Unit 4 notes

Measurement of Resistances

CLASSIFICATION OF RESISTANCES

For the purposes of measurements, the resistances are classified into three major groups based on their numerical range of values as under:

- Low resistance (0 to 1 ohm)
- Medium resistance (1 to 100 kilo-ohm) and
- High resistance (>100 kilo-ohm)

Accordingly, the resistances can be measured by various ways, depending on their range of values, as under:

1. Low resistance (0 to 1 ohm): AV Method, Kelvin Double Bridge, potentiometer, doctor ohmmeter, etc.

2. Medium resistance (1 to 100 kilo-ohm): AV method, wheat stone's bridge, substitution method, etc.

3. High resistance (>100 kilo-ohm): AV method, Fall of potential method, Megger, loss of charge method, substitution method, bridge method, etc.

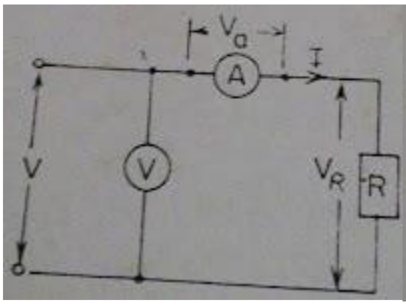
4.1 Measurement of medium resistances

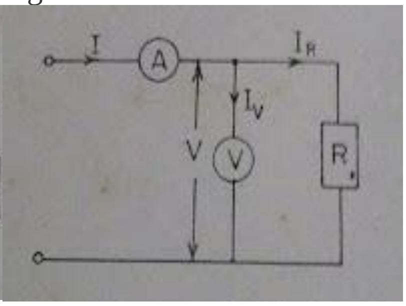
In this section, we will discuss the method of measurement of Medium Resistance. The different methods used for Medium resistance are as follows:

- Ammeter Voltmeter method
- Substitution Method
- Wheatstone Bridge Method
- Ohmmeter Method

4.1.1 Ammeter Voltmeter Method:

There are two possible connections for the measurement of Medium Resistance using Ammeter Voltmeter Method as shown in figure below:



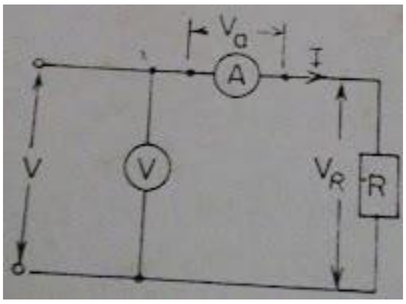


In both the cases, the reading of Voltmeter and Ammeter is taken. If the Voltmeter reading is V and Ammeter reading is I then the measured Resistance will be
Rm = V/I

This measured Resistance Rm will be the true value of the Resistance if and only if the Resistance of Ammeter is zero and that of Voltmeter is infinite. But actually this is not possible to achieve zero resistance Ammeter and infinite Resistance Voltmeter. Therefore measured value of resistance Rm will deviate from the true value R (Say).

So we will discuss both the circuit individually and will calculate the percentage error in the measurement.

Case1:



We consider first kind of connection as shown in figure 1 above. It is clear from the figure that Voltmeter is measuring the Voltage drop across the Ammeter as well as resistor.

So $V = Va + Vr$

Let current measured by Ammeter = I

Therefore, measured Resistance $Rm = V/I$

So, $Rm = (Va+Vr) / I =(IRa+IR) / I = Ra+R$

Therefore, the measured Resistance is the sum of Resistance of Ammeter and true Resistance. Therefore measured value will only represent true value if Ammeter Resistance Ra is Zero.

True value of Resistance $R = Rm – Ra$

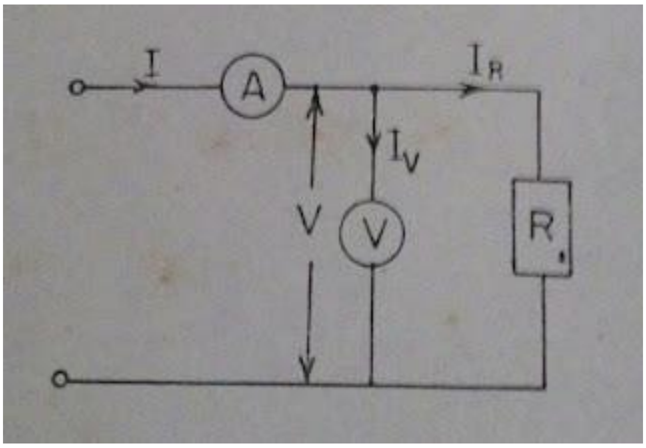
$= Rm(1-Ra/Rm)$

Relative Error $= (Rm-R)/R = Ra/R$

Therefore, Relative Error will be less if the true value of Resistance to be measured is high as compared to the internal Resistance of Ammeter. That’s why this method should be adopted when measuring high Resistance but it should be under Medium Resistance category.

Case2:

We will consider second connection in which Voltmeter is connected in which Voltmeter is connected toward Resistance R whose value is to be measured.



It is obvious from figure that Ammeter will read the current flowing through the Voltmeter and Resistance R. Therefore current measured by Ammeter $Ia = Iv+Ir$

So, $Ia = Iv+Ir$

$= V/Rv+V/R$ where Rv is Resistance of Voltmeter and V is Voltmeter reading.

Measured Resistance $Rm = V/Ia$

$= V/(V/Rv+V/R)$

$= RvR/(R+Rv)$

$= R/(1+R/Rv)$ ….Dividing Numerator and Denominator by Rv

Therefore, true value of Resistance $R = RmRv/(Rv-Rm)$

$= Rm(1-Rm/Rv)$

Therefore, true value of Resistance will only be equal to measured value if the value of Voltmeter Resistance Rv is infinite.

If we assume that the value of Voltmeter Resistance Rv is large as compared to the Resistance to be measured R, then $Rv>>>Rm$

So, True value $R = Rm(1+Rm/Rv)$

Thus from the above equation it is clear that the measured value of Resistance is smaller than the true value.

Relative Error $= (Rm-R)/R$

$= -R/Rv$

Therefore, it is clear from the expression of Relative Error that, error in measurement will be low if the value of Resistance under measurement is very less as compared to the internal Resistance of Voltmeter.

This is the reason; this method is used for the Contact Resistance Measurement. As the value of Contact Resistance is of the order of 20 micro Ohm which is very less as compared to the internal Resistance of Voltmeter.

The Voltmeter Ammeter Method for Cases1 and Case2 are simple method but it is not accurate method. The error in the value of Resistance depends on the accuracy of Ammeter as well as Voltmeter. If the accuracy of both the instrument are supposed 0.5% then when both the instrument read near full scale, the error in measurement of Resistance may vary from 0 to 1% while if both the instrument read near half scale then error may double and so on.

