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CHAPTER - 1

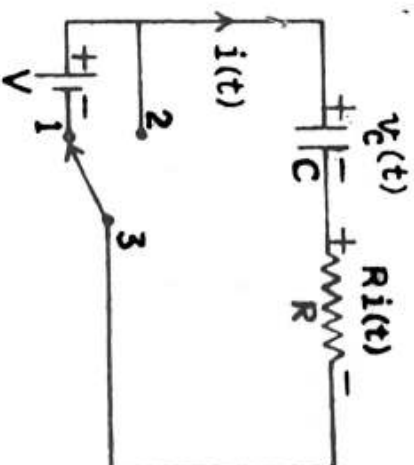
Electrical Circuits

Q1. Find transient charge of capacitor while charging through a resistor. (2014,15)

Ans. Consider a circuit having a capacitance C in series with a resistance R and suppose that a d.c voltage V is applied to it. As soon as the voltage is applied, a charging current flows through the circuit and the capacitor starts getting charged. After time t , let the charge on the capacitor plates be $q(t)$ and the potential difference between them be $V_c(t)$.

$$V_c(t) = \frac{1}{C} q(t).$$

...(1)



Applying Kirchhoff's voltage law to circuit we have

$$\frac{q}{C} + Ri - V = 0$$

$$\frac{dq}{dt} + \frac{1}{CR} q - \frac{V}{R} = 0.$$

$$\left\{ i = \frac{dq}{dt} \right\}, \quad \dots(2)$$

In order to solve this differential equation for q , we need to integrate it. This becomes convenient if we multiply through out by an integrating factor $\exp(t/CR)$:

$$\exp(t/CR) \cdot \frac{dq}{dt} + q \cdot \frac{1}{CR} \exp(t/CR) = \frac{V}{R} \exp(t/CR).$$

$$\frac{d}{dt}[q(\exp(t/CR))] = \frac{V}{R} \exp(t/CR). \quad \dots(3)$$

Integrating with respect to time we get,

$$q \exp(t/CR) = \frac{V}{R} CR \exp(t/CR) + A.$$

$$q = VC + A(\exp(-t/CR)) \quad \dots(4)$$

Where A is the constant for integration. Its value can be found from the known initial condition of the circuit.

at $t = 0$, $q = 0$.

From eq. (4), $A = -VC$.

$$\therefore q = VC[1 - \exp(-t/RC)] \quad \dots(5)$$

In above equation.

$$t \rightarrow \infty, q \rightarrow VC$$

This being independent of time, is just the steady state charge q_0 .

Let us now examine the dimensions of CR.

$$(CR) = [\text{Farad}][\text{ohm}] = \frac{[\text{Coulomb}]}{[\text{Volt}]}[\text{ohm}] = [\text{sec}].$$

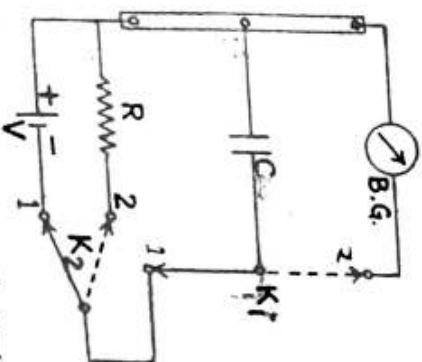
Thus CR has the dimension of time & denoted by τ . Now equation

(5) becomes

$$q(t) = q_0[1 - \exp(-t/\tau)].$$

Q2. Discuss measurement of high resistance by leakage method. (2014)

Ans. The value of a high resistance can be determined by studying the discharge of a known capacitor through this resistance. The circuit arrangement is shown in figure.



Circuit for measurement of a high resistance

The capacitor C is charged to its steady state charge q_0 by turning the keys k_1 & k_2 to 1 for sufficiently long time. The capacitor is now discharged through the galvanometer by turning k_1 to 2. Let the first deflection amplitude be θ_0 with a Logarithmic decrement λ . Then we have

$$q_0 = q_s \theta_0 (1 + \lambda/2) \quad \dots(1)$$

Here, q_s is the charge sensitivity of the galvanometer.

The capacitor is now charged again to its steady state charge q_0 . It is allowed to discharge through the resistance R for a time t by turning the key k_2 to 2 while keeping k_1 connected to 1.

The charge q remaining on the capacitor after this time is given by equation as—

$$q = q_0 \exp(-t/RC) \quad \dots(2)$$

If this charge is now passed through the galvanometer and a first deflection amplitude of θ_1 is obtained, then we must have—

$$q = q_s \theta_1 (1 + \lambda/2) \quad \dots(3)$$

Combining equation (1), (2) & (3)—

$$\frac{\theta_0}{\theta_1} = e^{(t/RC)}.$$

$$R = \frac{t}{C \ln \left(\frac{\theta_0}{\theta_1} \right)} \quad \dots(4)$$

The resistance R can thus be Calculated. It is better to take a set of observations for θ_1 corresponding to different times t .

$$\ln \left(\frac{\theta}{\theta_0} \right) = \left(\frac{1}{RC} \right) t \quad \dots(5)$$

So, it could be a straight line passing through the origin and having

$$\text{a slope } m \text{ given by, } m = \frac{1}{RC}.$$

This experiment will yield the true value of the resistance provided that the capacitor is an ideal capacitor having an infinite resistance. If the capacitor has a finite resistance R , the resistance R evaluated as above will be a parallel combination of the high resistance R_h .

$$\frac{1}{R} = \frac{1}{R'} + \frac{1}{R_h}.$$

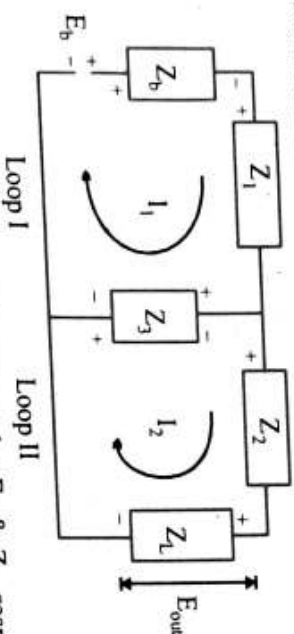
Now, R' can be obtained by repeating the above experiment with the capacitor being allowed to discharge by itself rather than through the external resistance. If the first deflection amplitude obtained after self-discharge of the capacitor for a time t be θ_1 , the leakage resistance R' of the capacitor is given by—

$$R' = \frac{t}{C \ln \left(\frac{\theta}{\theta_1'} \right)}$$

If a set of observation is taken in this case also R' , can be calculated from slope of a graph of $\ln(\theta_0/\theta_1')$ vs. t .

Q3. Perform mesh analysis of a T-network. (2014)

Ans. A T-network consists of three impedances Z_1, Z_2 and Z_3 arranged in the form of a 'T'. It is often used for delivering electrical power from a source to a load.



let the source voltage and impedance be E_b & Z_b , respectively and let the load impedance be Z_L . The entire circuit thus becomes a two loop network. The mesh equation are

$$\begin{aligned} Z_{11}I_1 + Z_{12}I_2 &= E_1 \\ Z_{21}I_1 + Z_{22}I_2 &= E_2 \end{aligned} \quad \dots(1)$$

Where, Z_{11} & Z_{22} are self impedances of loop I & II, respectively, Z_{12} and Z_{21} are their mutual impedances, E_1 & E_2 are respectively the sources voltages in the loop and I_1 and I_2 are the assumed mesh currents with their positive directions as shown in figure. By an examination of the network.

$$\begin{aligned} Z_{11} &= +Z_b + Z_1 + Z_3 \\ Z_{12} &= Z_{21} = -Z_3 \\ E_1 &= E_b, E_2 = 0 \end{aligned} \quad \dots(2)$$

Using Cramer's rule, we can now write down for I_1 and I_2

$$I_1 = \frac{\begin{bmatrix} E_1 & Z_{12} \\ E_2 & Z_{22} \end{bmatrix}}{\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}} = \frac{(E_1 Z_{22} - E_2 Z_{12})}{(Z_{11} Z_{22} - Z_{12} Z_{21})}$$

$$I_1 = \frac{E_b(Z_3 + Z_2 + Z_L)}{(Z_b + Z_1 + Z_3)(Z_3 + Z_2 + Z_L) - Z_3^2} \quad \dots(3)$$

$$I_1 = \frac{\begin{bmatrix} Z_{11} & E_1 \\ Z_{21} & E_2 \end{bmatrix}}{\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}} = \frac{Z_{11}E_2 - Z_{21}E_1}{(Z_{11}Z_{22} - Z_{21}Z_{12})}$$

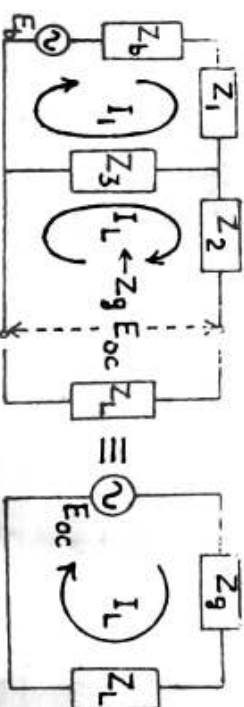
$$I_1 = \frac{Z_3 E_b}{(Z_b + Z_1 + Z_3)(Z_3 + Z_2 + Z_L) - Z_3^2} \quad \dots(4)$$

The voltage across the load impedance Z_L which is the output voltage of the circuit is, therefore, is given by.

$$\begin{aligned} E_{out} &= I_2 Z_L \\ &= \frac{Z_3 Z_L}{(Z_b + Z_1 + Z_3)(Z_3 + Z_2 + Z_L) - Z_3^2} \cdot E_b. \end{aligned}$$

Q4. State and prove Thevenin's Theorem. (2014,16,19)

Ans. This theorem states that "Current in an impedance Z_L connected to two terminals of a network is the same as if Z_L were connected to a voltage generator whose generated voltage is equal to the open circuit voltage at the terminals and whose internal impedance is equal to the impedance of the network looking back from the terminals with all generators replaced by their internal impedances".



The open-circuit voltage at the output terminals of the T-network is given by

$$E_{oc} = \frac{E_b Z_3}{(Z_b + Z_1 + Z_3)}$$

and the impedance between the output terminals looking back into T-network is given by—

$$Z_s = Z_2 + \frac{(Z_b + Z_1)(Z_3)}{Z_b + Z_1 + Z_3}$$

Therefore, from above circuit, the current I_L through Z_L will be,

$$I_L = \frac{E_{oc}}{Z_s + Z_L} = \frac{E_b Z_3 / (Z_b + Z_1 + Z_3)}{Z_2 + \frac{(Z_b + Z_1)Z_3}{Z_b + Z_1 + Z_3} + Z_L}$$

$$I_L = \frac{E_b Z_3}{(Z_b + Z_1 + Z_3)(Z_2 + Z_L) + (Z_b + Z_1)Z_3} \quad \dots(1)$$

The current I_L can be also be found independently from the mesh analysis of the T-network. The mesh equations are—

$$(Z_b + Z_1 + Z_3)I_1 - Z_3 I_L = E_b$$

$$-Z_3 I_1 + (Z_3 + Z_2 + Z_L)I_L = 0$$

Solving these for I_L , we have,

$$I_L = \frac{\begin{vmatrix} (Z_b + Z_1 + Z_3) & E_b \\ -Z_3 & 0 \end{vmatrix}}{\begin{vmatrix} (Z_b + Z_1 + Z_3) & -Z_3 \\ -Z_3 & (Z_3 + Z_2 + Z_L) \end{vmatrix}}$$

$$I_L = \frac{E_b Z_3}{(Z_b + Z_1 + Z_3)(Z_3 + Z_2 + Z_L) - Z_3^2}$$

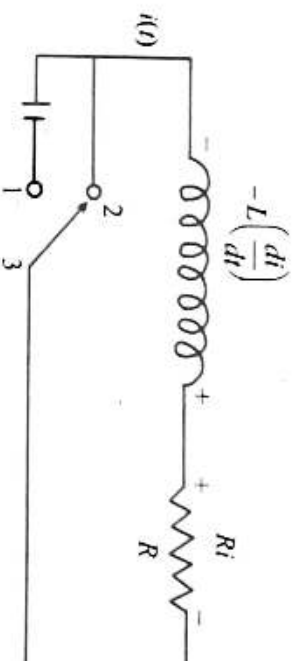
$$I_L = \frac{E_b Z_3}{(Z_b + Z_1 + Z_3)(Z_2 + Z_L) + (Z_b + Z_1)Z_3}$$

The equations (1) & (2) are identical. This verifies theorem for a T-network by Thevenin's theorem.

Q5. Discuss transient decay of current in an inductive circuit. (2014)

Ans. Suppose in the circuit the two way key is turned to 2 after the circuit has acquired steady state. Thus there is no external voltage acting in the circuit and the circuit current will gradually decay from

its steady value I_0 to 0. As soon as the current start decreasing, an induced voltage will appear across the inductance L . Its magnitude will now be $\left(-L \frac{di}{dt}\right)$ because (di/dt) is now a negative quantity. Its polarity will be such that it opposes the decrease in current by sending a current in the same direction as $i(t)$. Applying voltage law,



$$L \frac{di}{dt} + Ri = 0 \quad \dots(1)$$

Rearranging, this

$$\frac{di}{i} = -\frac{R}{L} dt \quad \dots(2)$$

Integrating this equation

$$\ln i = -\frac{R}{L} t + A' \quad \dots(3)$$

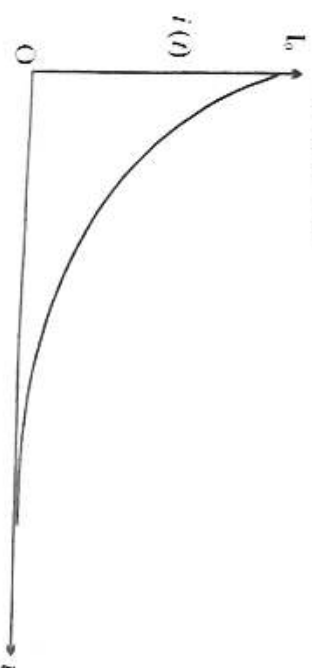
where, A' is the constant of integration.

at $t = 0$, $i(t) = I_0$.

$\therefore A' = \ln I_0$

Substituting this value in equation (3),

$$i = I_0 \exp(-t/\tau).$$



Q6. A potential difference of 10V is connected to a series combination of $L = 1.0H$ & $R = 100\Omega$. Calculate the time constant and transient current a time constant. (2014,18)

Ans. $V = 10V$, $L = 1H$, $R = 100\Omega$.

$$\text{time constant, } \tau = \frac{L}{R} = \frac{1}{100} = 0.01 \text{ sec.}$$

transient current at $t = \tau$.

$$i(t) = 0.632 I_0$$

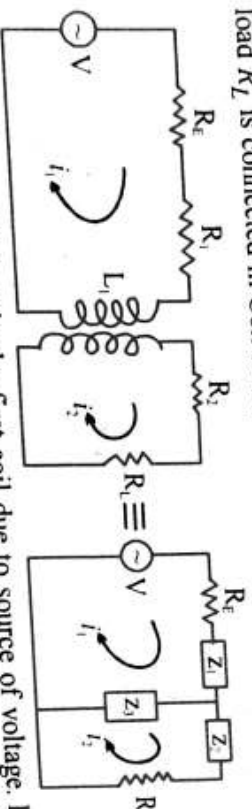
$$i(t) = 0.632 \times \frac{V}{R}$$

$$i(t) = 0.632 \times \frac{10}{100}$$

$$i(t) = 0.0632 \text{ Amp.}$$

Q7. Find equivalent circuit of transformer. (2014,15,17)

Ans. Let T network of two coils has impedances Z_1, Z_2, Z_3 . Since coils are made using thin wires, both coils have finite d.c. resistances. Let R_1 & R_2 represents d.c. resistances of these coils. Let energy source V of internal resistance R_E is connected in coil 1 & load R_L is connected in Coil no. 2.



