

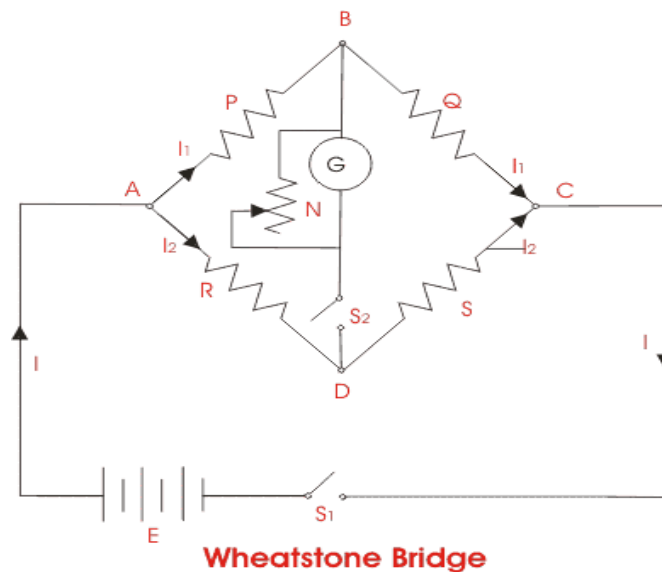
## MODULE - III

### BRIDGES

Medium Resistance measurement:

#### **Wheatstone bridge:**

Wheatstone bridge is widely used to measure electrical resistance accurately. As seen below, a bridge-like connection is made up of two known resistors, one variable resistor, and one unknown resistor. The variable resistor can be adjusted to zero current through the galvanometer. The ratio of two known resistors and the ratio of the adjusted value of variable resistance and the value of unknown resistance are exactly equal when the current through the galvanometer is zero. Using a Wheatstone bridge, the value of an unknown electrical resistance can be readily determined in this manner.



Working:

The figure below depicts the general layout of a Wheatstone bridge circuit. This circuit is a four-arm bridge, with electrical resistances  $P$ ,  $Q$ ,  $S$ , and  $R$  in arms  $AB$ ,  $BC$ ,  $CD$ , and  $AD$ , respectively.

$P$  and  $Q$ , two of these resistances, are known to be fixed electrical resistances; together, these two arms are called ratio arms. Through switch  $S_2$ , a precise and sensitive galvanometer is linked to terminals  $B$  and  $D$ . As indicated, a switch  $S_1$  connects the voltage source of this Wheatstone bridge to terminals  $A$  and  $C$ . Between point  $C$  and point  $D$  is connected a variable resistor  $S$ . By changing the value of the variable resistor, the potential at point  $D$  can be changed. Assume that currents  $I_1$  and  $I_2$  are moving via, respectively, the paths  $ABC$  and  $ADC$ . Since the voltage across  $A$  and  $C$  is fixed, changing the electrical resistance value of arm  $CD$  will also change the value of current  $I_2$ . One scenario where voltage drop across resistor  $S$ , or  $I_2$ , could occur if we keep adjusting the variable resistance.  $S$  becomes precisely equal to  $I_1 \cdot Q$ , the voltage drop across resistor  $Q$ . As a result, the potential difference between these two points is zero, meaning that the current flowing through the galvanometer is zero and the potential at point  $B$  equals the potential at point  $D$ . When the switch  $S_2$  is closed, the galvanometer's deflection is zero.