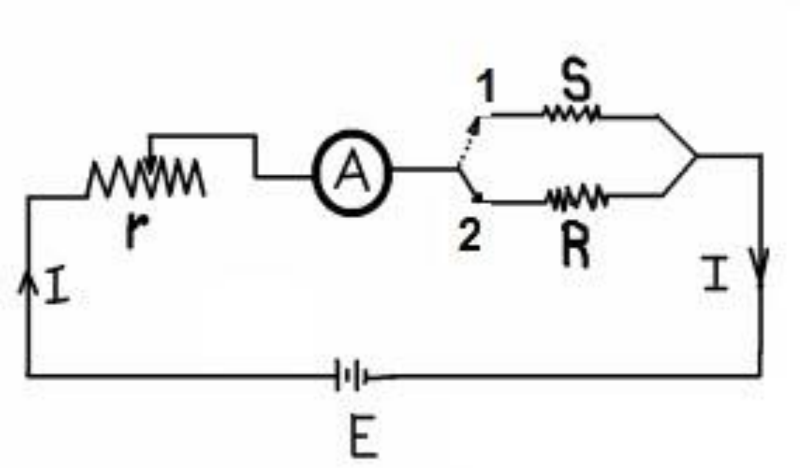
However this method is very useful where high accuracy is not required. The suitability of Case1 or Case2 depends on the value of Resistance to be measured. The division point between the two methods is at the Resistance for which both the method give same Relative Error.

So, $Ra/R = R/Rv$

$R = \sqrt{RaRv}$

4.1.2 Measurement of Medium Resistance by Substitution Method

In Substitution Method, the Resistance whose value is to be measured is compared with the Standard Resistance by some technique which is described in this section. The connection diagram for Substitution Method is given below.



Here, R is the unknown Resistance, S the Standard variable Resistance, A is Ammeter and r is Regulating Resistance.

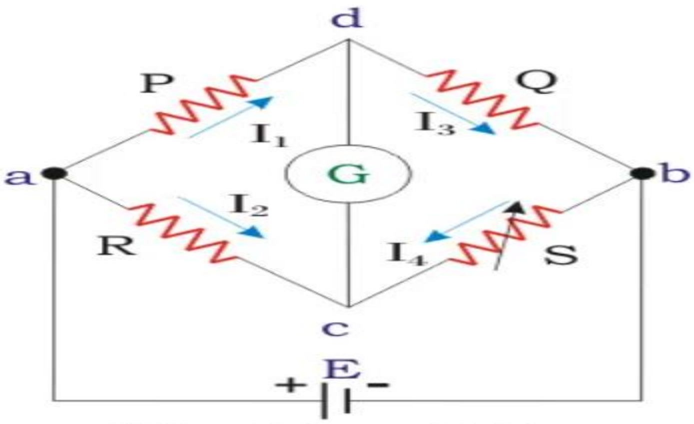
When we put the Switch at position 1 then R is connected in the circuit. The Regulating Resistance r is adjusted till the reading of Ammeter is at a chosen scale mark. Now the Switch is thrown to position 2 putting the Standard variable Resistance S in the circuit. Now the variable Resistor S is adjusted till the reading of Ammeter is same as when R was in the circuit. The setting of dial of S is read. Since the substitution of one resistance for another has left current unaltered, and provided that EMF of battery and position of Regulating Resistance r remain unaltered, the two Resistance R and S must be equal. Thus the value of unknown Resistance R is equal to the dial setting of Standard Resistance S.

This method of measurement is more accurate as compared to the Ammeter Voltmeter Method as in this method measurement is not affected by the accuracy of Ammeter. However, the accuracy of this method is greatly affected if there is any change in the Battery EMF during the time when the reading in two settings is taken. Therefore to avoid the error because of change of EMF of Battery, a Battery of enough capacity is used so that it remains constant during the entire period of testing.

The accuracy of this method also depend on resistance of circuit excluding R and S, upon the sensitivity of instrument and upon the accuracy with which the Standard Resistance S is known. This method is not widely used for simple Resistance measurement and is used in modified form for the measurement of High Resistance. The Substitution Method is however very important as it finds its use in application of bridge method and in high accuracy A.C measurement.

4.1.3 WHEATSTONE BRIDGE

For measuring accurately any electrical resistance Wheatstone bridge is widely used. There are two known resistors, one variable resistor and one unknown resistor connected in bridge form as shown below. By adjusting the variable resistor the current through the Galvanometer is made zero. When the current through the galvanometer becomes zero, the ratio of two known resistors is exactly equal to the ratio of adjusted value of variable resistance and the value of unknown resistance. In this way the value of unknown electrical resistance can easily be measured by using a Wheatstone Bridge. THEORY The general arrangement of Wheatstone bridge circuit is shown in the figure below. It is a four arms bridge circuit where arm AB, BC, CD and AD are consisting of electrical resistances P, Q, S and R respectively. Among these resistances P and Q are known fixed electrical resistances and these two arms are referred as ratio arms. An accurate and sensitive Galvanometer is connected between the terminals B and D through a switch S2. The voltage source of this Wheatstone bridge is connected to the terminals A and C via a switch S1 as shown. A variable resistor S is connected between point C and D.



Wheatstone Bridge

The potential at point D can be varied by adjusting the value of variable resistor. Suppose current I1 and current I2 are flowing through the paths ABC and ADC respectively. If we vary the electrical resistance value of arm CD the value of current I2 will also be varied as the voltage across A and C is fixed. If we continue to adjust the variable resistance one situation may comes when voltage drop across the resistor S that is I2.S is becomes exactly equal to voltage drop across resistor Q that is I1.Q. Thus the potential at point B becomes equal to the potential at point D hence potential difference between these two points is zero hence current through galvanometer is nil. Then the deflection in the galvanometer is nil when the switch S2 is closed.

Now, from Wheatstone bridge circuit

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

And

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

Now potential of point B in respect of point C is nothing but the voltage drop across the resistor Q and this is

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

Again potential of point D in respect of point C is nothing but the voltage drop across the resistor S and this is

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

Equating, equations (i) and (ii) we get,

$$\frac{V.Q}{P+Q}=\frac{V.S}{R+S}\Rightarrow\frac{Q}{P+Q}=\frac{S}{R+S}$$

$$\Rightarrow\frac{P+Q}{Q}=\frac{R+S}{S}\Rightarrow\frac{P}{Q}+1=\frac{R}{S}+1\Rightarrow\frac{P}{Q}=\frac{R}{S}$$

$$\Rightarrow R=SX\frac{P}{Q}$$

Errors in a Wheatstone Bridge

A Wheatstone bridge is a fairly convenient and accurate method for measuring resistance.

However, it is not free from errors as listed below:

1. Discrepancies between the true and marked values of resistances of the three known arms can introduce errors in measurement.

2. Inaccuracy of the balance point due to insufficient sensitivity of the galvanometer may result in false null points.

3. Bridge resistances may change due to self-heating (I 2R) resulting in error in measurement calculations.

4. Thermal emfs generated in the bridge circuit or in the galvanometer in the connection points may lead to error in measurement.

5. Errors may creep into measurement due to resistances of leads and contacts. This effect is however, negligible unless the unknown resistance is of very low value.