Let i_1 current flow in the first coil due to source of voltage. It cause an induced voltage in second coil which produces i_2 current through it. Current i_2 in second coil will induce a voltage in first coil through the mutual inductance which will oppose V . Thus voltage relation for the two circuits can be written as—

$$V = (R_1 + R_E)i_1 + L_1 \frac{di_1}{dt} - \frac{M di_2}{dt}$$

$$\text{and } 0 = (R_1 + R_L)i_2 + L_2 \frac{di_2}{dt} - \frac{M di_1}{dt}$$

Let ω be angular frequency of source voltage in coil 1. then phasor notation gives.

$$V = (R_1 + R_E)i_1 + j\omega L_1 i_1 - \frac{M}{j\omega} i_2$$

$$0 = (R_1 + R_L)i_2 + j\omega L_2 i_2 - \frac{M}{j\omega} i_1$$

Writing current & voltage relation for equivalent T-network

$$V = (R_E + Z_1 + Z_3)i_1 - Z_3 i_2$$

$$0 = (Z_2 + Z_3 + R_L)i_2 - Z_3 i_1$$

Comparing the respective equations

$$(R_E + Z_1 + Z_3) = R_E + R_1 + j\omega L_1$$

$$Z_3 = j\omega M$$

$$(R_L + Z_2 + Z_3) = R_L + R_2 + j\omega L_2$$

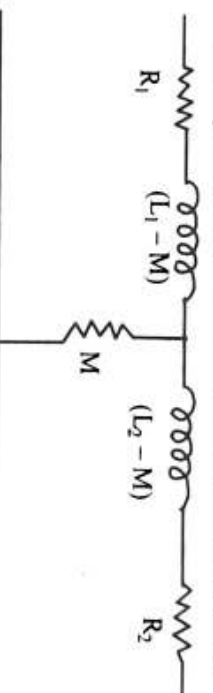
These equations will gives—

$$Z_1 = R_1 + j\omega(L_1 - M)$$

$$Z_2 = R_2 + j\omega(L_2 - M)$$

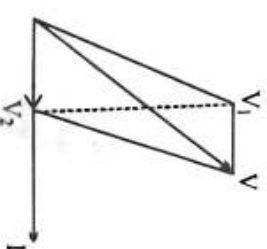
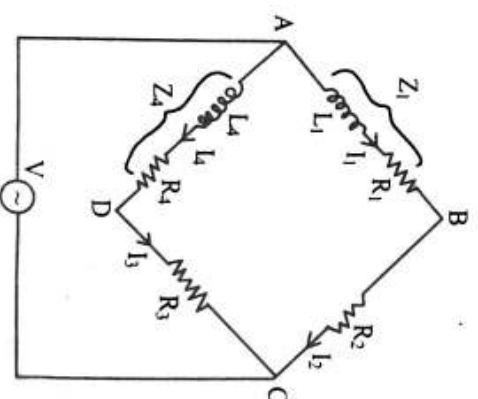
$$Z_3 = j\omega M$$

Thus equivalent T-network for transformer will becomes.



Q8. Write short notes on maxwell's bridge. (2014,16,19)

Ans. From the figure—



$$I_2 R_2 = I_3 R_3$$

$$I_1 R_1 = I_4 R_4$$

$$Z_1 = R_1 + jX_1 = R_1 + j\omega L_1$$

$$Z_4 = R_4 + jX_4 = R_4 + j\omega L_4$$

The inductance L_4 is a variable self-inductance of constant resistance, its inductance being of the same order as L_1 . The bridge is balanced by varying L_4 and one of the resistance R_2 or R_3 . Alternatively R_2 and R_3 can be kept constant and the resistance of one of the other two arms can be varied by connecting an additional resistance in that arm.

The balance condition is that

$$Z_1 Z_3 = Z_2 Z_4$$

$$(R_1 + j\omega L_1)(R_3 + j\omega L_3) = (R_2 + j\omega L_2)(R_4 + j\omega L_4)$$

Equating the real and imaginary parts on both sides, we have

$$R_1 R_3 = R_2 R_4$$

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

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

$$\text{and } \omega L_1 R_3 = \omega L_2 R_4$$

$$\text{or } L_1 = L_2 \frac{R_2}{R_3} = L_2 \frac{R_1}{R_4}$$

Hence, the unknown self inductance can be measured in terms of known inductance L_2 and the two resistors. Resistive & reactive terms balance independently and the conditions are independent of frequency. This bridge is often used for measuring the iron losses of the transformer at audio frequency.

The balance condition shown vectorially. The currents I_4 & I_3 are in phase with I_1 & I_2 .

This is obviously brought about by adjusting the impedances of different branches, so that these current lag behinds the applied voltage V by the same amount. At balance, the voltage drop V_1 across branch 1 is equal to that across branch 4 and $I_3 = I_4$. Similarly, voltage drop V_2 across branch 2 is equal to that across branch 3 and $I_1 = I_2$.

Q9. A Carbon resistor has four colour bands as brown, black, orange and gold. Calculate the correct value of the resistance of the carbon resistor. (2015)

Ans. First two bands denote the first two digits of the resistance value while the third band denotes the number of zero to be added to the first two digit in order to get resistance in ohms. The fourth band indicates the tolerance of the resistor.

Brown $\rightarrow 1$
Black $\rightarrow 0$
Orange $\rightarrow 3$
Gold $\rightarrow 5\%$

The resistance of given resistor is $10 \times 10^3 \pm 5\%$

Q10. A Carbon resistor as the following colour bend : Yellow, Violet, Orange, Silver. What information does it give about the resistor. (2016)

Ans. The resistance value is $47 \times 10^3 \pm 10\%$

Q11. Calculate the resistance of a carbon resistor having four colour bands as Green, Black, Red and Silver. (2018)

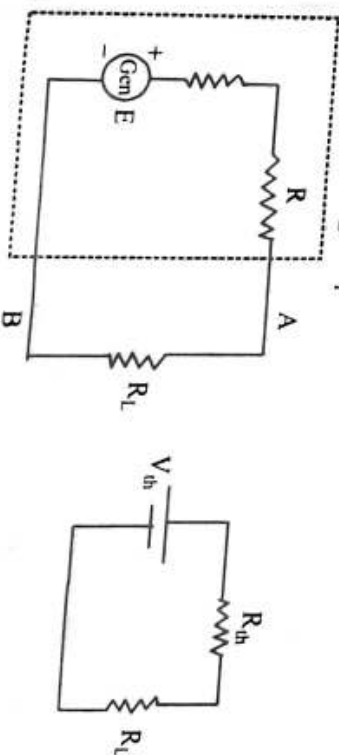
Ans. The resistance value is $50 \times 10^2 \pm 10\%$.

Q12. State and prove maximum power transfer theorem.

Ans. For a dc network maximum power transfer theorem states that— (2015,18)

A resistive load will abstract maximum power from a network when the load resistance is equal to the resistance of the network as viewed from output terminals, with all energy sources removed leaving behind their internal resistances. As shown in figure a load resistance R_L is connected across the terminals A and B of a network, which consists of a generator of emf E , and internal resistance R_g and a the connecting wires. Let $R_i = R_g + R =$ internal resistance of the network as viewed from terminal A and B.

According to this theorem, R_L will abstract maximum power from the network when $R_L = R_i$.



Circuit current $I = \frac{E}{R_L + R_i}$

Power consumed by load is $P_L = I^2 R_L$

$$P_L = \frac{E^2 R_L}{(R_L + R_i)^2}$$

For P_L to be maximum,

$$\frac{dP_L}{dR_L} = 0$$

Differentiating equation (1), w.r.t. R_L and equating it to zero, we get.

$$0 = E^2 \left[\frac{1}{(R_L + R_i)^2} - \frac{2R_L}{(R_L + R_i)^3} \right]$$

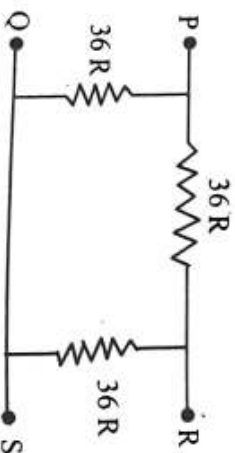
$$\Rightarrow 2R_L = R_L + R_i$$

$$\Rightarrow R_L = R_i$$

$\therefore$ Maximum Power,

$$(P_L)_{\max} = \frac{E^2 R_L}{4R_L^2} = \frac{E^2}{4R_L} = \frac{E^2}{4R_i}$$

Q13. Transfer the following network into T-network. (20)



Ans. Here $Z_A = Z_B = Z_C = 36R$

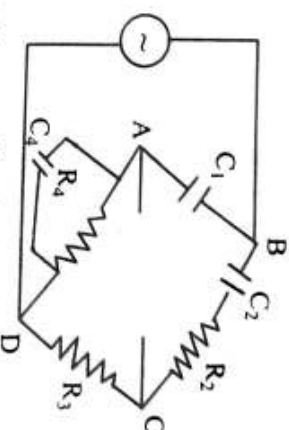
$$\text{Then, } Z_1 = \frac{Z_A Z_B}{Z_A + Z_B + Z_C} = \frac{36 \times 36}{36 + 36 + 36} = 12R.$$

$$\text{Similarly, } Z_2 = \frac{Z_B Z_C}{Z_A + Z_B + Z_C} = \frac{36 \times 36}{36 + 36 + 36} = 12R.$$

$$\& \quad Z_3 = \frac{Z_C Z_A}{Z_A + Z_B + Z_C} = \frac{36 \times 36}{36 + 36 + 36} = 12R.$$

Q14. Obtain capacity of a capacitor using schering bridge. (2011,13,15)

Ans. It is one of the very important and useful methods of measuring the capacitance and dielectric loss of a capacitor. In fact, it is a device for comparing an imperfect capacitor C_2 in terms of a loss-free standard capacitor C_1 . The imperfect capacitor is represented by its equivalent loss-free capacitor C_2 in series with a resistance r .



For high voltage applications, the voltage is applied at the junctions. The junction between arms 3 and 4 is earthed. Since capacitor impedance at lower frequencies are much higher than resistances, most of the voltage will appear across capacitors. Grounding of the junction affords safety to the operator from the high-voltage hazards while making balancing adjustment in arm 3 and 4.

$$Z_1 = \frac{-j}{\omega C_1}$$

$$Z_2 = r - \frac{j}{\omega C_2}$$

$$Z_3 = R_3$$

$$Z_4 = \frac{1}{(1/R_4) + j\omega C_4} = \frac{R_4}{1 + j\omega C_4 R_4}$$

For balance,

$$Z_1 Z_3 = Z_2 Z_4$$

$$\frac{-jR_3}{\omega C_1} = \left[r - \frac{j}{\omega C_2} \right] \left[\frac{R_4}{1 + j\omega C_4 R_4} \right]$$

$$\frac{-jR_3}{\omega C_1} (1 + j\omega C_4 R_4) = R_4 \left[r - \frac{j}{\omega C_2} \right]$$

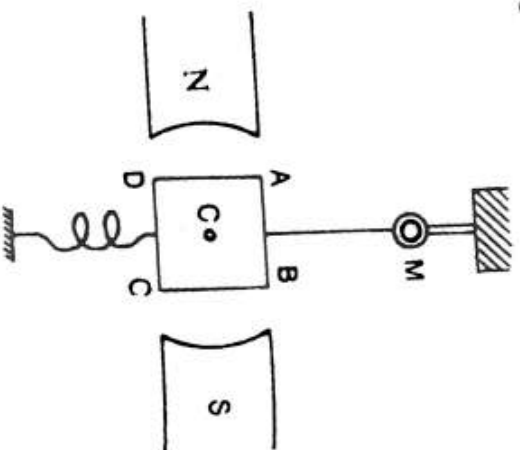
Separating, real and imaginaries, we have,

$$C_2 = C_1(R_4 / R_3).$$

$$\text{and, } r = R_3(C_4 / C_1).$$

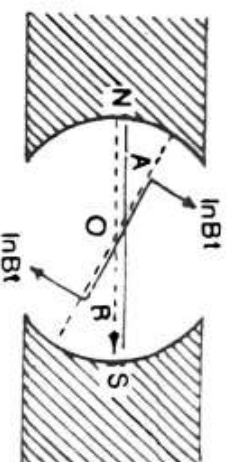
Q15. What is ballistic galvanometer? Find an expression for the current sensitivity of moving coil galvanometer. (2013,15,18)

Ans. Ballistic galvanometer is essentially a moving coil galvanometer which consists of rectangular coil EFGH of wire of many turns wound on a non-metallic frame. It is suspended by quartz fibre between two strong permanent magnetic poles N,S. A soft iron core C is fixed to the frame of the galvanometer at the centre of the coil and is detached from it. The pole pieces are cylindrical so that magnetic field is radial. In radial field plane of the coil remains in the direction of the field in every position. Iron core is used to concentrate the field in the central region of the pole pieces.



Moving coil galvanometer (a) front view

When current is passed through the coil the length sides EF and GH experience force governed by Fleming's left hand rule. As radial magnetic field B is used, the coil remains along magnetic field in every position. hence the length side experience equal and opposite magnetic force perpendicular to the plane of coil. These force constitute a deflecting couple and controlling couple is provided by the torsion in the suspension fibre. In equilibrium these two couples are equal.



Top view moving coil Galvanometer

Deflecting couple for one turn of coil = $iBlb$

For n turns deflecting couple = $nBlb$.

But Area of coil $A = l \times b$

In equilibrium $n i A B = C \theta$.

Where, C is couple per unit twist of suspension fibre and θ is the twist is fibre. Equation (1) indicates that the current is directly proportional to the deflection. The proportionality constant is called current sensitivity. If θ is measured (in mm) on a scale placed on meter away from the galvanometer by reflected light from plane mirror attached to the coil, then

$$I = \frac{C \theta}{n A B}$$

$$C_s = \frac{I}{\theta} = \frac{C}{n A B} \text{ is called current sensitivity.}$$

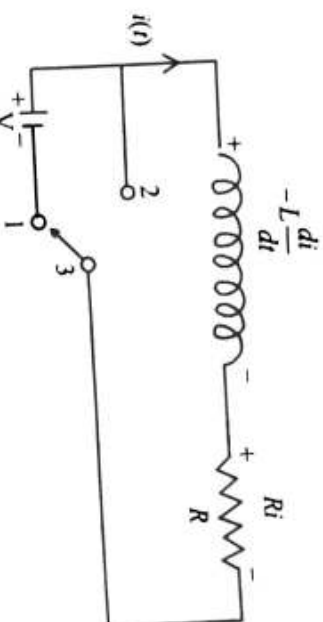
It is defined as the current to produced deflection of one mm on a scale place one meter away from the galvanometer. Hence

$$C_s = \frac{C}{n A B}$$

Galvanometer is more sensitive if less current is required to produce unit deflection. Hence, Galvanometer is made more sensitive by increasing number of turns, area of coil, magnetic flux density between pole pieces and decreasing couple per unit twist of fibre.

Q16. A voltage v is applied across a series combination of inductance L and a resistance R . show only by graphs how do the voltages across L and R vary with time during the transient state. (2016,18)

Ans. Consider a circuit having an inductance L in series with a resistance R and suppose a steady d.c. voltage V is applied to it.



Applying Kirschhoff's law—

$$L \frac{di}{dt} + Ri - V = 0$$

Rearranging, we get

$$\frac{1}{(V - Ri)} di = \frac{1}{L} dt$$

Integrating,

$$\frac{-1}{R} \ln(V - Ri) = \frac{t}{L} + C$$

Where, C is constant of integration.