Now, from the circuit of Wheatstone Bridge

$$\text{current } I_1 = \frac{V}{P + Q}$$

and

$$\text{current } I_2 = \frac{V}{R + S}$$

The voltage drop across the resistor  $Q$  is the only thing that represents the potential of point  $B$  with

respect to point C.

$$I_1 \cdot Q = \frac{V \cdot Q}{P + Q} \text{-----(i)}$$

Once more, the voltage drop across resistor S is the only thing that determines the potential of point D with respect to point C.

$$I_2 \cdot S = \frac{V \cdot S}{R + S} \text{-----(ii)}$$

When we solve equations (i) and (ii), we obtain,

$$\begin{aligned} \frac{V \cdot Q}{P + Q} &= \frac{V \cdot S}{R + S} \Rightarrow \frac{Q}{P + Q} = \frac{S}{R + S} \\ \Rightarrow \frac{P + Q}{Q} &= \frac{R + S}{S} \Rightarrow \frac{P}{Q} + 1 = \frac{R}{S} + 1 \Rightarrow \frac{P}{Q} = \frac{R}{S} \\ \Rightarrow R &= S \times \frac{P}{Q} \end{aligned}$$

Since the values of S and P/Q in the equation above are known, figuring out the value of R is simple.

Ratio arms and S, the electrical resistances P and Q of the Wheatstone bridge, are composed of specific ratios like 1:1, 10:1, or 100:1. One can continuously adjust the rheostat arm between 1 and 1,000  $\Omega$  or between 1 and 10,000  $\Omega$ .

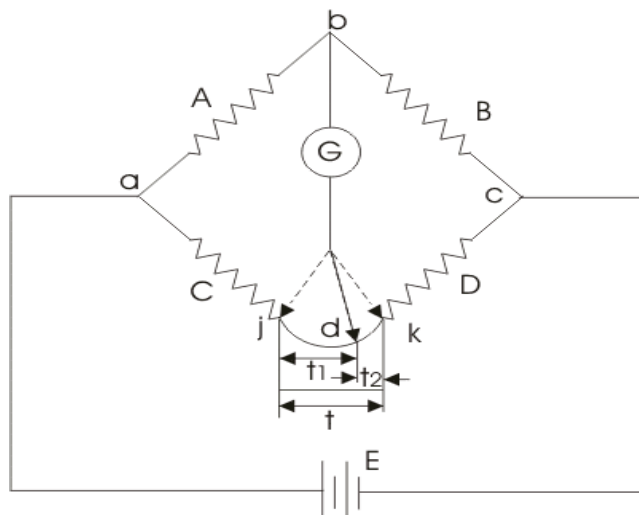
**Kelvin Bridge:**

High accuracy is offered by the Kelvin Bridge, a modified Wheatstone bridge. The question that now needs to be asking itself is: Where do we need the modifications? The simple answer to this is that there is an increase in net resistance because of the parts of the leads and contacts that need to be modified.

Let's examine the modified circuit for the Kelvin or Wheatstone bridges shown below: Here, t represents the lead's resistance.

The resistance that is unknown is C.

The standard resistance, or D, has a known value.



Now let's mark points j and k. The resistance t is added to D when the galvanometer is connected to the j point, resulting in an excessively low value of C. Now that the galvanometer is connected to the k point, the resistance C, which is unknown, will be high.

As we can see from the above figure, if we connect the galvanometer to point d, which is located

between j and k and divides t into the ratios t1 and t2, there will be no error.

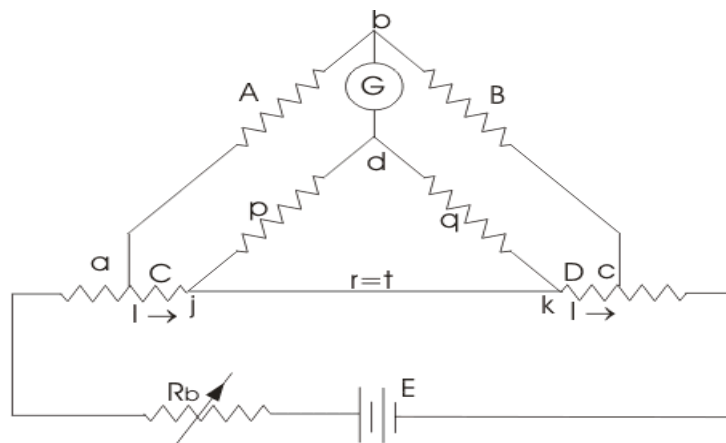
Low resistance measurement:

### Kelvin Double Bridge:

The second set of ratio arms is incorporated, as indicated below:

To counteract the effect of the connecting lead of electrical resistance  $t$ , the galvanometer is connected at the proper point between j and k using the ratio arms  $p$  and  $q$ . Voltage drop between a and b, or  $E$ , is equal to  $F$  (voltage drop between a and c) under the balance condition.

