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MI module 3- PPT 1

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Syllabus

Module 3

Classification, measurement of low, medium and high resistance- Ammeter voltmeter method(for low and medium resistance measurements)-Kelvin's double bridge-Wheatstones bridge- loss of charge method, measurement of earth resistance.

Measurement of self inductance-Maxwell's Inductance bridge, Measurement of capacitance –Schering's, Measurement of frequency-Wien's bridge.

Calibration of Ammeter, Voltmeter and Wattmeter using DC potentiometers.

High voltage and high current in DC measurements- voltmeters, Sphere gaps, DC Hall effect sensors.

Measurement of Resistance

Classification of resistances

(I) Low resistances - Less than 1Ω

(II) Medium Resistance - 1 Ω to 0.1MΩ

(III) High Resistances - greater than 0.1MΩ

(I) Measurement of medium resistance

(a) Ammeter- Voltmeter method

(b) Wheatstone method

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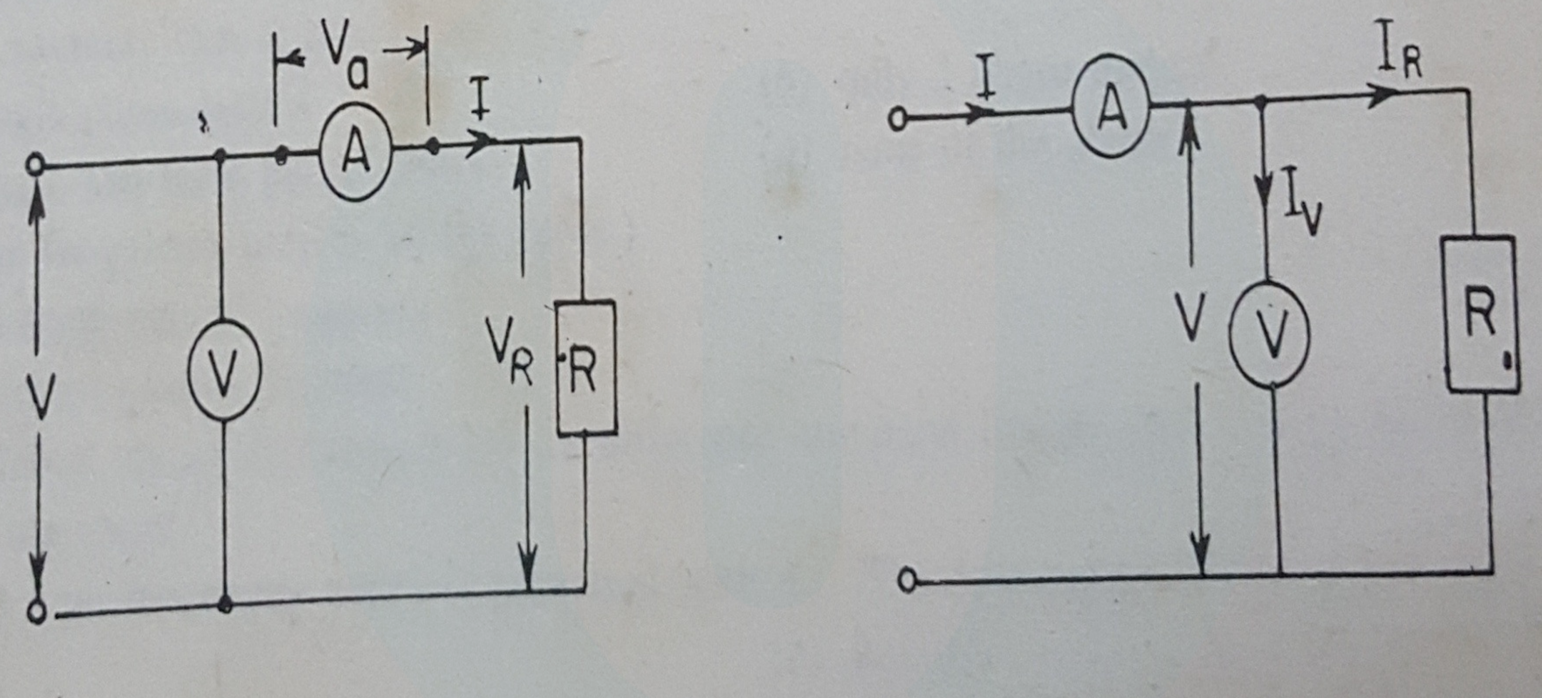
(i) Ammeter- Voltmeter method

- There are two types of connections.
- In both cases the measured value of resistance is given by:

$$R_m = \frac{\text{voltmeter reading}}{\text{ammeter reading}} = \frac{V}{I}$$

- R_m will be equal to the true value, R , if the ammeter resistance is zero and the voltmeter resistance is infinite, so that the conditions in the circuit are not disturbed.



(a) (b)

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- Consider circuit of Fig (a)
  - Ammeter measures the true value of the current through the resistance but the voltmeter does not measure the true voltage across the resistance.
  - Voltmeter indicates the sum of the voltage across the ammeter and the measured resistance.
  - Let R_a be the resistance of the ammeter.
  - $\therefore$ Voltage across the ammeter, $V_a = IR_a$

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– Now, measured value of resistance,

$$R_{m1} = \frac{V}{I} = \frac{V_R + V_a}{I} = \frac{IR + IR_a}{I} = R + R_a$$

– ∴ True value of resistance,

$$R = R_{m1} - R_a$$

$$= R_{m1}\left(1 - \frac{R_a}{R_{m1}}\right)$$

– Thus the measured value of resistance is higher than the true value. It is also clear from above that true value is equal to the measured only if ammeter resistance R_a is zero.

- Relative error, $\varepsilon_r = \frac{R_{m1} - R}{R} = \frac{R_a}{R}$

$\therefore$ the error in measurement will be small if the value of resistance under measurement is large as compared to the internal resistance of the ammeter

- Hence this circuit is used when measuring high resistance values.

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- Consider the circuit of Fig (b)
  - In this circuit the voltmeter measures the true value of voltage but the ammeter measures the sum of currents through the resistance and the voltmeter.
  - Let R_v be the resistance of the voltmeter
  - ∴ Current through the voltmeter, $I_v = \frac{V}{R_v}$
  - Measured value of resistance

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_V} = \frac{V}{\frac{V}{R} + \frac{V}{R_V}}$$

$$= \frac{1}{\frac{1}{R} + \frac{1}{R_v}} = \frac{R_v R}{R_v + R} = \frac{R}{1 + \frac{R}{R_V}}$$

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- True value of resistance,

$$R = R_{m2}\left(1 + \frac{R}{Rv}\right)$$

$$R_{m2}R_{v} + R_{m2}R = RR_{V}$$

$$R_{m2}R_{v} = RR_{V} - RR_{m2} = R(R_{v} - R_{m2})$$

$$R = \frac{R_{m2}R_{V}}{R_{V} - R_{m2}} = R_{m2}\left(\frac{1}{1 - \frac{R_{m2}}{R_{V}}}\right)$$

- ∴ the true value of resistance is equal to the measured value only if the resistance of the voltmeter, R_v, is infinite.
- However, if the resistance of voltmeter is very large as compared to the resistance under measurement, then

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- $R_v >> R_{m2}$, $\therefore$ R_{m2}/R_v is very small.

$$R = R_{m2}\left(1 + \frac{R_{m2}}{R_v}\right)$$

- Thus the measured value of resistance is smaller than the true value.
- Relative error , $\varepsilon_r = \dfrac{R_{m2} - R}{R} = \dfrac{R_{m2} - R_{m2} - \dfrac{R_{m2}^2}{R_v}}{R} = \dfrac{R_{m2}^2}{R_v R}$

$$R_{m2} \approx R$$

$$\therefore \varepsilon_r = \frac{R}{R_v}$$

- The error in measurement will be small if the value of resistance under measurement is very small compared to resistance of voltmeter.

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- ∴Circuit (b) should be used for measuring low resistance values.
- The ammeter-voltmeter method is a simple method but it is a rough method because the accuracy is limited by accuracy of ammeter and voltmeter used.

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(ii) Wheatstone bridge

- A very important device for the measurement of medium resistance.
- It is used for making comparison measurements and operates upon null indication principle.
- This makes it a very accurate instrument because the indication is independent of the calibration of the null indicating instrument.

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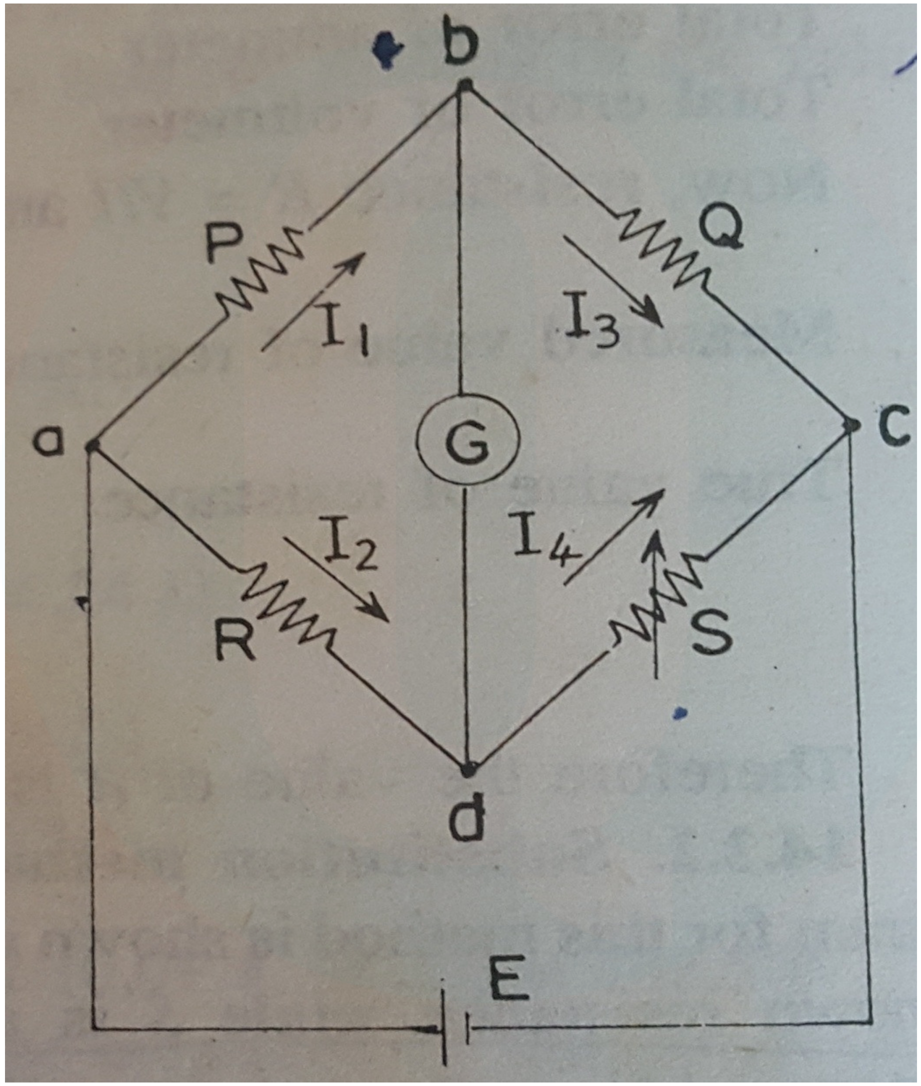

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- It has four resistive arms, consisting of resistances P,Q,R and S with a source of emf and a null detector, usually a galvanometer G
- The current through the galvanometer depends on the potential difference between points b and d.
- The bridge is said to be balanced when there is no current through the galvanometer or when the potential difference across the galvanometer is zero.