At $t = 0$, $i = 0$

$$\therefore C = \frac{-\ln V}{R}$$

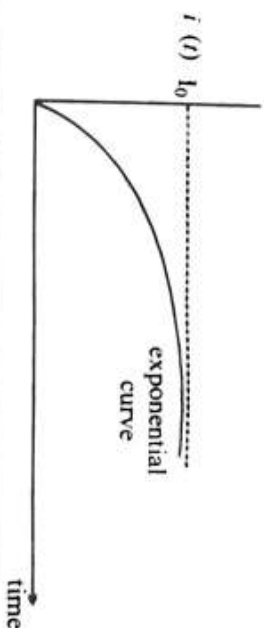
$$\text{Now, } \frac{-1}{R} \ln \left(\frac{V - Ri}{V} \right) = \frac{t}{L}$$

$$\left(1 - \frac{Ri}{V} \right) = \exp \left\{ \frac{-R}{L} t \right\}$$

$$1 = \frac{V}{R} \left[1 - \exp \left\{ \frac{-Ri}{L} \right\} \right]$$

$$i = I_0 [1 - \exp \{-t / \tau\}]$$

$$\text{where, } I_0 = \frac{V}{R} \text{ \& } \tau = \frac{L}{R}$$



Q17. Define Quality Factor Q of a resonant circuit. (2016)

Ans. The Q factor of an R-L-C series circuit can be defined in two different ways—Firstly, It is given by the voltage magnification produced in the circuit at resonance. At resonance, current has maximum value $I_0 = V/R$. Voltage across either coil or capacitor = $I_0 X_{L0}$ or $I_0 X_{C0}$. Supply voltage $V = I_0 R$.

$$\therefore \text{Voltage magnification } = \frac{V_{C0}}{V} = \frac{I_0 X_{L0}}{I_0 R}$$

$$Q \text{ factor} = \frac{\text{reactive power}}{\text{active power}} = \frac{X_{L0}}{R} = \frac{w_0 L}{R}$$

$$= \frac{\text{reactance}}{\text{resistance}}$$

$$\text{or } Q\text{-factor} = \frac{V_{C0}}{V} = \frac{I_0 X_{C0}}{I_0 R} = \frac{\text{reactive power}}{\text{active power}}$$

$$= \frac{X_{C0}}{R} = \frac{\text{reactance}}{\text{resistance}} = \frac{1}{w_0 CR}$$

$$\therefore Q \text{ factor} = \frac{w_0 L}{R} = \frac{2\pi f_0 L}{R} = \tan \phi$$

Second, The Q factor may also be defined as

$$Q\text{-factor} = 2\pi \frac{\text{maximum stored energy}}{\text{energy dissipated per cycle}}$$

$$Q\text{-factor} = \frac{2\pi \left(\frac{1}{2} L I_0^2 \right)}{I^2 R T_0} = \frac{2\pi L (\sqrt{2} I)^2}{I^2 R (1/F_0)}$$

$$= \frac{I_0^2 2\pi f_0 L}{I^2 R} = \frac{w_0 L}{R} = \frac{1}{w_0 CR}$$

Q18. A T-network has the impedances $Z_1 = Z_2 = Z_3 = (75 + j30)$ ohms. Calculate the impedances of an equivalent π -network. (2016,18)

Ans. Given, $Z_1 = Z_2 = Z_3 = (75 + j30) = Z$, then,

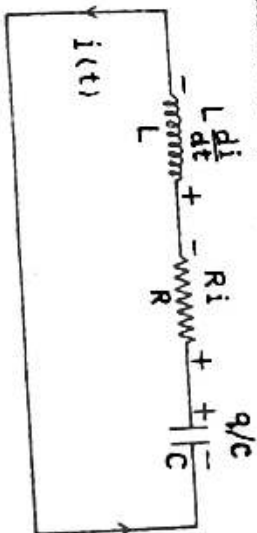
$$Z_A = Z_B = Z_C = \frac{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}{Z_2}$$

$$= \frac{3Z^2}{Z} = 3Z = 3(75 + j30)$$

$$Z_A = Z_B = Z_C = 225 + j150.$$

Q19. A capacitor C having an initial charge q_0 is discharged through an inductance L and a resistance R in series. Write down the differential equation for the charge on the capacitor during the transient state. State the condition for the discharge to be oscillatory. (2016)

Ans. Consider a circuit having a capacitance C in series with an inductance L and a resistance R as shown in Fig., and suppose that the capacitor has an initial charge q_0 on its plates. The initial potential difference between the capacitor plates would, therefore, be q_0/C . This would act as a potential source in the circuit and would send a transient current $i(t)$ through the circuit in the direction shown in Fig. The current results in a voltage drop Ri across the resistance and



an induced voltage $L \frac{di}{dt}$ across the inductance L with its polarity as marked in the figure. We can now apply Kirchhoff's voltage law to this circuit. We thus have

$$-L \frac{di}{dt} - Ri + \frac{q}{C} = 0,$$

where q is the charge remaining on the capacitor plates at time t . Since q is decreasing with time, the current i and di/dt are given by

$$i = \frac{dq}{dt}, \frac{di}{dt} = -\frac{d^2q}{dt^2} \quad \dots(2)$$

Substituting from equation (1) in (2), we get

$$L \frac{d^2q}{dt^2} + R \frac{dq}{dt} + \frac{q}{C} = 0.$$

Rearranging and making some substitutions, this equation becomes

$$\frac{d^2q}{dt^2} + 2k \frac{dq}{dt} + \omega^2 q = 0, \quad \dots(3)$$

where,

$$k = \frac{R}{2L}, \omega = \frac{1}{\sqrt{LC}}.$$

Equation (3) is a linear second-order differential equation. It can be solved by assuming a trial solution of the form

$$q = A \exp(mt), \quad \dots(4)$$

Where A and m are some constants whose values are yet to be found out. Differentiating equation (4) and substituting in equation (5), we have

$$(m^2 + 2km + \omega^2)q = 0,$$

For this equation to be true at all times t , the quantity within brackets must vanish because $q(t) \neq 0$ for all t . Thus

$$m^2 + 2km + \omega^2 = 0 \quad \dots(5)$$

which is a quadratic equation with m as the unknown and k and ω as the known coefficients. The solution of equation (5) is

$$m = -k \pm \sqrt{k^2 - \omega^2}$$

Substituting this value of m in equation (4), we get the two possible solutions of equation (3). These are

$$q = A \exp\{-k + \sqrt{k^2 - \omega^2}\} t,$$

$$\text{and } q = A \exp\{-k - \sqrt{k^2 - \omega^2}\} t,$$

The two solutions are equally valid for any value of the constant A . In general, they can be different for the two solutions. So we take the constant to be A_1 in the first case and A_2 in the second case. We

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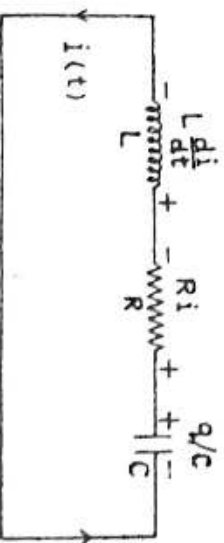
$$Z_A = Z_B = Z_C = \frac{Z(Z_2 + Z_2Z_3 + Z_3Z_1)}{Z_2}$$

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as marked in the figure. We can now apply Kirchhoff's voltage law to this circuit. We thus have

$$-L \frac{di}{dt} - Ri + \frac{q}{C} = 0. \quad \dots(1)$$

where q is the charge remaining on the capacitor plates at time t . Since q is decreasing with time, the current i and di/dt are given by

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The two solutions are equally valid for any value of the constant A . In general, they can be different for the two solutions. So we take the constant to be A_1 in the first case and A_2 in the second case. We

also know that if there are two equally valid solutions for any differential equation, their sum would also be a valid and more general solution. Thus the general solution of equation (3) can be written as

$$q = A_1 \exp \{-k + \sqrt{k^2 - \omega^2}\} t + A_2 \exp \{-k - \sqrt{k^2 - \omega^2}\} t \quad \dots (6)$$

Equation (6) describes the variation of the charge q on the capacitor with time t .

$$\text{For } k^2 < \omega^2, R < \sqrt{(4L)/C}$$

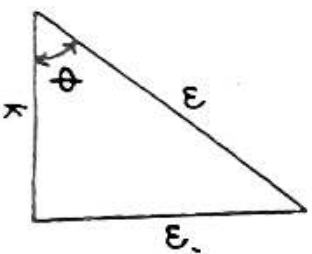
In this case the number $p (= \sqrt{k^2 - \omega^2})$ will be an imaginary number. Let it be $j\omega'$ where $j = \sqrt{-1}$ and ω' is given by

$$\omega' = \sqrt{\omega^2 - k^2} = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Therefore, the final solution of the differential equation in this case will be obtained by replacing p by $j\omega'$ in equation. We thus have

$$\begin{aligned} q(t) &= \frac{q_0}{j\omega'} \left[(k + j\omega') e^{(-k + j\omega')t} + (-k + j\omega') e^{(-k - j\omega')t} \right] \\ &= q_0 e^{-kt} \left[\frac{1}{\omega'} \frac{e^{j\omega' t} - e^{-j\omega' t}}{2j} + \frac{e^{j\omega' t} + e^{-j\omega' t}}{2} \right] \\ &= q_0 e^{-kt} \left[\frac{1}{\omega'} \sin \omega' t + \cos \omega' t \right] \quad \dots (7) \end{aligned}$$

where we have used the exponential representations for sine and cosine functions. Since $\omega^2 = \omega'^2 + k^2$, ω , ω' and k can be represented by the sides of a right angled triangle as shown in Fig.



Substituting for k and ω' in terms of ω and ϕ , where ϕ is defined by the equation

$$\phi = \tan^{-1} \frac{\omega'}{k},$$

equation (7) becomes

$$q(t) = q_0 e^{-kt} \frac{\omega}{\omega'} \sin(\omega' t + \phi). \quad \dots (8)$$

The current $i(t)$ through the circuit is, therefore, given by

$$\begin{aligned} i(t) &= -\frac{dq}{dt} \\ &= -q_0 e^{-kt} \frac{\omega}{\omega'} [-k \sin(\omega' t + \phi) + \omega' \cos(\omega' t + \phi)] \\ &= -q_0 e^{-kt} \frac{\omega^2}{\omega'} [-\cos \phi \sin(\omega' t + \phi) + \sin \phi \cos(\omega' t + \phi)] \\ &= -q_0 e^{-kt} \frac{\omega^2}{\omega'} \sin \omega' t \quad \dots (9) \end{aligned}$$

equations (8) and (9) give the charge on the capacitor and the circuit current when R is less than $\sqrt{(4L)/C}$. We can not draw graphs showing variation of $q(t)$ and $i(t)$ with time. Since they both contain sine function, they must be oscillatory.

Q20. Explain damping in moving coil galvanometer. How will you measure a capacitance using a ballistic galvanometer? (2016)

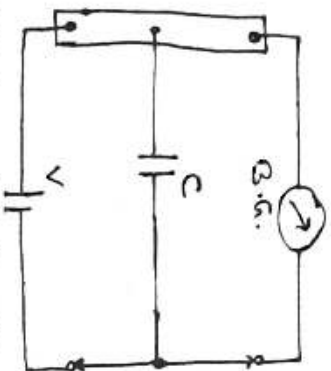
Ans. Damping means dissipation of energy of rotation. This dissipation of energy is due to partly to mechanical effects and due to electromagnetic effects from the coil circuit.

Mechanical damping is mostly due to friction produced occurring to motion of coil in the air surrounding it.

A small dissipation of energy is associated with fixing of suspensions (elastic hysteresis).

Electromagnetic damping is produced by the induced effects when the coil moves in the magnetic field and a closed path is provided for the current to flow. The electromagnetic damping is because of eddy current produced & current circulated in the coil circuit by emf generated in the coil when it rotates.

The capacitance is defined as the ratio of charge Q stored in the capacitor voltage V between its plate. The charge can be measured by a ballistic galvanometer as in circuit shown—



The capacitor is first connected to the voltage source and charged sufficiently long so that, for all practical purposes, it acquires the steady state charge Q . It is now connected to the ballistic galvanometer. A transient current passes and the galvanometer shows deflection amplitude θ_1 with successive amplitude decreasing with logarithmic decrement λ . the charge Q is then given by—

$$Q = q_s \theta_1 \left[1 + \frac{\lambda}{2} \right]$$

& therefore capacity C can be calculated

$$\text{as } C = \frac{q_s}{V} \theta_1 \left[1 + \frac{\lambda}{2} \right]$$

Q21. show the vector diagrams for the voltages $\vec{V}_R$, $\vec{V}_L$ & $\vec{V}_C$ in a series resonant circuit when the frequency of the applied voltage is (i) less than (ii) equal to, (iii) more than the resonant frequency of the circuit. State the nature of the circuit behaviour in each case. (2015, 16, 19)

Ans. Consider an alternating voltage $v(t)$ applied to a series circuit as shown in Let (i) be the resulting current

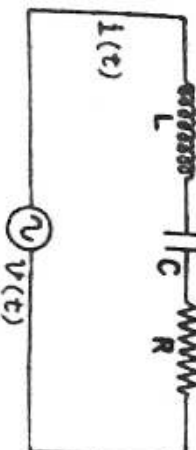


Fig. A series resonant circuit.

Applying Kirchhoff's voltage law we get

$$v(t) = Ri(t) + L \frac{di(t)}{dt} + \frac{1}{C} \int i(t) dt. \quad \dots (1)$$

An identical equation will hold good between corresponding vectors

$$V = RI + L \frac{dI}{dt} + \frac{1}{C} \int Idt,$$

where the voltage vector V

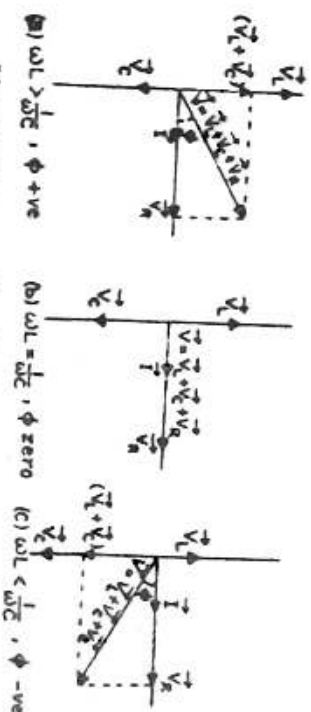
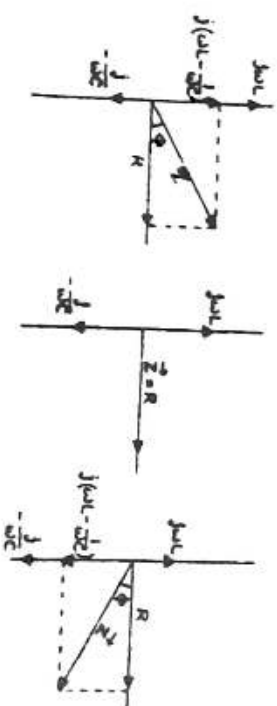
Substituting for dI/dt and $\int Idt$ equation (1) becomes

$$V = RI + j\omega LI + \frac{1}{j\omega C} I$$

$$\text{or, } \frac{V}{I} = R + j \left(\omega L - \frac{1}{\omega C} \right) = R + jX = Z,$$

where Z is the complex impedance of the circuit. It has a real part R and an imaginary part $(\omega L - 1/\omega C)$ which may be positive, zero or negative according as ωL is greater than, equal to or less than $1/(\omega C)$. Z for the three cases. In every case it can be expressed as :

$$Z = |Z| e^{j\phi}$$



Vector diagrams for the series resonant circuit

where

$$|Z| = \sqrt{R^2 + X^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\phi = \tan^{-1} \frac{X}{R} = \tan^{-1} \frac{\omega L - \frac{1}{\omega C}}{R}$$

The current I can then be written as

$$I = \frac{V}{Z} = \frac{V_0 e^{j\omega t}}{|Z| e^{j\phi}} = I_0 e^{j(\omega t - \phi)}$$

where

$$I_0 = V_0 / \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

The potential drops V_R , V_L and V_C across the three circuit elements R , L and C are given by

$$V_R = RI, V_L = j\omega L I, V_C = -\frac{j}{\omega C} I.$$

complete vector diagram for the three cases mentioned above is shown in Figs. (a), (b) and (c).

From foregoing analysis and the vector diagrams, following conclusions can be summarized :

- (i) Current amplitude I_0 is $V_0 / \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ and is

thus frequency dependent.

- (ii) The circuit has a complex impedance having a resistance R and a reactance X which is the resultant of an inductive reactance $j\omega L$ and capacitive reactance $-j/\omega C$. The reactance and therefore, the impedance are frequency dependent. Three cases can be distinguished:

- (a) If $\omega > 1/\sqrt{LC}$, $\omega L > \frac{1}{\omega C}$, the reactance X will be positive and the circuit will behave as an inductive circuit.

- (b) If $\omega = 1/\sqrt{LC}$, $\omega L = \frac{1}{\omega C}$, the reactance X will be zero and the circuit will behave as a resistive circuit.

- (c) If $\omega < 1/\sqrt{LC}$, $\omega L < \frac{1}{\omega C}$, the reactance X will be negative and the circuit will behave as a capacitive circuit.

The three cases are shown diagrammatically in Fig. (a), (b) and (c) respectively.

- (iii) The phase difference between current and voltage is ϕ given by equation. This is also frequency dependent.

- (a) If $\omega > 1/\sqrt{LC}$, $\omega L > 1/(\omega C)$, ϕ will be positive and current will lag behind the voltage.

