Electrical & Electronic Measuring Instruments

- **Module 2** – CO2 - Summarize appropriate methods for measurement of various electrical quantities

Module 2

Measurement of resistance –Classification of resistance, methods of measurement of resistance - Ammeter-Voltmeter method-Wheatstone bridge (Derivation and circuit needed)

List the types of cable faults -Location of earth fault and short circuit fault in underground cables using Murray loop test.

Measurement of inductance-Maxwell's inductance Bridge(Derivation and circuit needed)

Measurement of capacitance-Schering bridge (no derivation and phasor diagram).

Dynamometer type wattmeter – construction and working.

Single phase Energy meter-Induction type (construction and working).

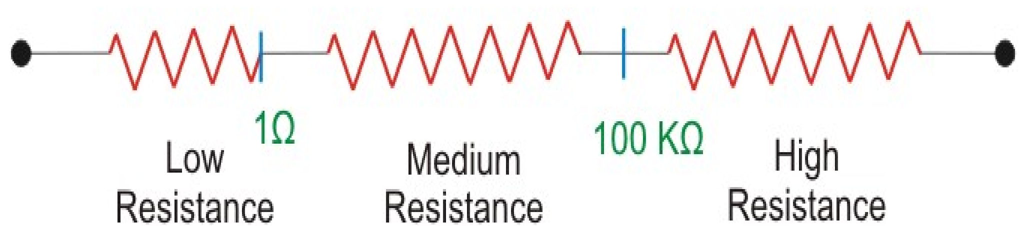
MEASUREMENT OF RESISTANCE, INDUCTANCE&CAPACITANCE

Classification of resistances

Low resistance: Resistance of the order of 1ohm and under.

Medium resistance: 1ohm to 100 Kilo ohm or 0.1Mega ohm.

High resistance: 100 k ohm and above.



- CLASSIFICATION OF RESISTANCE:

(a) Low Resistances -Resistances below the value of 1ohm fall under this category. In fact such values are met in armature dc machine, series windings of large machines, in ammeter, shunts etc.

(b)Medium Resistances: Resistances value which lies between 1 Ω ohm and 100 k Ω comes under this category. Majority of the electrical appliances have resistances within this limits. Shunt field, potentiometer slide wire are the examples.

CLASSIFICATION OF RESISTANCE:

- (c) High Resistances: Resistances beyond the value of 100 k Ω are called high resistances. Eg: Resistance of cable insulation, resistance of insulator disk.

Measurement methods

- Low R ➔ Voltmeter Ammeter method

  Potentiometer method
- Medium R ➔ Wheatstone bridge

  Voltmeter ammeter method
- High R ➔ Megger

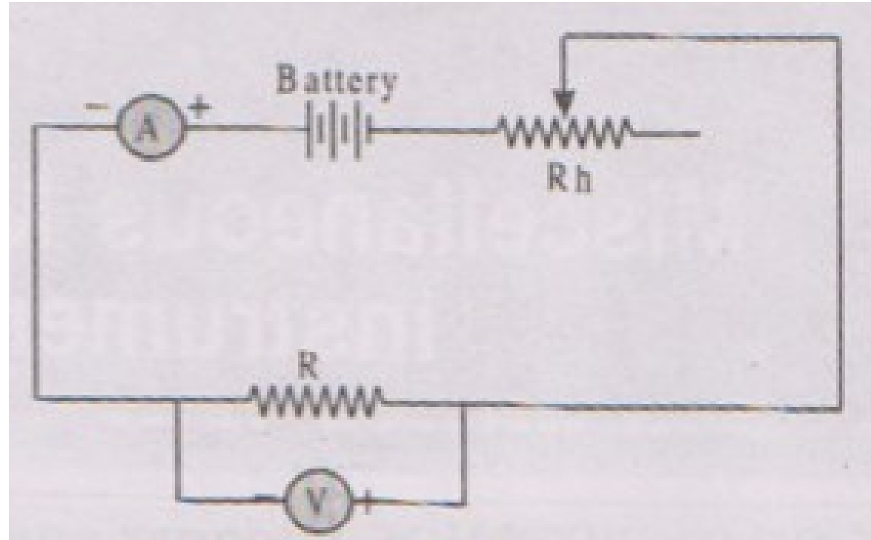
  Loss of charge method

Measurement of Low Resistance (<1Ω) :

- **Ammeter-voltmeter Method**
- **Kelvin's Double Bridge Method**
- **Potentiometer Method**

Ammeter-Voltmeter Method:

- It is the simplest method of measuring electrical resistances by the application of ohm's law.



