ELECTRICAL MEASUREMENT LAB

(EEE-352)

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Syllabus

Note: Minimum of nine experiments from the following:

1. Calibration of ac voltmeter and ac ammeter
2. Measurement of form factor of a rectified sine wave and determine source of error if r.m.s.value is measured by a multi-meter
3. Measurement of phase difference and frequency of a sinusoidal ac voltage using C.R.O.
4. Measurement of power and power factor of a single phase inductive load and to study effect of capacitance connected across the load on the power factor
5. Measurement of low resistance by Kelvin's double bridge
6. Measurement of voltage, current and resistance using dc potentiometer
7. Measurement of inductance by Maxwell's bridge
8. Measurement of inductance by Hay's bridge
9. Measurement of inductance by Anderson's bridge
10. Measurement of capacitance by Owen's bridge
11. Measurement of capacitance by De Sauty bridge
12. Measurement of capacitance by Schering bridge
13. Study of Frequency and differential time counter
14. College may add any two experiments in the above list

List of Experiments

1. To study and perform Calibration of ac voltmeter and ac ammeter
2. Measurement of form factor of a rectified sine wave and determine source of error if r.m.s.value is measured by a multi-meter.
3. To determine the unknown value of inductance by comparing with a variable standard self inductance using Maxwell's Inductance bridge.
4. Measurement of inductance by Hay's bridge
5. Measurement of inductance by Anderson's bridge
6. Measurement of capacitance by Owen's bridge
7. Measurement of capacitance by Schering bridge
8. Measurement of low resistance by Kelvin's double bridge
9. Measurement of voltage, current and resistance using dc potentiometer

Experiment No.1

Aim: To study and perform Calibration of ac voltmeter and ac ammeter

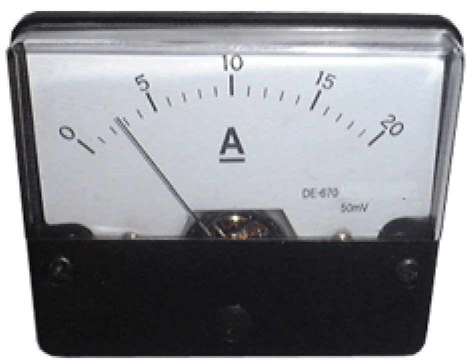
OBJECTIVE: Introduction to various Supply Systems, Ammeter, Voltmeter, Wattmeter, Energy meter, Tachometer, Rheostat, Loading Devices, Transformer.

Apparatus Required: Demonstration of various instruments like Ammeter, Voltmeter, Wattmeter, Energy Meter, Tachometer, Rheostat, Various Capacitors, Various Resistors, AC and DC Power Supply.

Theory of Experiment:

AMMETER

Ammeter is employed for measuring of current in a circuit and connected in series in the circuit. As ammeter is connected in series, the voltage drop across ammeter terminals is very low. This requires that the resistance of the ammeter should be as low as possible. The current coil of ammeter has low current carrying capacity whereas the current to be measured may be quite high. So for protecting the equipment a low resistance is connected in parallel to the current coil and it is known as shunt resistance



Analog Ammeter

VOLTMETER

(a) Voltmeter is employed to measure the potential difference across any two points of a circuit. It is connected in the parallel across any element in the circuit. The resistance of voltmeter is kept very high by connecting a high resistance in series of the voltmeter with the current coil of the instrument. The actual voltage drop across the current coil of the voltmeter is only a fraction of the total voltage applied across the voltmeter which is to be measured.

Analog voltmeter

Result: We have studied and perform the Calibration of ac voltmeter and ac ammeter.