$E = F$  for a zero galvanometer deflection. We arrive at the same conclusion once more:  $t$  is ineffective. Equation (2), however, is helpful since it provides error when:



$$\text{or } \frac{A}{A+B} \times I \left( C + D + \frac{p+q}{p+q+t} \times t \right) = I \times \left( C + \frac{p}{p+q+t} \times t \right)$$

$$\Rightarrow C = \frac{A}{B} \times D + \frac{q}{p+q+t} \left( \frac{P}{Q} - \frac{p}{q} \right) \dots \dots \dots (2)$$

$$\text{If } \frac{A}{B} = \frac{p}{q} \text{ then } C = \frac{A}{B} \times D$$

High resistance measurement:

### Direct Deflection Method:

The HighResistanceMeasurement using the DirectDeflectionMethod is a technique employed to measure the electrical resistance of high-resistance components or materials. This method is particularly useful when dealing with resistances that are beyond the range of typical ohmmeters. Here's a simplified explanation of the Direct Deflection Method:

Components:

Voltage Source:

A stable and known voltage source is connected to the resistor under test.

Amplifier:

An amplifier is utilized to amplify the small current passing through the high-resistance element.

Sensitive Galvanometer:

A sensitive galvanometer, with a high resistance, is connected in parallel to the resistor being measured. The galvanometer provides a direct deflection proportional to the current passing through it.

Calibrated Scale:

The galvanometer is associated with a calibrated scale, allowing the user to read the deflection in terms of resistance.

Operation:

Application of Voltage:

The known voltage is applied across the high-resistance component.

Current Flow:

Due to the applied voltage, a smallcurrent flowsthrough the high-resistancematerial.

Galvanometer Deflection:

The current passing through the resistor causes a deflection in the sensitive galvanometer. Thedeflection isproportional to theresistance of thehigh-resistance component.

Calibration:

The scale associated with the galvanometer is calibrated so that the deflection can be directly read as resistance.

Reading:

The user reads the calibrated scale to determine the resistance of the high-resistance element.

Advantages:

Suitability for High Resistances:

This method is particularly useful for measuring resistances that are beyond the measurement range of standard ohmmeters.

Direct Deflection:

The deflection of the galvanometer provides a direct indication of the resistance, simplifying the measurement process.

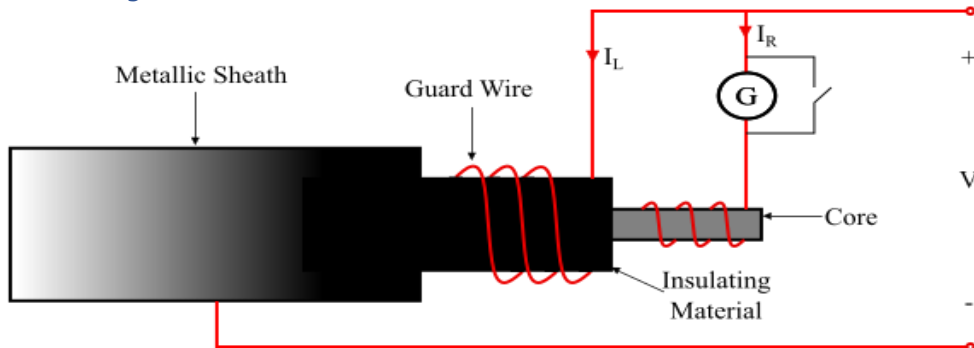
Limitations:

Sensitivity:

The accuracy of this method depends on the sensitivity of the galvanometer and the stability of the voltage source.