6. There may also be personal errors in finding the proper null point, taking readings, or during calculations.

Errors due to inaccuracies in values of standard resistors and insufficient sensitivity of galvanometer can be eliminated by using good quality resistors and galvanometer.

Temperature dependent change of resistance due to self-heating can be minimized by performing the measurement within as short time as possible.

Thermal emfs in the bridge arms may cause serious trouble, particularly while measuring low resistances. Thermal emf in galvanometer circuit may be serious in some cases, so care must be taken to minimize those effects for precision measurements. Some sensitive galvanometers employ all-copper systems (i.e., copper coils as well as copper suspensions), so that there is no junction of dissimilar metals to produce thermal emf. The effect of thermal emf can be balanced out in practice by adding a reversing switch in the circuit between the battery and the bridge, then making the bridge balance for each polarity and averaging the two results.

4.2 MEASUREMENT OF LOW RESISTANCES

The methods used for measurement of medium resistances are not suitable for measurement of low resistances. This is due to the fact that resistances of leads and contacts, though small, are appreciable in comparison to the low resistances under measurement. For example, a contact resistance of 0.001 Ω causes a negligible error when a medium resistance of value say, 100 Ω is being measured, but the same contact resistance would cause an error of 10% while measuring a low resistance of value 0.01 Ω.

Hence special type of construction and techniques need to be used for measurement of low resistances to avoid errors due to leads and contacts. The different methods used for measurement of low range resistances are

(i) Voltmeter-ammeter method,
(ii) Kelvin's double-bridge method, and
(iii) Potentiometer method.

4.2.1 Voltmeter-ammeter method for low resistance measurement:

In principle, the voltmeter-ammeter method for measurement of low resistance is very similar to the one used for measurement of medium resistances, as described in Section 4.1.1 This method, due to its simplicity, is very commonly used for measurement of low resistances when accuracy of the order of 1% is sufficient. The resistance elements, to be used for such measurements, however, need to of special construction. Low resistances are constructed with four terminals as show in figure below.

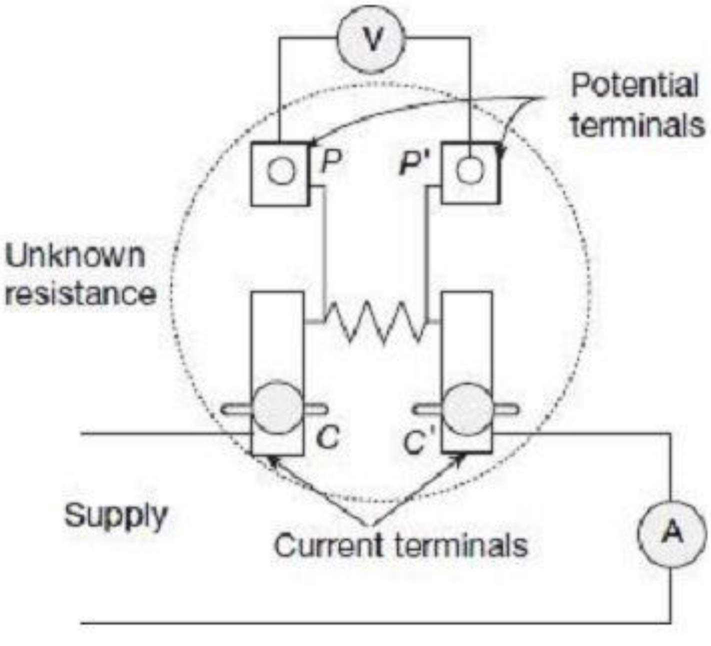


Figure Voltmeter-ammeter method for measuring

One pair of terminals CC', called the current terminals, is used to lead current to and from the resistor. The voltage drop across the resistance is measured between the other pair of terminals PP', called the potential terminals. The voltage indicated by the voltmeter is thus simply the voltage drop of the resistor across the potential terminals PP' and does not include any contact resistance drop that may be present at the current terminals CC’.

Contact drop at the potential terminals PP' are, however, less itself, since the currents passing through these contacts are extremely small (even zero under 'null' balance condition) owing to high resistance involved in the potential circuit. In addition to that, since the potential circuit has a high resistance voltmeter in it, any contact resistance drop in the potential terminals PP' will be negligible with respect to the high resistances involved in the potential Circuit.

Value of the unknown resistance RX in this case is given by Precise measurement in this method requires that the voltmeter resistance to be appreciably high, otherwise the voltmeter current will be an appreciable fraction of the current actually flowing through the ammeter, and a serious error may be introduced in this account.

4.2.2 Kelvin's Double-Bridge Method for Measuring Low Resistance:

Kelvin's double-bridge method is one of the best available methods for measurement of low resistances. It is actually a modification of the Wheatstone bridge in which the errors due to contacts and lead resistances can be eliminated. The connections of the bridge are shown in Figure.

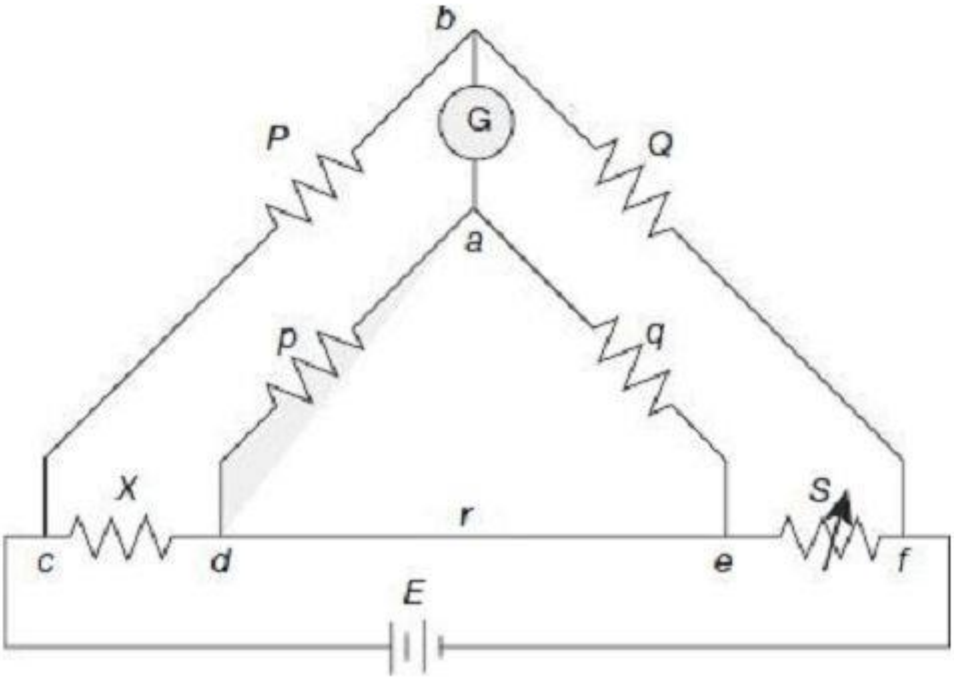


Figure Kelvin' s double bridge Kelvin's double bridge

incorporates the idea of a second set of ratio arms, namely, p and q, and hence the name 'double bridge'.