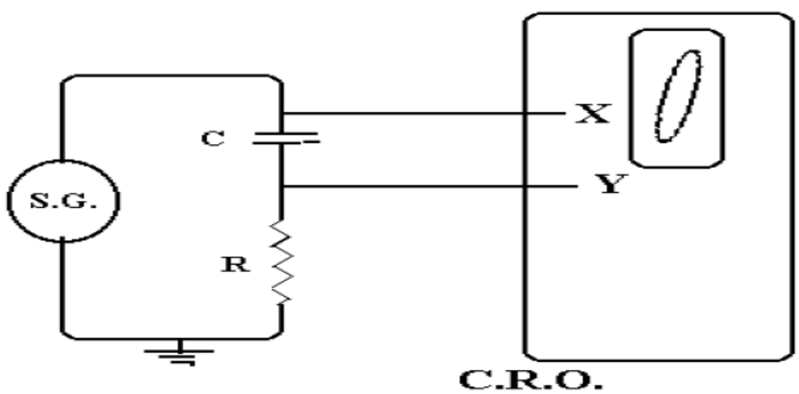
Experiment No. 2

Aim: Measurement of form factor of a rectified sine wave and determine source of error if r.m.s.value is measured by a multi-meter.

Apparatus Used: Signal generator, CRO, capacitor, variable resistor and connecting terminals.

Theory: When an AC current is sent through an R-C circuit, the current direction is same in both the elements, R and C. But the voltage directions are different. The voltage across the resistor is in the direction of current and the voltage across the condenser lags behind the current by 90^0. Because of this, the resultant voltage also lags behind the current by some angle (Φ) called phase difference. Since the current can't be measured directly by a CRO, the voltage across the resistor is given to CRO, which represents the current direction. So the phase difference is the angle between the voltage across the resistor and the resultant voltage.

Circuit Diagram:



Observation Table:

Table

Resistance (R) = Ω Capacitance (C) = μF

S.No.	Applied Frequency f (Hz)	Angular Frequency $\omega = 2\pi f$ (Rad/sec)	Theoretical Phase $\Phi_1 = Tan^{-1}(\frac{1}{\omega C R})$	A (mm)	B (mm)	Practical Phase $\Phi_2 = Sin^{-1}(\frac{A}{B})$
1.						
2.						
3.						
4.						
5.						
6.						

Procedure: The connections are made as shown in the circuit and as said in the description. The time base (X-plates) band switch is kept in external mode. The gain band switch of Y-plates is kept in desired range, so as to get complete maximum size ellipse on the screen. The maximum deflection (B) from the mean position and the deflection (A) at t = 0, from the mean position are measured using the divisions on the screen. The experiment is repeated by varying the frequency (f) of the signal generator in equal steps. The values of f, A and B are noted in the table. The values of resistance and capacitance are also noted.

Precautions: 1.The size of the ellipse should be maximum, to minimize the error of measurement.

2. The time base (X-plates) band switch should be kept in external mode.

Results: The calculated value of Φ1 and Φ2 are equal

Experiment No. 3

Aim: To determine the unknown value of inductance by comparing with a variable standard self inductance using Maxwell's Inductance bridge.

Apparatus Used:

S. No.	Name of the apparatus	Quantity
1.	Transformer 230/15v	1 NOS
2.	Bread board	1 NOS
3.	Resistors	4 NOS
4.	Variable Resistor	1 NOS
5.	Inductors	2 NOS
6.	Digital Multimeter	1 NOS

Theory: This bridge circuit measures an inductance by comparison with a variable standard self inductance.

The connections and the phasor diagrams for balance conditions are shown below.

