LABORATORY MANUAL

Electrical Measurements Lab

Department of Electrical Engineering

JORHAT ENGINEERING COLLEGE
ASSAM - 785007

Course Code	Course Title	Hours per week L-T-P	Credit C
EI181411	Electrical Measurements Lab	0-0-2	1

Course Objectives:
The Electrical Measurement Lab gives idea about how to visualize and work in laboratory and how to work in a team. Students understand the application of various A.C. and S.C. Bridge in practical Electrical and Instrumentation Engineering field. Students learn about how to measure Resistance, Inductance, Capacitance, Voltage, Current, Power, Power Factor and Electrical Energy using different experiments in the Lab.

Course Outcomes (CO)
After completing this course

1. Student will be able to measure the resistance, inductance and capacitance using DC and AC bridges.

2. Student will be able to calibrate and test single phase energy meter and to measure 3-phase active power with 3-phase R-L load.

3. Student will be able to calibrate and test single phase current and potential transformers and measures the core loss in magnetic circuit.

Experiment No.	Title of the Experiment
1	To Measure the Low Resistance of a Wire Using Student Kelvin Double Bridge and hence Verify the result in MULTISIM.
2	To Measure the inductance of a given coil by Anderson Bridge method and hence Verify the result in MULTISIM..
3	To Measure Unknown Inductance and Capacitance by Maxwell's L/C Bridge and hence Verify the result in MULTISIM.
4	To Measure unknown value of Capacitance using Wien Bridge and hence Verify the result in MULTISIM.
5	To Measure the Value of unknown Capacitance by Schering Bridge and hence Verify the result in MULTISIM.
6	To determine the self-inductance of an unknown coil by using Owen's bridge and hence Verify the result in MULTISIM..
7	Measurement of capacitance by De-Sauty's bridge and hence Verify the result in MULTISIM.
8	To Measure 3-phase Power by Two Wattmeter Method
9	To understand the working Principle of Thermocouple
10	To understand the working principle of Strain gauge
11	To understand the working principle of RTD

Text book:
- A.K. Sawhney – Electrical and Electronic Measurements and Instrumentation Dhanpat rai & Co. ⬜
- Electronic Instrumentations H.S. Kalsi.
- Electrical Measurement and Measuring Instruments by U.A Bakshi, A.V. Bakshi.

Student Profile

Name	
Roll Number	
Department	
Year	

Student Performance

Sl. No.	Title of the Experiment	Remarks
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

Office Use	
Checked and found	
……………………………………………	
Grade/ Marks	
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Signature	
……………………………………………	

Experiment No. – 1

Aim- To Measure the Low Resistance of a Wire Using Kelvin Double Bridge and hence Verify the result in MULTISIM..

Objective - Kelvin's double bridge may be used for precision measurement of four-terminal low resistances. Four terminal resistors have two current leading terminals and two potential terminals across which the resistance equals the marked nominal value. This is 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 eliminated any contact resistance at the current lead-in terminals.

Circuit Diagram –
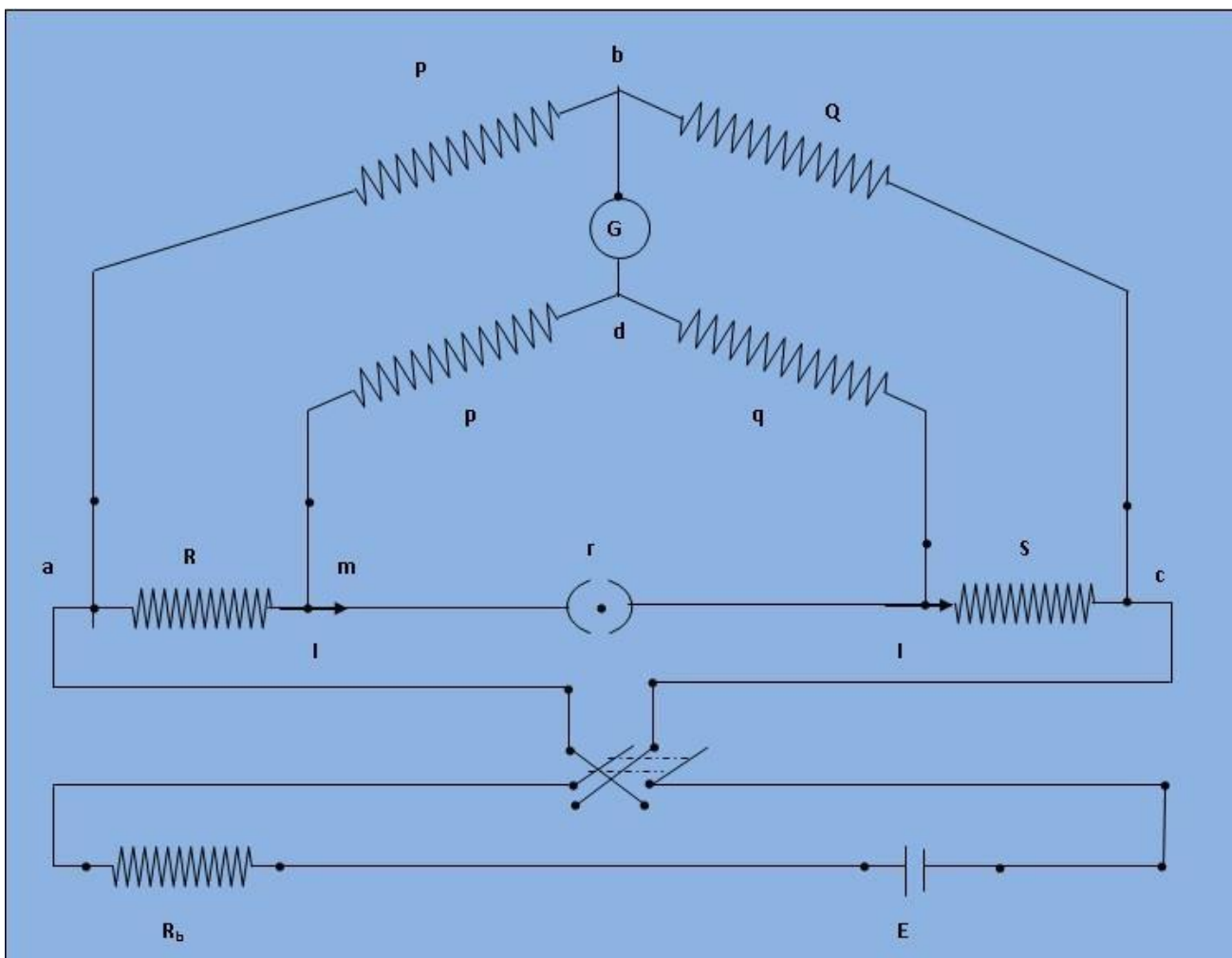
Theory –
The kelvin double bridge incorporates the idea of a second set of ratio arms - hence the name double bridge- and the use of four terminal resistors for the low resistance arms. Figure 1 shows the schematic diagram of kelvin bridge. The first ratio arms are P and Q. The second set of ratio arms 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.

$$E_{ab} = \frac{P \times E_{ab}}{(P+Q)} and E_{ac} = I \times \{R + S + r \times \frac{(p+q)}{(p+q+r)}\}$$

$$E_{amd} = I \times \{R + \frac{p}{(p+q)} \times \frac{r \times (p+q)}{(p+q+r)}\} = I \times (R + \frac{pr}{(p+q+r)})$$
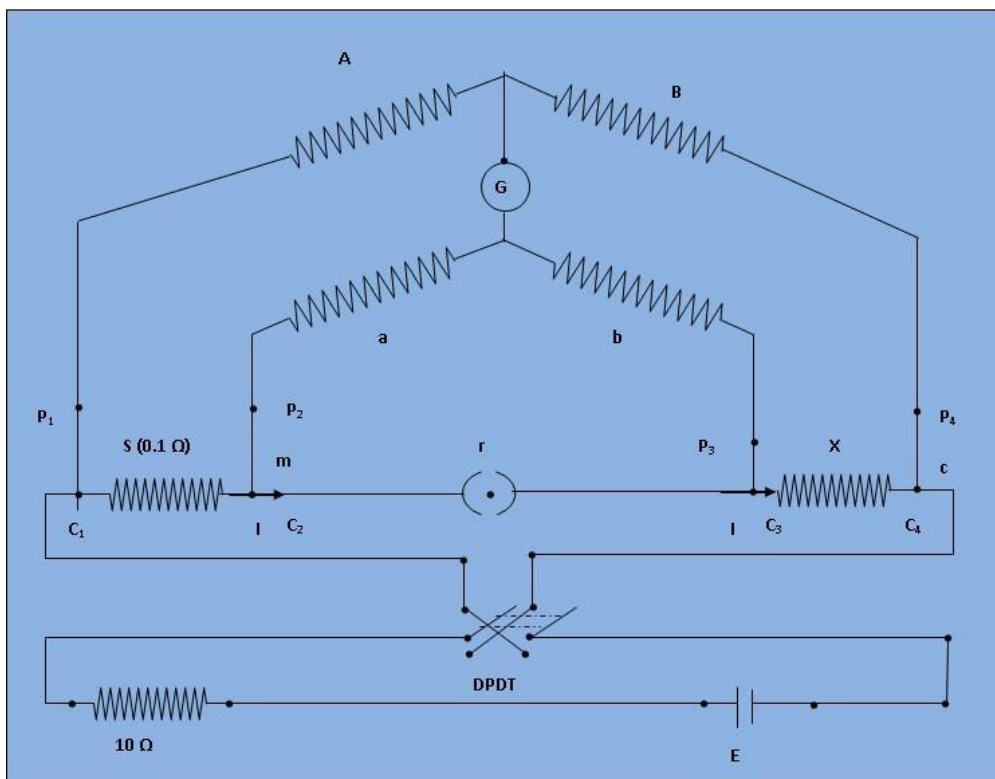
For zero galvanometer deflection, $E_{ab} = E_{amd}$