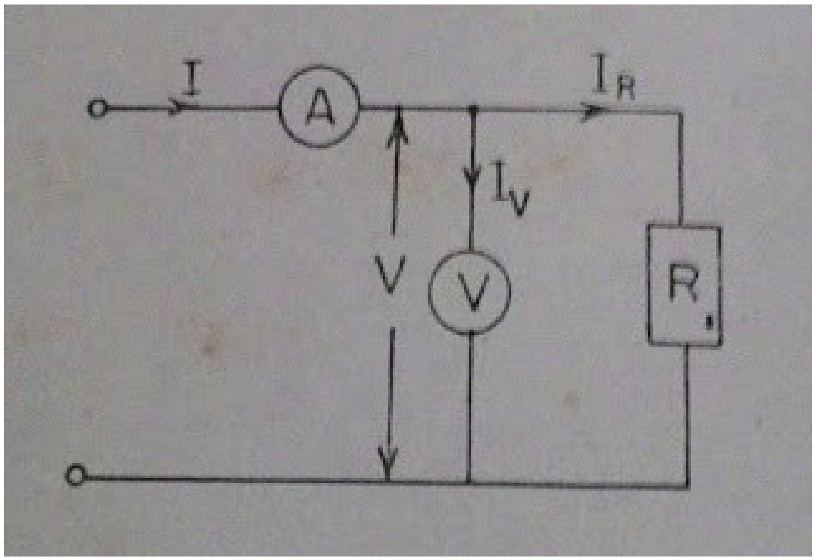
- The value of R, the unknown resistance can be measured by connecting a voltmeter across R and an ammeter in series with it.
- The whole set is connected to a source of supply through a switch and variable resistor Rh.

- A set of readings of voltmeter and ammeter are taken for different values of Rh and the resistance value is calculated by using **Ohms Law i.e., R = V/I**.
- The average of the values is taken into consideration.
- The disadvantages of this method are

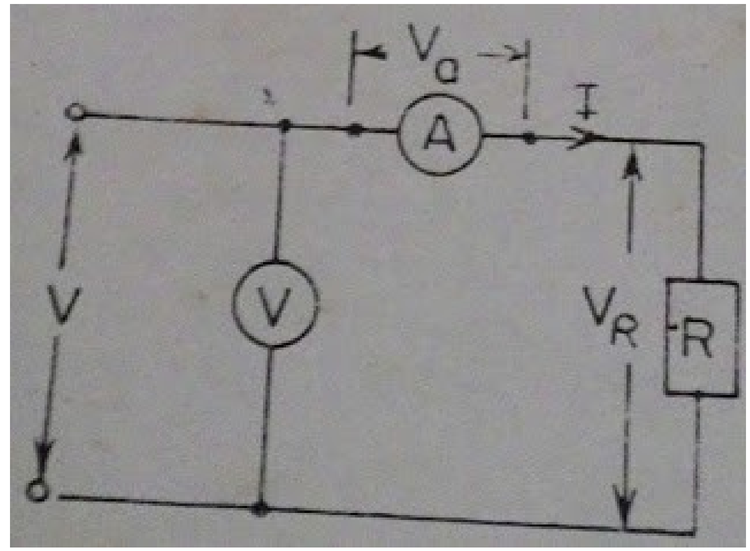
(a) The ammeter reads current of voltmeter which gives a wrong R value, leading to error.

(b) The value of resistance obtained does not correlate to the normal temperature of working of the resistance element.

- There are two possible connections for the measurement of Resistance using Ammeter Voltmeter Method



- The ammeter measures the summation of current flowing through the voltmeter and the unknown resistance R.
- Voltmeter measures correct voltage across R.



- The ammeter measures the true value of current through the resistance
- The voltmeter measures the sum of voltage drops across the ammeter and the unknown resistance R.

Measurement of Medium Resistance (1Ω to 100kΩ) :

- **Ammeter-voltmeter Method**
- **Substitution Method**
- **Wheatstone Bridge Method**
- **Ohmmeter Method**

WHEATSTONE BRIDGE

- The Wheatstone bridge is widely used for precision measurement of medium resistance.
- The Wheatstone bridge works on the principle of null deflection.