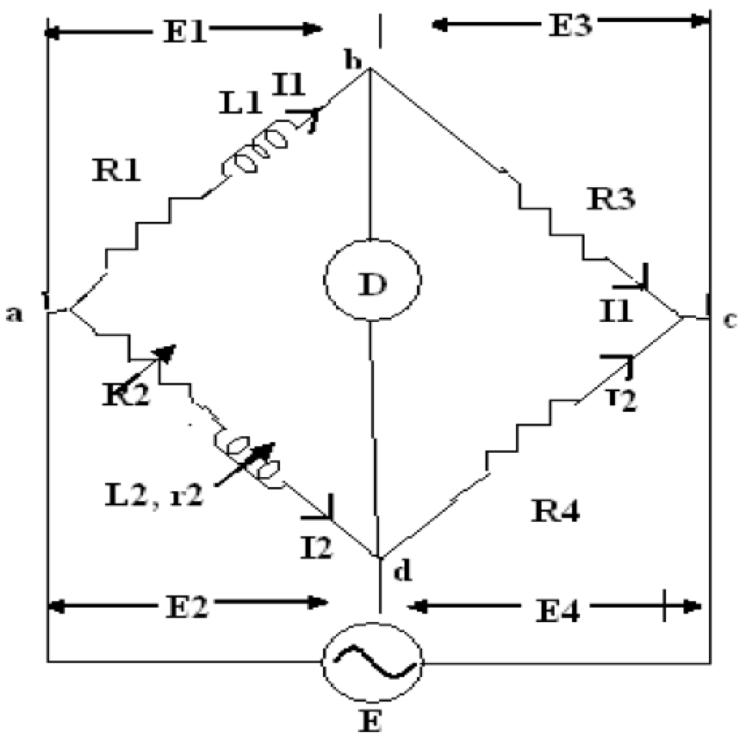
Let, L1 = unknown inductance of resistance R1,

L2 = variable inductance of fixed resistance r2,

R2 = variable resistance connected in series with inductor L2,

R3, R4 = known non-inductive resistances.

Circuit Diagram:



At balance, L1 = R3L2/R4 , R1= R3(R2+r2)/R4.

Procedure:

1. Connect the circuit as shown in the figure.
2. Connect the unknown inductance in L1.
3. Connect the multimeter between ground and output of imbalance amplifier.
4. Vary R2, from minimum position, in clockwise direction.
5. If the selection of R2 is correct the balance point can be obtained at minimum position.
6. Vary R2 for fine balance adjustment.

Observation Table:

S. No.	R2	R3	C1	L1= R3L2 / R4	True value of L1
1					
2					
3					

Result: Actual and practical values of Inductances are found to be nearly equal.

Experiment No. 4

Aim: Measurement of inductance by Hay's bridge

Apparatus Used:

S. No.	Name of the apparatus	Quantity
1	Lab trainer kit	1
2	Multimeter	1
3	Unknown inductor	1

Theory: The Hay's Bridge differs from Maxwell's bridge by having resistor R1 in series with standard capacitor C1 instead of in parallel. It is immediately apparent that for large phase angles, R1 should have a very low value. The Hay's circuit is therefore more convenient for measuring high Q coils. The balance equations are again derived by substituting the values of the impedance of the bridge arms into the general equation for bridge balance. On separating real and imaginary terms, the balance equations are:

$$R_1R_x + L_x/C_1 = R_2R_3 \quad \text{------------- (1)}$$

$$R_x/\omega C_1 = \omega L_x R_1 \quad \text{--------------- (2)}$$

Both equations 1 & 2 consist of L & R. By solving the above equations

$$R_x = \frac{\omega^2 C_1^2 R_1 R_2 R_3}{1+\omega^2 C_1^2 R_1^2} \quad \text{--------------- (3)}$$

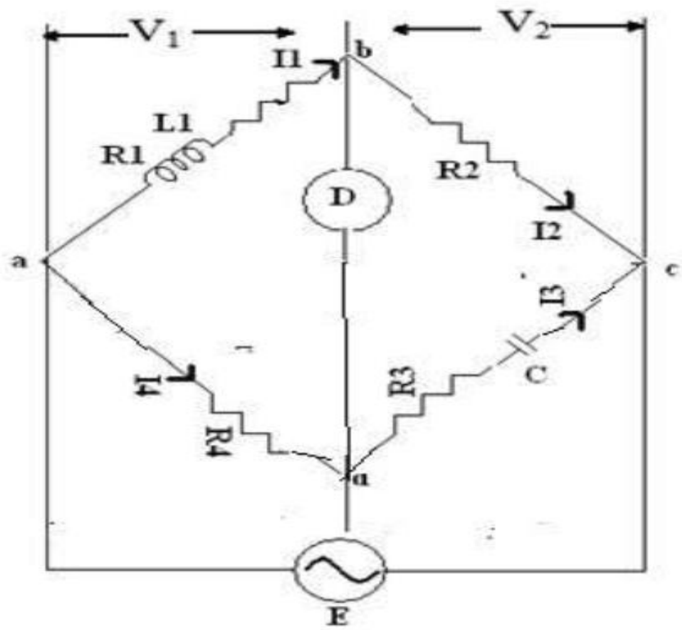
$$L_x = \frac{R_2 R_3 C_1}{1+\omega^2 C_1^2 R_1^2} \quad \text{--------------- (4)}$$