X is the unknown low resistance to be measured, and S is a known value standard low resistance. 'r' is a very low resistance connecting lead used connect the unknown resistance X to the standard resistance S. All other resistances P, Q, p, and q are of medium range. Balance in the bridge is achieved by adjusting S.

Under balanced condition, potentials at the nodes a and b must be equal in order that the galvanometer G gives "null" deflection. Since at balance, no current flows through the galvanometer, it can be considered to be open circuited and the circuit can be represented as shown in Figure below.

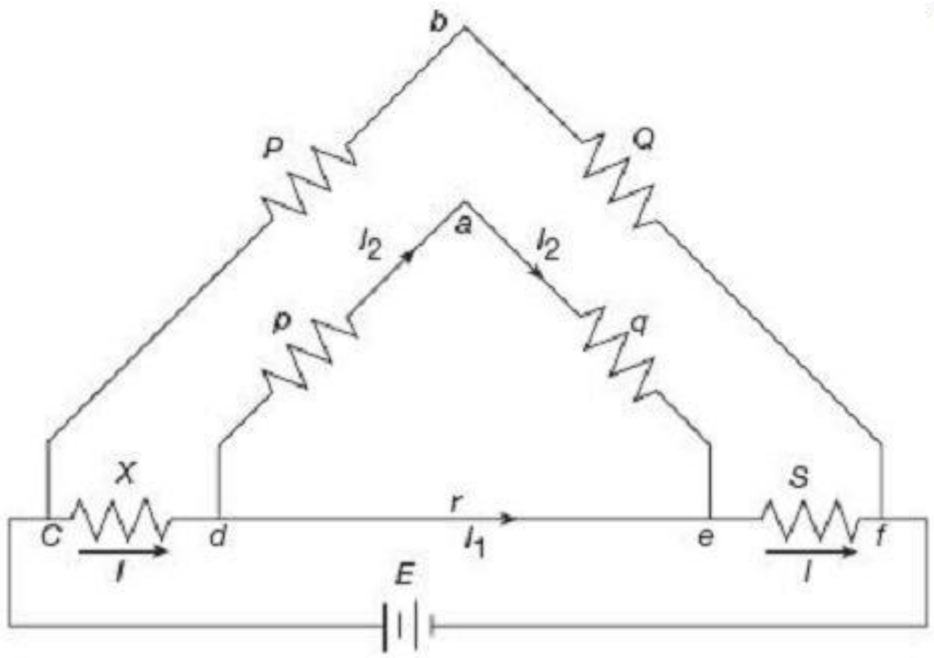


FIG. 12 Kelvin' s double-bridge under balanced condition

Since under balanced condition, potentials at the nodes a and b are equal, the we must have ... the balance equation Vcb = Vcda can now be re-written as.

4.2.3 Potentiometer Method for Measuring Low Resistance

The circuit for measurement of low value resistance with a potentiometer is shown in Figure below.

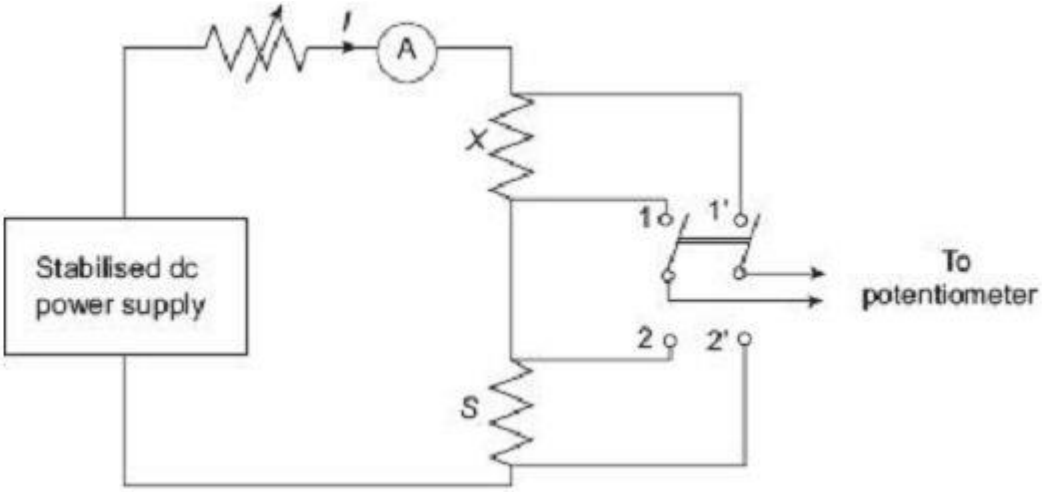


Figure Measurement of low resistance using potentiometer

The unknown resistance X is connected in series with a standard known resistance S.

Current through the ammeter in the circuit is controlled by a rheostat. A two-pole double throw switch is used. When the switch is in the position 1-1', the unknown resistance X gets connected to the potentiometer, whereas when the switch is at position 2-2', the standard resistance S gets connected to the potentiometer.

Potentiometers are believed to give reasonably accurate values of potentials.

Thus, with the switch in position 1-1', the potentiometer reading is the voltage drop across the unknown resistance, given by Without changing any of the circuit parameters, now if the switch is thrown to position 2-2', potentiometer now reads the voltage drop across the standard resistance, given by From Eqs (21) and (22), we get Knowledge of accurate value of the standard resistance S can thus give reasonably accurate values of the unknown resistance X.

Accuracy of this method however, depends on the assumption that the value of current remains absolutely constant during the two sets of measurements. Therefore, an extremely stabilized dc power supply is required in this method.

Value of the standard resistor S should be of the same order as the unknown resistance X. The ammeter inserted in the circuit has no other function rather than simply indicating whether there is any current is flowing in the circuit is not. Exact value of the current is not required for final calculations. It is however, desired that the current flowing through the circuit be so adjusted that the voltage drop across each resistor is of the order of 1 V to be suitable for accurate measurement by commercially available potentiometers.

4.3 MEASUREMENT OF HIGH RESISTANCES

High resistances of the order of several hundreds and thousands of megohms (MW) are often encountered in electrical equipment's in the form of insulation resistance of machines and cables, leakage resistance of capacitors, volume and surface resistivity of different insulation materials and structures.

4.1 Difficulties in Measurement of High Resistance

1. Since the resistance under measurement has very high value, very small currents are encountered in the measurement circuit. Adequate precautions and care need to be taken to measure such low value currents.

2. Surface leakage is the main difficulty encountered while measurement of high resistances. The resistivity of the resistance under measurement may be high enough to impede flow of current through it, but due to moisture, dust, etc., the surface of the resistor may provide a lower resistance path for the current to pass between the two measuring electrodes. In other words, there may thus be a leakage through the surface. Leakage paths not only pollute the test results, but also are generally variable from day to day, depending on temperature and humidity conditions.