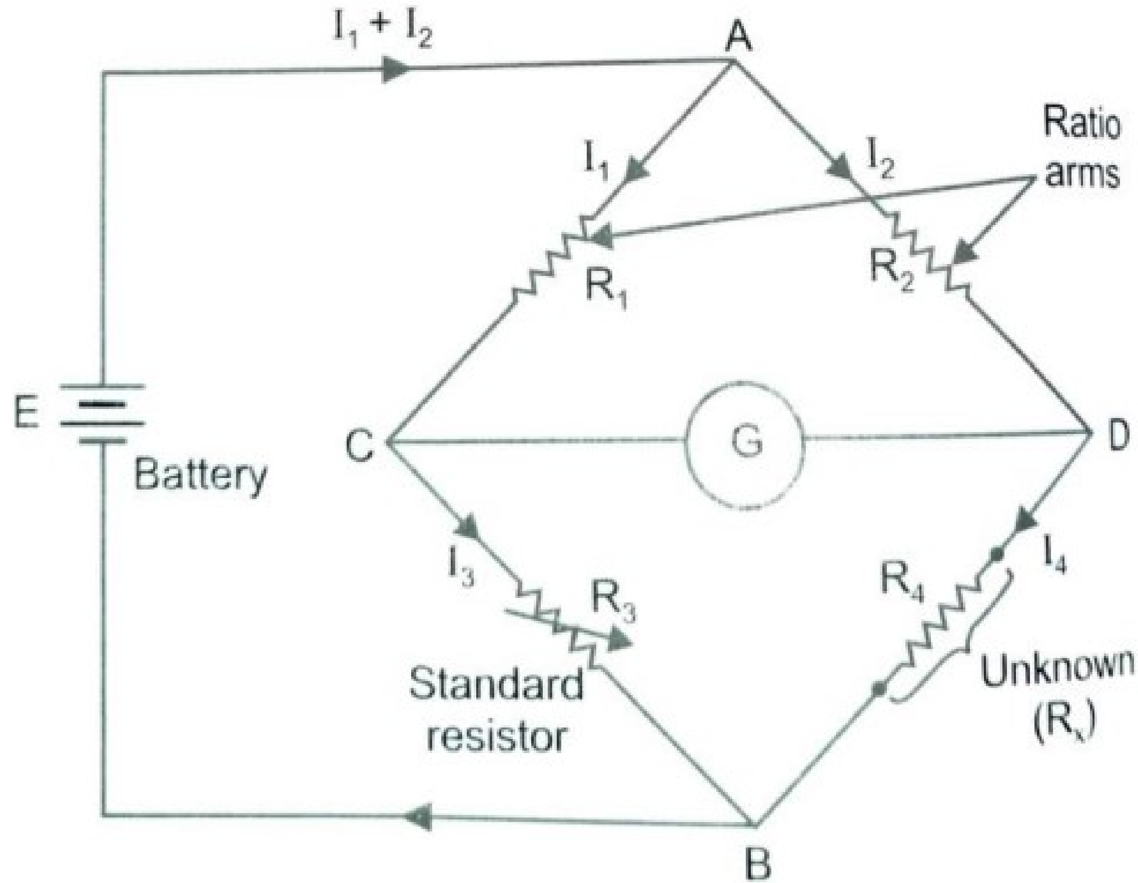


Fig. 6.6. Wheatstone bridge.

- The bridge has four resistive arms, together with a source of e.m.f. (a battery) and null detector, galvanometer (G) or other sensitive current meter
- The resistors R1 and R2 are called ratio arms while the resistor R3 is called the standard arm.
- The current through the galvanometer depends on the potential difference between the points C and D.
- The bridge is said to be balanced when the potential difference across the galvanometer is zero volt so that there is no current through the galvanometer.
- Hence the bridge is balanced when potential of points C and D is equal.

$$I_1R_1 = I_2R_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

- When the current through the galvanometer is zero, the following conditions should be satisfied

$$I_1 = I_3 = \frac{E}{R_1+R_3}$$

$$I_2 = I_4 = \frac{E}{R_2+R_4}$$

Substituting the values of I_1 and I_2, in Eqn. (1), we get

$$\frac{E}{R_1+R_3} \times R_1 = \frac{E}{R_2+R_4} \times R_2$$

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

$R_1 (R_2 + R_4) = R_2 (R_1 + R_3)$

$R_1 R_2 + R_1 R_4 = R_1 R_2 + R_2 R_3$

$R_1 R_4 = R_2 R_3$ --(2)

Eqn. (2) is the well known expression for balance of the Wheatstone bridge.