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

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

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

Eq (2) is the usual working equation for the kelvin bridge. It indicates that the resistance ofconnecting lead, r, has no effect on the measurement, provided that the two sets of ratio arms have equal ratios.

Procedure –

1. Circuit is connected as shown in the circuit diagram.

2. The value of resistances A and a is set to 1000 Ω by setting the plugs at the marked positions and the values of B, b at 1000 Ω by setting the dial. The key K is opened. The bridge will act as a wheatstone bridge. A null deflection galvanometer will ensure the relationship A/a = B/b.
3. The key K is closed. The rheostat is adjusted to obtain 2A current in the circuit.
4. Keeping the resistances, A and a at 1000 Ω and B, b is varied to obtain null reading on the galvanometer. The value of B, b is noted down at balanced position from the dial.
5. The direction of current is reversed by operating the two-way switch 's' and the balanced position is obtained.
6. The values of A and a is set at 1 Ω and 1000 Ω position and step 5 and step 4 is repeated.
7. Step 5 is repeated through step 6 for different line currents 3A, 4A and 5A.

Observation Table –

Voltage: 12 V

Sl. No	R$_S$ (Ω)	Current (A)	R$_A$ (Ω)	R$_B$ (Ω)	R$_a$ (Ω)	R$_b$ (Ω)	Unknown Resistance, S (Ω)	Measured Value of S (Ω)	% Error
1									
2									
3									
4									
5									

Calculation –

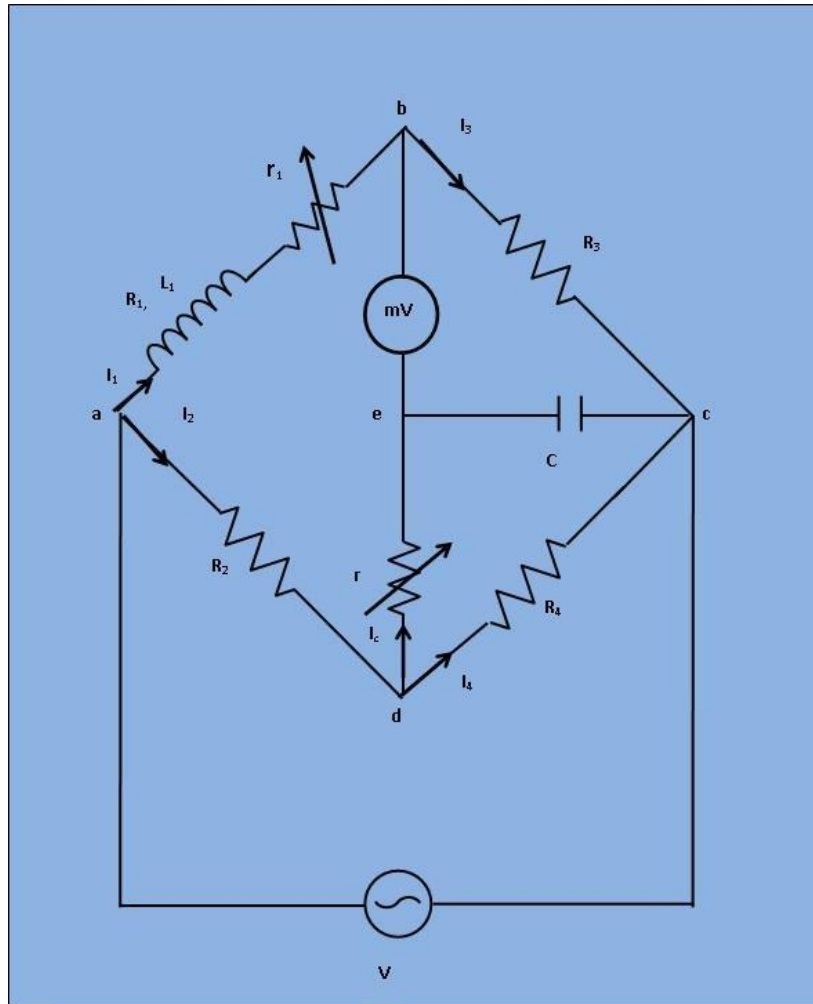Formula for the calculation of Percentage Error -

$$\%Error = \frac{(True\ value\ of\ S - Measured\ value\ of\ S) \times 100}{True\ value\ of\ S}$$

Result and Conclusion:

Experiment No – 2

Aim - To Measure the inductance of a given coil by Anderson Bridge method and hence Verify the result in MULTISIM..

Circuit Diagram –

Theory –

This bridge is a modification of the Maxwell's inductive and capacitive bridge. In this method, the self-inductance is measured in terms of a standard capacitor. This method is applicable for precise measurement of self-inductance over wide range of values. Figure 1 shows the circuit diagram of the bridge for balance conditions.

Let, L_1=Self-inductance is to be measured.
   R_1= Resistance of self-inductor.
   r_1= Resistance connected in series with self-inductor.
   r, R_2, R_3, R_4= Known non-inductive resistances.
   C= Fixed standard capacitor.

At balance,

$$I_1 = I_3 \text{ and } I_2 = I_C + I_4$$

now,

$$I_1 R_3 = \frac{I_C}{j\omega C} \qquad \text{then} \quad I_C = I_1 j\omega C R_3 ...(1)$$

Writing the other balance equations,

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + r I_C ...(2)$$

$$I_C\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_C)R_4$$

Substituting the value of IC in equation (2), we get

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_1 j\omega C r R_3$$

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega C r R_3) = I_2 R_2 ...(3)$$

$$j\omega C R_3 I_1\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_1 j\omega C R_3)R_4$$

$$I_1(j\omega C r R_3 + j\omega C R_3 R_4) = I_2 R_4 ...(4)$$

From equations (3) and (4), we get by equating real and imaginary parts,

$$R_1 = \frac{R_2 R_3}{R_4} - r_1 ...(5)$$

$$L_1 = C\left(\frac{R_3}{R_4}\right)[r(R_4 + R_2) + R_2 R_4] ...(6)$$

An examination of balance equation reveals that to obtain easy convergence of balance, alternate adjustments of r1 and r should be done as they appear in only eq. (1) and (2).

Procedure –
1. Supply Voltage (3V) is applied from the signal generator with arbitrary frequency. The value of the unknown air cored coil is set from 'Set Inductor Value' tab.
2. The supply is switched on to get the millivoltmeter deflection.
3. The value of r_1, R_1, R_3, R_4, r and C is chosen from the resistance and capacitance box. The values are varied to some particular values to achieve 'Null' point.
4. The millivoltmeter pointer is observed to achieve 'Null' point.
5. When 'Null' is achieved, from the 'Measure Inductor Value' tab 'Simulate' is clicked. The calculated values are observed of unknown inductor (l_1) and it's Internal Resistance (R_1).
6. The dissipation factor of the unknown capacitor is also observed which is $\frac{\omega L}{r}$. defined as
   Where, $\omega = 2\pi f$.