The expressions for the unknown inductance & resistance are consists of frequency term under balanced condition when two phase angles are equal, their tangents are also equal. Hence,

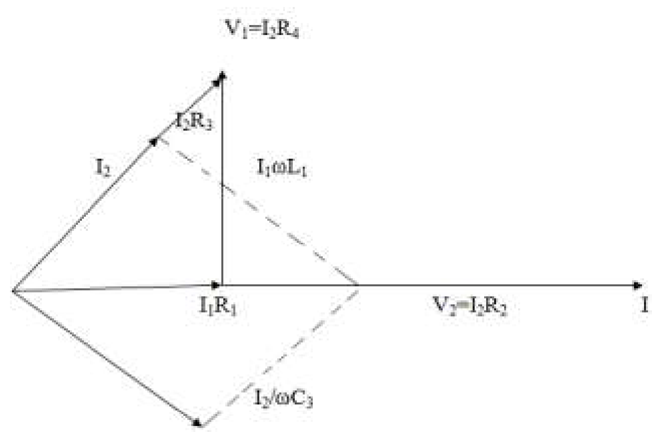
$$\tan\theta_L = \tan\theta_C \text{ (or) } Q = \frac{1}{\omega C_1 R_1} \quad \text{-------- (5)}$$

Substituting (5) in (4)

Circuit Diagram:



Phasor Diagram:



Procedure:

1. Switch ON the trainer & check the power supply.
2. Connect the unknown value of inductance (high Q) in arm marked Lx.
3. Vary R2 for fine balance adjustment.
4. The balance of bridge can be observed by using head phone. Connect the output of the bridge at the input of the detector.
5. Connect the head phone at output of the detector, alternately adjust R1 and proper selection of R3 for a minimum sound in the head phone.
6. Finally disconnect the circuit and measure the value of R1 at balance point using any multimeter. By substituting R1, R3 and C1 the unknown inductance can be obtained.

Observation Table:

S.No.	R2 (KΩ)	R3 (Ω)	C1 (μF)	Lx (mH)	L mH
1					
2					
3					

Result: After balancing the bridge, the values of R1 R3 and C1 are measured and found that the calculated value of Lx is almost equal to the actual value.

Experiment No. 5

Aim: Measurement of inductance by Anderson's bridge

Apparatus Used:

S. No.	Name of the apparatus	Quantity
1.	Transformer 230/15v	1 NOS
2.	Bread board	1 NOS
3.	Resistors	6 NOS
4.	Variable Resistor	1 NOS
5.	Inductors	2 NOS
6.	Capacitors	1 NOS
7.	Digital Multimeter	1 NOS

Theory: In this bridge, the self inductance is measured in terms of a standard capacitor. This method is applicable for precise measurement of self-inductance over a very wide range of values. Figure below show the connections and the phasor diagram of the bridge for balanced conditions.

Let L1 = self inductance to be measured, R1 = resistance of self-inductor, r,R2,R3,R4 = known non-inductive resistance r1 = resistance connected in series with self-inductor,

At, balance, I1 =I3 and I2 = IC +I4.

Now, $I1R3 = IC/j\omega C$ therefore, $IC = I1j\omega CR3$.

Writing the other balance equations.