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- This occurs when the voltage from point ‘b’ to point ‘a’ equals voltage from point ‘d’ to point ‘a’.
- Under balanced condition, $I_1 P = I_2 R \quad \rightarrow (1)$
- For galvanometer current to be zero, following conditions also exist

$$I_1 = I_3 = \frac{E}{P + Q} \quad \rightarrow (2)$$

$$I_2 = I_4 = \frac{E}{R + S} \quad \rightarrow (3)$$

where E= emf of battery

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- Substituting equations ② and ③ in ①

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

$$PR + PS = PR + QR$$

$$\therefore PS = QR$$

- If three resistances are known then, fourth can be determined by using the equation

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

- Where R = unknown resistance; S= standard arm;

  P and Q = ratio arms

(II) Measurement of Low resistance

- Methods used for measurement of medium resistances are unsuitable for measurement of low resistance i.e. resistance $<1\Omega$.
- The resistance of leads and contacts, though small, are appreciable in comparison to the low resistance to be measured.
- Hence special type of construction & techniques have to be used to avoid errors due this.

(a) Ammeter- Voltmeter method

- The method is same as that used for measurement of medium resistances.
- Low resistances are constructed with four terminals.

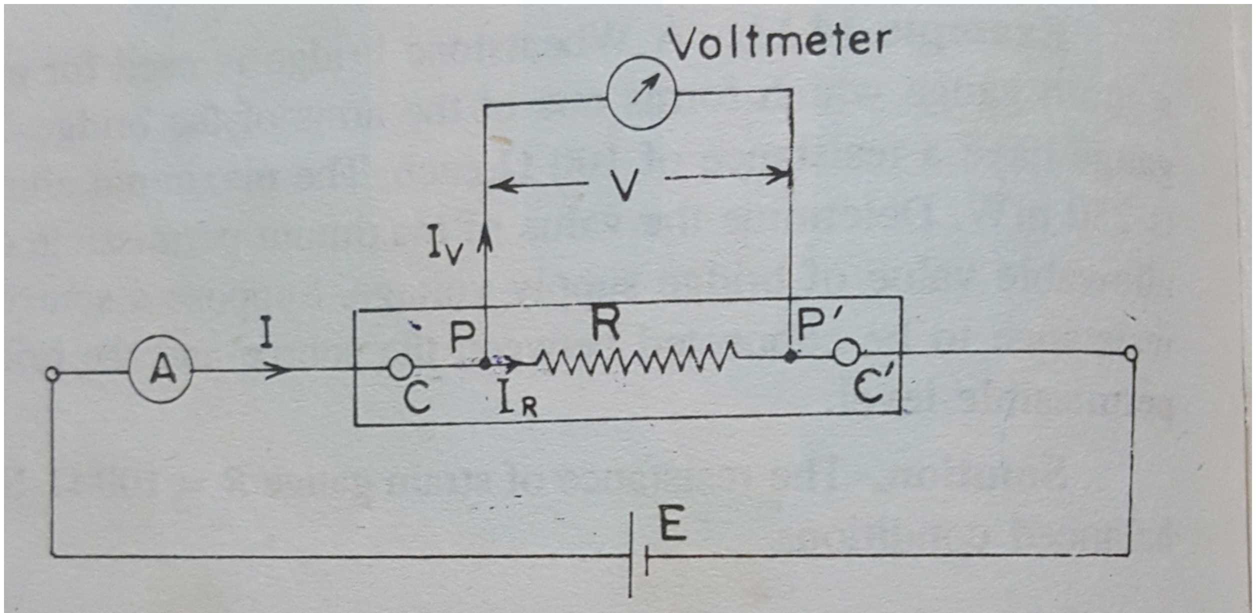

Fig. 14.15. Ammeter voltmeter method for measuring 4 terminal resistances.

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- One pair of terminals CC’ (called current terminals) is used to lead current to and from the resistor.
- The voltage drop is measured between the other two terminals PP’ called potential terminals.
- The voltage V measured by voltmeter is IR times resistance R between terminals PP’ and does not include any contact resistance drop that may be present at the current terminals CC’.
- Contact resistance drop at the potential terminals need not be a source of error as this contact resistance is part of the potential circuit which has a high value of resistance.

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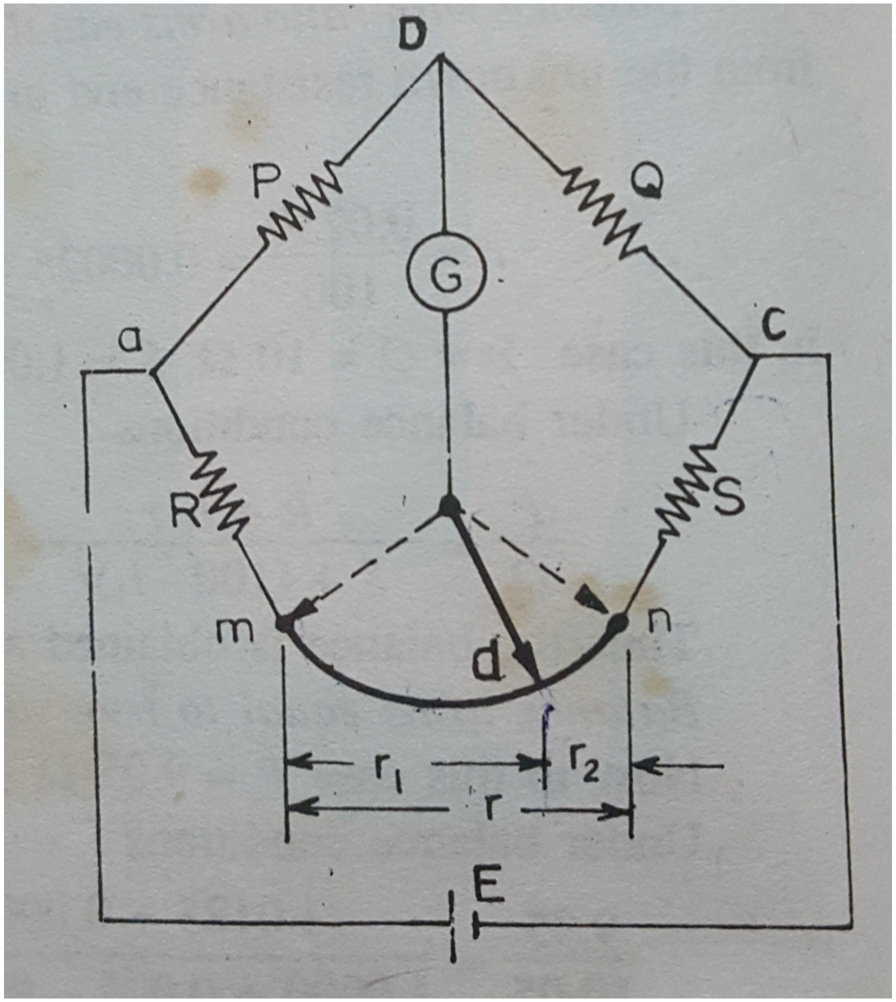
(b) Kelvin Double Bridge

- Modification of Wheatstone bridge.



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- Consider the bridge circuit where *r* represents the lead that connects the unknown resistance *R* to standard resistance *S*.
- Two galvanometer connections are possible. The connection may be either to point *m* or to point *n*.
- When galvanometer is connected to point *m*, the resistance *r* is added to standard resistance *S*, resulting in the indication of too low an indication for unknown resistance *R*.

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- When connection is made to point *n*, the resistance *r* is added to the unknown resistance resulting in indication of too high a value for *R*.
- Suppose the connection is made to any intermediate point *d*. If at point *d* the resistance is divided into two parts, r_1 and r_2, such that

$$\frac{r_1}{r_2} = \frac{P}{Q}$$

- Then the presence of r_1, the resistance of connecting leads, causes no error in the result.

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$$R + r_1 = \frac{P}{Q}(S + r_2) \rightarrow (1)$$

but $\dfrac{r_1}{r_2} = \dfrac{P}{Q}$

or $\dfrac{r_1}{r_1 + r_2} = \dfrac{P}{P+Q}$

$$r_1 = \frac{P}{P+Q} r \qquad [\because r_1 + r_2 = r]$$

$$r_2 = \frac{Q}{P+Q} r$$

Substituti ng r_1 and r_2 in eqn (1)

$$\left(R + \frac{P}{P+Q} r\right) = \frac{P}{Q}\left(S + \frac{Q}{P+Q} r\right)$$

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$$R + \frac{P}{P+Q}r = \frac{P}{Q}S + \frac{P}{P+Q}r$$

$$\therefore\ R = \frac{P}{Q}S$$

∴By making the connection at *d*, the resistance of the leads does not affect the result.

- But this is not a practical method as it would be difficult to determine the correct point of galvanometer connection.
- By a simple modification, if two actual resistance units of correct ratio is connected between points *m and n*, the galvanometer can be connected to the junction of the resistors.