Observation Table –

Voltage: 3 V, Frequency: 500 Hz

Sl. No.	r_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	C (pF)	r (Ω)	Given value of L (mH)	Measured value of L (mH)	%Error
1									
2									
3									
4									
5									

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ L - Measured\ value\ of\ L) \times 100}{Given\ value\ of\ L}$$
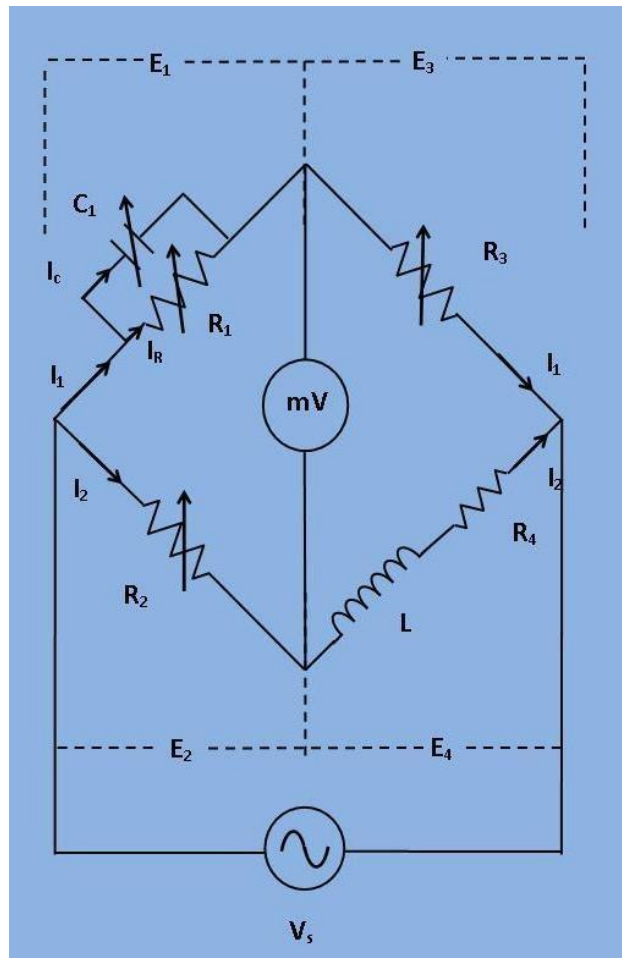
Result and Conclusion:

Experiment No – 3

Aim - To Measure Unknown Inductance and Capacitance by Maxwell's L/C Bridge and hence Verify the result in MULTISIM.

Objective - To determine the self-inductance of an unknown coil.

Circuit Diagram –

Theory –
Here,

    L = Unknown Inductance,

    R_4 = Effective resistance of unknown Inductance coil,

    R_1, R_2, R_3 = Known non-inductive resistance,

    C_1 = Standard variable capacitor.

The balance equation for the branch can be written as:

$$(R_4 + j\omega L) * (\frac{R_1}{1 + j\omega C_1 R_1}) = R_2 R_3;$$

$$R_1 R_4 + j\omega L R_1 = R_2 R_3 + j\omega R_2 R_3 C_1 R_1;$$
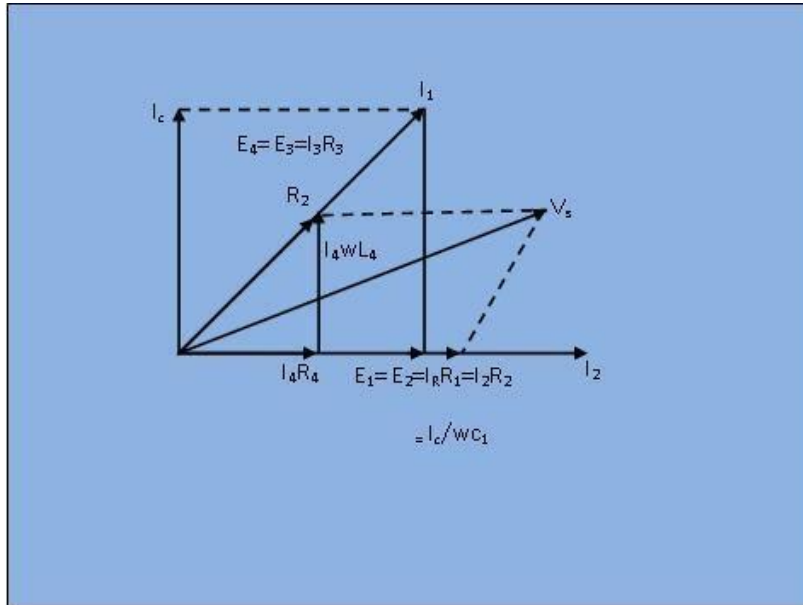
Equating the real and imaginary parts,

$$R_4 = \frac{R_2 R_3}{R_1} \ldots \ldots (1)$$

$$L = R_2 R_3 C_1 \ldots \ldots (2)$$

Two variables R_1 and C_1 which appear in one of the two balance equations (i.e. equation (1) and (2)) and hence the two equations are independent. The expression for Q factor can be written as:

$$Q = \frac{\omega L}{R_4} = \omega C_1 R_1$$

Phasor Diagram –

Procedure –
1. All the components are connected as shown in the diagram.
2. The product of $R_2 R_3$ is set at a convenient value and the balanced condition is obtained by varying R_1 and C_1.
3. The ranges for R_1 and C_1 is decided through which they are varied without bringing database at noise C.R.O.
4. The procedure is repeated with different values of the product $R_2 R_3$ and upon the readings the maximum accuracy for the measurement is decided.

Observation Table –

Voltage: 3 V, Frequency: 50 Hz

Sl. No.	R1 (Ω)	R2 (Ω)	R3 (Ω)	C1 (nC)	Given value of L (H)	Measured value of L (H)	%Error
Air Core							
1							
2							
3							
4							
5							
Iron Core							
6							
7							
8							
9							
10							

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ L - Measured\ value\ of\ L) \times 100}{Given\ value\ of\ L}$$
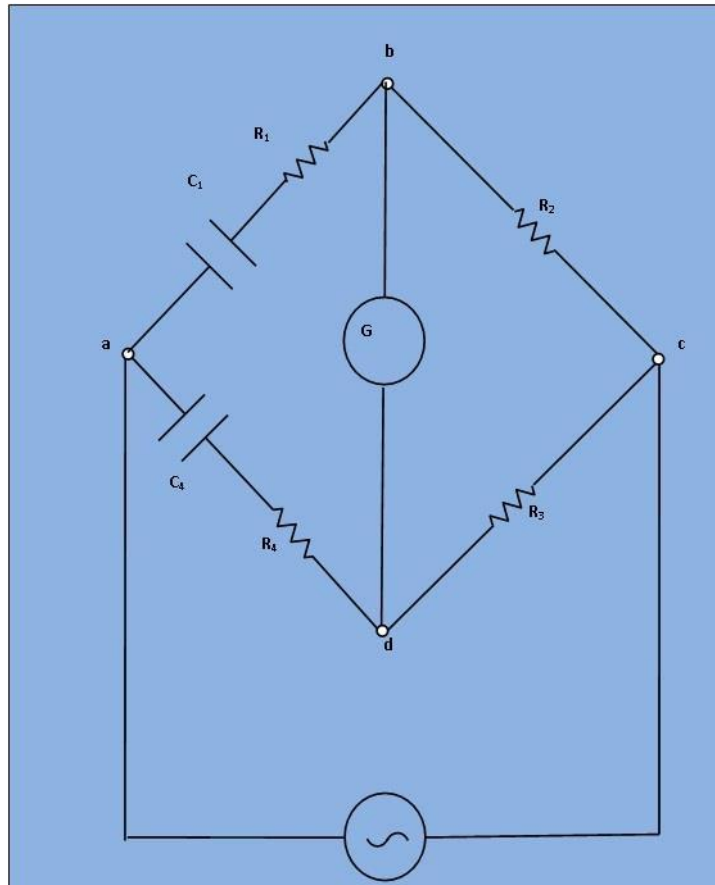
Result and Conclusion:

Experiment No – 4

Aim - To Measure unknown value of Capacitance using Wien Bridge and hence Verify the result in MULTISIM.

Objective - To determine the capacitance of an unknown capacitor.

Circuit Diagram –

Theory –
Let,

C_1 = Capacitor whose capacitance is to be measured,
R_1 = A series resistance representing the loss in the capacitor C_1,
C_4 = A standard capacitance with series resistance of R_4,
R_2 and R_3 = Non-inductive resistances.

At balance,

$$\left(R_1 + \frac{1}{j\omega C_1}\right) \cdot R_3 = \left(R_4 + \frac{1}{j\omega C_4}\right) \cdot R_2 \quad ....(1)$$

$$R_1 R_3 + \frac{R_3}{j\omega C_1} = R_2 R_4 + \frac{R_2}{j\omega C_4} \quad ....(2)$$

Equating the real and imaginary terms,

$$R_1 R_3 = R_2 R_4$$

$$R_1 = \frac{R_2 R_4}{R_3}$$

and , $\quad \dfrac{R_3}{j\omega C_1} = \dfrac{R_2}{j\omega C_4}$

$$C_1 = \frac{C_4 R_3}{R_2}$$

If the bridge in Fig.1 is used to measure capacitance, it may be written as

$$C_1 = \frac{C_4 R_3}{R_2} \ldots\ldots\ldots (3)$$

$$R_1 = \frac{R_2 R_4}{R_3} \ldots\ldots\ldots (4)$$

The dissipation factor of capacitance C_1 is defined as,

$$D_1 = \omega C_1 R_1 \ldots\ldots\ldots (5)$$

While in measurement of capacitance C_1, R_1 is not a separate unit but represents the equivalent series resistance of the capacitor and thus can be determined in terms of the elements of the bridge.