- (b) If $\omega = 1/\sqrt{LC}$, $\omega L = 1/(\omega C)$, ϕ will be zero and current and voltage will be in the same phase.

- (c) If $\omega < 1/\sqrt{LC}$, $\omega L < 1/(\omega C)$, ϕ will be negative and current will lead the voltage.

This is again illustrated in the vector diagrams of Fig.

Q22. Obtain expression for the average power consumed in an a.c. circuit. Show that the current through a pure inductance is wattless. (2016)

Ans. Power is the rate of doing work. In a mechanical system it is expressed as

$$P = F \frac{dx}{dt},$$

where F is the driving force and dx is the distance moved in a time dt . In an electrical system, it is the electrical charge that moves and the potential difference provides the necessary driving force. It has already been shown that the electrical power P is given by the product of potential difference across the circuit and current through it.

In an a.c. circuit, since voltage and current are both time dependent, power will also vary with time. The instantaneous power $p(t)$ at any instant t will be

$$p(t) = v(t) i(t) \quad \dots (1)$$

If we take the voltage to be $V_0 \sin \omega t$, then the general expression for current will be

$$i(t) = I_0 \sin(\omega t + \phi),$$

where I_0 is the amplitude of current and ϕ is the phase difference between voltage and current. Substituting for $v(t)$ and $i(t)$ in equation (1), we get

$$p(t) = V_0 I_0 \sin(\omega t + \phi) \\ = \frac{V_0 I_0}{2} [\cos \phi - \cos(2\omega t + \phi)]$$

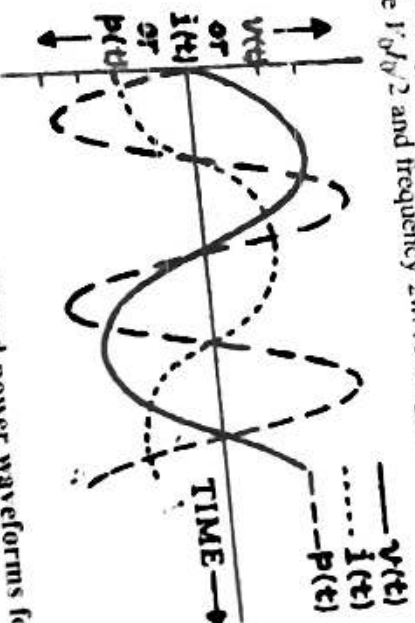
The nature of variation of $p(t)$ with time thus depends on the value of ϕ for the particular circuit under consideration. We consider some special cases.

(i) **purely inductive circuit** : For such circuits, $\phi = -\frac{\pi}{2}$.

Therefore,

$$p(t) = -\frac{V_0 I_0}{2} \sin 2\omega t.$$

Thus the power consumed by the circuit varies as a sine wave of amplitude $V_0 I_0 / 2$ and frequency 2ω . Average of



Voltage, current and power waveforms for a purely inductive circuit.

$p(t)$ over one cycle is, therefore, zero. Thus the average power consumed by a purely inductive circuit is zero; for half of the cycle source gives power to the circuit while for the remaining half, circuit gives an equal amount of power to the source. A current through a purely inductive circuit is, therefore, known as wattless current.

Q23. A Capacitor of capacitance $05 \mu\text{F}$ and leakage resistance $10 \text{ M}\Omega$ is charged to a certain voltage and then insulated. Find the time the voltage will take to fall to half of its original value. (2017)

Ans. The voltage between the capacitor plates is given by—

$$V_c(t) = V[1 - \exp(-t/\tau)]$$

$$(V_C)_{\text{final}} = \frac{V}{2} \quad (V)_{\text{initial}} = V,$$

$$\tau = RC = 10 \times 10^6 \times 0.5 \times 10^{-6} = 5$$

$$\therefore V_C = V[1 - \exp(-t/\tau)].$$

$$\frac{1}{2} = 1 - \exp(-t/\tau).$$

$$\exp(-t/5) = \frac{1}{2} = 0.5$$

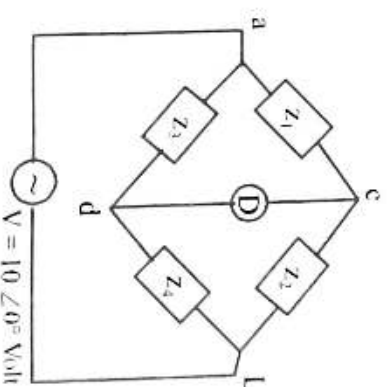
$$-t/5 = -0.693$$

$$t = 3.4657 \text{ seconds.}$$

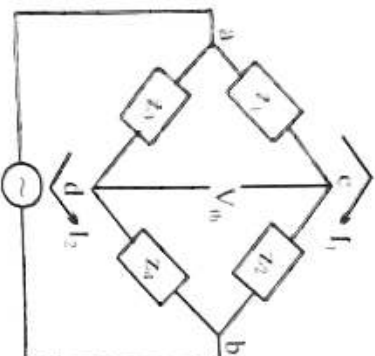
Q24. A voltage $10 \angle 0^\circ$ volt is applied to the schering bridge having $Z_1 = -j0.8k\Omega$, $Z_2 = 1.0k\Omega$, $Z_3 = -j1.6k\Omega$, $Z_4 = 2k\Omega$. Find its Thevenin equivalent circuit and calculate the open circuit voltage across the detector arm. (2017)

Ans. Given $Z_1 = -j0.8k\Omega$, $Z_2 = 1.0k\Omega$, $Z_3 = -j1.6k\Omega$, $Z_4 = 2k\Omega$. Calculate Thevenin voltage (V_{th}) {open circuit voltage}. Current,

$$I_1 = \frac{V}{Z_1 + Z_2} \\ = \frac{10 \angle 0^\circ}{-j0.8 + 1.0} \text{ mA} = (6.1 + j4.88) \text{ mA}$$



$$\text{Current, } I_2 = \frac{V}{Z_3 + Z_4} = \frac{10 \angle 0^\circ}{-j1.6 + 2} = (3.053 + j2.443) \text{ mA}$$



Voltage across, $Z_1 = V_{ac} = Z_1 I_1$

$$= (-j0.8)(6.1 + j4.88)$$

$$= (3.904 - j4.88)$$

$$= 6.249 \angle -51.34^\circ \text{ Volt.}$$

Voltage across $Z_3, V_{ad} = Z_3 I_2$

$$= (-j1.6)(3.053 + j2.443)$$

$$= 6.256 \angle -51.33^\circ \text{ Volt.}$$

Thevenin voltage, $V_{th} = V_{cd}$

$$= V_c - V_d = -V_a + V_c + V_a - V_d$$

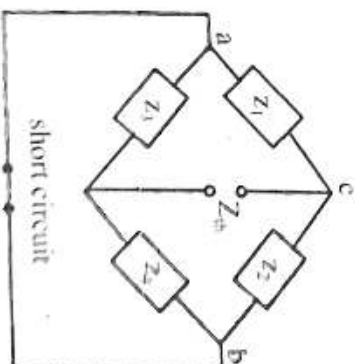
$$= -(V_a - V_c) + (V_a - V_d)$$

$$= -V_{ac} + V_{cd}$$

$$= -(3.904 - j4.88) + (3.9088 - j4.8848)$$

$$= (4.8 \times 10^{-3} - j4.8 \times 10^{-3}) \text{ Volt}$$

$$V_{th} = 6.788 \times 10^{-3} \angle -45^\circ \text{ Volt.}$$



Calculate Thevenin impedance (Z_{th}). To find Thevenin impedance replace voltage source with its internal resistance.

$$Z_{th} = (Z_1 \parallel Z_2) + (Z_3 \parallel Z_4)$$

$$= \frac{Z_1 Z_2}{Z_1 + Z_2} + \frac{Z_3 Z_4}{Z_3 + Z_4}$$

$$= \frac{(-j0.8)(1.0)}{(-j0.8 + 1.0)} + \frac{(-j1.6)(2)}{(-j1.6 + 2)}$$

$$= (0.39 - j0.488) + (0.781 - j0.976)$$

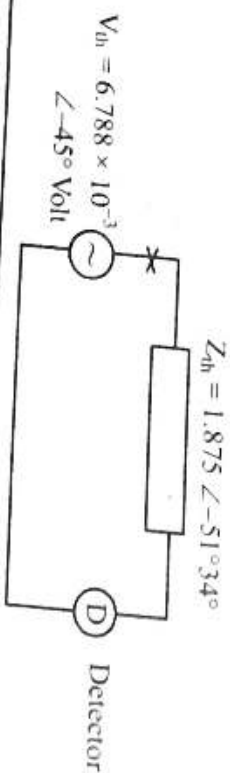
$$= (1.171 - j1.464) \text{ k}\Omega$$

$$= 1.875 \angle -51.34^\circ \text{ k}\Omega$$

$$= 1.875 \angle -51.34^\circ \text{ k}\Omega$$

$$= 1.875 \angle -51.34^\circ \text{ k}\Omega$$

Thus thevenin equivalent circuit



Q25. A 50KVA transformer has primary voltage of 6600V and secondary voltage of 256V and has 32 secondary turns. Calculate the number of primary turns, & primary and secondary currents. (2017)

$$\text{Ans. } \frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$\frac{256}{6600} = \frac{32}{N_1}$$

$$\frac{256}{6600} = \frac{32}{N_1}$$

$$N_1 = \frac{32 \times 6600}{256} = 825.$$

$$P = 50 \text{ KVA} = 50 \times 10^3 \text{ VA.}$$

$$P = I_1 V_1 \Rightarrow 50 \times 10^3 = I_1 \times (6600).$$

$$I_1 = \frac{50 \times 10^3}{6600} = 7.57 \text{ Ampere}$$

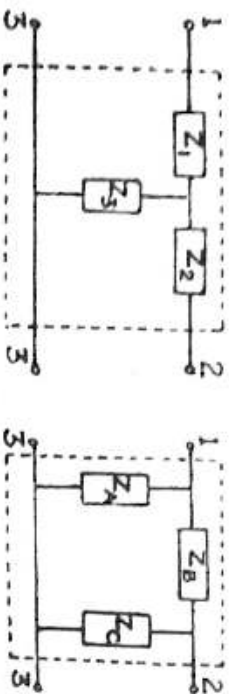
$$I_1 V_1 = I_2 V_2$$

$$I_2 = \frac{7.57 \times 6600}{256} = 195.31 \text{ Ampere}$$

Q26. Write short note on equivalence of T and π network.

(2013,17)

Ans. The T and π networks can be made electrically equivalent by a proper choice of their impedances. Both are three terminal network with terminal 3 common between input and output.



If they are to be equivalent, the impedance between any two of these terminals must be the same for both the network. Equating the impedances between terminals 1-2, 2-3 and 1-3, we get three equations as follows—

$$Z_1 + Z_3 = \frac{Z_A(Z_B + Z_C)}{Z_A + Z_B + Z_C} \quad \dots(1)$$

$$Z_1 + Z_2 = \frac{Z_B(Z_C + Z_A)}{Z_A + Z_B + Z_C} \quad \dots(2)$$

$$Z_2 + Z_3 = \frac{Z_C(Z_A + Z_B)}{Z_A + Z_B + Z_C} \quad \dots(3)$$

Adding up these equations, we get

$$Z_1 + Z_2 + Z_3 = \frac{(Z_A Z_B + Z_B Z_C + Z_C Z_A)}{(Z_A + Z_B + Z_C)} \quad \dots(4)$$

Subtracting equation (1), (2), (3) from equation (4), we have—

$$Z_2 = \frac{Z_B Z_C}{Z_A + Z_B + Z_C}$$

$$Z_3 = \frac{Z_C Z_A}{Z_A + Z_B + Z_C}$$

$$Z_1 = \frac{Z_A Z_B}{Z_A + Z_B + Z_C}$$

The above equations show impedance of an equivalent T-network in terms of known impedances of π -network. They are known as π -to-T-transformation.

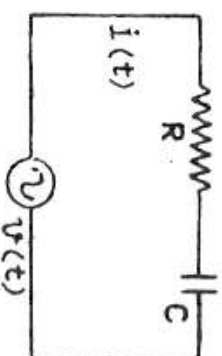
Q27. What is wattless current?

(2018)

Ans. Current and voltage in A.C. Circuits has a phase difference of ϕ . Since average power delivered by the source is $VI \cos \phi$, the recomponent of current, $I \sin \phi$ is called wattless current because when voltage and current are 90° out of phase, no power is consumed in the circuit due to this component.

Q28. In an a.c circuit with R and C in series find expression for current and phase between current and voltage using vector symbols for voltage and current. Draw vector diagram for current and voltage. (2018)

Ans. Consider a circuit as shown in Fig. and let $i(t)$ be the current through it. Kirchhoff's voltage law then yields



$$v(t) = Ri(t) + \frac{1}{C} \int i dt.$$

Corresponding equation between voltage and current vectors is

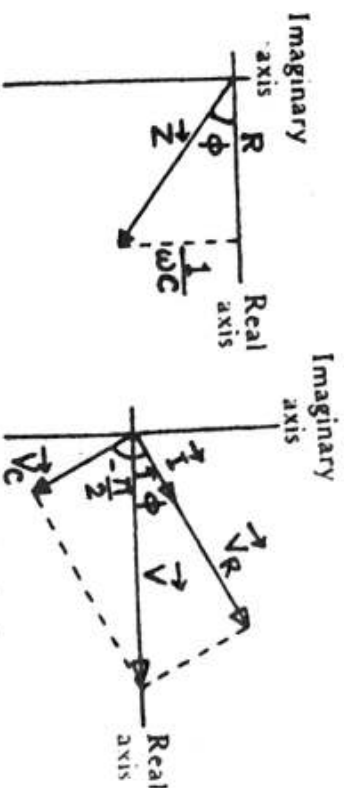
$$V = RI + \frac{1}{C} \int I dt.$$

where the voltage vector V is given by the equation Substituting for $\int I dt$ from equation (5.21),

$$V = \left[R + \frac{1}{j\omega C} \right] I.$$

$$\text{or, } \frac{V}{I} = \left[R - \frac{j}{\omega C} \right] = (R + jX_C) = Z, \quad \dots(1)$$

where Z is the complex impedance of the circuit as shown in



Vector diagrams for the circuit of

It can also be expressed in terms of its magnitude $|Z|$ and the angle ϕ between Z and the real axis as follows :

$$Z = |Z| e^{-j\phi},$$

where

$$\begin{cases} |Z| = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}} \\ \phi = \tan^{-1} \frac{X_C}{R} = \tan^{-1} \frac{1}{\omega C R} \end{cases}$$

The vector current I can now be written as

$$I = \frac{V}{Z} = \frac{V_0 e^{j\omega t}}{|Z| e^{-j\phi}} = I_0 e^{j(\omega t + \phi)}, \quad \dots(2)$$

where

$$I_0 = V_0 / \sqrt{R^2 + \frac{1}{\omega^2 C^2}} \quad \dots(3)$$

The potential drops V_R and V_C across the two circuit elements R and C are

$$V_R = RI, \quad V_C = -\frac{j}{\omega C} I \quad \dots(4)$$

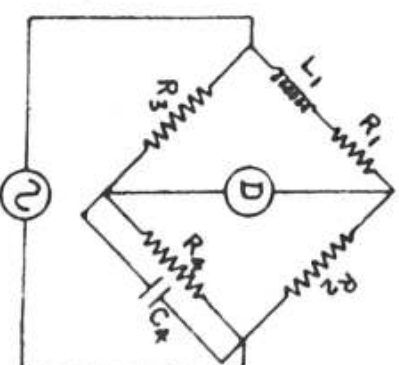
Complete vector diagram showing I , V_R , V_C , and V is given in Fig. along with the impedance vector Z .

The general conclusions from equations (1), (2), (3) and (4) may be summarized as follows :

- (i) Current amplitude I_0 is equal to $V_0 / \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$ which implies that the current depends on the frequency ω in addition to the circuit constants C and R and applied voltage.
- (ii) Current leads the voltage by an angle ϕ given by equation (2). ϕ is also frequency dependent; larger the frequency smaller will be the phase angle ϕ and vice versa.
- (iii) The circuit has a complex impedance whose real part is equal to the total resistance R in the circuit and imaginary part is equal to the capacitive reactance X_C .

Q29. Find expression for self inductance of a coil using Maxwell's bridge.