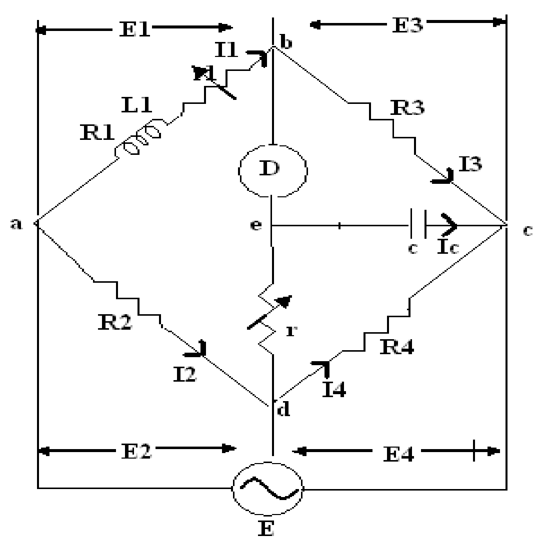
$I1(r1+R1+j\omega L1) = I2R2 + ICr$ and $IC(r+1/j\omega C) = (I2-IC)\ R4$

By substituting IC value and equating real and imaginary parts

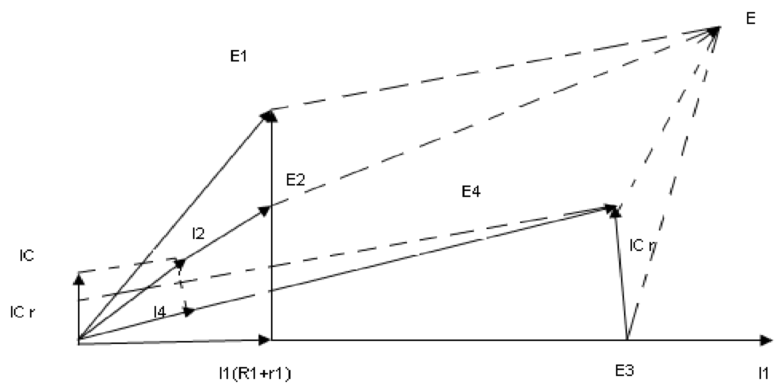
$R1 = R2R3/R4 - r1$

$L1 = C\ R3/R4\{\ r(R4+R2)+R2R4\}$

Circuit Diagram:



Phasor Diagram:



Procedure:

1. Connect the circuit as shown in the figure.
2. Connect the unknown inductance in L1.
3. Select any value of r.
4. Connect the multimeter between ground and output of imbalance amplifier.
5. Vary r1 and r, from minimum position, in clockwise direction.
6. Calculate the inductance L1 by substituting known values.

Observation Table:

S. No.	Actual value of L in mH	R in ohms	Practical value of L in mH

Results: The unknown inductance is determined using the Anderson's bridge.

Experiment No. 6

Aim: Measurement of capacitance by Owen's bridge

Apparatus Used:

S. No.	Name of the apparatus	Quantity
1.	Transformer 230/15v	1 NOS
2.	Bread board	1 NOS
3.	Resistors	2 NOS
4.	Variable Resistor	1 NOS
5.	Inductors	1 NOS
6.	Capacitors	2 NOS
7.	Digital Multimeter	1 NOS

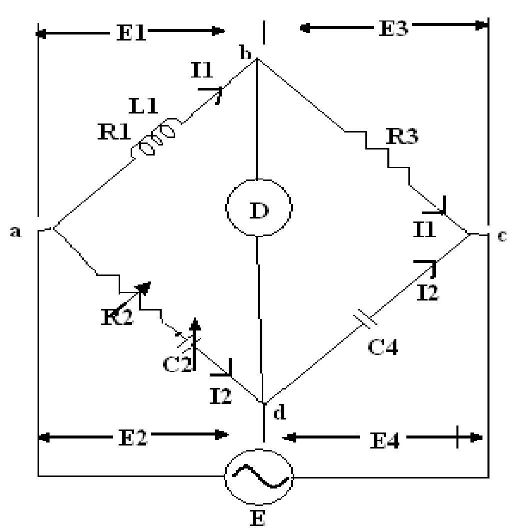
Theory: This bridge is used for measurement of an inductance in terms of capacitance.

Let L1 = unknown self-inductance of resistance R1, R3 = fixed non-inductive resistance, R2 = variable non-inductive resistance, C4 = fixed standard capacitor, C2 = variable standard capacitor.

