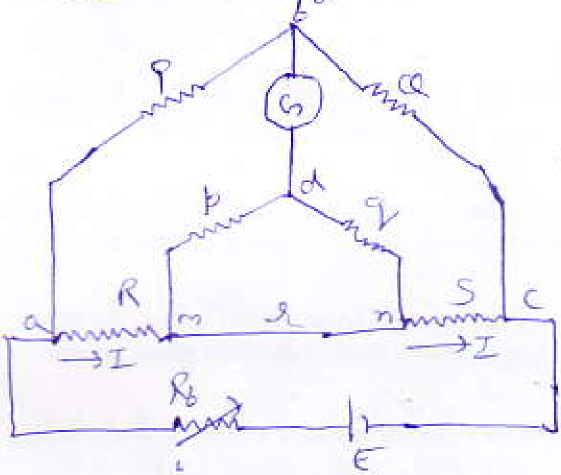
Q1) Explain the method of low resistance measurement by Kelvin's double bridge method

Q2) Explain Maxwell's Inductance Capacitance bridge.

Q3) Explain the loss of charge method for measurement of resistance

Q4) Explain Anderson's bridge

Sol 1) The Kelvin double is a modification of the wheatstone bridge and provides greatly increased accuracy in measurement of low value resistances. The Kelvin double bridge incorporates the idea of a second set of ratio arms — hence the name double bridge and the use of four terminal resistors for the low resistance arms.



As shown in figure the first set 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 leads of resistance r between the known resistance R and the standard resistance S.

The ratio p/q is made equal to P/Q. Under balance conditions there is no current through the galvanometer which means that the voltage drop between a and b, E_{ab} is equal to voltage drop E_{amd} between a and d.

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

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

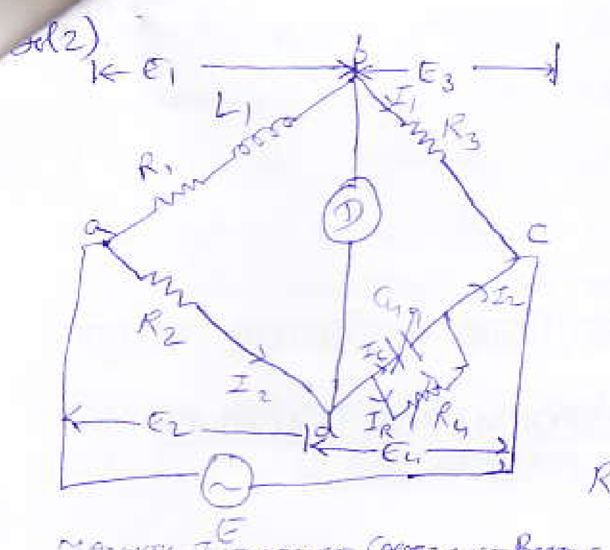
At balance $E_{ab} = E_{amd}$

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

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

Now if $\frac{P}{Q} = \frac{p}{q}$ so $R = \frac{P}{Q}S$

Sol(2)



MAXWELL INDUCTANCE CAPACITANCE BRIDGE

In this bridge, an inductance is measured by comparison with a standard variable capacitance. The connections is shown in the diagram

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

For the bridge to be balanced

$Z_1 Z_4 = Z_2 Z_3$ Here Z_1, Z_2, Z_3 & Z_4 are impedances of arms of ac bridge.

where $Z_1 = R_1 + j\omega L_1$

$Z_2 = R_2$, $Z_3 = R_3$

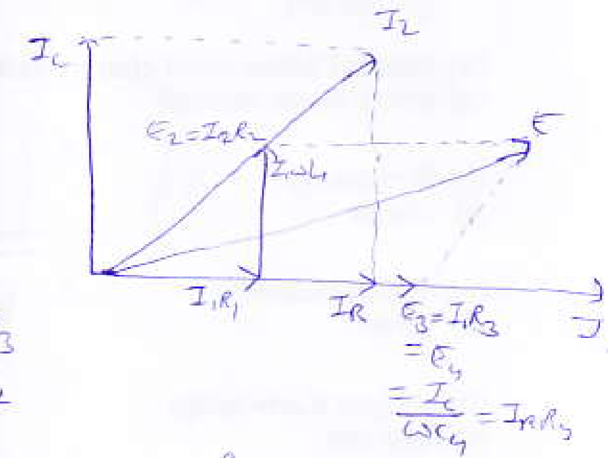
$Z_4 = \dfrac{R_4}{1 + j\omega C_4 R_4}$

So writing the equation for balance

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

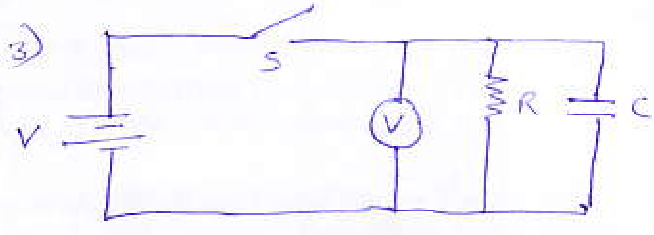
$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega C_4 R_4 R_2 R_3$$

Separating the real and imaginary part we have $R_1 = \dfrac{R_2 R_3}{R_4}$ and $L_1 = R_2 R_3 C_4$



PHASOR DIAGRAM

Sol. 3)



LOSS OF CHARGE METHOD

The insulation resistance R to be measured is connected in parallel with a capacitor C and a electrostatic voltmeter. The capacitor is charged to some 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 period of time during discharge.

