 5502A to the wattmeter under test and ensure correct wiring.
3. Set the Fluke 5502A to output a known power level by configuring both voltage and current (e.g., 100 W).
4. Set the wattmeter to the appropriate range.
5. Measure the applied power and record the reading.
6. Compare the wattmeter reading with the reference power output from the Fluke 5502A.
7. If necessary, adjust the wattmeter calibration according to the manufacturer's instructions.
8. Repeat the process at different power levels (e.g., 10 W, 50 W, 200 W) to ensure accuracy across the range.

Result: Record all readings in a calibration report and analyze the data to determine if the meters are within acceptable tolerance limits.

Precautions:

1. Ensure all equipment is de-energized before making connections or adjustments.
2. Follow safety protocols for handling electrical equipment, including proper use of insulated tools and wearing appropriate personal protective equipment (PPE).
3. Connection should be neat and tight.