Time-Consuming:

Compared to modern electronic methods, the Direct Deflection Method may be relatively time-consuming.

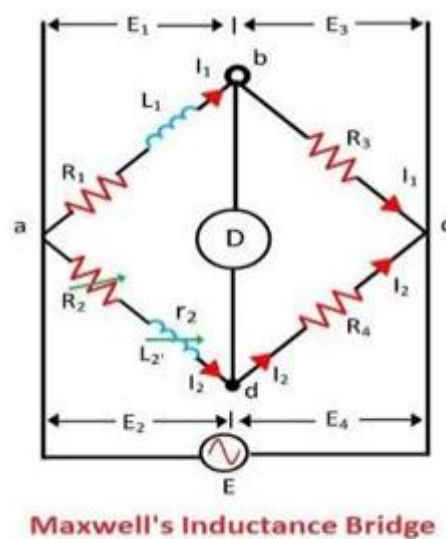


As seen in the figure, the current  $I_R$  between the conductor core and the metal sheath is measured by the galvanometer (G). The guard wire wound on the insulation carries the leakage current ( $I_L$ ) over the insulating material's surface; the  $I_L$  does not pass through the galvanometer. Consequently,  $R = V/I_R$  represents the cable's resistance.

Measurement of inductance:

### Maxwell's Bridge:

**Definition:** The Maxwell bridge is the type of bridge used to measure the circuit's self-inductance. This is the wheatstone bridge in its enhanced form. The Maxwell bridge operates on the comparison principle, which states that an unknown inductance's value can be ascertained by comparing it to a known or standard value. By comparing the unknown resistance in these kinds of bridges to the known value of the standard self-inductance, the resistance's value can be ascertained. The figure below displays the connection diagram for the balancing Maxwell bridge.



Let  $L_1$  be the resistance's unknown inductance.  $R_1$ .  $L_2$ : Variable resistance with fixed inductance  $r_1$ .

Inductor  $L_2$  is connected in series with variable resistance  $R_2$ . The non-inductance resistance is known as  $R_3$ ,  $R_4$ .

$$L_1 = \frac{R_3}{R_4} L_2$$

At balance,

$$R_1 = \frac{R_3}{R_4} (R_2 + r_2)$$

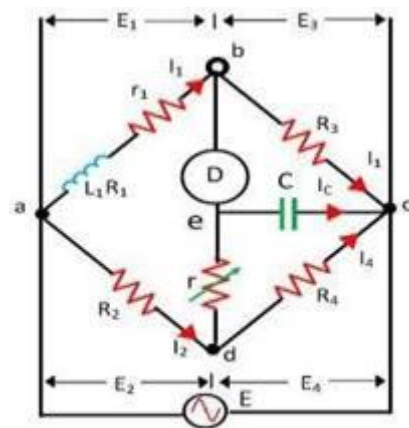
With the aid of the resistance box, the resistance values of the  $R_3$  and  $R_4$  range from 10 to 1000 ohms. Sometimes more resistance is added to the circuit in order to balance the bridge.

### Anderson's Bridge:

**Definition:** The circuit's self-inductance can be accurately measured using the Anderson's bridge. The bridge is an improved version of the inductance-capacitance bridge developed by Maxwell. The standard fixed capacitance that connects the two arms of the Anderson bridge is compared to the unknown inductance.

#### Constructions of Anderson's Bridge:

There are four arms on the bridge: ab, bc, cd, and ad. The resistance and unknown inductance make up the arm ab. The three remaining arms are made up of purely resistive arms that are linked in series with the circuit. Together with the CD arm, the variable resistor and static capacitor are reconnected in series. The terminals a and c receive the voltage source.