The effect of leakage paths on measurements can be eliminated by the use of guard circuits as described by Figure.

Figure (a) shows a high resistance RX being mounted on a piece of insulation block. A battery along with a voltmeter and a micro-ammeter are used to measure the resistance by voltmeter-ammeter method. The resistance RX under measurement is fitted on the insulating block at the two binding posts A and B. IX is the actual current flowing through the high resistance and IL is the surface leakage current flowing over the body of the insulating block. The micro-ammeter, in this case, thus reads the actual current through the resistor, and also the leakage current (I = IX + IL.).

Measured value of the resistance, thus computed from the ratio E/I, will not be the true value of RX, but will involve some error. To avoid this error, a guard arrangement has been added in FIG. 14(b). The guard arrangement, at one end is connected to the battery side of the micro-ammeter, and the other end is wrapped over the insulating body and surrounds the resistance terminal A. The surface leakage current now, flows through this guard and bypasses the micro-ammeter. The micro-ammeter thus reads the true of current IX through the resistance RX. This arrangement thus allows correct determination of the resistance value from the readings of voltmeter and micro-ammeter.

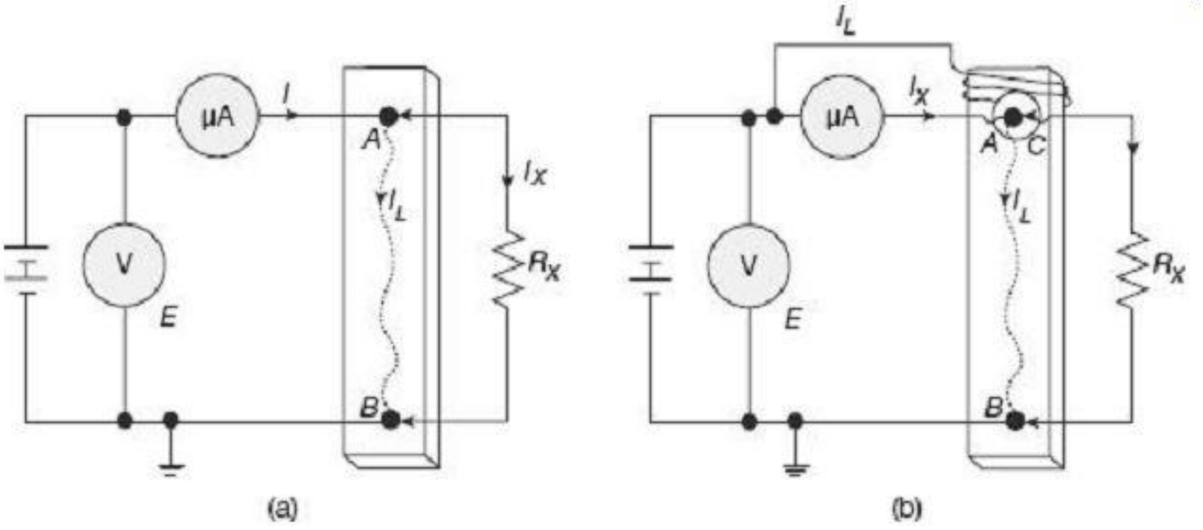


Figure Guard circuit for measurement of high resistance: (a) Circuit without guard (b) Circuit with guard

3. Due to electrostatic effects, stray charges may be induced in the measuring circuit.

Flow of these stray charges can constitute a current that can be comparable in magnitude with the low value current under measurement in high resistance circuits.

This may thus, cause errors in measurement. External alternating electromagnetic fields can also affect the measurement considerably. Therefore, the measuring circuit needs to be carefully screened to protect it against such external electrostatic or electromagnetic effects.

4. While measuring insulation resistance, the test object often has considerable amount of capacitance as well. On switching on the dc power supply, a large charging current may flow initially through the circuit, which gradually decays down. This initial transient current may introduce errors in measurement unless considerable time is provided between application of the voltage supply and reading the measurement, so that the charging current gets sufficient time to die down.

5. High resistance measurement results are also affected by changes in temperature, humidity and applied voltage inaccuracies.

6. Reasonably high voltages are used for measurement of high resistances in order to raise the current to substantial values in order to be measured, which are otherwise extremely low. So,

the associated sensitive galvanometers and micro-ammeters need to be adequately protected against such high voltages.

Taking these factors into account, the most well-known methods of high resistance measurements are (i) direct deflection method, (ii) loss of charge method, and (iii) megohmmeter or meggar.

4.3.2 Direct Deflection Method for High Resistance Measurement

The direct deflection method for measuring high resistances is based on the circuit described in Figure, which in effect is the voltmeter-ammeter method. For measurement of high resistances, a sensitive galvanometer is used instead of a micro ammeter as shown in Figure. A schematic diagram for describing the direct deflection method for measurement of insulation resistance of a metal sheathed cable is given in Figure.

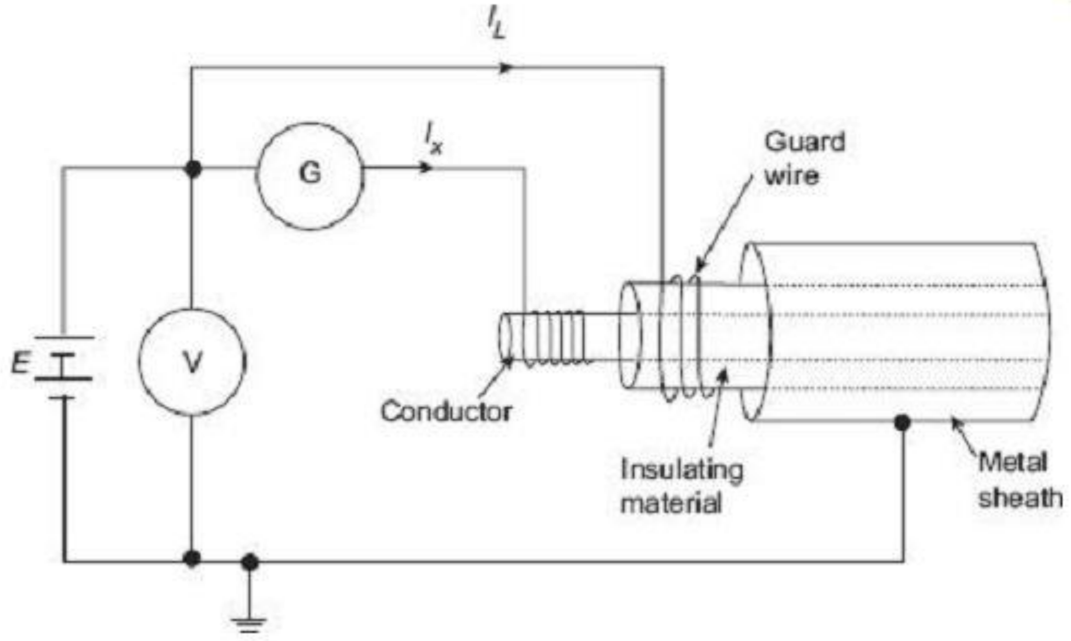


Figure: Measurement of cable insulation resistance

The test specimen, cable in this case, is connected across a high voltage stable dc source; one end of the source being connected to the inner conductor of the cable, and the other end, to the outer metal sheath of the cable. The galvanometer G, connected in series as shown in FIG. 15, is intended to measure the current IX flowing through the volume of the insulation between the central conductor and the outer metal sheath. Any leakage current IL flowing over the surface of the insulating material is bypassed through a guard wire wound on the insulation, and therefore does not flow through the galvanometer.