At balance, $(R1+j\omega L1)(1/j\omega C4) = (R2 + 1/j\omega C2)\,R3$.

Separating the real and imaginary terms, we obtain: L1 = R2R3C4 and R1 = R3C4/C2.

Circuit Diagram:



Phasor Diagram:

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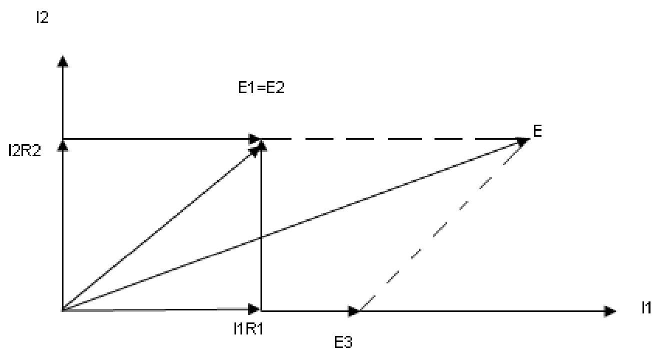


Procedure:

1. Connect the circuit as shown in the figure.
2. Connect the unknown inductance in L1.
3. Select any value of R1, R4 and C3..
4. Connect the multimeter between ground and output of imbalance amplifier.
5. Vary R1 and R4, from minimum position, in clockwise direction.
6. If the bridge does not balance change the value of C3.
7. Calculate the inductance L1 by substituting known values.

Observation Table:

S.NO	R2	R4	C3	L1= R2C3R4	True value of L1

Result: Actual and practical values of Inductances are found to be nearly equal.

Experiment No. 7

Aim: Measurement of capacitance by Schering bridge

Apparatus Used:

S. No.	Name of the apparatus	Quantity
1.	Transformer 230/15v	1 NOS
2.	Bread board	1 NOS
3.	Resistors	2 NOS
4.	Variable Resistor	1 NOS
5.	Inductors	1 NOS
6.	Capacitors	3 NOS
7.	Digital Multimeter	1 NOS

Theory: Schering bridge is one of the most important of the a.c. bridge. It is extensively used in measurement of capacitance.

At balance, $\{r1+ 1/(j\omega C1)\}\ \{R4/(1+j\omega C4R4)\} = R3/(j\omega C2)$

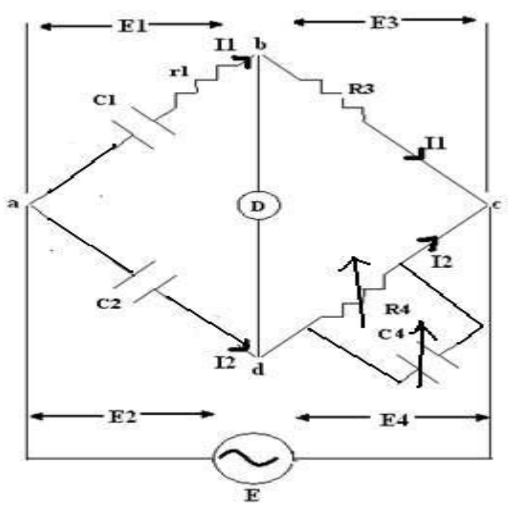
$\{r1+ 1/(j\omega C1)\}\ R4 = R3/(j\omega C2) * \{(1+j\omega C4R4)\}$

$r1R4 - \{(jR4)/(\omega C1)\} = \{ (-jR3)/(\omega C2)\} + \{(R3R4C4)/(C2)\}$

Equating real and imaginary terms,

$r1 = R3C4/C2$ and $C1 = C2R4/R3$

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in the figure.
2. Select any value of C1.
3. Connect the multimeter between ground and output of imbalance amplifier.
4. Vary R4 and C4, from minimum position, in clockwise direction.
5. If the selection of C1 is correct the balance point can be obtained at minimum position.

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6. If that is not the case, select another C1.