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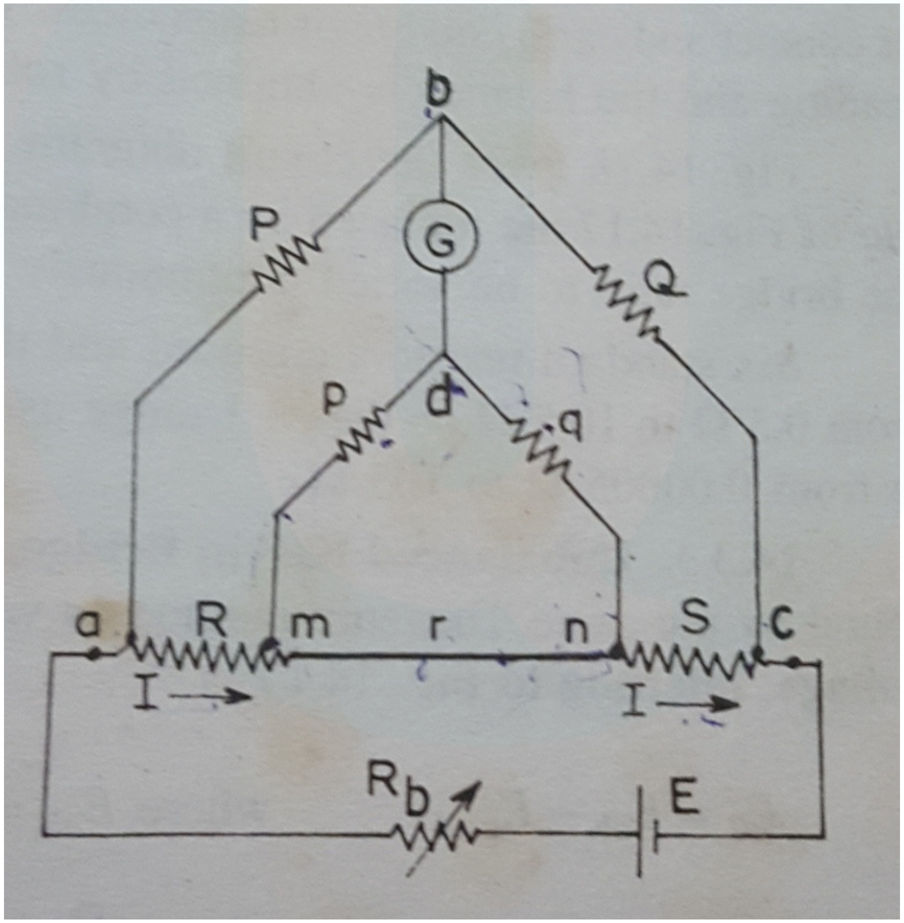
∴ The actual Kelvin's Double bridge incorporates the idea of a second set of ratio arms and the use of 4 terminal resistors for low resistances.



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- The first of 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 appropriate potential between points *m* and *n* to eliminate the effect of connecting lead of resistance *r* between the known resistance *R*, and standard resistance *S*.
- The ratio *p/q* is made equal to *P/Q*.
- Under balance condition there is no current through the galvanometer, which means that the voltage drop between *a and b*, E_{ab} is equal to the voltage drop E_{amd} between *a and c*.

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$$E_{ab} = \frac{P}{P+Q} \cdot E_{ac} \quad \text{and} \quad E_{ac} = I\left[R+S+\frac{(p+q)r}{p+q+r}\right]$$

$$E_{amd} = I\left[R + \frac{p}{(p+q)}\left\{\frac{(p+q)r}{p+q+r}\right\}\right]$$

$$= I\left[R + \frac{pr}{p+q+r}\right.$$

For zero galvanometer deflection $E_{ab} = E_{amb}$

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

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

$$PR+PS+\frac{(p+q)rP}{p+q+r} = (P+Q)\left[R+\frac{pr}{p+q+r}\right]$$

$$\cancel{PR}+PS+\frac{(p+q)rP}{p+q+r} = \cancel{PR}+QR+\frac{Ppr}{p+q+r}+\frac{Qpr}{p+q+r}$$

$$PS+\cancel{\frac{prP}{p+q+r}}+\frac{qrP}{p+q+r} = QR+\cancel{\frac{Ppr}{p+q+r}}+\frac{Qpr}{p+q+r}$$

$\div$ by Q

$$\frac{PS}{Q}+\frac{qr}{p+q+r}\cdot\frac{P}{Q} = R+\frac{pr}{p+q+r}$$

$$\frac{PS}{Q}+\frac{qr}{p+q+r}\cdot\frac{P}{Q}-\frac{pr}{p+q+r} = R$$

$$\frac{PS}{Q}+\frac{qr}{p+q+r}\left[\frac{P}{Q}-\frac{p}{q}\right] = R$$

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Now if $\frac{P}{Q} = \frac{p}{q}$, then this equation becomes, $R = \frac{P}{Q} S$

$\therefore$ The resistance of the connecting lead, r, has no effect on the measurement, provided the two set of ratio arms have equal ratios.

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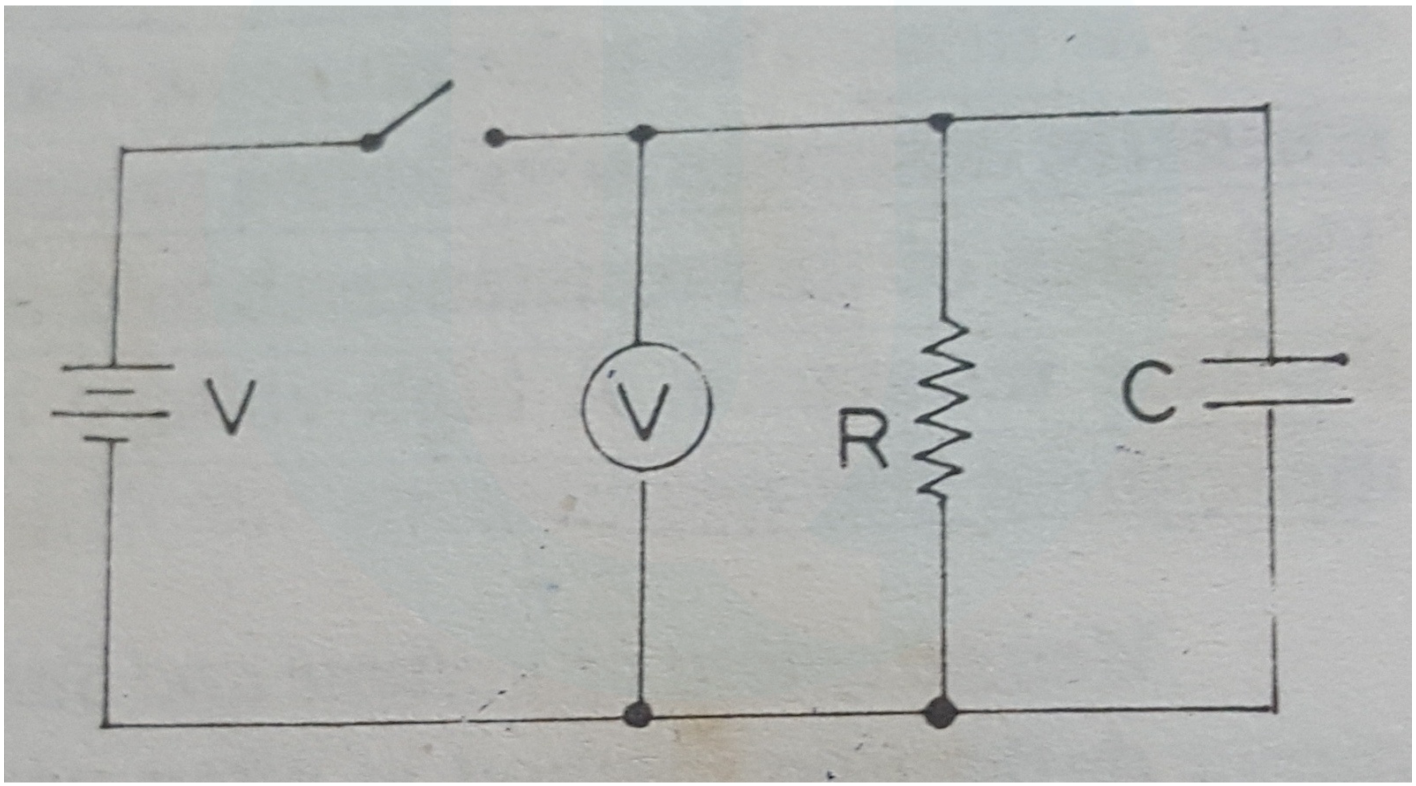
III. Measurement of High resistance

Loss of charge Method



- The insulation resistance R to be measured is connected in parallel with a capacitor C and an electrostatic voltmeter.
- The capacitor is charged to a suitable voltage, by means of a battery having voltage V and is then allowed to discharge through the resistance.
- The terminal voltage is observed over a considerable over a considerable period of time during discharge.

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- The voltage across the capacitor at any instant t after the application of voltage is

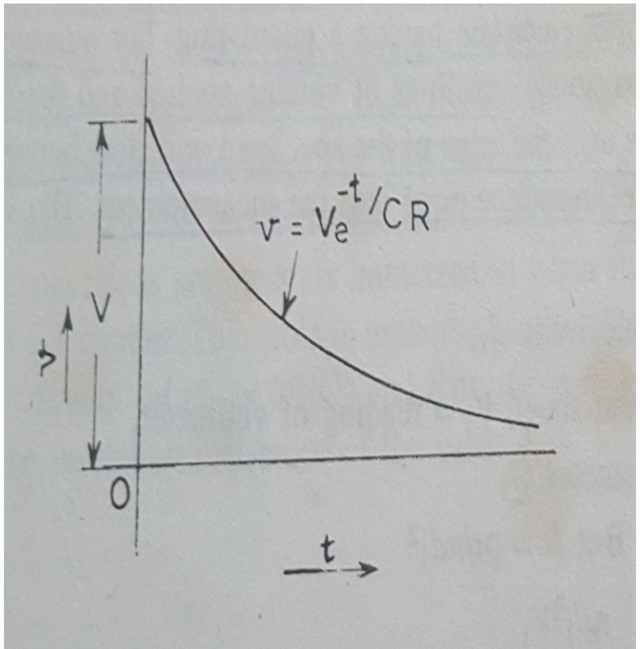

Fig. 14.25. Variation of voltage with time.

$$v = Ve^{(-t/RC)}$$

$$\frac{V}{v} = e^{(t/RC)}$$

$$\log_e \frac{V}{v} = \frac{t}{RC}$$

$$R = \frac{t}{C \log_e V/v} = \frac{0.4343\, t}{C \log_{10} V/v}$$

- If the resistance R is very large the time for an appreciable fall in voltage is very large and thus this process may become time consuming.