A more detailed scheme for measurement of insulation resistance of a specimen sheet of solid insulation is shown in Figure.

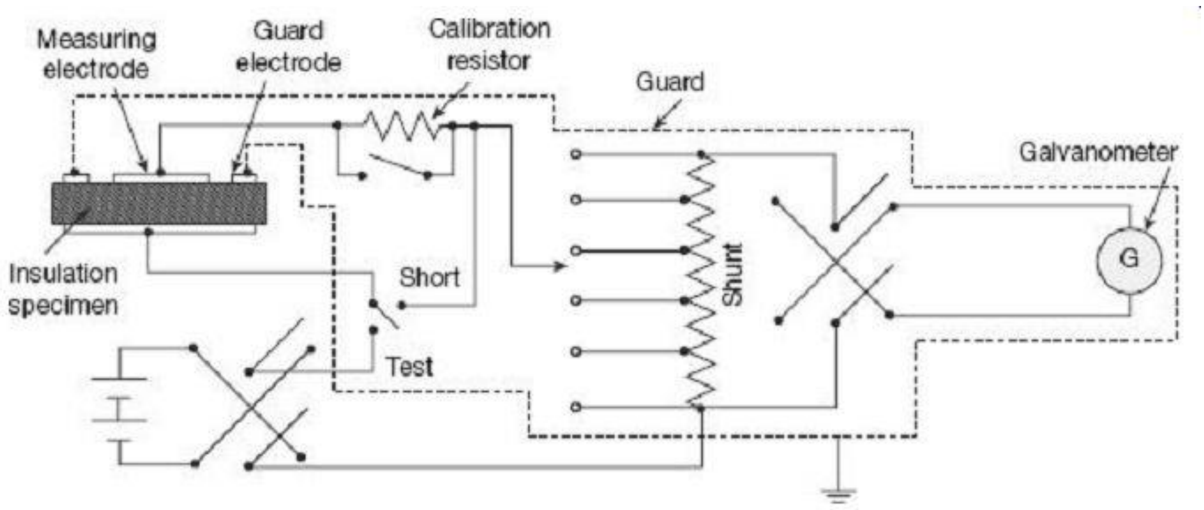


Figure: Measurement of high resistance by direct deflection method

A metal disk covering almost the entire surface is used as electrode on one side of the insulation sheet under measurement. On the other side of the insulating sheet, the second electrode is made of a smaller size disk. A guard ring is placed around the second electrode with a small spacing in between them. This guarding arrangement bypasses any surface leakage current on the insulator or any other parts of the circuit from entering the actual measuring circuit. The galvanometer thus reads specifically the volume resistance of the insulation specimen, independent of any surface leakage.

A calibrated Ayrton shunt is usually included along with the galvanometer to provide various scale ranges and also to protect it.

The galvanometer scale is graduated directly in terms of resistance. After one set of measurement is over, the galvanometer is calibrated with the help of a high value (˜ 1 MΩ) calibrating resistor and the shunts.

In case the insulation under measurement has high inherent capacitance values (like in a cable), there will be an initial inrush of high capacitive charging current when the dc source is first switched on. This charging current will, however, decay down to a steady dc value with time. To protect the galvanometer from such initial rush of high current, the Ayrton shunt connected across the galvanometer should be placed at the highest resistance position . Thus, initially the galvanometer is bypassed from the high charging current.

After the test is complete, it is required that the test specimen should be discharged, especially if it is of capacitive in nature. The 'test-short' switch is placed in the 'short' position so that any charge remaining in the insulation specimen is discharged through the short circuited path.

The change-over switch across the battery enables tests at different polarities. The switch across the galvanometer enables reversal of the galvanometer connections.

A special technique, Price's guard-wire method is employed for measurement of insulation resistance of cables which do not have metal sheath outside. The schematic diagram of such a measurement system is provided in Figure.

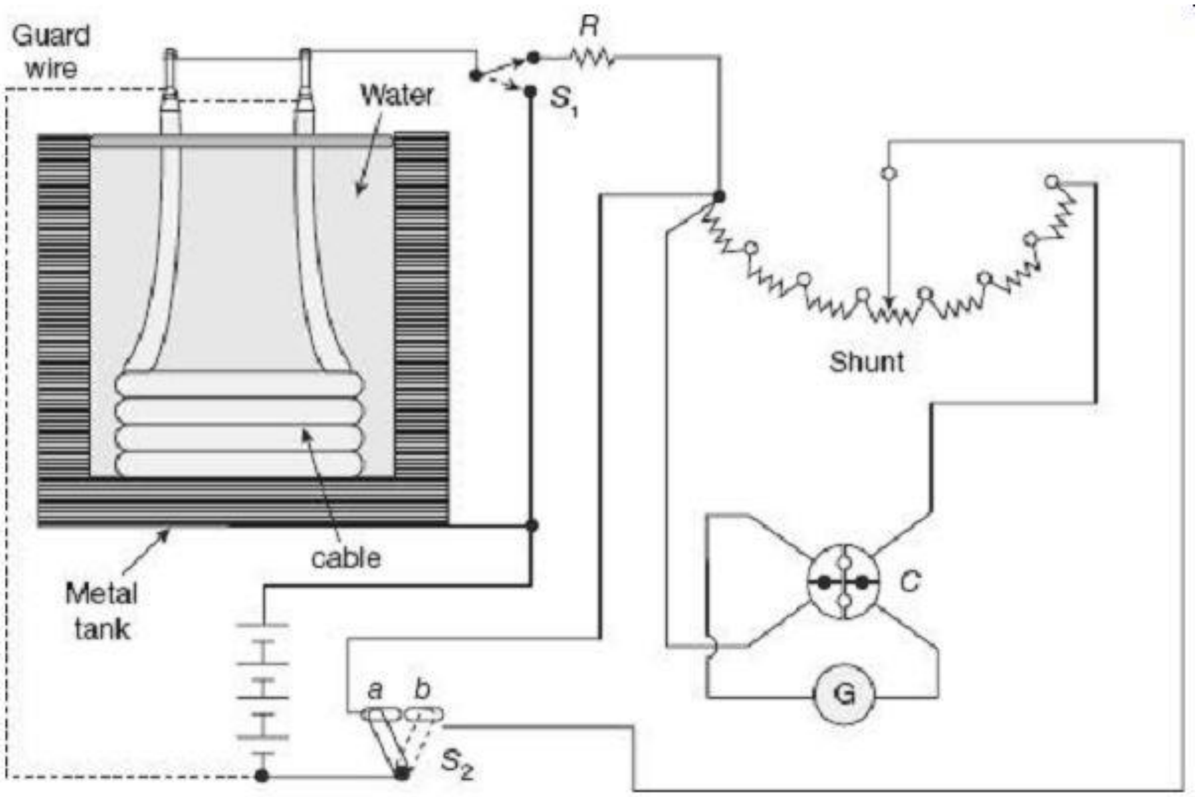


Figure: Measurement of high resistance by Price' s guard-wire method.