Thus the unknown resistor $R_4 = \frac{R_2 R_3}{R_1}$

Products of resistances of opposite arms are equal.

- Limitations of Wheatstone bridge
- 1. In case of measurement of low resistance, the resistance of the leads and contacts becomes significant, resulting in introduction of an error. This error can be eliminated by using **Kelvin's double bridge.**
- 2. While measuring high resistances, the resistance of the bridge becomes so large that the galvanometer becomes insensitive to imbalance.
- 3. The Wheatstone bridge cannot be used for measuring high resistances in mega ohms.
- 4. Heating effect of current causes change in resistances of the bridge arms

Measurement of High Resistance (>100kΩ)

- **Direct Deflection Method**
- **Loss of Charge Method**
- **Megger**

CABLE FAULTS

- Cables are generally laid directly in the ground or in ducts in the underground distribution system. For this reason, there are little chances of faults in underground cables.
- However, if a fault does occur, it is difficult to locate and repair the fault because conductors are not visible. The following are the faults most likely to occur in underground cables :
- **Open-circuit fault**
- **Short-circuit fault**
- **Earth fault.**

1.Open Circuit Fault:

- When there is a break in the conductor of a cable, it is called **open circuit fault.**
- The open-circuit fault can be checked by a **megger**.
- Three conductors of the 3-core cable at the far end are shorted and earthed.
- Then resistance between each conductor and earth is measured by a megger.
- The megger will indicate zero resistance in the circuit of the conductor that is not broken.
- However, if the conductor is broken, the megger will indicate infinite resistance in its circuit.

2.Short Circuit Fault:

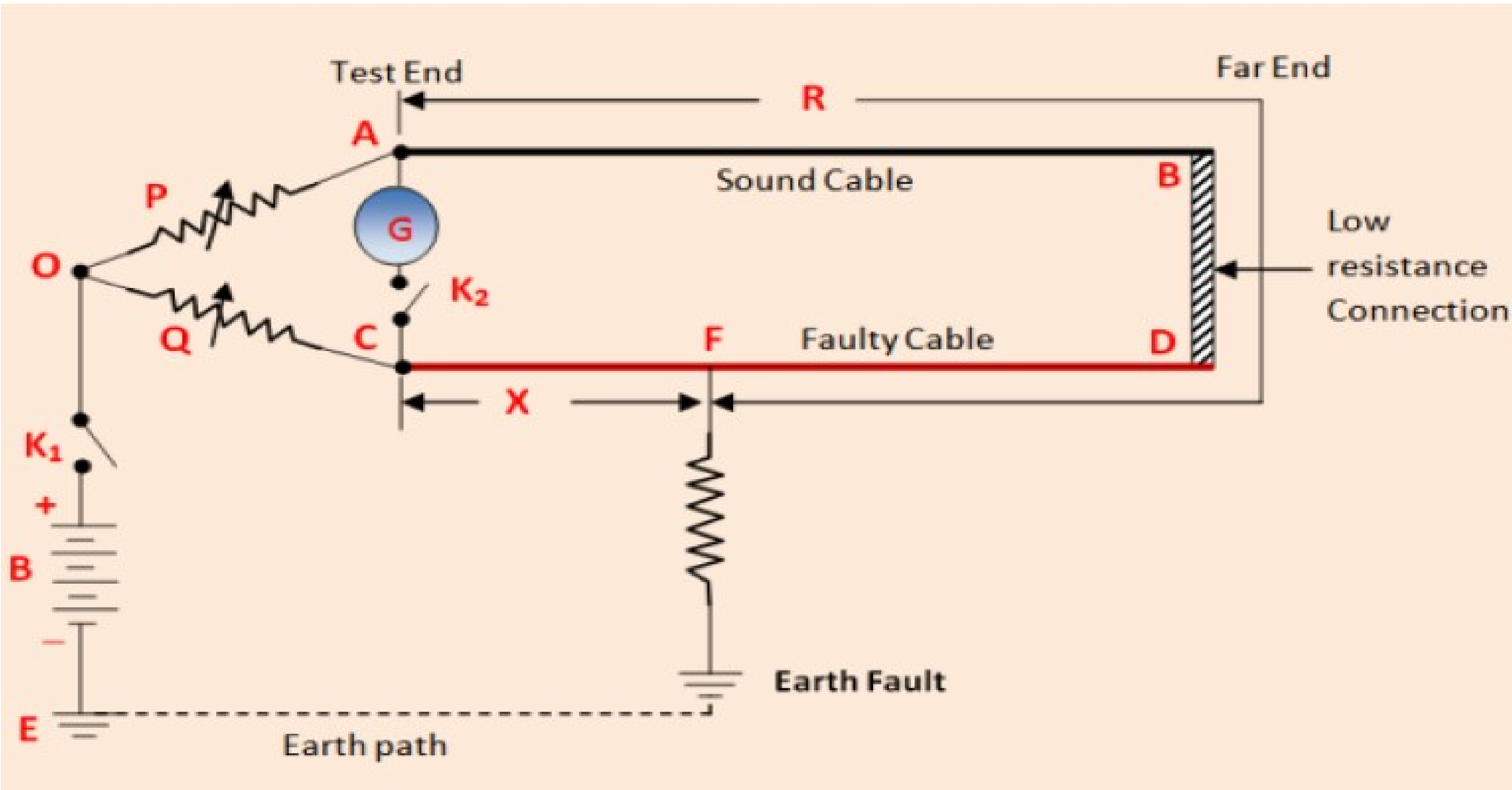
- When two conductors of a multi-core cable come in electrical contact with each other due to insulation failure, it is called a **short circuit fault**.
- The two terminals of the megger are connected to any two conductors. If the megger gives zero reading, it indicates short-circuit fault between these conductors. The same step is repeated for other conductors taking two at a time.