Ans. The bridge is arranged as shows in Fig. We have



Maxwell's bridge.

$$\left. \begin{aligned} Z_1 &= R_1 + j\omega L_1, \\ Z_2 &= R_2, \\ Z_3 &= R_3, \\ Z_4 &= R_4 / (1 + j\omega C_4 R_4). \end{aligned} \right\}$$

Substituting in the bridge balance condition, we get

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

$$\text{or, } \frac{R_1}{R_2} + j \frac{\omega L_1}{R_2} = \frac{R_3}{R_4} + j\omega C_4 R_3$$

Equating real and imaginary parts separately

$$\left. \begin{aligned} R_1 &= R_2 \frac{R_3}{R_4} \\ \text{and, } L_1 &= R_2 R_3 C_4 \end{aligned} \right\} \dots (1)$$

By varying R_4 and C_4 , the two conditions can be satisfied independently. Equations (1) can then be used to calculate L_1 and its effective resistance R_1 .

Q30. A 12V potential difference is connected to a series combination of $C=2.0\mu\text{F}$ and $R=1.0\text{M}\Omega$. Calculate the maximum charge in the capacitor and time constant the circuit. (2015)

Ans. $q = VC[1 - \exp(-t/RC)]$.

at $t \rightarrow \infty, q \rightarrow VC$.

$$q_{\text{max}} = VC = 12 \times 2 \times 10^{-6} = 24 \times 10^{-6} \text{ C}$$

time constant, $\tau = RC$

$$\tau = 1.0 \times 10^6 \times 2 \times 10^{-6}$$

$$\tau = 2 \text{ sec.}$$

Q31. A T-network has the impedances $Z_1 = Z_2 = Z_3 = (25 + 10j)$ ohms. Calculate the impedances of an equivalent π -networks. (2019)

Ans. Given, $Z_1 = Z_2 = Z_3 = (25 + 10j)$.

$$Z_A = Z_B = Z_C = \frac{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}{Z_2}$$

$$\begin{aligned} &= \frac{3Z^2}{Z} = 3Z \\ &= 3(25 + 10j) \\ &= 75 + 30j \end{aligned}$$

Q32. Write short notes on moving coil galvanometer. (2019)

Ans. A galvanometer is an instrument for detecting or measuring electric currents. We shall confine our discussion to the d.c. galvanometer. It utilises the force of interaction between the current and a known magnetic field to produce and observable deflection. The conductor carrying the current is taken in the form of a coil

while the magnetic field may be either that of that either of a permanent magnet, it is possible to keep the coil fixed in position and use the resultant of the magnetic fields due to the current and the magnet to deflect a small magnetic needle. The deflection will then be a function of the current in the coil and can yield its value provided other parameters are known. Such galvanometers are known as fixed coil moving magnet galvanometers. A simple example is the tangent galvanometer. The other possibility is to keep the magnet fixed in position and make the coil movable under the combined influence of its own current and the magnetic field. The angular deflection of the coil will then yield the value of current after appropriate manipulations. Such galvanometers are known as moving coil galvanometers.

Q33. Write short notes on Current Sensitivity. (2019)

Ans. $C_s = \frac{C}{2000 NAB}$

C_s is the current required to produce a deflection of one mm on the scale. It is known as current sensitivity of galvanometer. Smaller the value of C more sensitive is the galvanometer. The value of C_s is usually measured experimentally by passing a current i and measuring the deflection ϕ_0 .

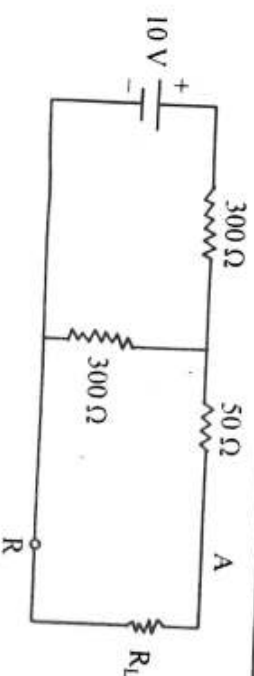
Q34. What is the time constant for growth of current through an inductive resistance (L,R) in series? (2019)

Ans. $I = I_0(1 - e^{-Rt/L})$.

Time constant of the LR circuit is equal to $\frac{L}{R}$. It is defined as the time in which current attains the value equal to 0.63 times the maximum steady value.

Q35. State Thevenin's theorem. Obtain Thevenin's equivalent circuit & obtain I_L when (i) $R_L = 50\Omega$ (2019)

(ii) $R_L = 200\Omega$.



Ans. Chapter 1, Question 4.

(i) $R_L = 50\Omega$

$$I_L = \frac{E_b Z_3}{(Z_b + Z_1 + Z_3)(Z_3 + Z_2 + Z_L) - Z_3^2}$$

$$I_L = \frac{(300 + 300)(300 + 50 + 50) - 300^2}{10 \times 300}$$

$$I_L = \frac{(600)(400) - 90000}{10 \times 300} = \frac{150000}{10 \times 300}$$

$$I_L = 0.02 \text{ A.}$$

(ii) $R_L = 200\Omega$

$$I_L = \frac{10 \times 300}{(300 + 300)(300 + 50 + 200) - 300^2}$$

$$= \frac{(600)(550) - 90000}{10 \times 300}$$

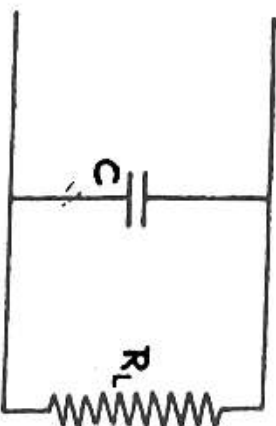
$$= \frac{3000}{240000} = 0.0125 \text{ A.}$$

CHAPTER - 2

Basic Semi - Conductor Electronics

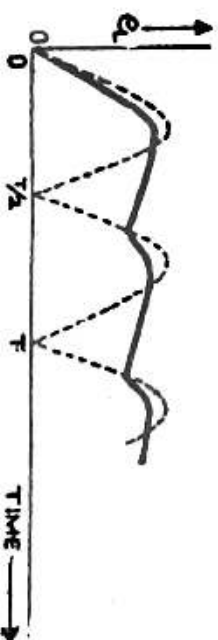
Q1. Explain working of Capacitor filter in a full wave rectifier. or Derive RC filters. (2014,18)

Ans. The circuit is shown. When the voltage across R_L rises, the capacitor gets charged. When the voltage falls, it discharges sending an additional current through R_L , hence an additional voltage across R_L that tends to maintain e_L constant. Thus the variations in e_L are reduced. This is illustrated in Fig. The action of a capacitor filter can also be explained in an alternative way. The diode current consists of a d.c. part and an a.c. part. The d.c. part goes through R_L because the capacitor offers an infinite impedance to direct currents. However, for the a.c. part, the capacitor offers a low impedance. By choosing the value of C appropriately, this impedance can be made small in comparison to R_L so that most of the a.c.



A capacitor filter.

part is by passed through C . The ripple voltage across R_L is, therefore, reduced.



Waveforms in a capacitor filter,

For a given value of R_L , larger the capacitance C , smaller will be its impedance which will result in better by passing of a.c. component, i.e., smaller ripple factor. Likewise, for a given value of C , larger the

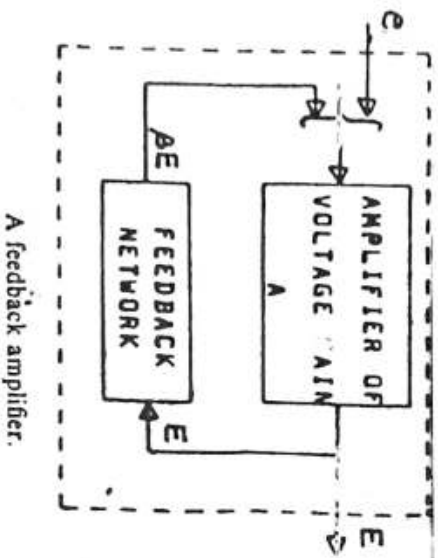
resistance R_L , smaller will be the fraction of a.c. flowing through it which will result in lower ripple factor. An approximate calculation shows that the ripple factor for a full-wave rectifier with a capacitor filter is directly proportional to the ratio of capacitive reactance and the load resistance. This is given by

$$r = \frac{\pi X_C}{\sqrt{3} R_L} = \frac{1}{4\sqrt{3} f C R_L},$$

where X_C is the reactance of the capacitor at the frequency $2f$ of the dominant alternating part of the rectifier output.

Q2. Discuss negative feedback amplifier. (2015,16,18,19)

Ans. The block diagram of a feedback amplifier is shown in Fig. input voltage e is amplified by an amplifier whose voltage gain is A . The output is applied to a feedback network which



A feedback amplifier.

derives a fraction β of the output and superimposes it on the input signal e . If E is the output in equilibrium condition, the resultant input voltage is given by $(e + \beta E)$. This amplified A time by the amplifier, must equal the output E in order to maintain the equilibrium. Thus

$$(e + \beta E)A = E \quad \dots(1)$$

The combination of the amplified and the feedback network is known as *feedback amplifier*. Applying an input e to this combination, an output E is obtained so that the effective voltage gain A_f of the feedback amplifier is given by

$$A_f = \frac{E}{e} = \frac{A}{(1 - A\beta)}$$

Thus the gain A_f of the feedback amplifier is different from the gain A of the amplifier alone. A is also known as the *nominal gain* or the *open-loop gain* of the amplifier.

The factor $A\beta$ represents the factor by which the input signal is multiplied in going through the amplifier and back around the loop through the feedback network. It is known as the *loop transmission* or the *loop gain* or the *return ratio*. It can be expressed from equation (1) as

$$A\beta = \frac{\beta E}{(e + \beta E)} = \frac{\text{feedback signal}}{\text{resultant input signal}} \quad \dots(2)$$

If the feedback signal is in the same phase as the input signal, $A\beta$ will be positive and less than 1 so that equation (2) yields $A_f > A$, i.e., the voltage gain will increase as a result of feedback. This type of feedback is known as *regenerative* or *positive feedback*.

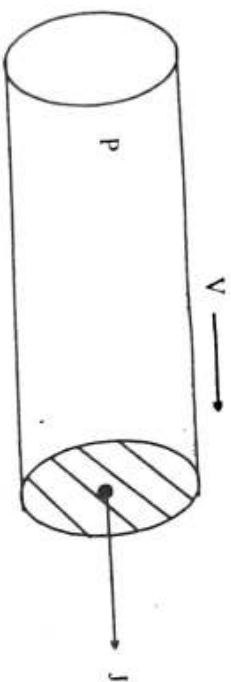
For feedback signals in opposite phase with the input signal, several possibilities exist. If its magnitude $|\beta E| < |e|$, $A\beta$ will be negative so that $A_f < A$. If $|e| < |\beta E| < |2e|$, then $A\beta > 2$ so that $|A_f| < |A|$. Thus for $0 < |\beta E| < |2e|$, the feedback reduces the gain. This type of feedback is known as *degenerative* or *negative feedback*. $|\beta E|$ larger than $|2e|$ results in increase of gain and is, therefore, categorized as positive or regenerative feedback.

Q3. Define mobility of charge carriers. Obtain expression for conductivity of semiconductor. (2014,15)

Ans. Mobility is defined as the ease with which an electron can flow through the conductor.

When we apply a constant electric field E , to a metal, the free electrons would be accelerated and the velocity would increase indefinitely with time. However, because of collision of electrons, electrons lose energy of a steady-state condition is reached where a finite value of drift velocity V_d is attained. The drift velocity V_d is in the direction opposite to that of the electric field & its magnitude is proportional to E .

If a semiconductor is placed in an external electric field, its charge carried experience a force and move in the direction of field. It is often more convenient to talk in terms of the current density J rather than the total current I through a conductor. Let ρ be the density of free electrons/charges in a conductor and v their average velocity. within this conductor, consider a cylindrical region with its axis in the direction of v , its length equal to v & its cross-section as unity.



The charge contained in this cylinder is ρV . All this charge but no more will pass the cross-section in one second. Hence, the current through unit cross-section i.e., current density,

$$J = \rho V \quad \dots(1)$$

Now, let us consider a semiconductor placed in an external field E , so that electron & holes acquire average drift velocities equal to V_e & V_h , respectively.

Then, from equation, the current density J_e due to the drift of electron is

$$J_e = n e V_e \quad \dots(2)$$

& that due to the hole is

$$J_p = np V_h \quad \dots(3)$$

Thus, the net current density, J drift through the semiconductor becomes

$$J_{\text{drift}} = e(n V_e + p V_h).$$

The drift velocities are directly proportional to the field E , hence it is convenient to introduce a new parameter, the mobility μ , defined as the drift velocity per unit electric field, Thus—

$$\mu_e = \frac{V_e}{E}, \quad \dots(4)$$

$$\mu_h = \frac{V_h}{E}, \quad \dots(5)$$

from equation (4), (5).

$$J_{\text{drift}} = eE(n\mu_e + p\mu_h).$$

Therefore the conductivity σ of the semiconductor, which is equal to current density per unit electric field is given by—

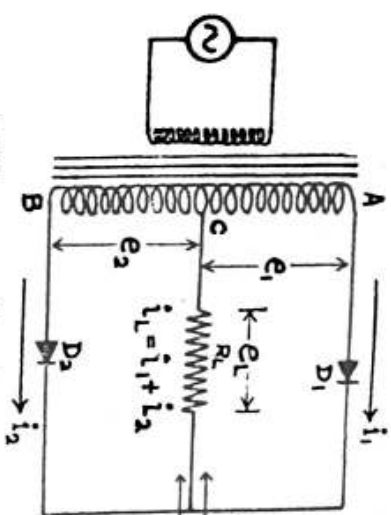
$$\sigma = e(n\mu_e + p\mu_h).$$

Q4. Draw circuit of a full wave rectifier a find expression for ripple factor of this rectifier. (2014,15,16,18,19)

Ans. A full-wave rectifier uses two identical diodes with equal capacitances C_f . The alternating voltage is applied through a center-tap

transformer as shown in Fig. Referred to the center-tap C, when one end of the secondary is positive, the other end will be negative and vice versa. Thus, if the voltage between A and C is

$$e_1 = E_0 \sin \omega t,$$



A full-wave rectifier circuit.

that between B and C will be

$$e_2 = -E_0 \sin \omega t.$$

For time t between 0 and $T/2$, e_1 is positive so that diode D_1 conducts while diode D_2 does not conduct because e_2 is negative. Likewise for $T/2 \leq t \leq T$, diode D_2 conducts while D_1 does not. The currents i_1 and i_2 through the two diodes are

$$\left. \begin{aligned} i_1 &= \frac{E_0 \sin \omega t}{(r_f + R_L)}, i_2 = 0 & \text{for } 0 \leq t \leq T/2 \\ i_1 = 0, i_2 &= \frac{E_0 \sin \omega t}{(r_f + R_L)}, i_2 = 0 & \text{for } T/2 \leq t \leq T \end{aligned} \right\} \quad \dots(1)$$

i_1 and i_2 flow through R_L in the same direction and, therefore, add up to give a load current i_L as follows :

$$\left. \begin{aligned} i_L &= \frac{E_0}{(r_f + R_L)}, \sin \omega t = 0 & \text{for } 0 \leq t \leq T/2 \\ i_L &= -\frac{E_0}{(r_f + R_L)}, \sin \omega t = 0 & \text{for } T/2 \leq t \leq T \end{aligned} \right\}$$

The output voltage e_L is, therefore, given by

$$e_L = \begin{cases} \frac{E_0}{(1+r_f+R_L)} \sin \omega t, & \text{for } 0 \leq t \leq T/2 \\ \frac{E_0}{(1+r_f+R_L)} \sin \omega t, & \text{for } T/2 \leq t \leq T \end{cases} \quad \dots(2)$$