The unsheathed cable, except at the two ends where connections are made, is immersed in water in a tank. For testing of the cable insulation, the cable core conductor acts as one electrode and in the absence of the metal sheath outside, the water and the tank act as the other electrode for measurement. The cable is immersed in slightly saline water for about a day and at nearly constant ambient temperature.

The two ends of the cables are trimmed as shown in Figure, thus exposing the core conductor as well as some portion of the insulation. The core conductors are connected together to form one electrode of the measuring system. A guard circuit is formed by twisting a bare wire around the exposed portion of the insulation at the two stripped ends of the cable. This guard wire is connected to the negative terminal of the supply battery.

The positive terminal of the battery is connected to the metal tank. This enables any surface leakage current to bypass the galvanometer and pass directly to the battery. Thus, the galvanometer will read only true value of the current flowing through volume of the insulation, and not the additional surface leakage current.

The D'Arsonval galvanometer to be used is normally of very high resistance and very sensitive to record the normally extremely low insulation currents. An Ayrton universal shunt is usually included along with the galvanometer to provide various scale ranges and also to protect it. The galvanometer scale is graduated directly in terms of resistance. After one set of measurement is over, the galvanometer is calibrated with the help of the high value (˜ 1 MΩ) calibrating resistor R and the shunt. The resistance R and the shunt also serve the purpose of protecting the galvanometer from accidental short circuit current surges. The 4-terminal commutator C, as shown in Figure is used for reversal of galvanometer connections.

Since the cable will invariably have high capacitance value, there will be an initial inrush of high capacitive charging current when the dc source is first switched on. This charging current will, however, decay down to a steady dc value with time. To protect the galvanometer from such initial rush of high current, the switch S2 is placed on position a so that initially the galvanometer is bypassed from the high charging current. Once the capacitor charging period is over and the current settles down, the switch S2 is pushed over to position b to bring the galvanometer back in the measurement circuit. The contacts a and b are sufficiently close enough to prevent the circuit from breaking while the switch S2 is moved over.

After the test is complete, it is required that the test specimen should be discharged. The switch S1 is used for this purpose, so that any charge remaining in the insulation specimen is discharged through itself.

4.3.3 Loss of Charge Method for High Resistance Measurement

In this method, the resistance to be measured is connected directly across a dc voltage source in parallel with a capacitor. The capacitor is charged up to a certain voltage and then discharged through the resistance to be measured. The terminal voltage across the resistance-capacitance parallel combination is recorded for a pre-defined period of time with a help of a high-resistance voltmeter (electrostatic voltmeter or digital electrometers).

Value of the unknown resistance is calculated from the discharge time constant of the circuit. Operation of the loss of charge method can be described by the schematic circuit diagram of Figure.

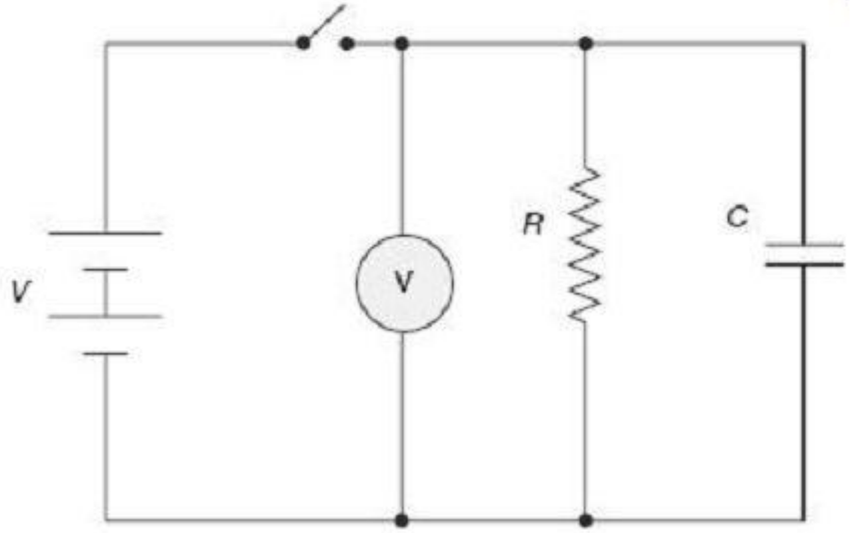


Figure: Loss of charge method for measurement of high resistance

In Above Figure, the unknown resistance R to be measured is connected across the capacitor C and their parallel combination is connected to the dc voltage source.

Let the capacitor is initially charged up to a voltage of V while the switch is kept ON.

Once the switch is turned OFF, the capacitor starts to discharge through the resistance R.

During the discharge process, the voltage v across the capacitor at any instant of time t is given by Thus, the insulation resistance can be calculated as With known value of C and recorded values of t, V and v, the unknown resistance R can be estimated using (24).

The pattern of variation of voltage v with time is shown in Figure.

Capacitor discharge pattern Great care must be taken to record the voltages V and v and also the time t very precisely, otherwise large errors may creep in to the calculation results.

This method, though simple in principle, require careful choice of the capacitor. The capacitor C itself must have sufficiently high value of its own leakage resistance, at least in the same range as the unknown resistance under measurement. The resistance of the voltmeter also needs to be very high to have more accurate results.

4.3.4 Megohmmeter, or Meggar, for High Resistance Measurement

One of the most popular portable type insulation resistance measuring instruments is the megohmmeter or in short, meggar. The meggar is used very commonly for measurement of insulation resistance of electrical machines, insulators, bushings, etc. Internal diagram of a meggar is shown in Figure.

The traditional analog deflecting-type meggar is essentially a permanent magnet crossed-coil shunt type ohmmeter.

The instrument has a small permanent magnet dc generator developing 500 V dc (some other models also have 100 V, 250 V, 1000 or 2500 V generators). The generator is hand driven, through gear arrangements, and through a centrifugally controlled clutch switch which slips at a predefined speed so that a constant voltage can be developed. Some meggars also have rectified ac as power supply.