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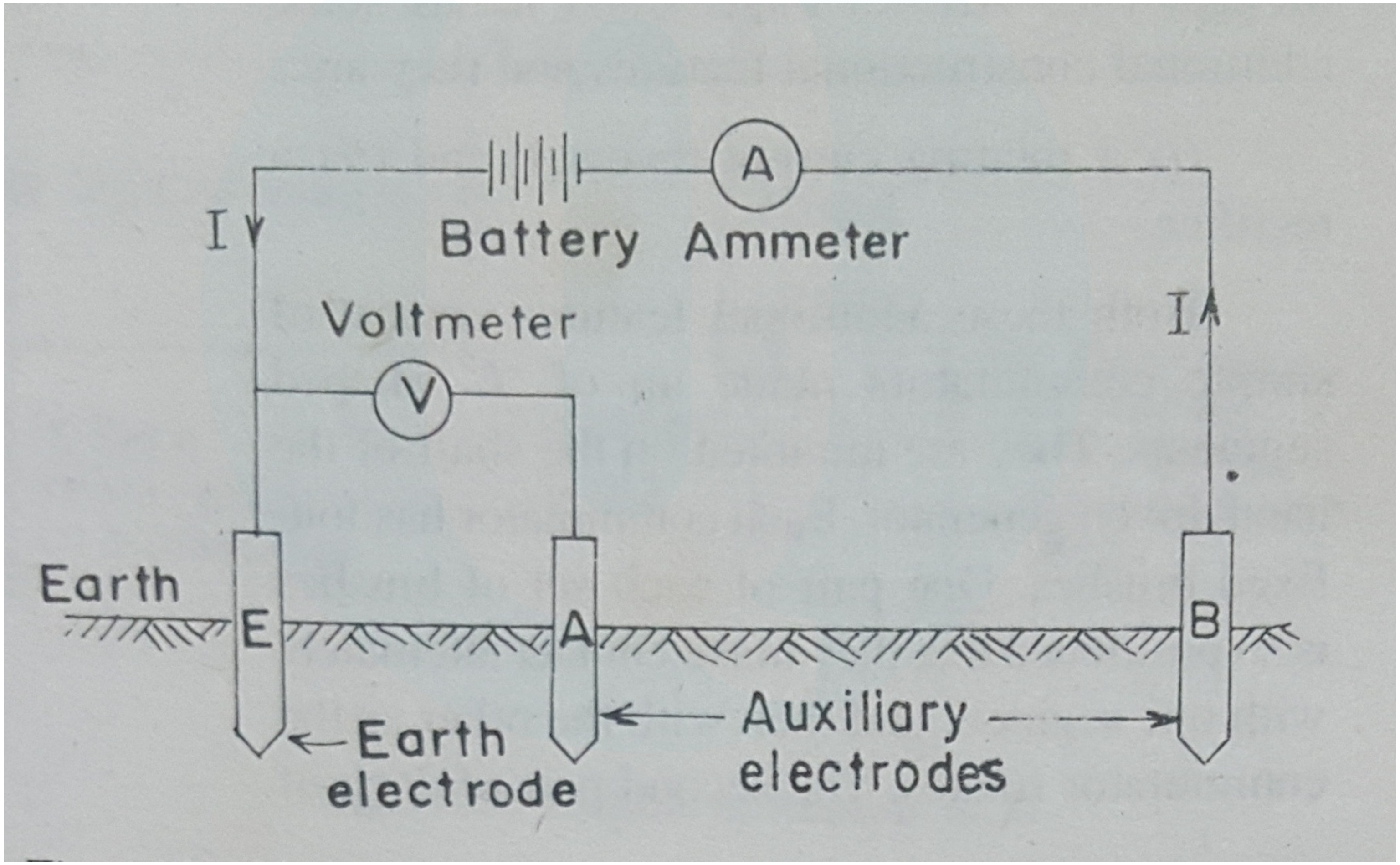
- Also the voltage time curve will thus be very flat and unless great care is taken in measuring voltages at the beginning and end of time t, a serious error may be made in the ratio V/v causing error in the measured value of R.
- More accurate results can be obtained by measuring change in voltage directly and calling this change e, equation for R becomes

$$R = \frac{0.4343\, t}{C \log_e \dfrac{V}{V - e}}$$

Measurement of Earth resistance

a) Fall of potential method



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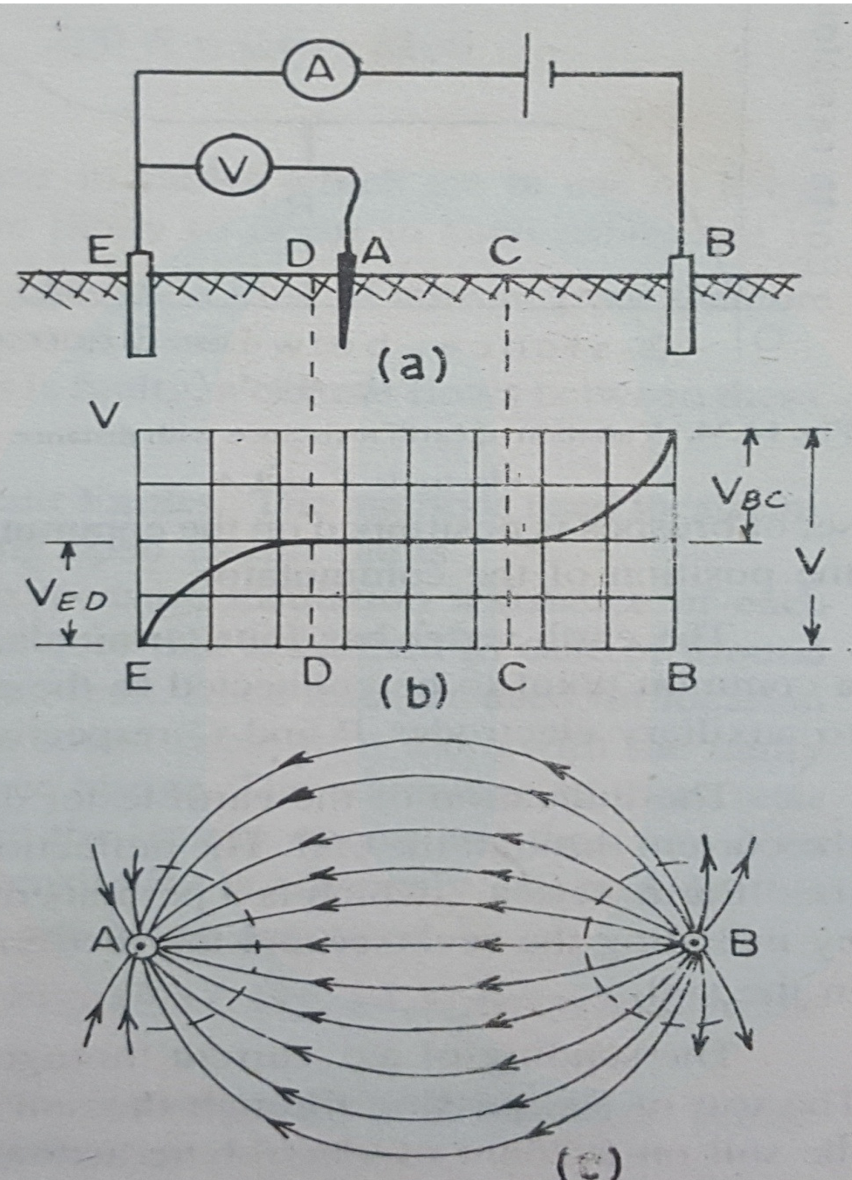

Fig. 14.33. Distribution of potentials between two earthing electrodes.

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- A current is passed through earth electrode E to an auxiliary electrode B inserted in earth at a distance away from the earth electrode.
- A second auxiliary electrode A is inserted in earth between E and B.
- The potential difference V between E and A is measured for a given current I.
- The flow of ground currents is shown in fig (c)
- The lines of the first electrode current diverge and those of the second electrode current converge.
- As a result the current density is much greater in the vicinity of the electrodes than at a distance from them.

- The potential distribution between the electrodes shown in fig (b) shows that the potential rises in the proximity of electrodes E and B and is constant along the middle section.
- The resistance of earth is given by $R_E=V/I$ or $R_E=V_{EA}/I$
- The position of electrodes E and B is fixed and the position of electrode A is changed and resistance measurements are done for various positions of electrode A.
- A graph is plotted between earth resistance against distance between electrode E and A.

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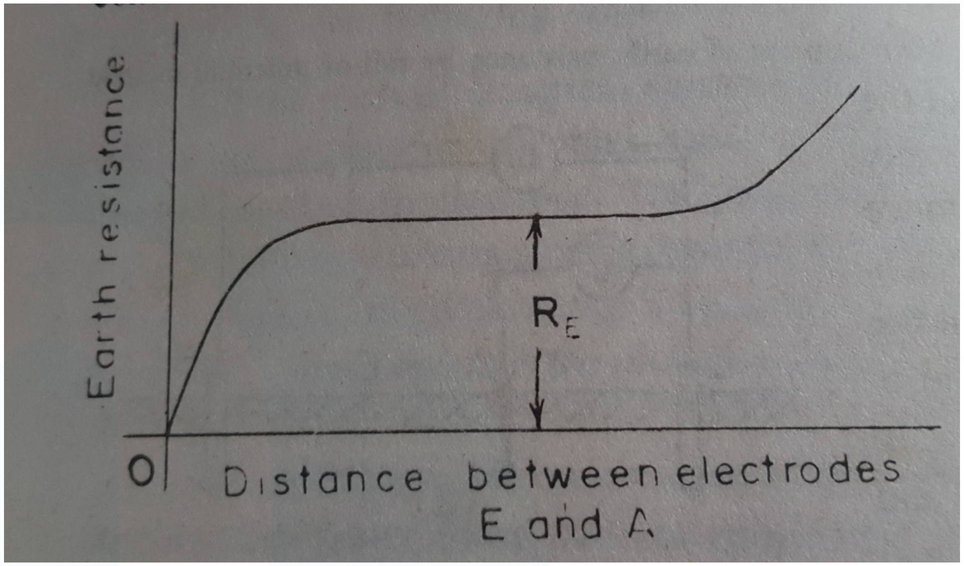
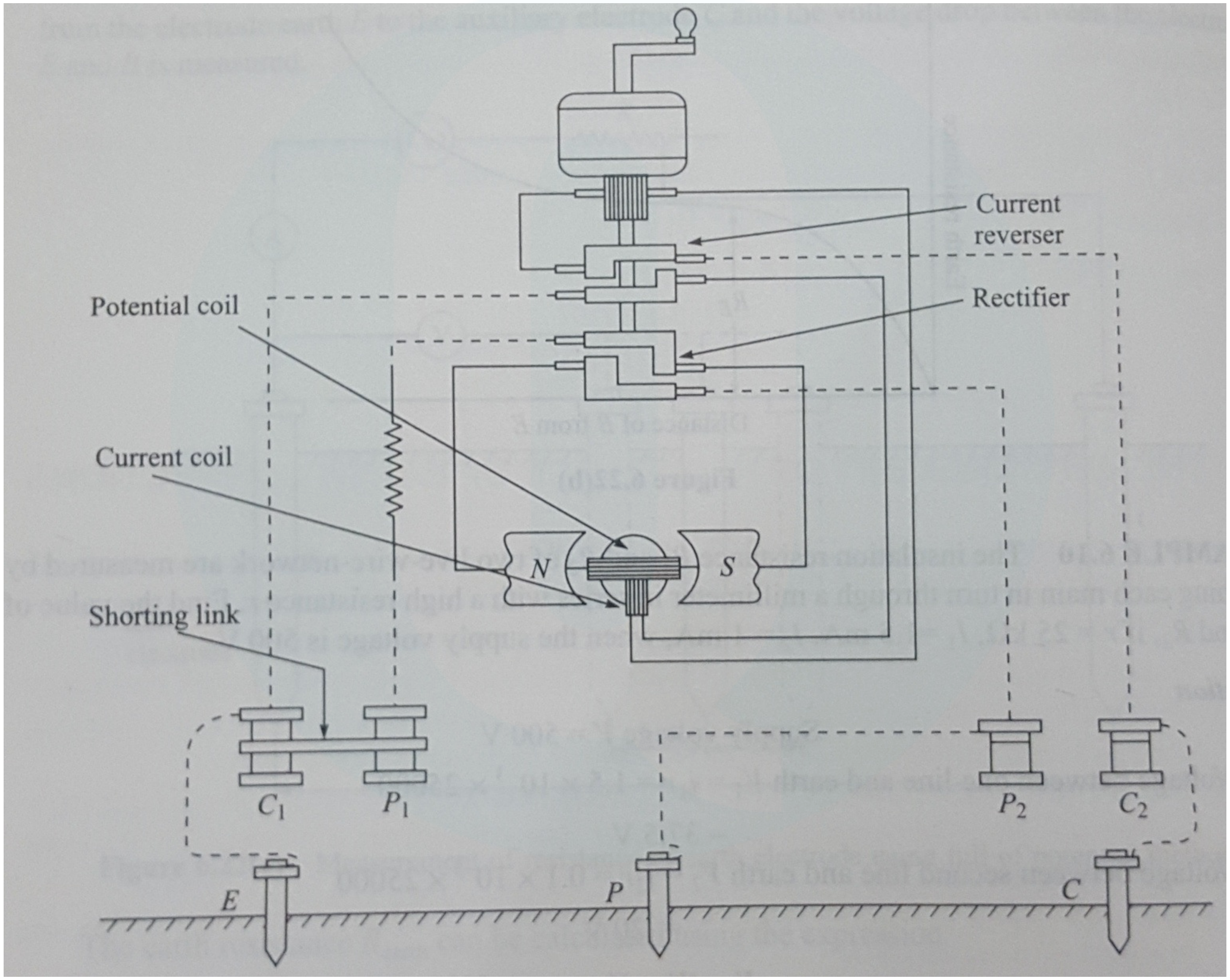
- The measured value of earth resistance depends upon the position of the auxiliary electrode A.
- When distance between electrodes E and A is increased, earth resistance becomes constant and when A approaches B, resistance increases again.