The waveforms for e_1, i_1, e_2, i_2, i_R and e_L in the case of a half wave rectifier, the output voltage e_L can be expressed as a sum of a d.c. part and an alternating part. The d.c. part e_{Ldc} can be obtained by substituting from equations. This is

$$e_{Ldc} = \frac{2E_0}{\pi(1+r_f/R_L)} = \frac{2\sqrt{2}}{\pi} \frac{E_{Lac}}{(1+r_f/R_L)} \quad \dots(3)$$

which is exactly twice the value obtained for a half wave rectifier If $R_L > r_f$, we have

$$e_{Ldc} = \frac{2E_0}{\pi}$$

Therefore, the rectification constant K is obtained as

$$K = \frac{2\sqrt{2}}{\pi} \frac{1}{(1+r_f/R_L)} \times 100 \text{ per cent,}$$

which will have a maximum value of 90% when $R_L > r_f$. The alternating part of the output voltage may be obtained by substituting from equations (2) and (3) in equation :

$$e_{Lac} = \begin{cases} \frac{E_0 \sin \omega t}{(1+r_f/R_L)} - \frac{2E_0}{\pi(1+r_f/R_L)} & \text{for } 0 \leq t \leq T/2 \\ -\frac{E_0 \sin \omega t}{(1+r_f/R_L)} + \frac{2E_0}{\pi(1+r_f/R_L)} & \text{for } T/2 \leq t \leq T \end{cases} \quad \dots(4)$$

Therefore, its mean square value will be

$$\begin{aligned} e_{Lac\text{ rms}}^2 &= \frac{1}{T} \int_0^T e_{Lac}^2 dt \\ &= \frac{1}{T} \left[\frac{E_0^2}{(1+r_f/R_L)^2} \left\{ \int_0^{T/2} (\sin \omega t - 2/\pi)^2 dt + \int_{T/2}^T (\sin \omega t + 2/\pi)^2 dt \right\} \right. \\ &\quad \left. - \frac{E_0^2}{(1+r_f/R_L)^2} \sqrt{\frac{\pi^2 - 8}{2}} \right] \end{aligned}$$

The r.m.s. ripple voltage is then

$$e_{Lac\text{ rms}} = \frac{E_0}{(1+r_f/R_L)} \sqrt{\frac{\pi^2 - 8}{2}}$$

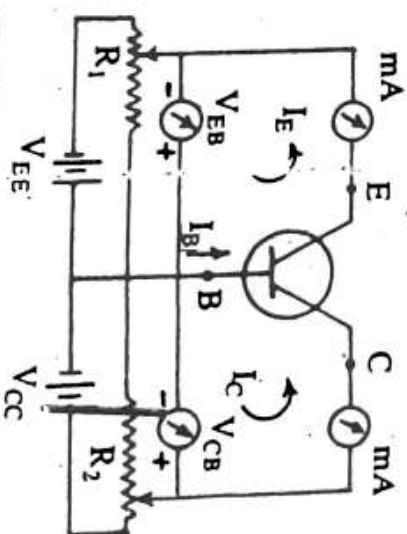
The ripple factor r for the full wave rectifier is, thus, obtained as

$$r = \frac{e_{Lac\text{ rms}}}{e_{Ldc}} \sqrt{\left(\frac{\pi^2 - 8}{8} \right)} \approx 0.48$$

Q5. Draw and Explain the Characteristic of a Transistor in Common-Base Configuration. (2014)

Ans. Common Base Configuration

The circuit arrangement for determining C_B characteristic of a *npn* transistor is shown in fig. Source of EMF V_{EE} in the Emitter Base provides forward bias V_{BE} , which can be changed with the help of the potential divider R_1 , similarly reverse bias V_{CB} between Collector and base is obtained from the potential divider R_2 across d.c. source V_{CC} in the output circuit. Emitter current I_E is fixed to the desired value.



Circuit for studying characteristic of *npn* transistor

Using R_1 collector current I_C is measure using millimeter in output circuit.

We have four variable current and voltage in this configuration namely, emitter current (I_E) and emitter voltage (V_E in the input side and collector current (I_C) and collector voltage (V_C) in the output side. Thus we can have four characteristics : two input and two output.

These Characteristics are :

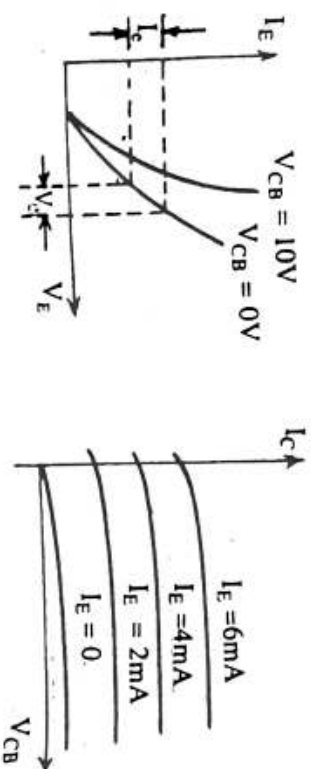
(a) $I-V$ Characteristics :

- (i) variation of V_E with I_E for constant V_C
- (ii) variation of I_C with V_C for constant I_E

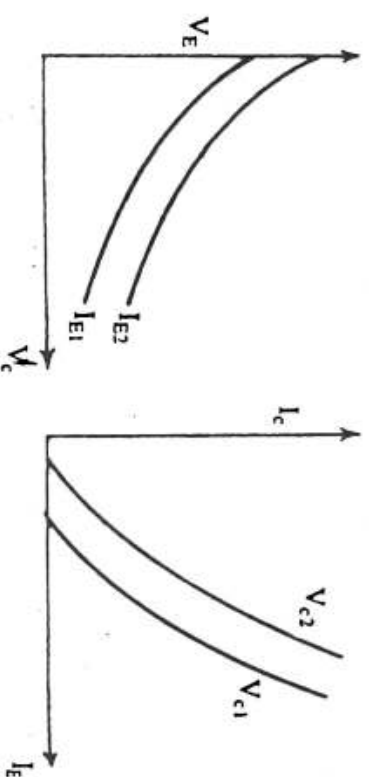
(b) Transfer characteristics :

- (i) variation of V_E with I_C for constant I_E
- (ii) variation of I_C with I_E for constant V_C

These curve are



(a) Input characteristic, (b) Output characteristic, (c) Transfer voltage characteristic, (d) Transfer current characteristic

Static characteristic $n-p-n$ transistor in CB configuration.

Out of these, only two of them are most important. One is output and the other is the input characteristic. Although as long as collector is reverse biased, all the electrons injected into the region will be collected by the collector, V_C has no effect on I_C . A small dependence of I_C on V_C comes due to the fact that the thickness of base collector junction increases with V_C . Thus the effective width of the base charge normally I_C increases with V_C because minority charge carriers are

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less likely to be lost through recombination. Thus one can write for CB configurator

$$I_C = f(I_E, V_C)$$

$$\text{and, } V_E = f(I_E, V_C)$$

For small changes in I_E and V_C we have

$$\delta V_E = \left(\frac{\partial V_E}{\partial I_E} \right)_{V_C} \delta I_E + \left(\frac{\partial V_E}{\partial V_C} \right)_{I_E} \delta V_C$$

$$\delta I_C = \left(\frac{\partial I_C}{\partial I_E} \right)_{V_C} \delta I_E + \left(\frac{\partial I_C}{\partial V_C} \right)_{I_E} \delta V_C$$

The coefficients

$$\left(\frac{\partial V_E}{\partial I_E} \right)_{V_C} = h_{ib} = \text{emitter resistance in } CB$$

$$\left(\frac{\partial V_E}{\partial V_C} \right)_{I_E} = h_{rb} = \text{reverse voltage amplification in } CB$$

$$\left(\frac{\partial I_C}{\partial I_E} \right)_{V_C} = h_{fb} = \text{forward current amplification in } CB$$

$$\left(\frac{\partial I_C}{\partial V_C} \right)_{I_E} = h_{ob} = \text{collector conductance in } CB.$$

All these parameters can be obtained from Static characteristic curve mentioned above. Emitter resistance is equal to reciprocal of slope of input characteristic curve. Reverse voltage amplification is equal to the slope of transfer voltage characteristic. The slope of transfer current characteristic give forward current amplification and slope of output characteristic gives the collector conductance.

Q6. What is amplitude modulation. (2014,15,17,19)

Ans. Amplitude modulation may be defined as a system in which the maximum amplitude of the carrier wave is made proportional to the instantaneous value (amplitude) of the modulating or baseband signal.

If $x(t)$ is modulating signal and carrier signal is given by the expression

$$c(t) = A \cos \omega_c t.$$

Then the equation of AM wave will be

$$s(t) = x(t) \cos \omega_c t + A \cos \omega_c t.$$

This equation describes the AM wave in time domain.

Q7. Show that the maximum power due to side band is 50% of the carrier power. (2015,19)

Ans. The distribution of power in AM between the carrier and sidebands is easier to determine using the spectrum of a carrier modulated by a sinusoidal message signal, from which we obtain normalized power distribution.

Power in carrier :

$$P_c = \frac{V_c^2}{2}.$$

Power in upper side frequency :

$$P_{USF} = \frac{(V_m/2)^2}{2} = \frac{V_m^2}{8} = \frac{m^2 V_c^2}{8} = \frac{m^2 P_c}{4}.$$

Power in lower side frequency :

$$P_{LSF} = P_{USF} = \frac{m^2 P_c}{4}.$$

Power in side frequency :

$$P_{SF} = P_{LSF} + P_{USF} = \frac{m^2 P_c}{2}.$$

Total power in AM waveform :

$$P_t = P_c + P_{SF} = P_c + \frac{m^2 P_c}{2}.$$

$$P_t = P_c \left[\frac{1+m^2}{2} \right].$$

P_{SF} is the side frequency power which is a fraction $m^2/2$ of the power in the carrier. Thus P_{SF} increases with modulation factor. The maximum total side frequency power $P_{SF \text{ max}}$ is 50% of the carrier power, and this is obtained when $m = 1$ i.e., 100% modulation.

Q8. Obtain expression for power in amplitude modulated wave. (2014,15,18)

Ans. We know that general expression of AM wave is given by

$$s(t) = A \cos \omega_c t + x(t) \cos \omega_c t.$$

The total power P of the AM wave is the sum of the carrier power P_c and sideband power P_s .

Carrier Power :

The carrier power P_c is equal to the mean square (ms) value of the carrier term $A \cos \omega_c t$ i.e.,

P_c = mean square value of $A \cos \omega_c t$.

$$P_c = \frac{1}{2\pi} \int_0^{2\pi} A^2 \cos^2 \omega_c t dt$$

$$P_c = \frac{A^2}{2}.$$

Sideband power :

The side band power P_s is equal to the mean square value of the sideband term $x(t) \cos \omega_c t$.

P_c = mean square value of $x(t) \cos \omega_c t$.

$$P_c = \frac{1}{2\pi} \int_0^{2\pi} x^2(t) \cos^2 \omega_c t dt.$$

$$P_c = \frac{1}{2\pi} \int_0^{2\pi} \frac{1}{2} [2 \cos^2 \omega_c t] x^2(t) dt.$$

$$P_s = \frac{1}{2\pi} \int_0^{2\pi} \frac{1}{2} x^2(t) dt + \frac{1}{2\pi} \int_0^{2\pi} x^2(t) \cos^2 \omega_c t dt$$

In AM generation, a Band pass filter (BPF) or a tuned circuit tuned to carrier frequency ω_c is used to filter out the second integral term.

Therefore,

$$P_s = \frac{1}{2\pi} \int_0^{2\pi} \left[\frac{1}{2} x^2(t) \right] dt$$

P_s = mean square (ms) value of $\frac{1}{2} x^2(t)$.

$$P_s = \frac{1}{2} \overline{x^2(t)}.$$

However, the total sideband power P_s is due to equal contribution of upper and lower sidebands. Hence the power carried by the upper and the lower sidebands will be—

$$P_{s(USB)} = P_{s(LSB)} = \frac{P_s}{2} = \frac{1}{4} \overline{x^2(t)}$$

Therefore, the total power P_t of the AM signal is the sum of the carrier power P_c and sideband power P_s .

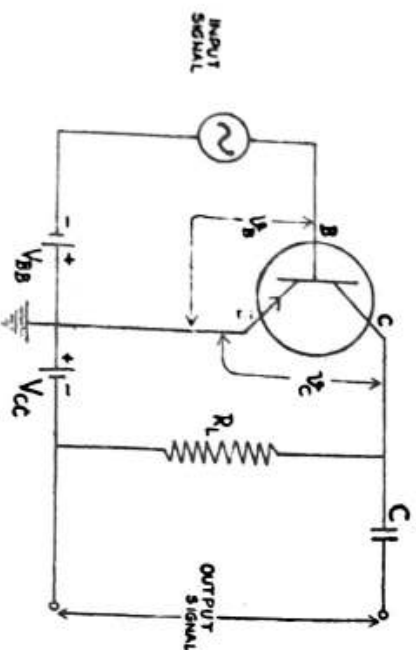
$$P_t = P_c + P_s = \frac{1}{2} A^2 + \frac{1}{2} \overline{x^2(t)}$$

$$P_t = \frac{1}{2} [A + \overline{x^2(t)}]$$

Q9. Write short notes on load line.

(2014,18)

Ans. A relation between the instantaneous values of collector voltage and collector current can be obtained by applying Kirchhoff's voltage law to the output circuit shown in fig.



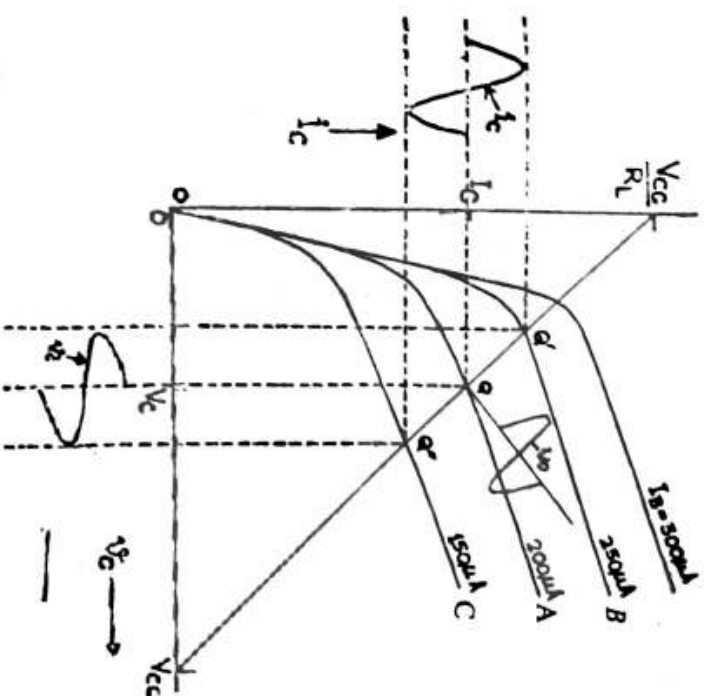
$$V_c = V_{cc} - I_c R_L$$

Where V_c is actually the negative voltage on the collector. Rearranging we get

$$I_c = -\frac{1}{R_L} V_c + \frac{V_{cc}}{R_L}$$

Which represents a straight line having slope $(-1/R_L)$ and

intercept on y-axis equal to $\frac{V_{cc}}{R_L}$. This line is known as load line.



Q10. Write short notes on voltage regulation by zener diode.

(2014,18)

Ans. Zener Diode as Voltage Stabiliser

Zener Diode can be used to provide a constant voltage from a source whose voltage may vary over sufficient range the circuit arrangement is shown in Fig. Zener Diode is connected in reverse bias across load R_L . The series resistance R absorbs all voltage fluctuations so as to maintain constant voltage E_0 across the load equal to V_Z so long input voltage does not fall below V_Z

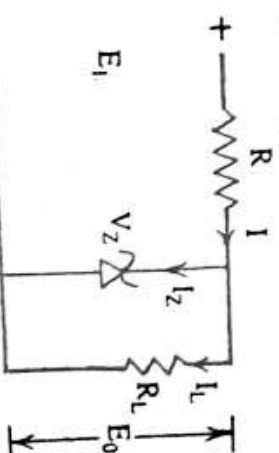


Fig. Zener Diode as Regulator

To understand the analysis zener diode, we should understand the off state and on state of it.

when Zener is "off" $I_Z = 0$ then $E_0 = \frac{E_1}{R + R_L} \times R_L$

when Zener is "on", $E_0 = V_Z$ and $I_Z = I - I_L$.

Case I—when E_1 and R_L are fixed E_0 remains fixed as zener current is zero.