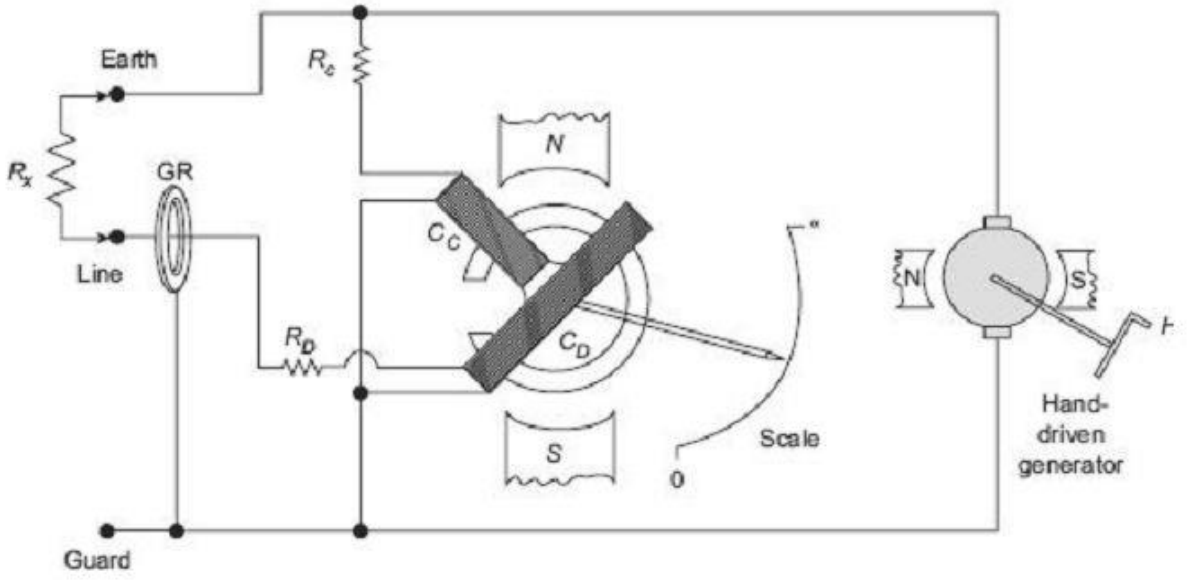
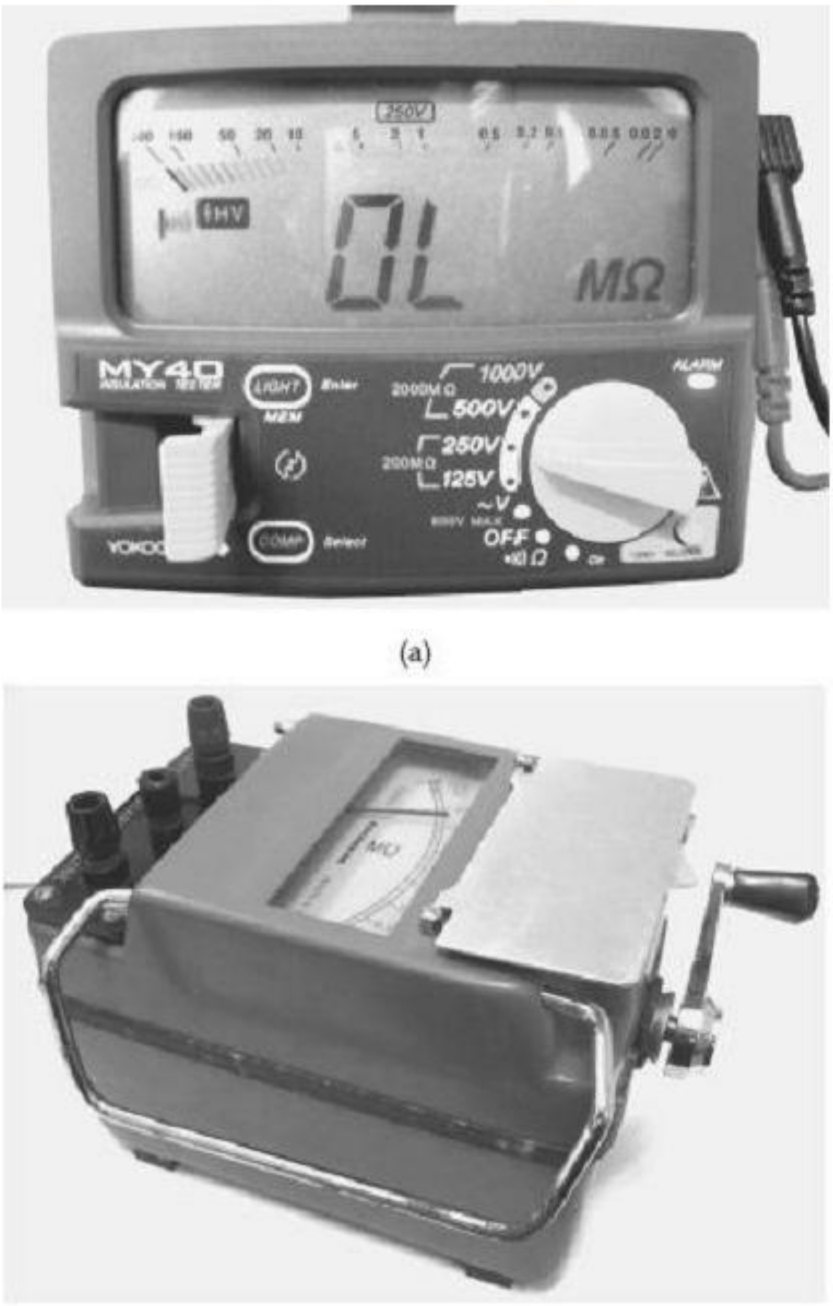


Figure: Meggar for high resistance measurement

The moving system in such instruments consists of two coils, the control coil CC and the deflecting coil CD. Both the coils are mounted rigidly on a shaft that carries the pointer as well. The two coils move in the air gap of a permanent magnet. The two coils are arranged with such numbers of turns, radii of action, and connected across the generator with such polarities that, for external magnetic fields of uniform intensity, the torque produced by the individual coils are in opposition thus giving an astatic combination. The deflecting coil is connected in series with the unknown resistance RX under measurement, a fixed resistor RD and then the generator. The current coil or the compensating coil, along with the fixed resistance RC is connected directly across the generator. For any value of the unknown, the coils and the pointer take up a final steady position such that the torques of the two coils are equal and balanced against each other. For example, when the resistance RX under measurement is removed, i.e., the test terminals are open-circuited, no current flows through the deflecting coil CD, but maximum current will flow through the control coil CC. The control coil CC thus sets itself perpendicular to the magnetic axis with the pointer indicating '8 Ω' as marked in the scale shown in Figure. As the value of RX is brought down from open circuit condition, more and more current flows through the deflecting coil CD, and the pointer moves away from the '8 Ω' mark clockwise on the scale, and ultimately reaches the '0 Ω' mark when the two test terminals are short circuited.

The surface leakage problem is taken care of by the guard-wire arrangement. The guard ring and the guard wire diverts the surface leakage current from reaching the main moving system and interfering with its performance.

Photographs of some commercially available meggars are shown in Figure.



(a)

(b)

Figure: Commercial meggars: (a) Analog type (WACO) (b) Digital type (Yokogawa)