3.Earth Fault:

- When the conductor of a cable comes in contact with earth, it is called **earth fault** or **ground fault**.
- one terminal of the megger is connected to the conductor and the other terminal connected to earth. If the megger indicates zero reading, it means the conductor is earthed.

Murray Loop Test For Location Of Faults In Underground Cables

Earth fault test:



In this test, the sound cable is used to connect in between test end and far end of the faulty conductor.

Let,
AB is sound cable,
CD is faulty cable,
The Earth fault occurs a point F
Far end D point of the faulty cable is connected to far end Sound cable point B through a low resistance.
Two variable resistance (i.e P. Q) is connected to the end A point of sound cable and C point of faulty cable respectively.

- A battery is connected to point O and Earth point E through a switch K1. And a galvanometer G is connected in between point A and C through a switch K2.
- Let,
- R = Resistance of the conductor loop upto fault point F from the test end point A, i.e resistance of portion AF.
- X= Resistance in between two points C and F. note that, P, Q,R and X are the four arms of the Wheatstone bridge.
- Now, the switch K1 and K2 are closed respectively. Then the variable resistance P & Q are varied till the galvanometer shows zero deflection.

In the balance position of the bridge, we get

$$\frac{P}{Q} = \frac{R}{X}$$

$$\frac{P}{Q} + 1 = \frac{R}{X} + 1$$

$$\frac{P+Q}{Q} = \frac{R+X}{X}$$

If r is the resistance of each cable, then R + X = 2r

$$\therefore \quad \frac{P+Q}{Q} = \frac{2r}{X}$$

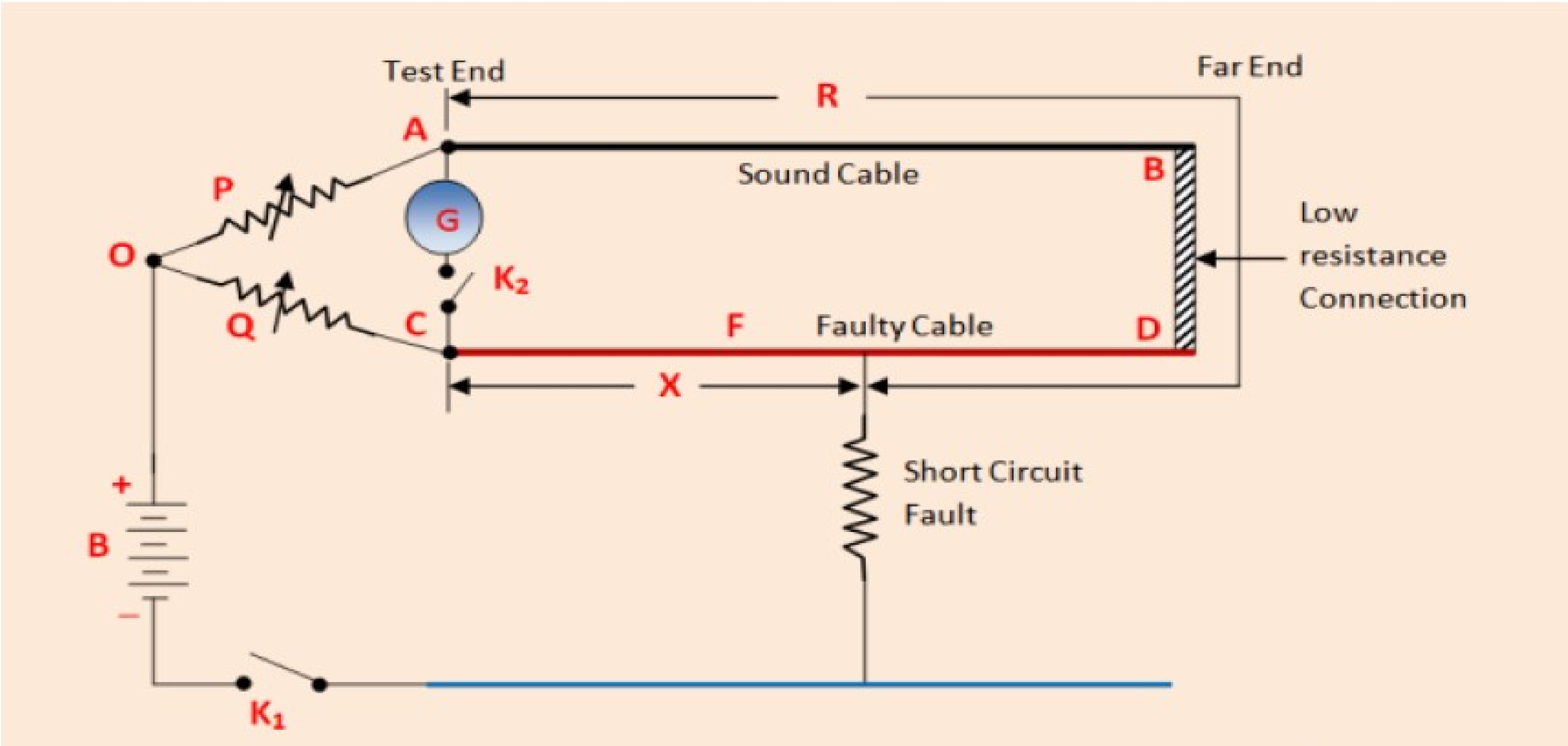
$$or, \quad X = \frac{Q}{P+Q} \text{ x } 2r$$

$$d = \frac{Q}{P+Q} \text{ x } 2 \text{ (cable length)}$$

Note

fault resistance does not affect the balancing of the bridge. But, if the fault resistance is high, the sensitivity of the bridge is reduced.

Short circuit test:



- It is the same procedure as earth fault test. For short circuit test, battery terminal is connected to the point O and the other point is connected to another faulty cable.
- Let, R = Resistance of the conductor loop upto fault point F from the test end point A, i.e resistance of portion AF. X= Resistance in between two points Cand F.
- note that , P,Q,R and X are the four arms of the Wheatstone bridge. Now, the switch K1 and K2 are closed respectively. Then the variable resistance P & Q are varied till the galvanometer shows zero deflection. In the balance position of the bridge, we get

$$\frac{P}{Q} = \frac{R}{X}$$

Or, $$\frac{P}{Q} + 1 = \frac{R}{X} + 1$$

Or, $$\frac{P+Q}{Q} = \frac{R+X}{X}$$

If r is the resistance of each cable, then R + X = 2r

$$\therefore \quad \frac{P+Q}{Q} = \frac{2r}{X}$$

$or,\quad X = \frac{Q}{P+Q} \text{ x } 2r$

Or, $X = \frac{Q}{P+Q} \text{ x } (\text{loop length})\text{ meters}$