7. Calculate the Capacitance by substituting known values.

Observation Table:

S.NO	C4	C1	C2	R3	R4

Result: Hence the balanced condition of schering bridge is obtained and unknown value of capacitance is found.

Experiment No. 8

Aim: Measurement of low resistance by Kelvin's double bridge

Apparatus Used: Power Supply, Resistance Box, DPIC etc.

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. Fig.1. shows the schematic diagram of kelvin bridge. The first ratio arms is P and Q. The second set of ratio arms p and q is used to connect the galvanometer to a point d at the appropiate 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, $E_{ab}=E_{amd}$

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

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

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 of connecting lead, r, has no effect on the measurement, provided that the two sets of ratio arms have equal ratios.

Circuit Diagram:

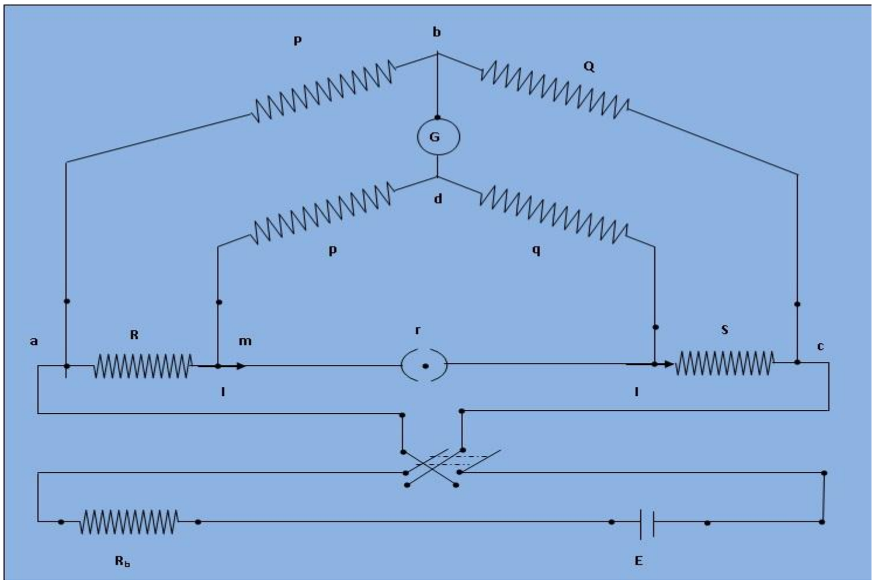

Fig. 1. The circuit diagram of Kelvin Double Bridge.

Procedure:

1. Connect the circuit as shown in the Fig. 1.
2. Set the value of the resistances A and a at 1000Ω by setting the plugs at the marked positions and the values of B, b at 1000Ω by setting the dial. Open the Key K. The bridge will act as a wheatstone bridge. A null deflection Galvanometer will ensure the relationship $\frac{A}{a}=\frac{B}{b}$.
3. Close the key K. Adjust the rheostat to obtain 2A current in the circuit.
4. Keeping the resistances A, a at 1000Ω, very B, b to obtain the Galvanometer null. Note the value B, b at balance position from the dial.
5. Reverse the direction of current by operating the two-way switch 's' and obtain the balance.
6. Set the values of A, a at 1 Ω and 1000Ω position and repeat step 5 and step 4.
7. Repeat step 5 through step 6 for different line currents 3A, 4A and 5A.

Result: We have performed the Kelvin's double bridge and measured precision of four-terminal low resistances.

Experiment No. 9

Aim: Measurement of voltage, current and resistance using dc potentiometer

Apparatus Used:

S. No.	Apparatus Name	Quantity
1	Adjustable DC Power Supply	1
2	Digital Multimeter	1
3	10 kΩ potentiometer	1
4	100 kΩ potentiometer	1

Theory: A potentiometer is a three terminal resistive device. The outer terminals present a constant resistance which is the nominal value of the device. A third terminal, called the wiper arm, is in essence a contact point that can be moved along the resistance. Thus, the resistance seen from one outer terminal to the wiper plus the resistance from the wiper to the other outer terminal will always equal the nominal resistance of the device. This three terminal configuration is used typically to adjust voltage via the voltage divider rule, hence the name potentiometer, or *pot* for short. While the resistance change is often linear with rotation (i.e., rotating the shaft 50% yields 50% resistance), other schemes, called *tapers*, are also found. One common non-linear taper is the logarithmic taper. It is important to note that linearity can be compromised (sometimes on purpose) if the resistance loading the potentiometer is not significantly larger in value than the potentiometer itself.