Anderson's Bridge

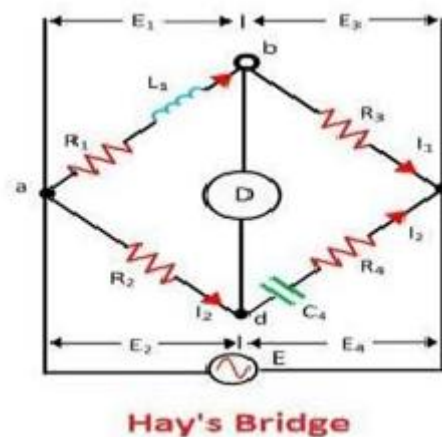
### Hay's Bridge:

**Definition:** In the arm ad, current  $I_2$  is the result of adding current  $I_C$  and  $I_4$ . The points a, d, and e as well as the emf across the arm ab are equal when the bridge is in balance. There will be voltage drops across the arm ab due to the phasor sum of the voltage across the arms ac and de.

#### Construction of Hay's Bridge:

The resistance  $R_1$  and the unidentified inductor  $L_1$  are positioned in arm ab. The standard capacitor  $C_4$ , which is connected across the arm CD, is compared to this unknown inductor. The capacitor  $C_4$  and resistance  $R_4$  are connected in series. The arms ad and bc, respectively, are connected to the remaining two non-inductive resistors,  $R_2$  and  $R_3$ . In order to create a balanced bridge, the  $C_4$  and  $R_4$  are adjusted. No current passes through the detector, which is connected

to points  $b$  and  $c$ , respectively, when the bridge is in a balanced state. Similar to how the potential drops across the arms  $ad$  and  $cd$  are equal, so too are they across the arms  $ab$  and  $bc$ .



Measurement of capacitance:

### Schering Bridge:

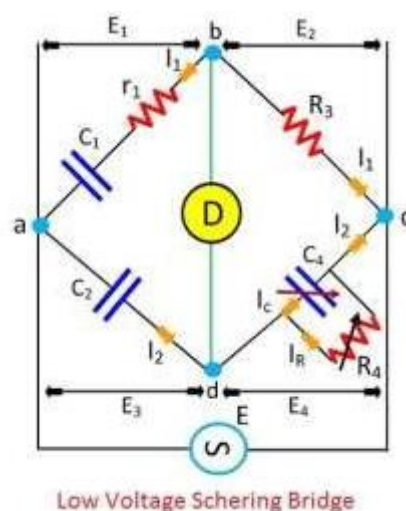
The bridge circuit typically consists of known resistors, capacitors, and an inductor, along with the unknown capacitor (the one being measured) and the unknown resistance (representing the dielectric loss). By adjusting the values of the known components until the bridge is balanced, one can determine the capacitance and dissipation factor (a measure of dielectric loss) of the unknown capacitor.

Let's The capacitor  $C_1$ , whose capacitance needs to be calculated, and the series resistance  $r_1$ , which stands for the capacitor's loss,  $C_1$ .

The capacitor  $C_2$  is a standard capacitor, which implies that it has no loss. A noninductive resistance is  $R_3$ .

A variable capacitor is  $C_4$ .

Parallel to the variable capacitor  $C_4$  is a variable non-inductive resistance,  $R_4$ .



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

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

$$r_1 R_4 - \frac{j R_4}{\omega C_1} = -j \frac{R_3}{\omega C_2} + \frac{R_3 R_4 C_4}{C_2}$$

Zero current flows through the detector when the bridge is in the balanced state, indicating that there is zero potential across the detector. Under equilibrium,  $Z_1/Z_2 = Z_3/Z_4$  and  $Z_1 Z_4 = Z_2 Z_3$ .

$$r_1 = \frac{R_3 C_4}{C_2} \dots \dots \dots equ(1)$$

$$C_1 = C_2 \left( \frac{R_4}{R_3} \right) \dots \dots \dots equ(2)$$

Thus, when comparing real and imaginary equations, equations (1) and (2) are obtained, which are balanced and frequent. A phasor diagram is used to determine the dissipation factor. The rate of energy loss due to vibration in electronic and mechanical instruments is determined by the dissipation factor.