- If electrodes are not placed correctly then it will cause error.
- The correct value of resistance is measured when A is placed such that the resistance lies in the flat part of the curve.

(b) Earth Tester



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- The earth tester consists of a pressure and a current coil. The each coil has two terminals, P_1, P_2, C_1,C_2.
- The pressure coil and the current coil are placed across the permanent magnet.
- Two terminals P_1 and C_1 are shorted to form a common point to be connected to earth electrode.
- The other two electrodes are connected to auxiliary electrodes P and C respectively.

- The tester has a rotating current reverser and rectifier. It consists of L shaped commutator segments and fixed brushes.
- The commutator is a device used for converting the direction of flow of current.
- It is connected in series with the armature of the hand driven dc generator.
- The brushes are used for transferring the power from the moving parts to the stationary parts of the device.

- Each commutator has 4 fixed brushes.
- One pair of each set of brushes is so positioned that they make contact alternately with one segment and then with the other as the commutator rotates.
- The second pair of each set of brushes is positioned on the commutator so that continuous contact is made with one segment whatever the position of the commutator.
- The potential coil and current coil are given supply from the hand driven dc generator which is rotated at a uniform speed.

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- The indication of the earth tester depends upon the ratio of the voltage across the pressure coil and the current through the current coil.
- The deflection of its pointer indicates the resistance of earth directly.
- Earth tester is a permanent magnet moving coil instrument and can operate on dc only, yet by including current reverser and rectifying device it is possible to make measurements with ac flowing in the soil.

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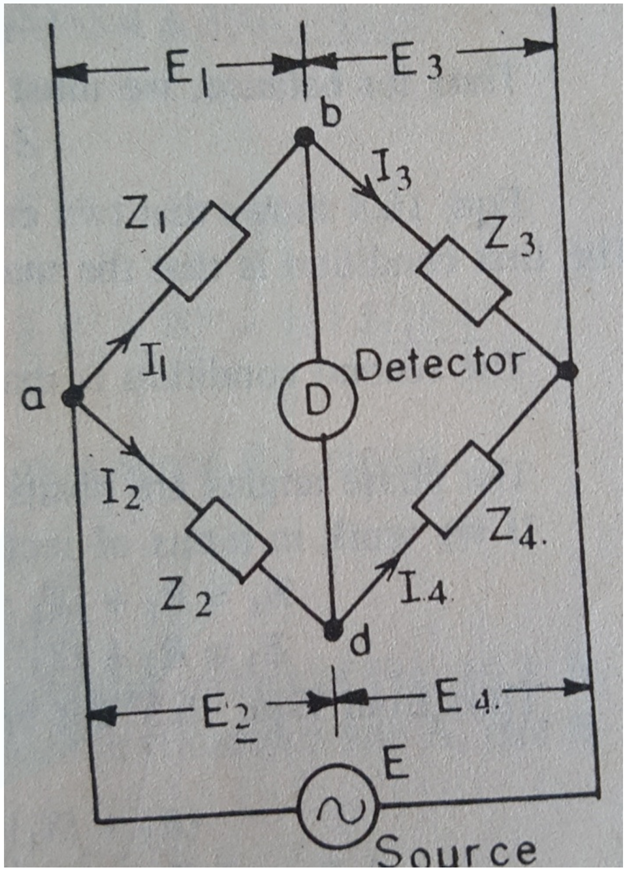
AC Bridges

- An ac bridge consists of 4 impedance arms, an ac source and a balance detector which is sensitive to small alternating potential differences.
- Used in the measurement of inductance, capacitance, dissipation factor, frequency etc



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General Equation of bridge balance

- When the bridge is balanced, there is no current through the detector.
- ∴ the potential difference between points b and d should be zero i.e. voltage drop from *a to b* should be equal to voltage drop from *a to d*, both in <u>magnitude and phase.</u>

$$E_1 = E_2$$

$$I_1 Z_1 = I_2 Z_2 \rightarrow (1)$$

$$I_1 = I_3 = \frac{E}{Z_1 + Z_3} \rightarrow (2)$$

$$I_2 = I_4 = \frac{E}{Z_2 + Z_4} \rightarrow (3)$$

- Substituting (2) and (3) in (1)

$$\mathbf{Z_1Z_4=Z_2Z_3}$$

- In polar form,

$$(Z_1\angle\theta_1)(Z_4\angle\theta_4) = (Z_2\angle\theta_2)(Z_3\angle\theta_3)$$

For balance

$$Z_1Z_4\angle\theta_1+\theta_4 = Z_2Z_3\angle\theta_2+\theta_3$$

- ∴Two conditions must be satisfied simultaneously when balancing an ac bridge.
- The first condition is that magnitude of impedances satisfy the relationship

$$Z_1Z_4=Z_2Z_3$$

- Second condition is that the phase angles should satisfy the relationship:

$$\angle\theta_1+\angle\theta_4=\angle\theta_2+\angle\theta_3$$

- Phase angles are positive for inductive impedance and negative for capacitive impedance.
- In terms of rectangular co-ordinates,

$$\mathbf{Z_1}=R_1+jX_1; \quad \mathbf{Z_2}=R_2+jX_{2;} \quad \mathbf{Z_3}=R_3+jX_3\,; \quad \mathbf{Z_4}=R_4+jX_4$$

- For balance,

$$\mathbf{Z_1Z_4=Z_2Z_3}$$

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$$(R_1 + jX_1)(R_4 + jX_4) = (R_2 + jX_2)(R_3 + jX_3)$$
$$R_1R_4 - X_1X_4 + j(X_1R_4 + X_4R_1) = R_2R_3 - X_2X_3 + j(X_2R_3 + X_3R_2)$$

A complex equation is satisfied only if real and imaginary parts of each side of the equation are separately equal.

$$R_1R_2 - X_1X_4 = R_2R_3 - X_2X_3$$
$$X_1R_4 + X_4R_1 = X_2R_3 + X_3R_2$$

Measurement of Self Inductance

(i) Maxwell's Inductance bridge

- This bridge circuit measures an inductance by comparison with a variable standard self- inductance.
- Let L_1= unknown inductance of resistance R_1.

  L_2 = variable inductance of fixed resistance r_2.

  R_2 = variable resistance connected in series with inductor L_2.

  R_3,R_4= known non-inductive resistances.

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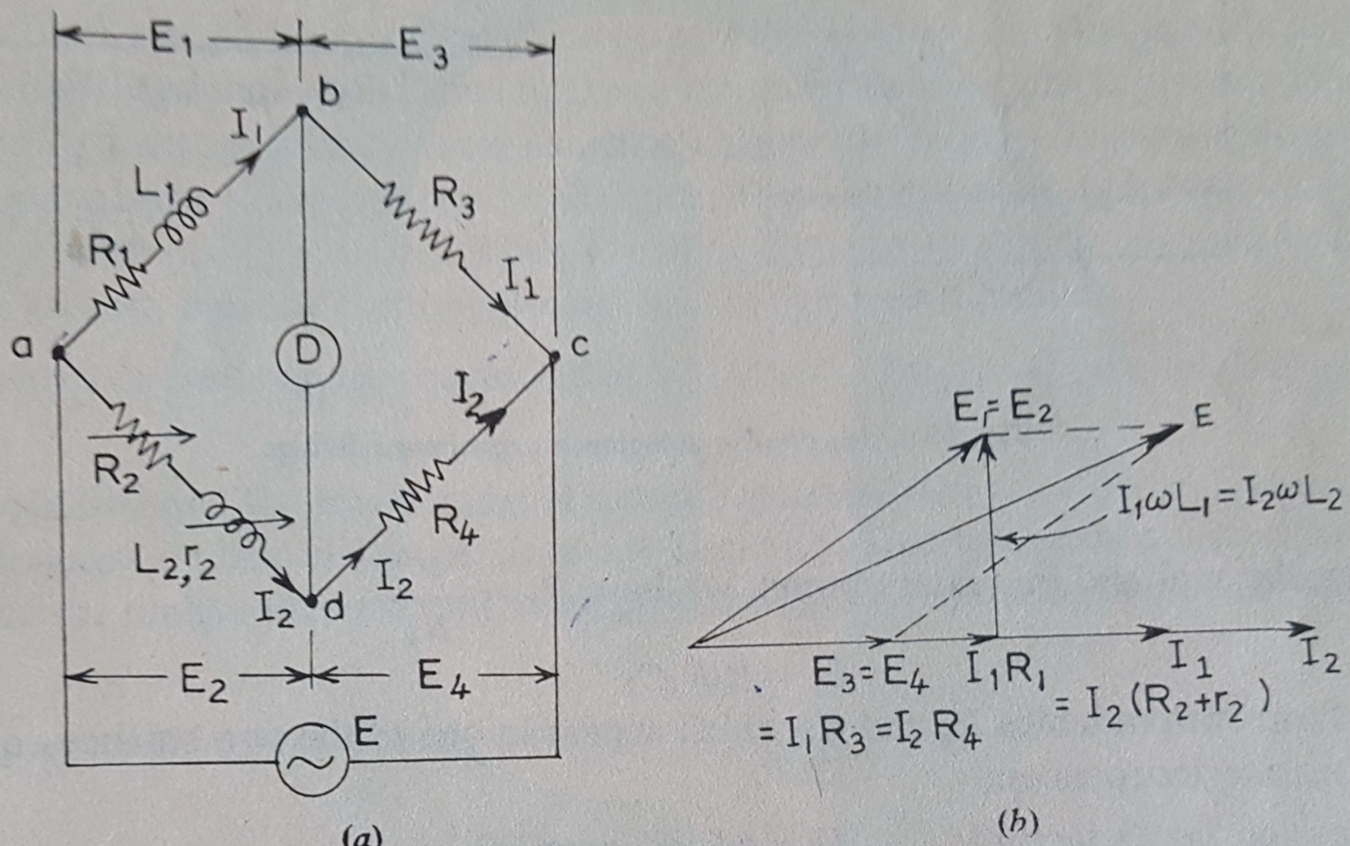

Fig. 16.3. Maxwell's inductance Bridge.