The voltage across the capacitor at any instant t after the application of voltage is $v = V \exp(-t/CR)$ or $\dfrac{V}{v} = \exp(-t/RC)$

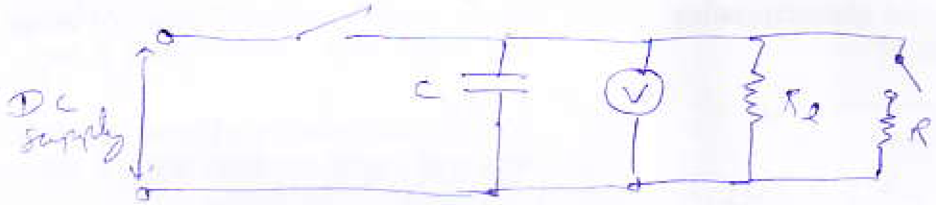
& Insulation resistance $R = \dfrac{t}{C \log_e V/v} = \dfrac{0.4343\,t}{C \log_{10} V/v}$

Actually in this method we do not measure the true value of resistance since we assume here that the value of resistance of electrostatic voltmeter and the leakage resistance of capacitor have infinite value. But in practice corrections must be applied to take into consideration the above two resistances. Below figure shows the actual circuit of the test where R_l represents the leakage resistance of capacitor. Then if R' is the resistance of R_l and R in parallel the discharge equation for capacitance gives

$$R' = \frac{0.4343t}{C \log_{10} V/v}$$

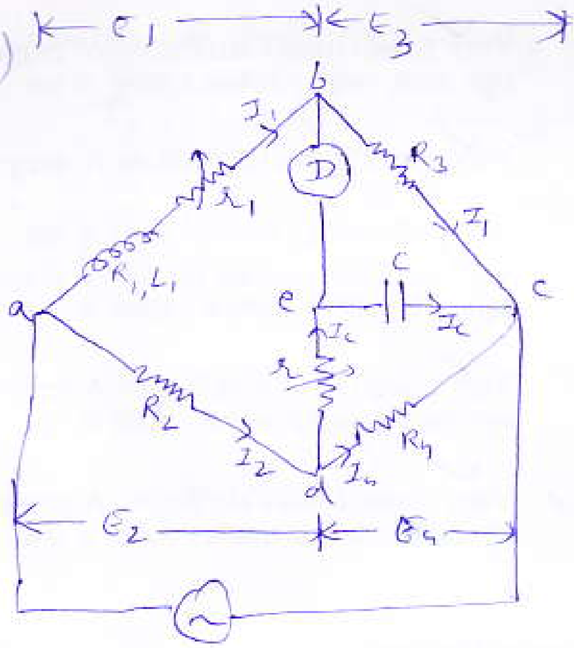
The test is then repeated with the unknown resistance R, disconnected and the capacitor discharging through R_l. The value of R_l obtained from the second test and substituted into the expression

$$R' = \frac{RR_l}{R+R_l}$$ in order to get the value of R.

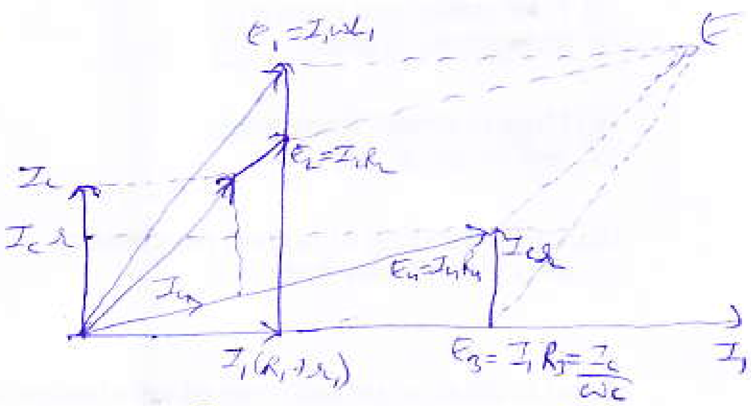


Loss of charge method considering effect of leakage resistance of capacitor

(4)



ANDERSON'S BRIDGE



PHASOR DIAGRAM

Above figure shows the connection and the phasor diagram of the bridge for balanced condition. This bridge is a modification of the Maxwell's Inductance Capacitance bridge. In this method, the self inductance is measured terms of a Standard Capacitor.

Let L_1 = Self inductance to be measured
R_1 = resistance of self inductor
r_1 = resistance connected in series with self inductor
r, R_2, R_3, R_4 = known non inductive resistances
C = fixed standard capacitor

At balance $I_1 = I_3$ and $I_2 = I_c + I_4$

Now $I_1 R_3 = I_c \times \frac{1}{j\omega C}$ $\therefore I_c = j\omega C I_1 R_3$

Writing other balance equations

$$I_1 (r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_c r$$

and $$I_c \left(r + \frac{1}{j\omega C}\right) = (I_2 - I_c) R_4$$

Substituting the value of $I_c = j\omega C I_1 R_3$ in above equations, we have

$$I_1 (r_1 + R_1 + j\omega L_1) = I_2 R_2 + j\omega C I_1 R_3 r$$

or $$I_1 (r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_2 R_2 \quad \text{——} \ (1)$$

and $$j\omega C I_1 R_3 \left(r + \frac{1}{j\omega C}\right) = (I_2 - I_1 j\omega C R_3) R_4$$

or $$I_1 (j\omega C R_3 r + j\omega C R_3 R_4 + R_3) = I_2 R_4 \quad \text{——} \ (2)$$

From eqn (1) & (2) eliminating the term I_2

$$I_1 (r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_1 \left(\frac{R_2 R_3}{R_4} + \frac{j\omega C R_2 R_3 r}{R_4} + j\omega C R_3 R_2 \right)$$

Separating real & imaginary part

$$R_1 = \frac{R_2 R_3}{R_4} - r_1 \quad \& \quad L_1 = C \frac{R_3}{R_4} \left[r (R_4 + R_2) + R_2 R_4 \right]$$