### De sauty's bridge:

If we ignore dielectric losses in the bridge circuit, this bridge gives us the best way to compare the two values of the capacitor. Below is a diagram of De Sauty's bridge.

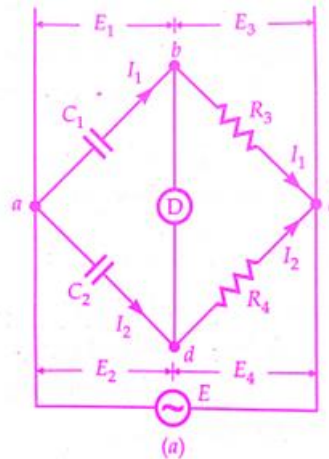
Between terminals 1 and 4, battery is applied. Arms 1-2 and 3-4 are made up of the capacitor  $c_1$ , whose value is unknown, which carries current  $i_1$ , as shown; arm 4-1 is made up of a standard capacitor, the value of which is already known; and arm 2-4 is made up of a pure resistor, which we assume to be non-inductive in nature. Let's find the expression for capacitor  $c_1$  using resistors and a standard capacitor.

It implies that the value of capacitor is given by the expression

$$\frac{1}{j\omega c_1} \times r_4 = \frac{1}{j\omega c_2} \times r_3$$

$$c_1 = c_2 \times \frac{r_4}{r_3}$$

We must change the values of either  $r_3$  or  $r_4$  without affecting any other bridge element in order to determine the balance point. This is the most effective way to compare the two capacitor values if all of the circuit's dielectric losses are disregarded.



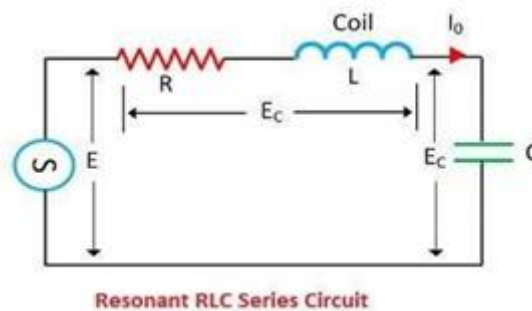
**Definition of Q Meter:** A Qmeter is a type of instrument that measures the electrical circuit's quality factor or storage factor at radio frequencies. One of the oscillatory system's parameters that illustrate the relationship between stored and dissipated energy is the quality factor.

The circuit's quality factor, which displays the total energy dissipated by it, is measured by the Q meter. The characteristics of the coil and capacitor are also explained. In a lab, the Q meter is used to measure the radiofrequency of the coils.

**Working Principle of Q meter:**

The Qmeter is series resonant in operation. When the circuit's capacitance and inductance reactance have equal magnitudes, a state known as resonance occurs. They create an oscillating electric and magnetic field in the inductor and capacitor, respectively.

The resistance, inductance, and capacitance characteristics of the resonant series circuit serve as the foundation for the Q-meter. A coil of resistance, inductance, and capacitance connected in series with the circuit is depicted in the figure below.



At frequency of resonance  $f_0$ ,

Capacitive reactance is equal to inductive reactance.

Capacitance reactance's value is

$$X_c = \frac{1}{2\pi f_0 C} = \frac{1}{\omega_0 C}$$

Inductive reactance at,

$$X_L = \frac{1}{2} \pi f_0 L = \frac{1}{\omega_0 L}$$

When the frequency resonant,

$$f_0 \frac{1}{2\pi\sqrt{LC}}$$

and at resonance, current turns into

$$I_0 = \frac{E}{R}$$