Case II—When E_1 varies but R_L is fixed—The Minimum voltage E_1 will be such that $I_Z = 0$ then

$$E_{1(\min)} = RI + IR_L = RI + E_0$$

If E_1 is more than I_Z current flows in Zener and $E_0 = V_Z$.

$$\therefore I_L = \frac{E_0}{R_L} = \frac{V_Z}{R_L}$$

Maximum Input voltage = $RI + V_Z = R(I_L + I_Z) + V_Z$

Case III—When E_1 fixed but R_L varies—As R_L is changed load current changes. There is definite range of R_L which will ensure that zener is in 'on' state. Then $E_0 = V_Z$.

$$\therefore \text{Minim } R_L = \frac{V_Z}{I_L(\text{Max})}$$

Any value of load smaller than this value will result in a voltage E_0 less than V_Z and Zener will be in 'off' state.

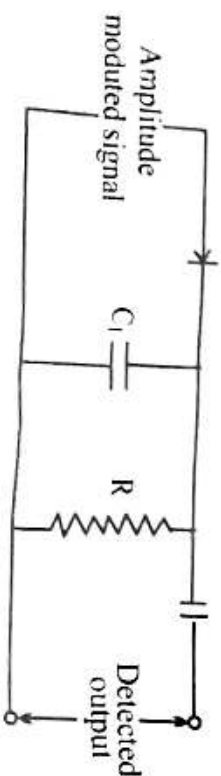
If R_L is increase then load current decreases. Because I is fixed thus I_Z increases. The maximum value of I_Z depends on power rating of diode. Thus

$$R_{L(\text{Max})} = \frac{V_Z}{I_L(\text{Min})} = \frac{V_Z}{(I - I_{ZM})}$$

If load exceeds this value the device will burn out as I_Z increases beyond.

Q11. Write short notes on Linear diode detector. (2014,15,16)

Ans.



The circuit diagram of a diode detector is shown. It is identical with that of a half-wave rectifier followed by a capacitor filter. The diode conducts only during positive half of the modulated signal.

This would have produced a voltage across R that consists of half wave pulse of varying amplitudes. However the capacitor C_1 is large enough to smooth out these pulses and gives a signal proportional to their amplitudes. It consists of low frequency modulating signal superimposed on a direct voltage.

Q12. Discuss working and application of CRO. (2013,15,16)

Ans. **Cathode Ray Oscilloscope**

Cathode Ray Tube—A cathode ray tube is a special purpose vacuum electron tube that is designed to give a visual display of electrical signals. Its essential features are shown in Fig. The whole tube can be divided into three parts : an electron gun, a deflection system and a fluorescent screen. We will describe them one by one.

Electron gun : The electron gun serves to provide a sharp beam of electrons focussed a point on the screen. It consists of a heating filament, a cathode and four coaxial cylindrical electrodes. They are respectively known as control grid, accelerator grid, first anode and second anode. The top surface of the cathode facing the fluorescent screen is coated with a low work function oxide coating so that electrons are emitted by thermionic emission. These electrons then pass through the remaining four electrodes and are formed into a sharp beam. The control grid is given a moderately negative potential while the accelerator grid is given a moderately negative potential while the accelerator grid is given a moderate or high positive potential with respect to the cathode. The two grids together determine the number of electrons attracted from the space charge near the cathode which ultimately determines the intensity of the display on the screen. However, for actual adjustment of the intensity, a single control is provided and this is the voltage on the control grid. The electron beam

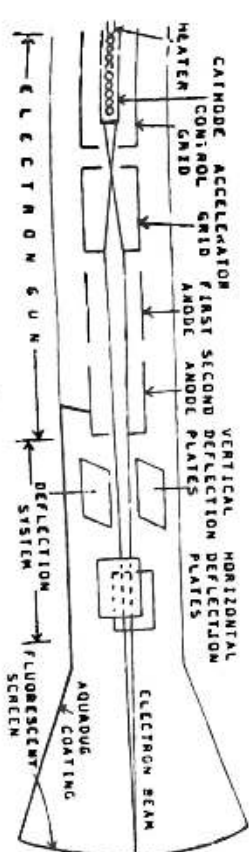


Fig. Essential features of a cathode ray tube.

then enters the anodes. First anode is operated at a moderately positive potential while the second anode at a high positive potential with respect to the cathode. The two anodes together serve to focus the electron beam into a sharp point on the fluorescent screen and also to give the electrons sufficient velocity so as to cause fluorescence when they strike the screen. The focussing is produced due to the converging effect of the electrostatic lines of force between the two anodes. It is achieved by varying the relative potential of the two anodes. The second anode potential is made fixed while that of the first is made variable and the variation provides the focus control. Typical voltages of the two anodes are about 2000 volts for the second anode and about 400 to 800 volts for the first.

Deflection systems : The electron beam coming out of the electron gun has to be deflected in accordance with the electrical signal to be displayed on the screen. The deflection can be achieved by applying either an electrostatic field or a magnetic field.

The electrostatic deflection system consists of two pairs of plane parallel plates, one horizontal and the other vertical. If a voltage is applied between the two plates of any pair, the electron beam bends toward the positive plate as it passes through the pair. The horizontal plates will, thus, produce a deflection in the vertical direction and are, therefore, known as *vertical deflection plates*. The plates mounted vertically are known as *horizontal deflection plates* for similar reasons. After emerging from the deflection plates, the electron beam travels in the direction of emergence to the screen and strikes it at a certain distance from the original position. The deflection x (or y) in the horizontal (or vertical) direction is given by

$$x \text{ (or } y) = \frac{Ll}{2d} \frac{V_d}{V_a}$$

Where L is the distance from the center of deflecting plates to the screen, l is the length of deflecting plates along the beam, d is the separation between them and V_d and V_a are, respectively, the voltages between deflecting plates and between cathode and second anode.

Magnetic deflection system consists of coils arranged such that if a current is passed through them, they produce magnetic field with flux lines perpendicular to the beam direction. One pair of coils produces horizontal flux lines; by Fleming's left hand rule the resulting deflection of electron beam will be in the vertical direction. The other pair of coils produces vertical flux lines and horizontal deflection of the beam. If the coils produce a uniform magnetic induction B over a length l of the beam, the deflection x (or y) on the screen is given by

$$x \text{ (or } y) = \sqrt{\frac{e}{2mV_a}} \frac{LlB}{L/B}$$

where e and m are the electronic charge and mass, respectively.

In either of the two deflection systems, different parts of an electron beam are deflected by slightly different amounts. This results in slight defocussing specially when the angle of deflection is large. The effect is more pronounced in the case of electrostatic deflection than in magnetic deflection. For this reason, magnetic deflection is preferred in cathode ray tubes having large screens, for example, television tubes. Electrostatic deflection system is preferable in cathode ray tubes for laboratory use because it does not draw any power so that the required amplifiers are easier to design and because it can be used at high frequencies also for which construction of suitable deflecting coils becomes difficult.

Fluorescent screen : The screens of cathode ray tubes have a coating of fluorescent material known as phosphors. They have the property that they emit light when high velocity electrons strike them. The most common phosphor has the commercial name Willemite and is zinc orthosilicate with traces of manganese added to it. Some other phosphors are zinc oxide, zinc sulphide etc. The intensity of emitted light for a given phosphor depends on the beam current, i.e., on (i) the number of electrons which depends on the grid voltage and (ii) their velocity which depends on the anode voltage. The colour depends on the phosphor used; common colours are greenish, bluish or yellowish. It is seen that the light persists for a finite time even after the bombardment by electrons has stopped. Persistence time ranges from a few micro-seconds to minutes for different fluorescent coatings. Short persistence is required for displaying rapidly changing patterns, for example, in a television tube while a long persistence is useful for studying short-lived transient phenomena.

The electrons after striking the screen must be returned to the cathode in order to have closed cycle and hence a continuous operation of cathode ray tube. For this purpose, the side walls of the tube are coated with any conducting material, usually aquadag which is conducting suspension of carbon particles. This coating returns the electrons to the second anode from where they travel through the outer circuit to the cathode.

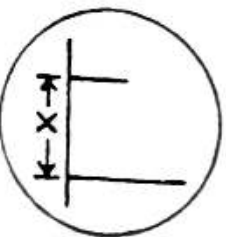
The common practice in cathode ray tubes is to keep the second anode at ground potential and all other electrodes at negative potential.

Some application of cathode ray Oscillograph are—

- (1) Measurement of direct or alternating voltages.
- (2) Measurement of time difference.
- (3) Visual display of waveshape of any periodic voltage.
- (4) Frequency comparison using to Lissajou's patterns.

Q13. Write short notes on Measurement of time differences by CRO.

Ans. Horizontal scale of a C.R.O. screen can be calibrated in terms of time as follows : If a sawtooth voltage is applied between horizontal deflection plates, the spot moves with a uniform speed from one end of the screen to the other, then comes back quickly and retraces the same path. A horizontal line will, therefore, be obtained on the screen; its length will be proportional to the amplitude of the sawtooth voltage. The time taken by the spot to travel this length is just the time period T of the sawtooth voltage. The length l of the line thus corresponds to a time-difference of T and any two points on this line having a separation x represent a time difference of t given by

$$t = (T/l) x$$


If two electrical signals occur at regular intervals, the interest can be measured by applying the signals to the Y-input of C.R.O. and a sawtooth voltage of known time period to the X-input. This will give a vertical deflection to the spot at two definite points along the horizontal line as shown in Fig. The separation between the points can be measured and the time interval worked out from equation. Intervals as short as nanoseconds (10^{-9} seconds) can be measured in this way.

Q14. Draw and discuss the characteristic of a zener diode. Explain zener breakdown.

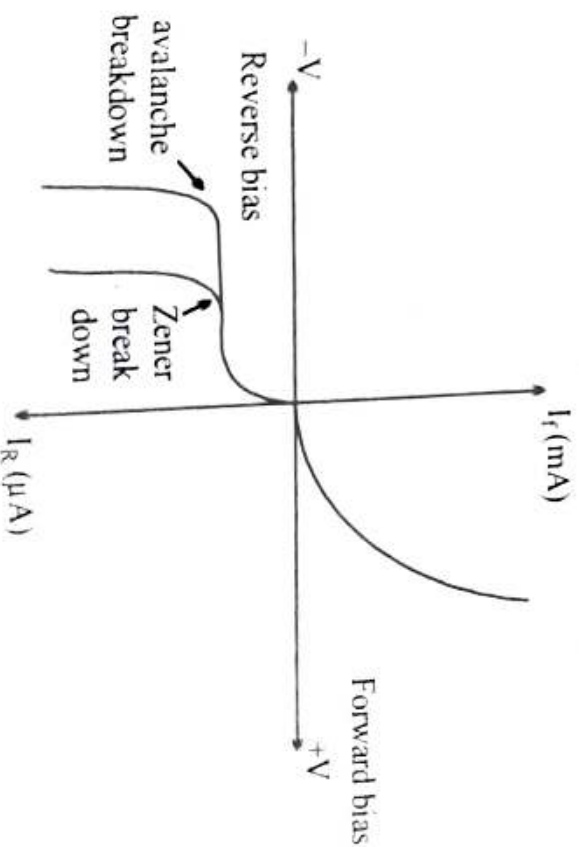
Ans. A properly doped crystal diode which has a sharp breakdown voltage is known as a zener diode.



It is the symbol of a zener diode. It may be seen that it is just like and ordinary diode except that the bar is turned into Z-shape. The zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage. A zener diode is always reverse connected. It has sharp breakdown voltage, called zener voltage, V_Z . The zener diode is not immediately burnt just because it has entered the breakdown region. As long as the external circuit connected to the diode limits the diode current to less than burn out value, the diode will not burn out.

We have seen that a PN-junction allows a very small current to flow when it is reverse biased. This current is due to the movement of minority carriers. It is almost independent of the voltage applied. However, if the reverse bias is made too high, the current through the PN-junction increases abruptly. The voltage at which this phenomenon occurs is called breakdown voltage. At this voltage, the crystal structure break down. In normal applications, this condition is avoided. The crystal structure will return to normal when the excess reverse bias is removed provided that overheating has not permanently damaged the crystal.

There are two process which can cause junction breakdown. One is called Zener breakdown and other is called avalanche breakdown. When reverse bias is increased, the electric field at the junction also increases. High electric field causes covalent bonds to break. Thus a large number of carriers are generated. This cause a large current to flow. This mechanism of breakdown is called zener-breakdown.



In case of avalanche breakdown, the increased electric field cause carriers break covalent bonds, thereby generating more carriers. Again these generated carriers are accelerated by the electric field. The break more covalent bonds during their travel. A chain reaction is thus established creating a large number of carriers. This gives rise to a high reverse current.

This mechanism is called avalanche breakdown.

Q15. Write short notes on LC Filters.

(2015)

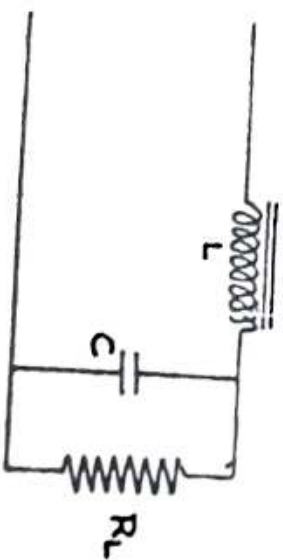
Ans. A combination of a series inductor and a shunt capacitor to form an L-section filter as shown in Fig. An approximate analysis yields the ripple factor for such a filter as

$$r = \frac{\sqrt{2}}{3} \frac{X_C}{X_L}, \quad (9.47)$$

where X_C and X_L are the reactances of C and L at the frequency 2ω of the dominant alternating part of the output. Thus,

$$r = \frac{\sqrt{2}}{12} \frac{1}{\omega^2 CL}. \quad (9.48)$$

Multiple L-section filters can also be used for still better filtering.



An L-section filter.

The ripple factor will then be given by

$$r = \frac{\sqrt{2}}{3} \frac{X_{C1} X_{C2}}{X_{L1} X_{L2}}$$

A very efficient filter circuit is obtained by adding a shunt capacitor before an L-section filter to form what is known as a π -section filter, shown in Fig. This filter can be thought of

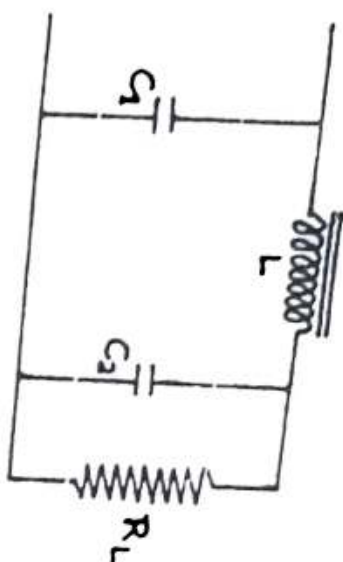


Fig. A π -section filter.

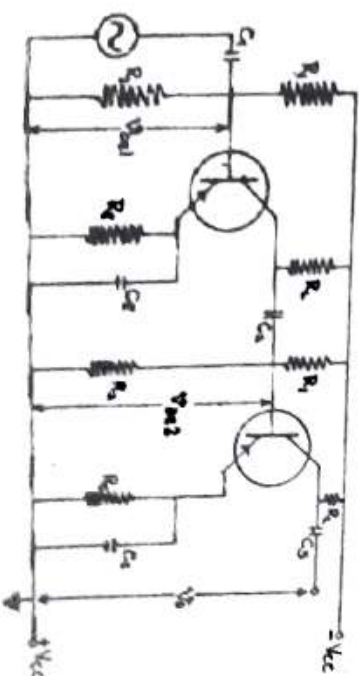
as a capacitor filter followed by an L-section filter so that the ripple factor can be approximately given by :

$$r = \frac{\pi}{3} \sqrt{\frac{2}{3}} \frac{V_{C1} V_{C2}}{V_L R_L} \approx 0.55 \frac{V_{C1} V_{C2}}{V_L R_L}$$

Q16. Write short notes on Middle frequency response. (2015)

Ans. Middle frequency, defined as the range of frequencies over which all reactance in series can be treated as short circuit while those in shunt can be treated as open circuit. This implies that all reactances can be ignored and the behaviour can be expected to be frequency independent.

The only reactance in the circuit is that of the coupling capacitor C_2 . It is so large that its reactance $1/\omega C_2$ is assumed to be negligible over this range of frequencies. C_2 can then be ignored from the equivalent circuit shown in fig.