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$$\mathbf{Z_1Z_4=Z_2Z_3}$$

$$(R_1+j\omega L_1)R_4=((R_2+r_2)+j\omega L_2)R_3$$

Equating real parts ;

$$R_1R_4=(R_2+r_2)R_3$$

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

Equating imaginary parts;

$$j\omega L_1R_4=j\omega L_2R_3$$

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

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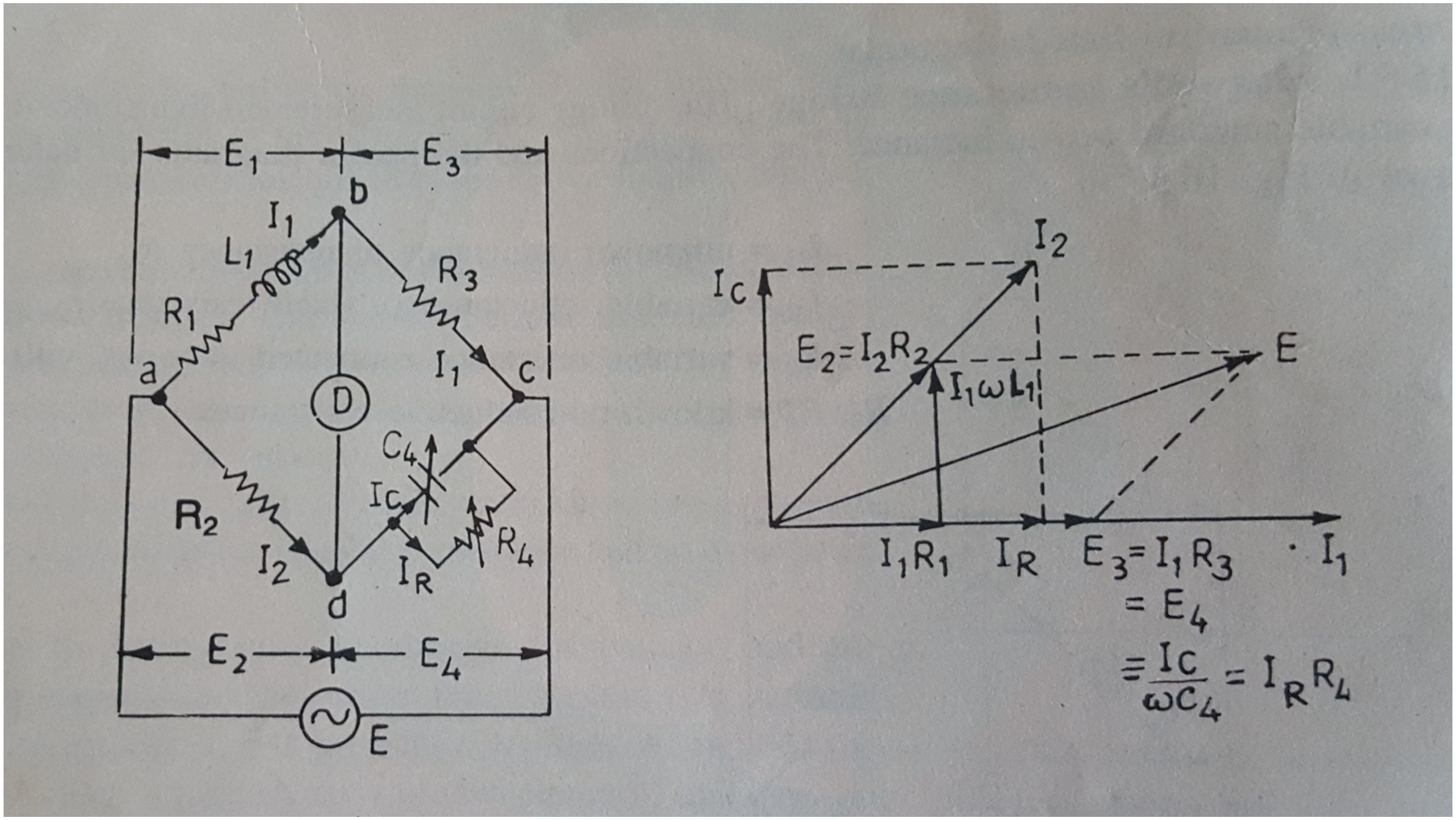
(ii) Maxwell's Inductance- Capacitance Bridge



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- In this bridge, an inductance is measured by comparison with a standard variable capacitance.
- Let, L_1 =unknown inductance

  R_1=effective resistance of inductor L_1

  R_2,R_3,R_4= known non- inductive resistances

  C_4=Variable standard capacitor
- At balance

$$(R_1 + j\omega L_1)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = R_2 R_3$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega R_2 R_3 C_4 R_4$$

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- Equating real terms,

$$R_1 = \frac{R_2R_3}{R_4}$$

- Equating imaginary terms,

$$L_1 = R_2R_3C_4$$

- Q factor, $Q = \omega L_1/R_1 = \omega C_4R_4$

Advantages

- The two balance equations are independent if R_4 and C_4 are the variable elements.
- Frequency does not appear in any of the two equations.
- Simple expression for unknowns L_1 and R_1 in terms of known bridge elements.

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Disadvantages

- The bridge requires a variable standard capacitor which may be expensive if calibrated to high degree of accuracy.
- Bridge is limited to measurement of low Q coils ($1<Q<10$)

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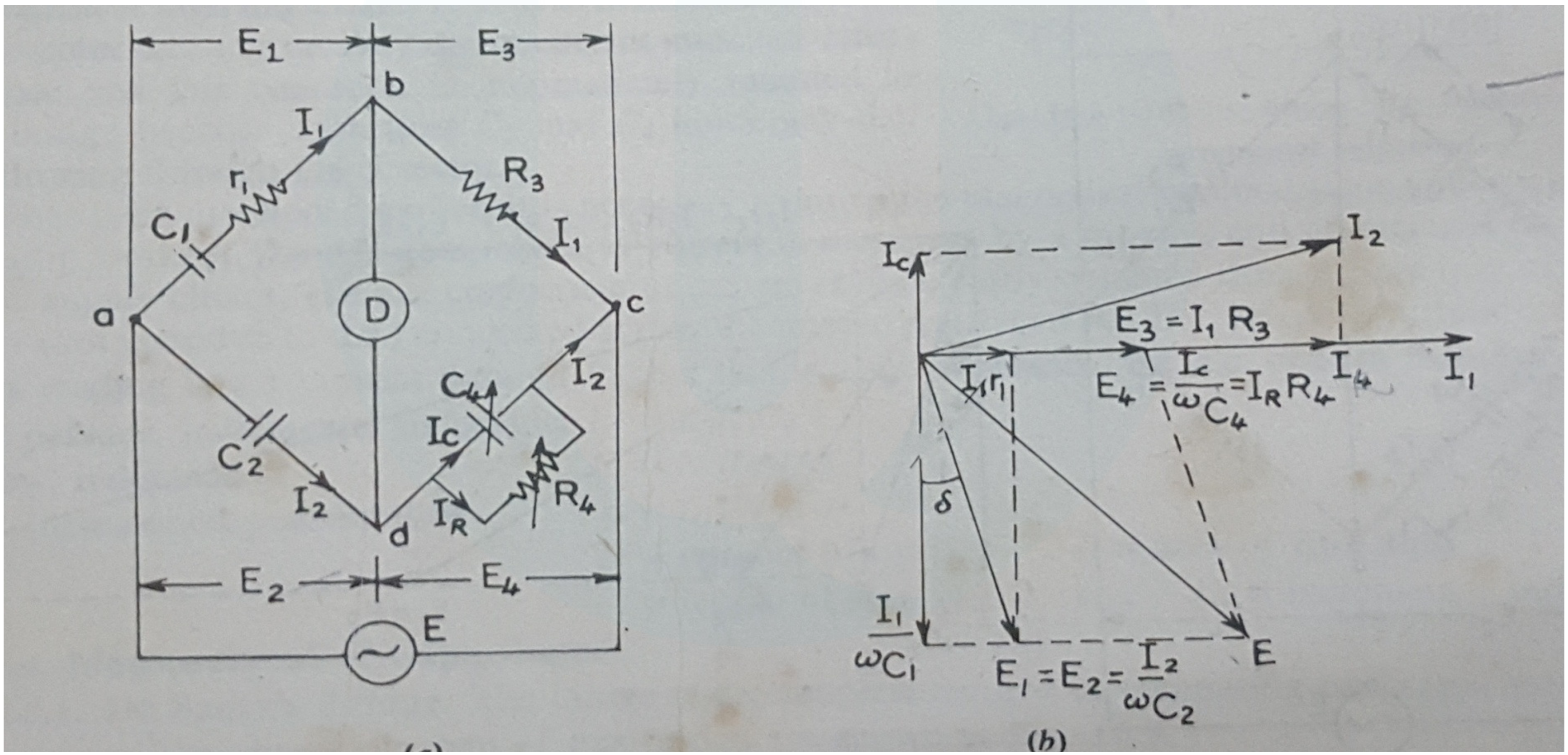
Measurement of Capacitance

Schering Bridge



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- It is used for precision measurement of capacitors on low voltages and for study of insulation and insulating structures at high voltages.
- Let C_1 = capacitor whose capacitance is to be determined

  r_1 = series resistance representing loss in C_1

  C_2 = standard capacitor

  R_3 = non inductive resistance

  C_4 = variable capacitor

  R_4 = variable non inductive resistance in parallel with C_4
- At balance

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

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

$$r_1 R_4 - \frac{jR_4}{\omega C_1} = -j\frac{R_3}{\omega C_2} + \frac{R_3 R_4 C_4}{C_2}$$

Equating real & imaginary terms

$$r_1 = R_3 \frac{C_4}{C_2}$$

$$C_1 = C_2 \frac{R_4}{R_3}$$

Two independent balance equations are obtained if C_4 and R_4 are chosen as variable elements.