Procedure –
1. The supply voltage is applied from the signal generator V=3 V at frequency 50 Hz. Also, the unknown capacitor value is set from the 'Set Capacitor Value' tab.
2. Then supply is switched on to get the millivoltmeter deflection.
3. The values of R_2, R_3, R_4 and C_4 are chosen from the resistance and capacitance box.
4. The millivoltmeter pointer is observed to achieve 'Null'.
5. When thee 'Null' is achieved simulation is carried out. The unknown capacitance (C_2) and unknown internal resistance (r_2) is observed.
6. The dissipation factor is also observed for the unknown capacitor.

Observation Table –

Voltage: 3 V, Frequency: 500 Hz

Sl. No.	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	C_4 (pF)	Calculated value of R_1 (Ω)	Dissipation Factor	Given value of C_1(μF)	Measured value of C1 (μF)	%Error
1									
2									
3									
4									
5									

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ C_1 - Measured\ value\ of\ C_1) \times 100}{Given\ value\ of\ C_1}$$

Result and Conclusion:

Experiment No – 5

Aim - To Measure the Value of unknown Capacitance by Schering Bridge and hence Verify the result in MULTISIM.

Objective - To Determine the Capacitance of an unknown Capacitor.

Circuit Diagram –
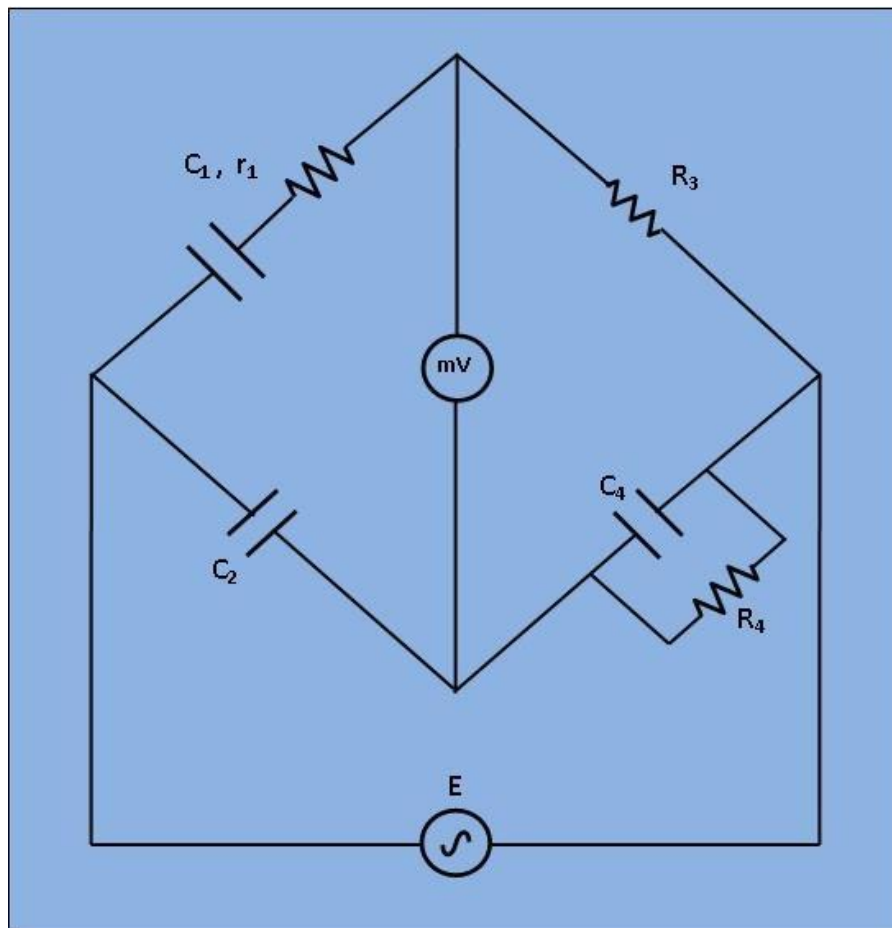
Theory –
Let, C_1=capacitor whose capacitance is to be measured.

$\quad$ R_1= a series resistance representing the loss in the capacitor C_1.

$\quad$ C_2= a standard capacitor.

$\quad$ R_3= a non-inductive resistance.

$\quad$ C_4= a variable capacitor.

$\quad$ R_4= a variable non-inductive resistance.

At balance,

$$\left(r_1 + \frac{1}{j\omega C_1}\right) \cdot \left(\frac{R_4}{j\omega C_4 R_4 + 1}\right) = \frac{R_3}{j\omega C_2} \ldots\ldots(1)$$

$$r_1 R_4 - \frac{jR_4}{\omega C_1} = -\frac{jR_3}{\omega C_2} + \frac{R_3 R_4 C_4}{C_2} \ldots\ldots(2)$$

Or Equating the real and imaginary terms in eq. (2), we obtain

$$r_1 = R_3 \cdot \frac{C_4}{C_2} \ldots\ldots(3)$$

$$C_1 = R_4 \cdot \frac{C_2}{R_3} \ldots\ldots(4)$$

And, two independent balance equations (3) and (4) are obtained if C_4 and R are chosen as the variable elements.

Dissipation factor

$$D_1 = \omega C_1 r_1 \ldots\ldots(5)$$

Procedure –
1. The supply voltage is applied from the signal generator V=3 V at frequency 50 Hz. Also, the unknown capacitor value is set from the 'Set Capacitor Value' tab.
2. Then supply is switched on to get the millivoltmeter deflection.
3. The values of C_2, R_3, C_4 and R_4 are chosen from the resistance and capacitance box. The values are varied to achieve 'Null'.
4. The millivoltmeter pointer is observed to achieve 'Null'.
5. When thee 'Null' is achieved simulation is carried out. The unknown capacitance (C_1) and unknown internal resistance (r_1) is observed.
6. The dissipation factor is also observed for the unknown capacitor.

Observation Table –

Voltage: 3 V, Frequency: 500 Hz

Sl. No.	R_3 (Ω)	R_4 (Ω)	C_2 (μF)	C_4 (pF)	Given Capacitor value (μF)	Measured Capacitor value (μF)	%Error
1							
2							
3							
4							
5							

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ the\ Capacitor\ -\ Measured\ value\ of\ the\ Capacitor) \times 100}{Given\ value\ of\ the\ Capacitor}$$

Result and Conclusion:

Experiment No – 6

Aim - To determine the self-inductance of an unknown coil by using Owen's bridge and hence Verify the result in MULTISIM..

Objective - To determine the self-inductance of an unknown coil.

Circuit Diagram –
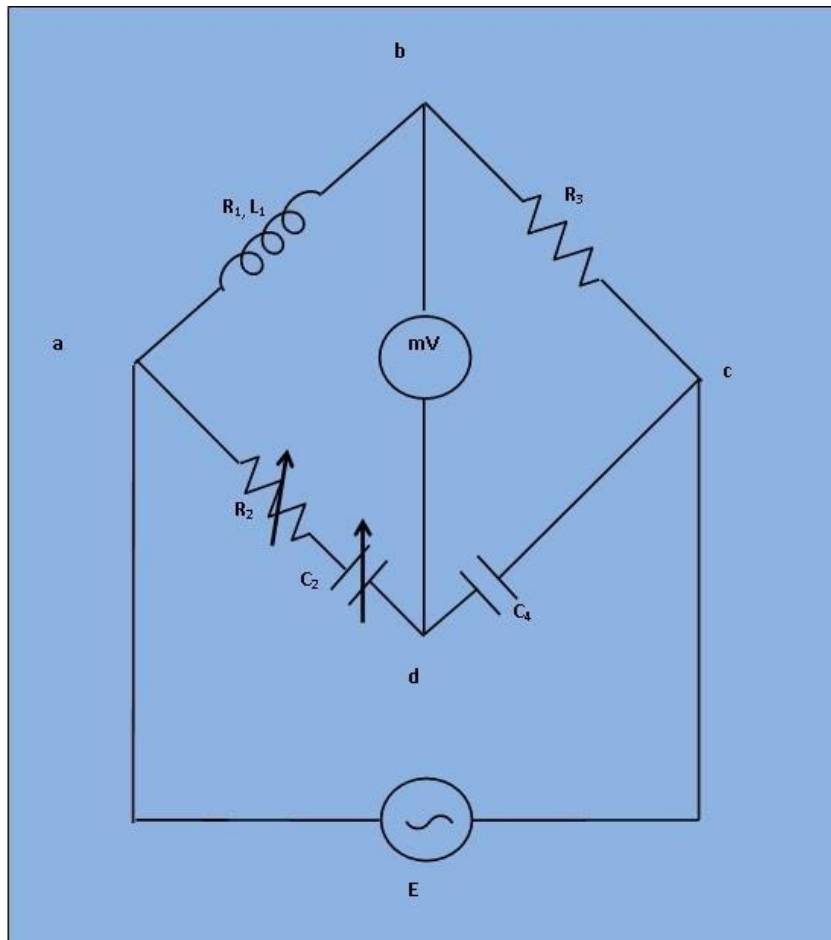
Theory –
Let,
L_1= Unknown self-inductance of resistance R_1,
R_2= Variable non-inductive resistance,
R_3= Fixed non-inductive resistance,
C_2= Variable standard capacitor,
C_4= Fixed standard capacitor.