If only a single outer terminal and the wiper are used, the device is merely an adjustable resistor and is referred to as a rheostat. These may be placed in-line with a load to control the load current, the greater the resistance, the smaller the current.

Circuit Diagram:

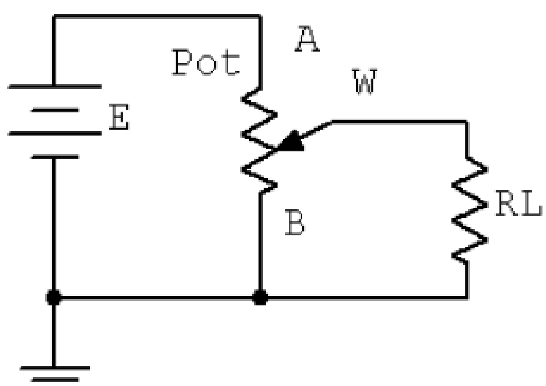

Figure 1

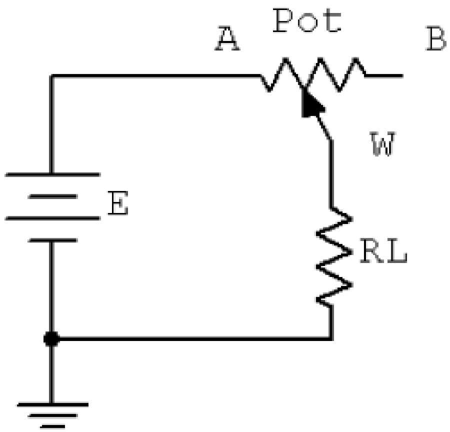

Figure 2

Procedure:

1. Using a 10 k pot, first rotate the knob fully counter-clockwise and using the DMM, measure the resistance from terminal A to the wiper arm, W. Then measure the value from the wiper arm to terminal B. Record these values in Table 1. Add the two readings, placing the result in the final column.
2. Rotate the knob 1/4 turn clockwise and repeat the measurements of step 1. Repeat this process for the remaining knob positions in Table 1. Note that the results of the final column should all equal the nominal value of the potentiometer.
3. Construct the circuit of Figure 2 using E = 10 volts, a 10 k potentiometer and leave RL open. Rotate the knob fully counter-clockwise and measure the voltage from the wiper to ground. Record this value in Table 2. Continue taking and recording voltages as the knob is rotated to the other four positions in Table 2.
4. Set RL to 47 k and repeat step 3.
5. Set RL to 4.7 k and repeat step 3.
6. Set RL to 1 k and repeat step 3.
7. Using a linear grid, plot the voltages of Table 2 versus position. Note that there will be four curves created, one for each load, but place them on a single graph. Note how the variance of the load affects the linearity and control of the voltage.
8. Construct the circuit of Figure 3 using E = 10 volts, a 100 k potentiometer and RL = 1 k. Rotate the knob fully counter-clockwise and measure the current through the load. Record this value in Table 3. Repeat this process for the remaining knob positions in Table 3.
9. Replace the load resistor with a 4.7 k and repeat step 8.

Observation Table:

Table 1

Position	RAW	RWB	RAW + RWB
Fully CCW			
1/4			
1/2			
3/4			

Table 2

Position	VWB Open	VWB 47k	VWB 4.7k	VWB 1k
Fully CCW				
1/4				
1/2				
3/4				
Fully CW				

Table 3

Fully CCW	Fully CCW	Fully CCW
Fully CCW		
1/4		
1/2		
3/4		
Fully CW		

Result: We have measured the value of voltage, current and resistance using dc potentiometer.