Dissipation factor, $D_1 = \tan\delta = \omega C_1 r_1$

$$= \omega\left(\frac{C_2 R_4}{R_3}\right) * \left(\frac{R_3 C_4}{C_2}\right)$$

$$= \omega R_4 C_4$$

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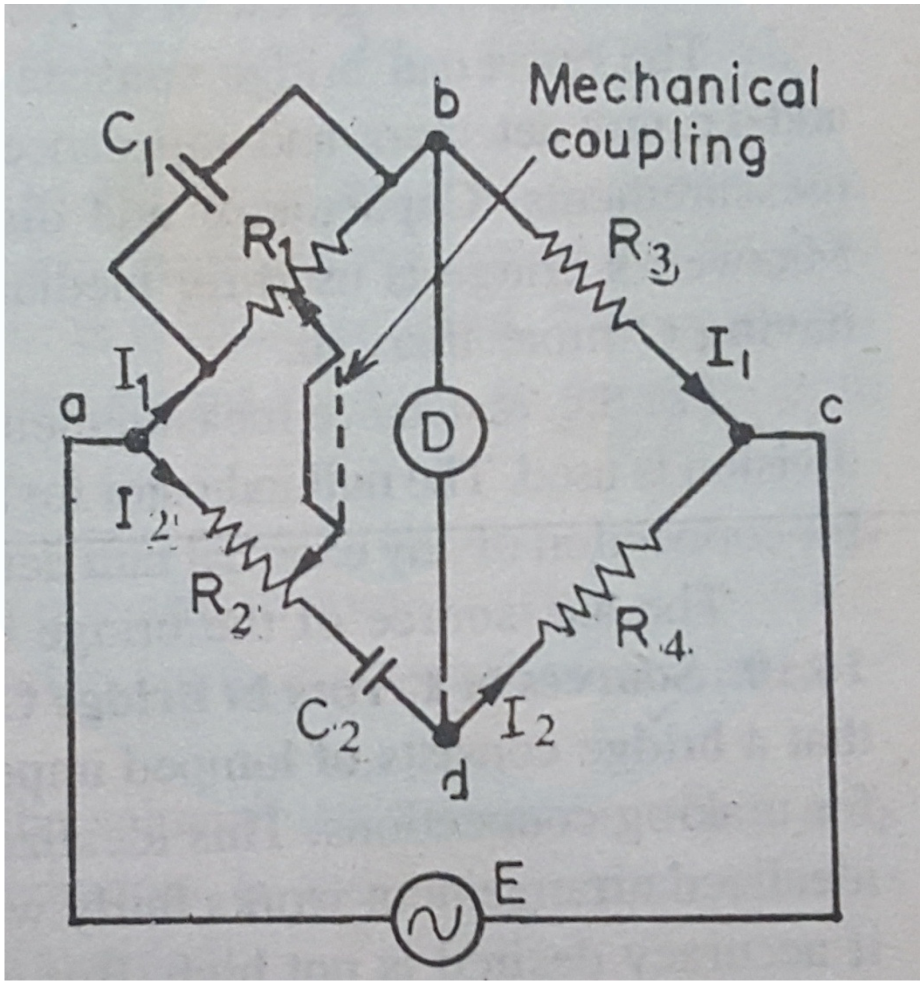
Measurement of frequency

Wien's Bridge



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- At balance $\left(\frac{R_1}{1+j\omega C_1R_1}\right)R_4 = \left(R_2 - \frac{j}{\omega C_2}\right)R_3$

$$\frac{R_4}{R_3} = \frac{\left(R_2 - \frac{j}{\omega C_2}\right)}{\left(\frac{R_1}{1+j\omega C_1R_1}\right)} = \frac{\left(R_2 - \frac{j}{\omega C_2}\right)(1+j\omega C_1R_1)}{R_1}$$

$$= \frac{R_2}{R_1} + j\omega C_1R_2 - \frac{j}{\omega C_2R_1} + \frac{C_1}{C_2}$$

- By equating real terms

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} \rightarrow (1)$$

- Equating imaginary terms

$$\omega C_1 R_2 - \frac{1}{\omega C_2 R_1} = 0$$

$$\omega C_1 R_2 = \frac{1}{\omega C_2 R_1}$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \rightarrow (2)$$

If components are so chosen that $R_1 = R_2 = R$ and $C_1 = C_2 = C$

Then eqn (1) becomes, $\frac{R_4}{R_3} = 2$

eqn (2) becomes, $f = \frac{1}{2\pi RC}$

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- Switches for resistors R_1 and R_2 are mechanically linked so as to fulfil the condition $R_1=R_2$
- As long as C_1 and C_2 are fixed capacitors equal in value and $R_4=2R_3$, Wien's bridge can be used as frequency determining device balanced by a single control.
- This control may be directly calibrated in terms of frequency.
- This bridge is suitable for frequencies from 100 Hz to 100kHz.

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DC Potentiometer

- A potentiometer is an instrument designed to measure an unknown voltage by comparing it with a known voltage.
- The known voltage may be a supplied by a standard cell or any other known voltage reference source.

Advantages

- Measurement is done using comparison method, so the degree of accuracy is high.
- Under balanced condition, no current flows and hence no power is consumed in the circuit containing unknown emf.

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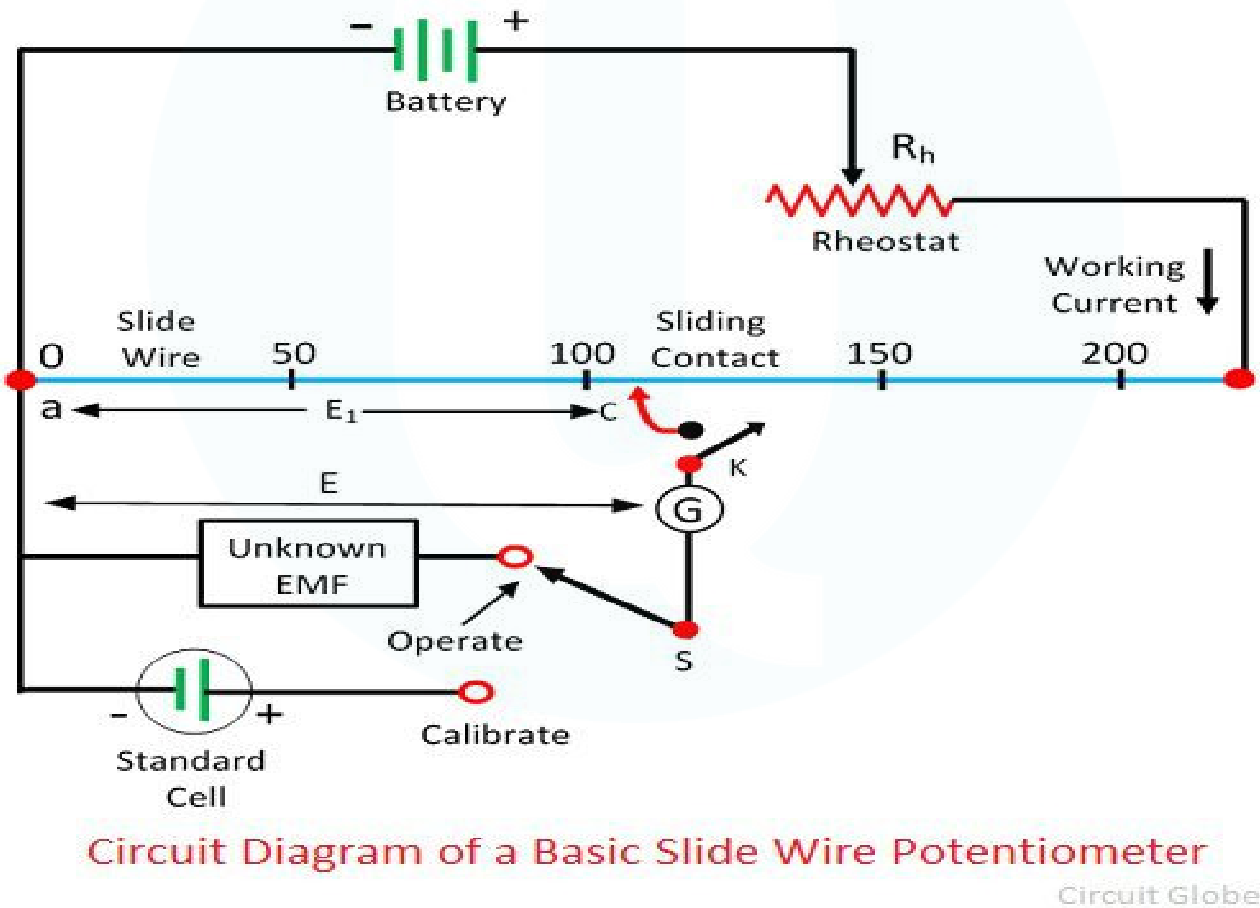
- Since it measures voltage, it can also be used to measure current by measuring voltage drop produced by unknown current passing through a known standard resistance.

Basic Potentiometer Circuit



Circuit Diagram of a Basic Slide Wire Potentiometer

- With the switch *S* in the *operate* position and galvanometer key *K* open, the battery supplies the working current through rheostat R and slide wire.
- The working current through the may be varied by changing the rheostat setting.
- The method for measuring the unknown voltage, E, depends upon finding a position for the sliding contact such that the galvanometer shows zero deflection when galvanometer key *K* is closed.
- Zero galvanometer deflection means that unknown voltage, E, is equal to the voltage drop E_1 across portion ac of the slide wire.

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- The slide wire has uniform cross section and hence uniform resistance along its entire length.
- A calibrated scale in cm, is placed along the slide wire so that the length can be read accurately from the slide wire.
- Since, resistance is known accurately, voltage drop along the slide wire can be controlled by adjusting the value of the working current.
- The process of adjusting the working current so as to match the voltage drop across a portion of sliding wire against standard reference source is known as Standardisation.

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Standardisation

- The slide wire shown in figure has a total length of 200cm & a resistance of 200Ω.
- The emf of standard cell is 1.0186V.
- Switch S is thrown to calibrate position and sliding contact is placed at 101.86cm mark on the slide wire scale.
- The rheostat R_h is adjusted so as to vary the working current.
- This adjustment is carried out till the galvanometer shows no deflection when key K is pressed.
- Under these conditions, the voltage drop along the 101.86cm portion of the slide wire has a resistance of 101.86Ω

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- The working current is adjusted to the value

$$\frac{1.0186}{101.86} = 0.01\text{A or } 10\text{mA}$$

- The voltage at any point along the slide wire is proportional to the length of the slide wire. ∴ 153.6cm = 1.536V.
- If potentiometer is calibrated once, its working current is never changed.