At balance condition,

$$(R_1 + j\omega L_1) \cdot \left(\frac{1}{j\omega C_4}\right) = \left(R_2 + \frac{1}{j\omega C_2}\right) \cdot R_3 \text{........ (1)}$$

Equating both the real and imaginary parts in eq.(1) and separating them,

$$L_1 = R_2 R_3 C_4 \dots\dots (2)$$

$$R_1 = R_3 \cdot \frac{C_4}{C_2} \dots\dots (3)$$

The balance may be obtained by variation of resistance R_2 and capacitor C_2.

Procedure –
1. The supply voltage is applied from the signal generator V=3 V at frequency 50 Hz. Also, the unknown inductor value is set from the 'Set Inductor Value' tab.
2. Then supply is switched on to get the millivoltmeter deflection.
3. The values of C_2, R_3, C_4 and R_4 are chosen from the resistance and capacitance box. The values R2 and C_2 are varied fixing the values of R_3 and C_4 to achieve 'Null'.
4. The millivoltmeter pointer is observed to achieve 'Null'.
5. When thee 'Null' is achieved simulation is carried out. The unknown inductor (L_1) and unknown internal resistance (R_1) is observed.
6. The dissipation factor is also observed for the unknown inductor.

Observation Table –

Voltage: 3 V, Frequency: 500 Hz

Sl.No.	R2 (Ω)	R3 (Ω)	C2 (μF)	C4 (μF)	Given Value of L (mH)	Measuredvalue of L (mH)	%Error
1							
2							
3							
4							
5							

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ L\ -\ Measured\ value\ of\ L) \times 100}{Given\ value\ of\ L}$$

Result and Conclusion:

Experiment No – 7

Aim - Measurement of capacitance by De-Sauty's bridge and hence Verify the result in MULTISIM.

Circuit Diagram –
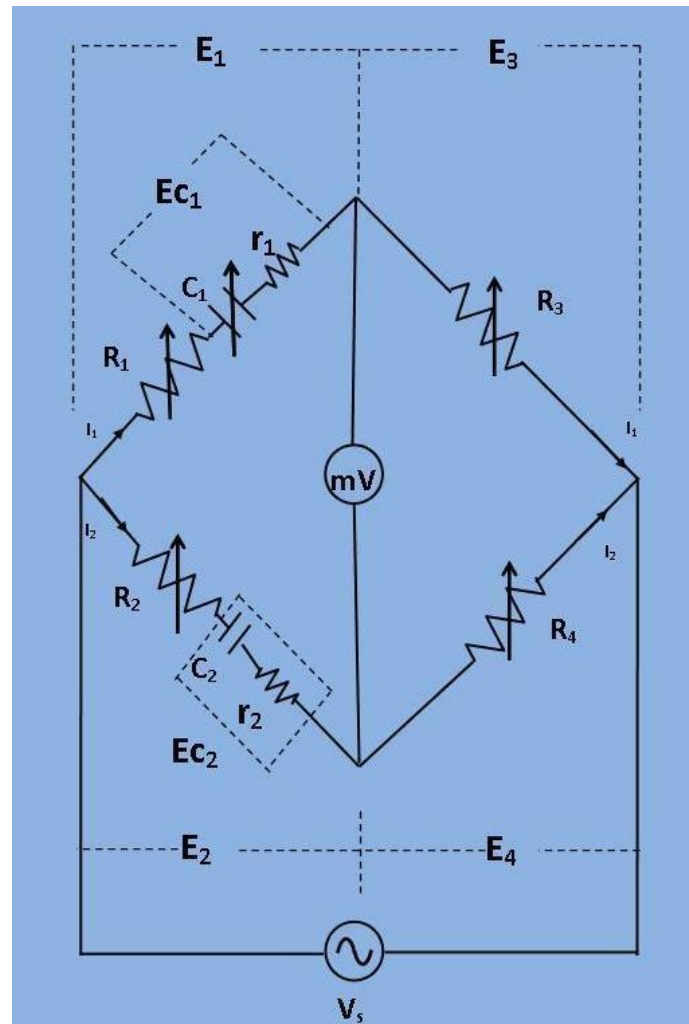
Theory –
Let,
C_1 = A standard capacitor.
C_2= A capacitor whose capacitance has to be measured.
r_1, r_2= Representing losses of their corresponding capacitors.
R_4, R_3= Non-inductive resistances.
R_1, R_2= They are connected in series with C1 and C2 respectively.

At balance condition,

$$\left(R_1 + r_1 + \frac{1}{j\omega C_1}\right) \cdot R_4 = \left(R_2 + r_2 + \frac{1}{j\omega C_2}\right) \cdot R_3$$

$$(r_1 + R_1) \cdot R_4 + \frac{R_4}{j\omega C_1} = (r_2 + R_2) \cdot R_3 + \frac{R_3}{j\omega C_2}$$

Equating both the real and imaginary parts and separate them,
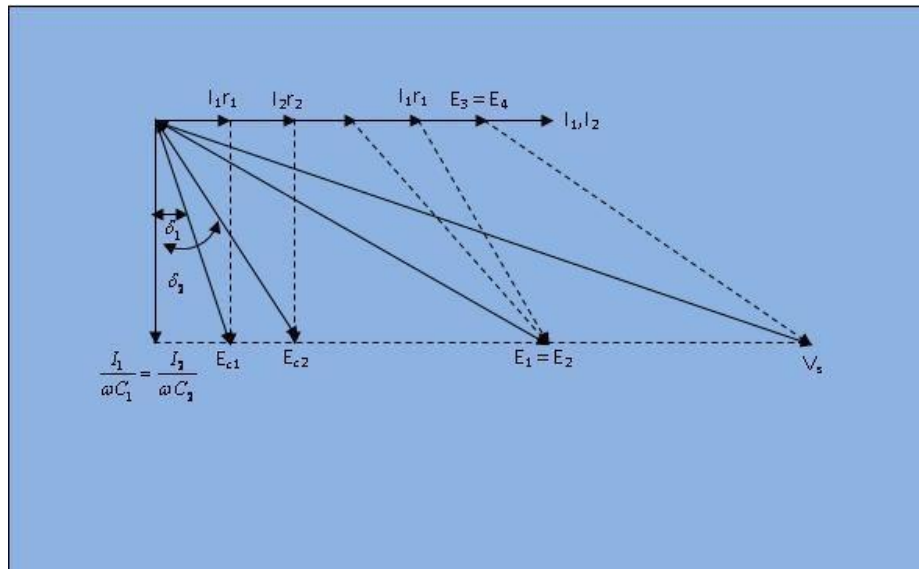
$$\frac{R_4}{R_3} = \frac{R_2 + r_2}{R_1 + r_1}$$

$$C_2 = \left(\frac{R_3}{R_4}\right) \cdot C_1$$

$$C_2 = \left(\frac{R_1 + r_1}{R_2 + r_2}\right) \cdot C_1$$

$$\frac{C_2}{C_1} = \frac{R_1 + r_1}{R_2 + r_2} = \frac{R_3}{R_4} \quad \dots \text{ eq.(1)}$$

The balance may be obtained by variation of resistances R_1, R_2, R_3 and R_4.

Phasor Diagram –

The angles δ_1 and δ_2 are the phase angles of C_1 and C_2 respectively. The dissipation factors for corresponding capacitors are

$$D_1 = \tan(\delta_1) = \omega C_1 r_1 \quad \text{and} \quad D_2 = \tan(\delta_2) = \omega C_2 r_2$$

From the eq. (1),

$$\frac{C_2}{C_1} = \frac{R_1 + r_1}{R_2 + r_2}$$

$$C_2 R_2 + C_2 r_2 = C_1 R_1 + C_1 r_1$$

Multiplying both sides by ω,

$$\omega C_2 R_2 + \omega C_2 r_2 = \omega C_1 R_1 + \omega C_1 r_1$$

$$D_2 - D_1 = \omega \cdot C_2 \cdot \left(R_1 \cdot \frac{R_4}{R_3} - R_2 \right)$$

Therefore, if the dissipation factor of one of the capacitors is known, the dissipation factor for the other can be determined.

Procedure –
1. The supply voltage is applied from the signal generator V=3 V at frequency 50 Hz. Also, the unknown capacitor value is set from the 'Set Capacitor Value' tab.
2. Then supply is switched on to get the millivoltmeter deflection.
3. The values of R_1, R_2, R_3, R_4 and C_1 are chosen from the resistance and capacitance box. The values are varied to achieve 'Null'.
4. The millivoltmeter pointer is observed to achieve 'Null'.
5. When thee 'Null' is achieved simulation is carried out. The unknown capacitance (C_2) and unknown internal resistance (r_2) is observed.
6. The dissipation factor is also observed for the unknown capacitor.

Observation Table –

Voltage: 3 V, Frequency: 500 Hz

Sl. No.	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	C_1 (pF)	Given value of Capacitor (μF)	Measured value of Capacitor (μF)	Dissipation Factor	%Error
1									
2									
3									
4									
5									

Calculation –
Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ Capacitor\ -\ Measured\ value\ of\ Capacitor) \times 100}{Given\ value\ of\ Capacitor}$$

Result and Conclusion:

Experiment No – 8

Aim - To Measure 3-phase Power by Two Wattmeter Method

Circuit Diagram –
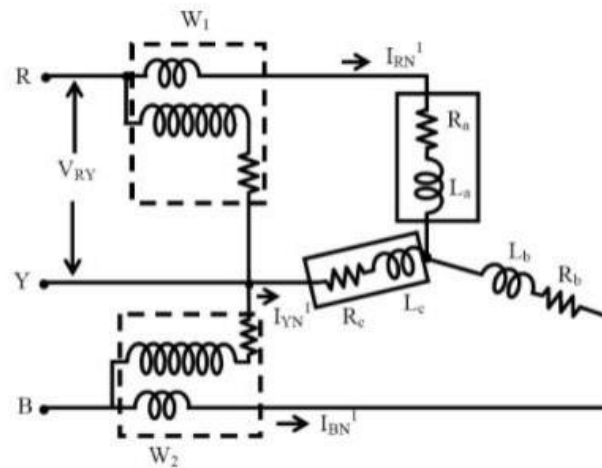
[Fig 1: Connection diagram for three phase power measurement using two wattmeter method]

Theory –
The connection diagram for the measurement of power in three phase power measurement circuit using two wattmeter's method is shown in figure 1. This is irrespective of the circuit connection star or delta. The circuit may be taken as balanced or unbalanced one, balanced type being only a special case. Please not the connection of two watt-meters. The current coil of the wattmeter's 1 and 2 in series with R and B phase with the pressure voltage coils being connected across R-Y and B-Y respectively. Y is the third phase in which no current coil is connected.

If star connected circuit is taken as an example the total instantaneous power consumed in the circuit is,

$$W = I_{RN} \cdot V(RN) + I_{YN} \cdot V(YN) + I_{BN} \cdot V_{BN} \ldots (1)$$

Each of the terms in the above expression equation (1) is the instantaneous power consumed by the phases. From the connection diagram, the circuit in and the voltages across the respective (current, pressure or voltage) coils in the wattmeter, W_1 are I_{RN} and $V_{RY} = V_{RN} - V_{YN}$.

So, the instantaneous power measured by the wattmeter W_1 is $W_1 = I_{RN} \cdot V_{RY}$.

Similarly, the instantaneous power measured by the wattmeter W_2 is. $W_2 = I_{BN} \cdot V_{BY} = I_{BN} \cdot (V_{BN} - V_{YN})$

Some of the two readings as given above is,

$$W_1 + W_2 = I_{RN}(V_{RN} - V_{YN}) + I_{BN}(V_{BN} - V_{YN})$$
$$= I_{RN}V_{RN} + I_{BN}V_{BN} - V_{YN}(I_{RN} + I_{BN}) - - - - - - (2)$$

and $I_{RN} + I_{BN} + I_{YN} = 0$
applying in equation (2),

$$W_1 + W_2 = I_{RN}V_{RN} + I_{BN}V_{BN} + V_{YN}I_{YN} - - - - - - - - (3)$$

Equation (1) is compared with equation (3) to give the total instantaneous power consumed in the circuit. They are found to be same. The phasor diagram of three phase balanced star connected circuit is shown in figure 2.
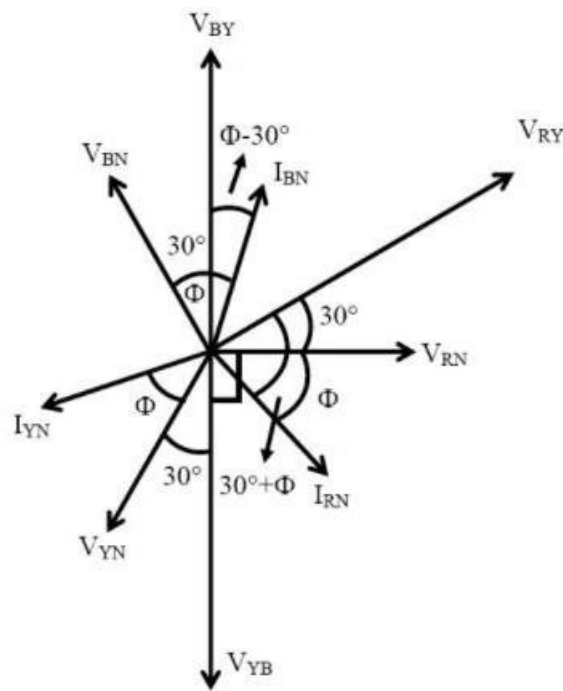
[Fig 2: Phasor diagram of three phase balanced star connected circuit]

Procedure–
Balanced Load –
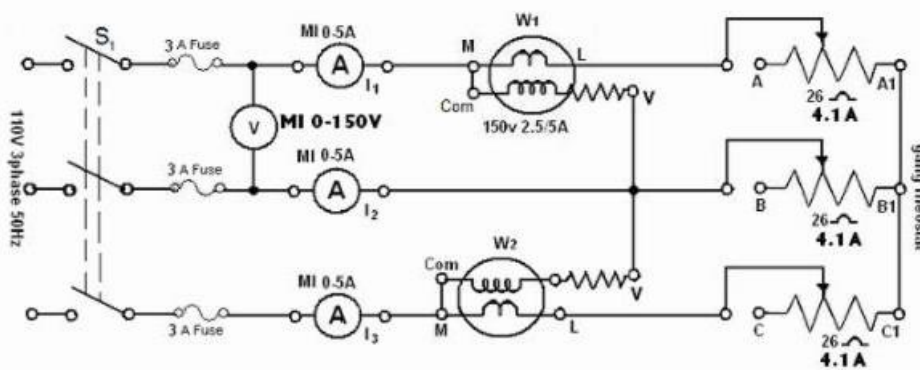
1. Circuit is connected as shown in the above figure.
2. The ganged rheostat is adjusted for maximum resistance.
3. The supply is switched on.

4. The switch S_1 is closed.
5. V_L, I_1, I_2 and I_3 are obtained from the meter readings. Wattmeter readings W_1 and W_2 are noted.
6. The load resistance is varied and five sets of observations are obtained.

Unbalanced Load –
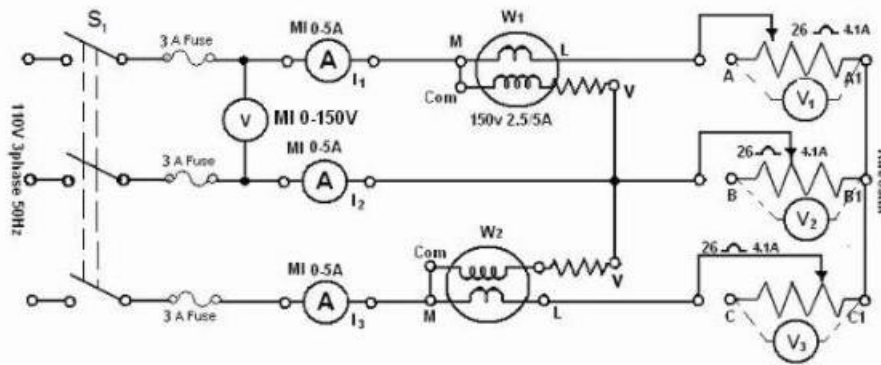
1. Circuited is connected as shown in the above figure.
2. The ganged rheostat is replaced by three separate rheostats of 26 Ω, 4.1 A and are connected in a star.
3. The three rheostats are adjusted to maximum values.
4. The supply is switched on and the autotransformer is set to 110 V.
5. Switch S_1 is closed and five sets of observations are noted.