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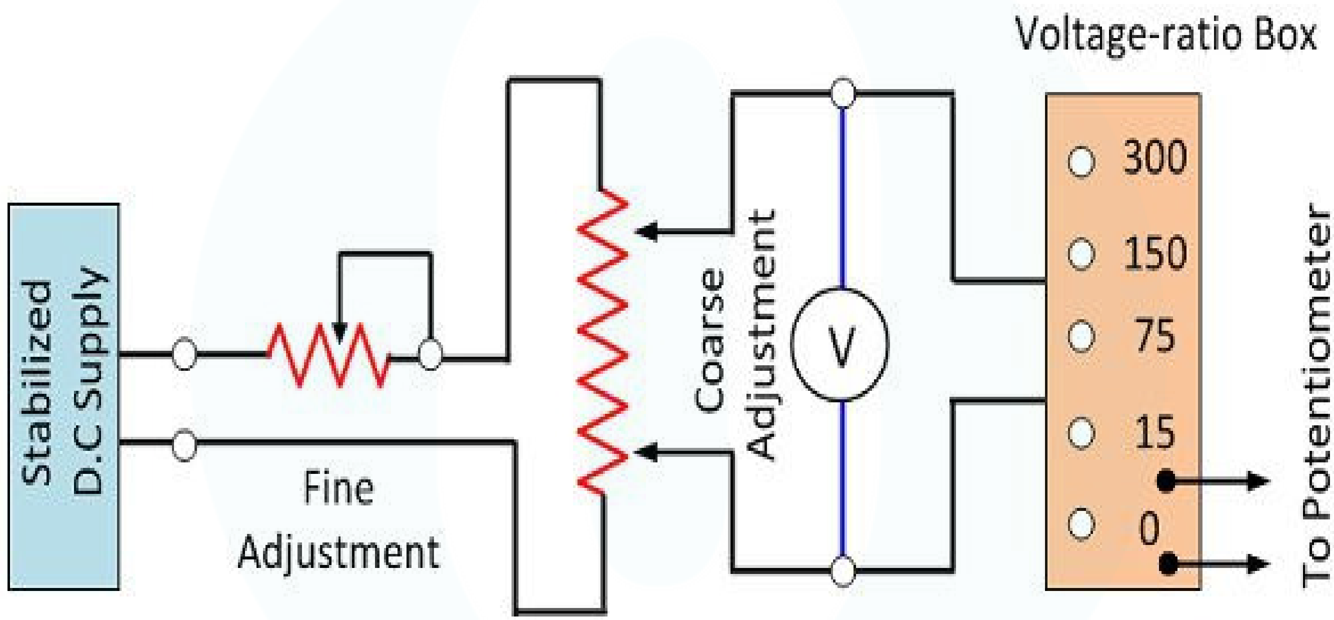
Application of DC potentiometer

1. Calibration of voltmeter



Calibration of Voltmeter with Potentiometer

Circuit Globe

- A stable dc supply is given to the calibration circuit because any change in supply voltage will cause corresponding change in voltmeter calibration.
- The potential divider network consists of two rheostats, one for coarse and the other for fine control of calibrating voltage.
- These controls are connected to the supply source and with the help of these controls it is possible to adjust the voltage so that the pointer coincides exactly with a major division of the voltmeter.
- The voltage across voltmeter is stepped down to a value suitable for application to a potentiometer with the help of a volt-ratio box as the maximum range of potentiometer is 1.6V.

- The potentiometer measures the true value of voltage. If the potentiometer reading does not agree with the voltmeter reading, a negative or positive error is indicated.
- A calibration curve may be drawn with the help of the voltmeter & potentiometer readings.

2) Calibration of ammeter

- A standard resistance of suitable value and sufficient current carrying capacity is placed in series with the ammeter under calibration.

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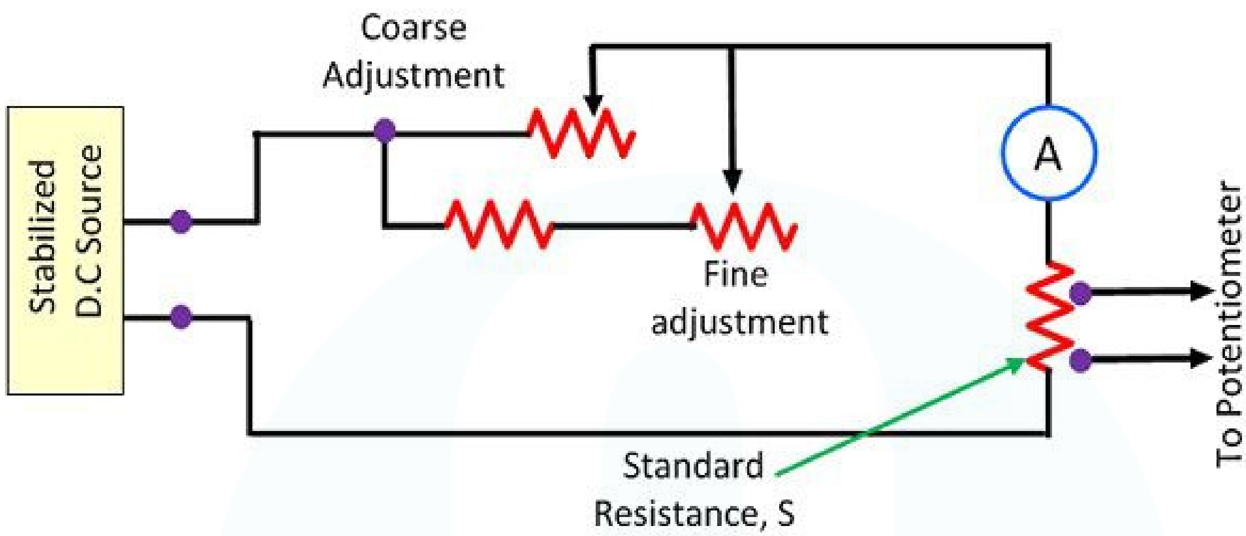

Calibration of an ammeter with Potentiometer

Circuit Globe

- The voltage across the standard resistor is measured with the help of potentiometer and the current through the standard resistance can be calculated using the equation, $I=V_s/S$.

where V_s= voltage across the standard resistor as indicated by potentiometer

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and S= resistance of standard resistor

- Since the resistance of the standard resistor is accurately known and the voltage across the standard resistor is measured by a potentiometer, this method of calibrating an ammeter is very accurate.
- A calibration curve indicating the errors at various scale readings of the ammeter may be plotted.

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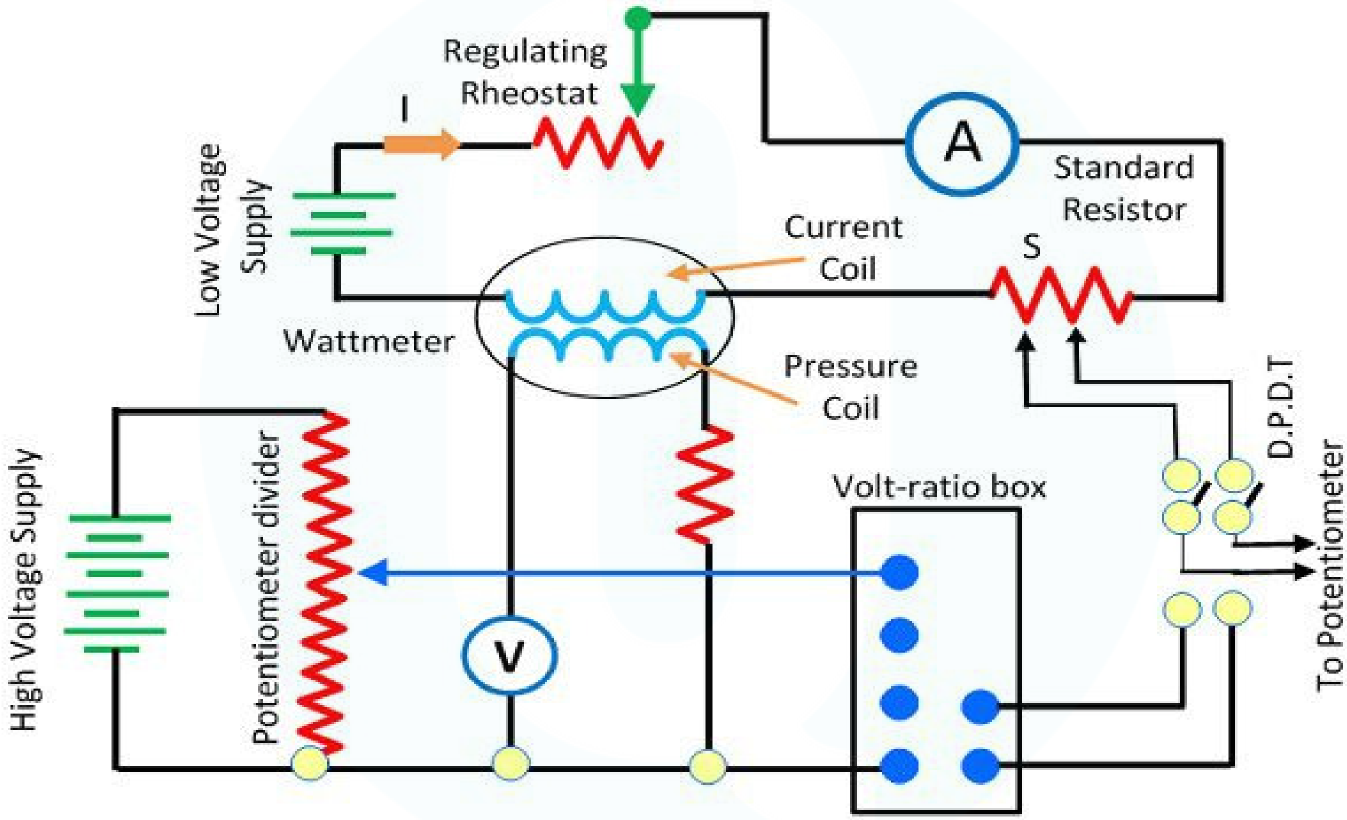
3) Calibration of Wattmeter



Calibration of Wattmeter with a DC Pontentioemter

Circuit Globe

- The current coil of the wattmeter is supplied from a low voltage supply and a series rheostat is inserted to adjust the value of current.
- The potential circuit is supplied from the high voltage supply.
- A volt ratio box is used to step down the voltage for the potentiometer to read. This type of arrangement is known as phantom loading.
- The voltage and current are measured in turn with the potentiometer using a DPDT switch.
- The true power is then VI and the wattmeter reading may be compared with this value.

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