Observation Table –

Balanced Load

Voltage: 100 V, Frequency: 50 Hz

Sl. No.	V_{RY}	I_R (A)	cos (V_{RY}, I_R)	V_{BY}	I_B (A)	cos (V_{BY},I_B)	I_3 (A)	W_1	W_2	W_C (Calculated Power)	W_M (Measured Power)	%Error
1												
2												
3												
4												
5												

Calculation –
Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ W_c - Measured\ value\ of\ W_M) \times 100}{Given\ value\ of\ W_c}$$

Unbalanced Load –

Sl. No.	V_R	V_Y	V_B	I_R (A)	I_Y(A)	I_B(A)	W_C (Calculated Power)	W_1	W_2	W_M(Measured Power)	%Error
1											
2											
3											
4											
5											

Calculation –

Formula for the calculation of Percentage Error -

$$\%Error = \frac{(Given\ value\ of\ W_c - Measured\ value\ of\ W_M) \times 100}{Given\ value\ of\ W_c}$$

Result and Conclusion:

Experiment No – 9

**Aim -** To understand the working Principle of Thermocouple

Theory –
Thermoelectric effect:

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a difference in temperature on each side. Conversely when a voltage is applied to it, it creates a temperature difference.

There are three basic effects that explain the working principle of a thermoelectric device.

1. Seebeck Effect: When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flow in the thermoelectric circuit. German–Estonian physicist Thomas Seebeck made this discovery in 1821. This is now known as the thermoelectric effect or Seebeck effect.
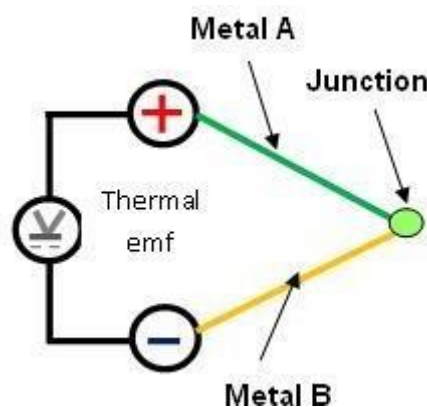

2. Peltier Effect: Peltier found that the junctions of dissimilar metals get heated or cooled, depending upon the direction in which an electrical current passed through them. Heat generated by current flowing in one direction is absorbed if the current is reversed. The effect always involves pairs of junctions. The Peltier effect is found to be proportional to the first power of the current, not to its square, as is the irreversible generation of heat caused by resistance throughout the circuit. In effect it transfers the heat from one side of a device to other.
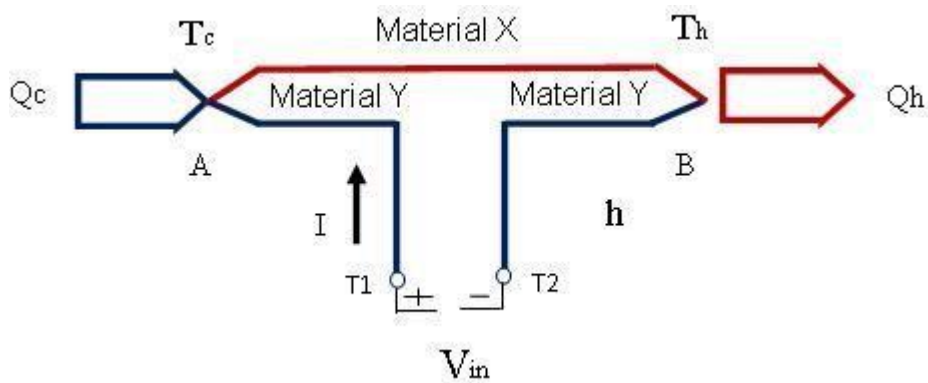
3. Thompson Effect: This describes the existence of temperature gradient while heating or cooling of a conducting material. Any current - carrying conductor (except superconductor), with a temperature difference between two points, will either absorb or emit heat, depending on the material.
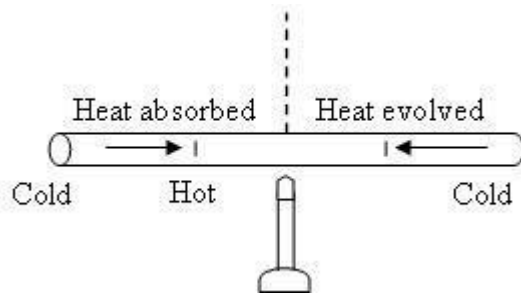
Observations and Graphs–

Result and Conclusion:

Experiment No – 10

Aim - To understand the working principle of Strain gauge

Theory –
 Strain gauge transducer transforms mechanical elongation and compression into measurable value.
Types of Strain Gauges based on principle of working:
1. Mechanical
2. Electrical
3. Piezoelectric

Gauge Factor:
The characteristics of the strain gauges are described in terms of its sensitivity (gauge factor). Gauge factor is defined as unit change in resistance for per unit change in length of strain gauge wire given as –

$$G.F. = (\Delta R/RG)/\varepsilon$$

Where,
ΔR = The change in resistance caused by strain
RG = is the resistance of the unreformed gauge and
E = is strain

Effect of Temperature –
The resistive type strain gauges are sensitive to temperature variation; therefore, it becomes necessary to account for variations in strain gauge resistance due to temperature change. Using dummy gauge in opposite arm of the active gauge compensates the temperature variation.
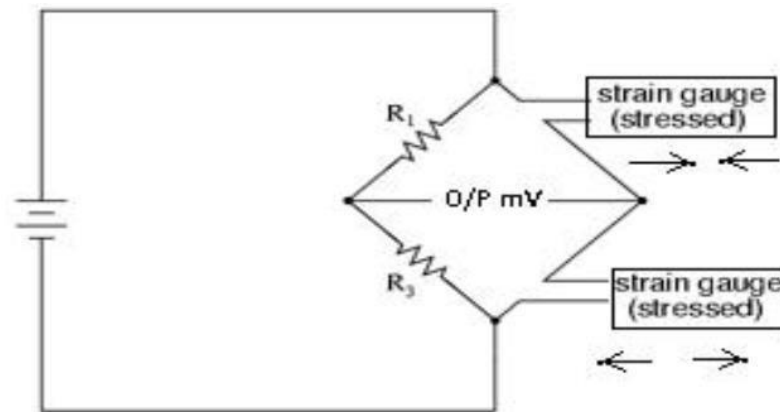
Arrangement –
In certain applications where equal and opposite strains are known to exist it is possible to attach similar gauges in a way that one-gauge experiences positive strain and other negative strain. Depending on the number of gauges used in the bridge, the circuit configurations are:
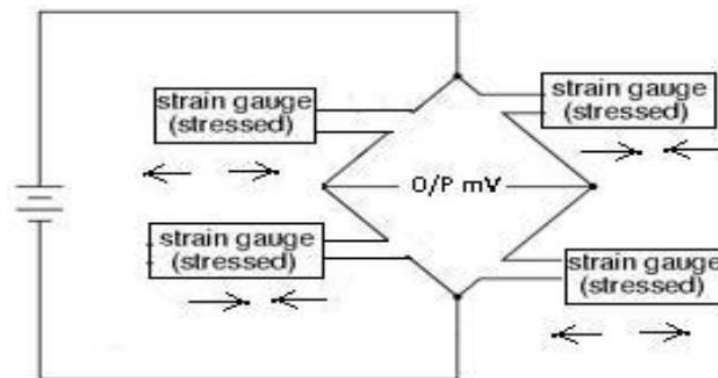
1. Quarter Bridge
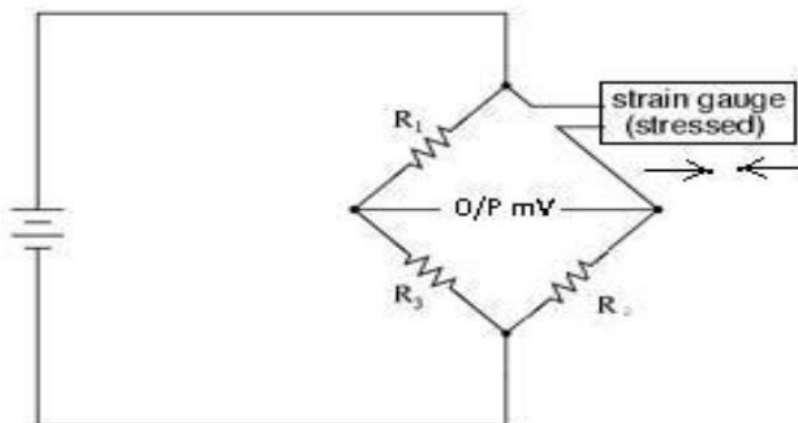
2. Half Bridge

3. Full Bridge

Procedure –
Level – 1

1. First select the material of the strain gauge from the available drop-down menu.
2. Select the value of input voltage V for the bridge in which strain gauge is connected.
3. Select the strain gauge resistance in Ωs.
4. Select the bridge configuration. Observe the connection diagram, by changing the selected configuration.

5. Select the gauge factor value from available drop-down menu.
6. Click on **configure** tab. The system is configured once the user confirms the values.

7. Now the weight tab gets enabled. Select the weight in Kg to be applied to the cantilever beam. Now the value of Rg is displayed.
8. Enter the expected **output value (e) in millivolts**. For calculations of output, click on **formula** tab.
9. Using formula, calculate the value of the output voltage and enter the answer in the box provided (0.00 format). Submit the answer using submit button.

10. If your calculation is correct you will get the message accordingly. If not, you need to repeat the calculations.
11. Change the value of **weight** and repeat the steps 7 to 10.

12. Minimum three calculations are necessary to plot the graph. After three calculations, the **plot** tab will be activated.
13. Click on Plot to see the graph. Study the graph of output voltage variation when weight is changed.
14. Hide the graph and repeat the experiment by varying the values of inputs or bridge types. Observe the graphs. For this use ' **Next set of values**' tab which is enabled now. Otherwise go to next level by clicking **'Level 2'** enabled tab.

Level – 2 –
## Study of effect of change in position of weight applied on Strain Gauge performance

1. When you move from level 1 to level 2, the configuration and selected weight remains same.
2. Now you can select the position of the weight attached to the beam. Originally the distance between strain gauge and the applied weight is 16 cm. Now if 14 cm position is selected the distance is reduced by 2 cm i.e. the distance between strain gauges fixed on the beam and the applied weight is 14 cm. You can observe this change in available diagram.
3. Observe the displayed output value. Compare this value with previous value. Refer to formula tab for calculations.
4. Minimum three calculations are necessary to plot the graph. After three calculations the plot tab will be activated.
5. Click on Plot to see the graph. Study the graph of output voltage variation when position is changed. Observe the graph carefully.
6. Hide the graph and move on to next level by clicking on 'Level3' tab.

Level – 3 –
Study of effect of change in temperature on the performance of Strain Gauge

1. When you move from level 2 to level 3, all the parameters including the position of the weight for level 1 and level 2 are freeze. The user can now select the temperature to which strain gauges are exposed i.e. ambient temperature.
2. Select the temperature in $^\circ$C from the drop-down menu. The reference temperature considered for previous level calculations is 20 $^\circ$C.
3. Observe the displayed value of R_g i.e. Resistance of strain gauge. Compare this value with previous value. Refer to formula tab for calculations.
4. Minimum three calculations are necessary to plot the graph. After three calculations the plot tab will be activated.
5. Click on Plot to see the graph. Study the graph of R_g value variation with change in temperature. After completion of all the parts, you can proceed to Post Test to find if you have understood all aspects of the experiment.

Circuit Diagram -
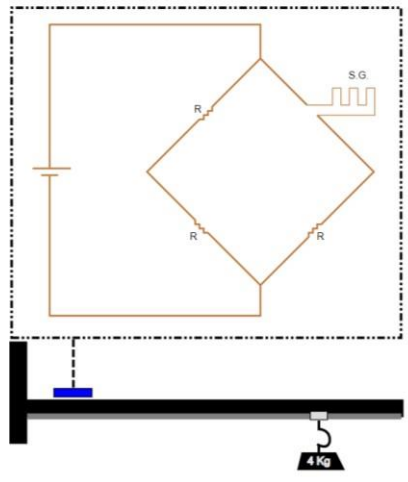
Observations and Graphs–

Result and Conclusion:

Experiment No – 11

Aim - To understand the working principle of RTD

Objective - Study static and dynamic characteristics of RTD and effect of various parameters on RTD performance.

Theory –
Temperature Measurement using RTD

For measurement of Temperature number of sensors are available. One of the most linear, stable, and reproducible temperature sensors is the RTD, Resistance Temperature Detector. In RTD, the output resistance changes with temperature. RTD is a positive temperature coefficient device. The resistance of the metal increases with temperature. The resistive property of the metal is called its resistivity. The resistive property defines length and cross-sectional area required to fabricate an RTD of a given value. The resistance is proportional to length and inversely proportional to the cross-sectional area and is given by the relationship

$R = \rho l/A$

Where 'R' is resistance of the metal, 'ρ' is the resistivity of the metal, 'l' is the length of the metal and 'A' is the area of cross section of the metal.
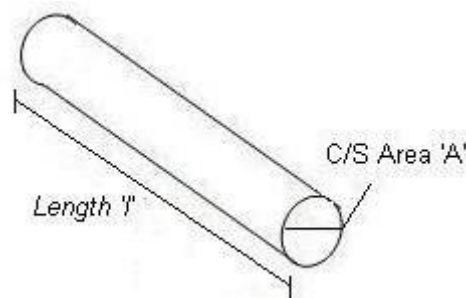
Resistance Temperature Detector (RTD)

Resistance Temperature Detector (RTD), as the name implies, is a sensor used to measure temperature by correlating the resistance with temperature. Most RTD elements consist of a length offine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure metal as mentioned below. The material property to have predictable change in resistance as the temperature changes, is used to determine temperature.

Commonly used RTD Materials:
• Platinum (most popular and accurate)
• Nickel
• Copper
• Balco (rare)
• Tungsten (rare)

Procedure –
Expt. 1: Static Characteristics of RTD

Study the change in resistance of RTD probe depending on the process temperature.
Step by step Procedure:
1. Select the material of RTD you want to use. Temperature coefficient (α) for the same will be displayed on the screen. Note this value.
2. Click on ' R_0' to get the value of R_0 for selected RTD. Note the same.
3. Click on 'Get Temp'. The temperature for which R_t is to be found will be displayed.
4. Using formula calculate the value of R_t and enter the answer in the box provided (upto 2 decimals with rounding off). Submit the answer using submit button.

5. If your calculation is correct, go to step 3. Repeat the procedure min 3 times.
6. If your calculation is wrong, you will be asked to repeat the same. Please refer to GET FORMULA tab and verify your calculations.

7. After finishing minimum 3 set of correct readings, you can see the graph by clicking on 'Plot'.
8. When the graph is displayed click Next tab to repeat the procedure with different reference resistance(R_0) value and with different materials.
9. Minimum 3 calculations are necessary to plot the graph.

10. Study the graphs for RTD performance with different reference resistance values and different materials

Expt. 2: Dynamic characteristics
Study the dynamic response of RTD probe
In this experiment, Platinum RTD is used for calculating the time constant values. The response of RTD for a step change in the input is plotted. The maximum temperature the RTD attains, is same as the temperature displayed by 'GET Temp' tab.

Step by step Procedure:
1. Select the RTD as bare element (make it on). With the standard dimensions considered for bare element, the time constant value will get displayed in the output box.

2. Verify this by using equation given under Get formula tab.
3. Now select the RTD dynamic performance with sheath. Select appropriate material and thickness value. The time constant value will get displayed in the output box.

Verify this by using equation given under formula tab.
4. Observe the change in the time constant values with different materials with different thickness.
5. Now select the RTD dynamic performance with thermowell. Select appropriate material, thickness and filling material. The time constant value will get displayed in the output box when thermowell material, thickness and filling material is selected.

Verify this by using equation given under formula tab.
6. Observe the change in the time constant values with different materials with different thickness.
    Also see the effect of change in filling material.
7. Click on plot button to observe the dynamic response (Time Vs Temperature).
8. Observe and verify response time of RTD which is generally 5 times the time constant value.

After completion of both the parts, you can proceed to Post Test to find out if you have understood all aspects of the experiment.

Graphs and Calculation

Calculation –

Material – Platinum
Resistance $(R_o) = 100\Omega$
Temperature $t_o = 0°C$

Formula for calculation of R_t –

$$R_t = R_o[1 + \alpha(t - t_o)]$$

1.

   Temperature(t) = 440 °C
   Value of R_t = 269.40 Ω

2.

   Temperature(t) = 358 °C
   Value of R_t = 237.83 Ω

3.

   Temperature(t) = 124°C
   Value of R_t = 147.74 Ω