The output voltage V_{s2} is then given by,

$$V_{s2} = -\epsilon_m \frac{R_L h_{fe}}{R_L + h_{fe}}$$

Therefore, the voltage gain of the first stage in the middle frequency range become

$$A_{m1} = -\epsilon_m \frac{R_L h_{fe}}{R_L + h_{fe}} \cdot \frac{1}{1 + R_L / h_{fe}}$$

Clearly, the gain is less than that of a corresponding single stage amplifier. The reduction is due to the loading of R_L by the input resistance of the next stage. The minus sign indicates a phase change of 180° as in the case of the single stage amplifier.

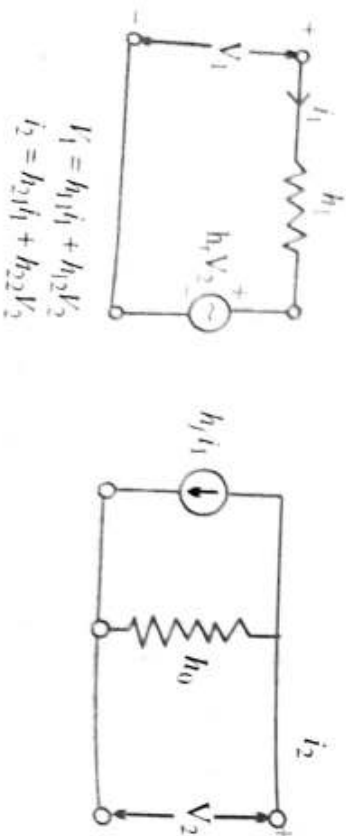
Q17. Why is the base in a BJT kept thin and lightly doped?

(2016,19)

Ans. Base region of a transistor is kept very small and very lightly doped so as to pass most of the injected charge carriers to the collector.

Q18. Define h-parameters for a BJT and obtain a relation between the current gains, in the common base and common-emitter configurations. (2016)

Ans. There are three transistor configurations CB, CE and CC. Each configuration will have its separate hybrid or h-parameters equivalent circuit which can be applied for any of three configurations. The equivalent circuit thus obtained for any type of configurations is also called as small-signal low frequency hybrid model of a transistor, h parameters are



or

$$V_1 = h_{11}I_1 + h_{12}V_2$$

$$I_2 = h_{21}I_1 + h_{22}V_2$$

Since, each term of equation has the units of volts, we can use Kirchhoff's voltage law to find a circuit that fits this equation. Relation Between current gain α and β —

We know that the emitter current I_e of a transistor is given as

$$I_e = I_B + I_C$$

I_B = Base current, I_C = Collector Current.

Dividing above equation by I_e on both sides we have,

$$\frac{I_e}{I_e} = \frac{I_B}{I_e} + 1$$

...(1)

But

$$\frac{I_C}{I_e} = \alpha \frac{I_C}{I_B} = \beta$$

Putting these values in the equation (1)

$$\frac{1}{\alpha} = \frac{1}{\beta} + \frac{1}{1 + \beta}$$

$$\alpha = \frac{\beta}{1 + \beta}$$

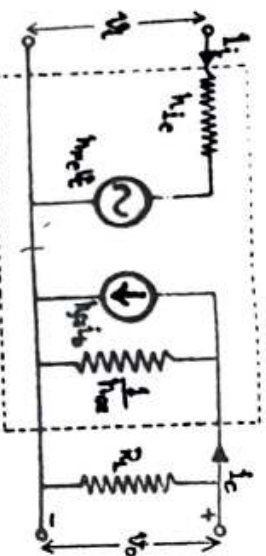
$$\alpha(1 + \beta) = \beta$$

$$\alpha = (1 - \alpha)\beta$$

$$\beta = \frac{\alpha}{1 - \alpha}$$

Q19. Draw the circuit diagram for a single stage common-emitter amplifier and obtain its current gain, voltage gain and power gain. (2016)

Ans. Replacing the transistor by its equivalent, we get the equivalent circuit for the common-emitter amplifier as shown in Fig. The d.c. bias sources have been omitted because the equivalent circuit is drawn for the alternating parts only. The blocking capacitor C is omitted because its reactance is assumed to be negligible over the range of frequencies over which the amplifier is to be used.



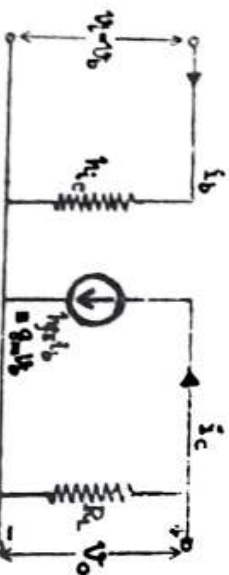
Equivalent circuit for the CE amplifier of fig. 1

The reverse voltage amplification factor h_{re} for most transistors is very small, typical values are $\sim 10^{-4}$. Therefore, the voltage generator in the input circuit can be ignored. Further, the output admittance is of the order of 10^{-5} mho. Therefore $1/h_{oe}$ is of the order of $100\text{k}\Omega$ while the load resistance R_L is typically $5\text{k}\Omega$. Therefore, $1/h_{oe}$ can be treated as effectively open circuit, hence ignored. The above equivalent circuit, thus, simplifies to the one shown in Fig. From this figure, we can write

$$v_i (= v_b) = h_{ie} i_b, \quad \dots (1)$$

$$i_c = h_{fe} i_b, \quad \dots (2)$$

$$v_o = -h_{fe} i_b R_L, \quad \dots (3)$$



Simplified equivalent circuit for the CE amplifier.

From equation (2), we get the current gain for the common-emitter amplifier as

$$A_{ic} = \frac{i_c}{i_b} = h_{fe} \quad \dots (4)$$

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Dividing equation (3) by equation (1), the voltage gain is obtained

$$A_{ve} = \frac{v_o}{v_i} = \frac{h_{fe}}{h_{ie}} R_L, \quad \dots (5)$$

But the ratio h_{fe}/h_{ie} must also be a characteristic constant of the transistor :

$$\frac{h_{fe}}{h_{ie}} = \frac{i_c/i_b}{v_b/i_b} = \left(\frac{i_c}{v_b} \right), \quad \dots (6)$$

which has the dimensions of a conductance, is denoted by g_m and is known as the *transconductance* between collector and base. Writing in terms of g_m , the voltage gain becomes

$$A_{ve} = -g_m R_L. \quad \dots (7)$$

Minus sign indicates that the output voltage will have a phase difference of 180° with the input voltage. Multiplying equations (4) and (7), we get the power gain for a CE amplifier as

$$\begin{aligned} A_{pe} &= |A_{ve}| A_{ic} \\ &= g_m h_{fe} R_L = \frac{h_{fe}^2}{h_{ie}} R_L. \end{aligned}$$

Since,

$$h_{fe} i_b = \frac{h_{fe}}{h_{ie}} v_b = g_m v_b,$$

the current source in the equivalent circuit of Fig. 2 can also be expressed as a function of input voltage rather than the input current. Since h_{fe} is high while h_{ie} has an intermediate value, the common-emitter amplifier gives high values for current gain, voltage gain and power gain.

Q20. State Barkhausen condition for oscillations in an amplifier with positive feedback. Draw the circuit diagram of a Hartley Oscillator.

(2016)

Ans. Barkhausen criterion states that the frequency of a sinusoidal oscillator determined by the condition that the loop gain phase shift is zero.

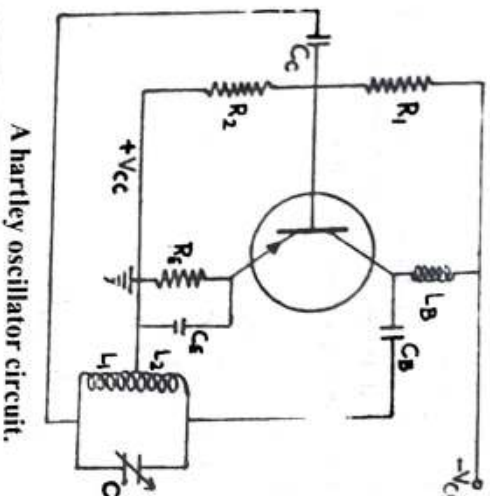
Hence, $-A\beta = 1$.

Another interpretation of Barkhausen Criterion is

$$A\beta = \frac{A}{1+A\beta} = \frac{A}{1-1} = \infty$$

Since, gain is infinity we will get fainter output with no input.

In the Hartley Oscillator circuit, shown, the collector and the base are connected to the two ends of the same inductance coil while the emitter is connected to a tapping in between. The position of the tap determines the amount of feedback *i.e.*, the value of β . The choke L_B offers a high impedance to the alternating part of the collector current and prevents it from flowing through the collector supply. The capacitor C_B similarly blocks the d.c. part of the collector current from reaching the tuned circuit.



A hartley oscillator circuit.

Q21. A voltage $v(t) = 200 \sin \omega t$ is applied across a full wave rectifier having a load resistance of $2.0k\Omega$. Assuming forward resistance of the diode to be zero and reverse resistance to be infinite. Calculate the efficiency and the output power.

Ans. $r_f = 0$, $R_L = 2.0k\Omega$, $V_0 = 200V$

(2017)

$$P_{d.c.} = \frac{4}{\pi^2} \cdot \frac{V_0^2}{(1 + r_f/R_L)^2 R_L}$$

$$P_{d.c.} = \frac{4}{\pi^2} \cdot \frac{(200)^2}{(1 + 0)^2 \times 2000}$$

$$P_{d.c.} = 8.114 \text{ W}$$

$$n = \frac{8}{\pi^2} \cdot \frac{1}{(1 + r_f/R_L)} \times 100\%$$

$$n = 81.139\%$$

Q22. An RC coupled CE amplifier uses a transistor with h -parameters : $h_{ie} = 6k\Omega$, $h_{fe} = 90$, $h_{re} = 0$, $h_{oe} = 0$. Calculate the mid frequency voltage gain for a load resistance R_L of $1k\Omega$. (2017)

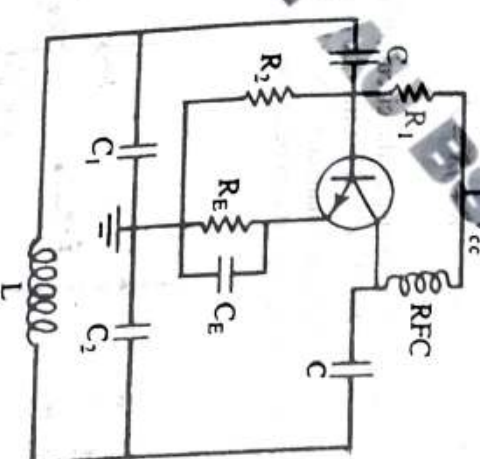
Ans. $A_{ve} = \frac{-h_{fe}}{h_{ie}} \cdot R_L = -\frac{90}{6} = \times 1000$

$A_{ve} = 15000$

Q23. Describe the circuit of colpits Oscillators.

(2017)

Ans. Colpits Oscillator



Colpits type oscillator.

If a common-emitter amplifying stage is supplying a load that is a tuned circuit and a feedback connection is made from the junction of the split load capacitor to the transistor input terminal, and if sufficient positive feedback is available, the circuit is Colpits type oscillator.

It is widely used in commercial signal generator's above 1MHz. This oscillator is similar to the Hartley oscillator. The RFC has the same function as in the Hartley oscillator. The voltage developed across C_1 provides the regenerative feedback required for sustained oscillations. The value of L , C_1 and C_2 determine the frequency of oscillation give by

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ where } C = \frac{C_1 C_2}{C_1 + C_2}$$

Q24. Draw and explain the characteristic of a P-N junction diode.

(2018)

Ans. An identical equation will hold good between corresponding vectors

$$V = RI + L \frac{dI}{dt} + \frac{1}{C} \int Idt. \quad \dots (1)$$

where the voltage vector V

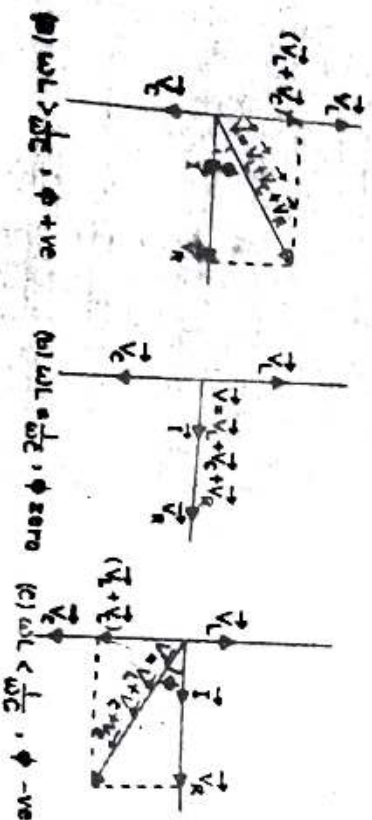
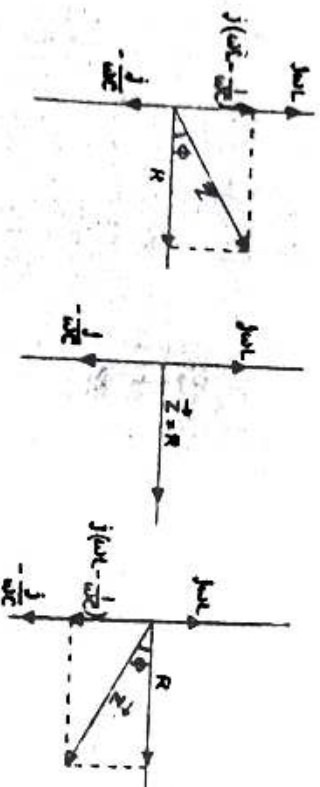
Substituting for dI/dt and $\int Idt$ equations (1) becomes

$$V = RI + j\omega LI + \frac{1}{j\omega C} I$$

$$\text{or, } \frac{V}{I} = R + j \left(\omega L - \frac{1}{\omega C} \right) = R + jX = Z, \quad \dots (2)$$

where Z is the complex impedance of the circuit. It has a real part R and an imaginary part $(\omega L - 1/\omega C)$ which may be positive, zero or negative according as ωL is greater than, equal to or less than $1/(\omega C)$. Z for the three cases. In every case it can be expressed as :

$$Z = |Z| e^{j\phi}$$



where

$$|Z| = \sqrt{R^2 + X^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2},$$

$$\phi = \tan^{-1} \frac{X}{R} = \tan^{-1} \frac{\omega L - \frac{1}{\omega C}}{R}$$

The current I can then be written as

$$I = \frac{V}{Z} = \frac{V_0 e^{j\omega t}}{|Z| e^{j\phi}} = I_0 e^{j(\omega t - \phi)},$$

where

$$I_0 = V_0 / \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2}.$$

The potential drops V_R , V_L and V_C across the three circuit elements R , L and C are given by

$$V_R = RI, V_L = j\omega LI, V_C = -\frac{j}{\omega C} I.$$

Complete vector diagram for the three cases mentioned above is shown in Figs. (a), (b) and (c).

From foregoing analysis and the vector diagrams, following conclusions can be summarized :

- (i) Current amplitude I_0 is $V_0 / \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2}$ and is thus frequency dependent.

- (ii) The circuit has a complex impedance having a resistance R and a reactance X which is the resultant of an inductive reactance $j\omega L$ and capacitive reactance $-j/\omega C$. The reactance and therefor, the impedance are frequency dependent. Three cases can be distinguished:

- (a) If $\omega > 1/\sqrt{LC}$, $\omega L > \frac{1}{\omega C}$, the reactance X will be positive and the circuit will behave as an inductive circuit.

- (b) If $\omega = 1/\sqrt{LC}$, $\omega L = \frac{1}{\omega C}$, the reactance X will be zero and the circuit will behave as a purely resistive circuit.

zero and the

- (c) If $\omega < 1/\sqrt{LC}$, $\omega L < \frac{1}{\omega C}$, the reactance X will be negative and the circuit will behave as a capacitive circuit.

The three cases are shown diagrammatically in Fig.

(a), (b) and (c) respectively.

- (iii) The phase difference between current and voltage is ϕ given by equation. This is also frequency dependent.

- (a) If $\omega > 1/\sqrt{LC}$, $\omega L > 1/(\omega C)$, ϕ will be positive and current will lag behind the voltage.
- (b) If $\omega = 1/\sqrt{LC}$, $\omega L = 1/(\omega C)$, ϕ will be zero and current and voltage will be in the same phase.

- (c) If $\omega < 1/\sqrt{LC}$, $\omega L < 1/(\omega C)$, ϕ will be negative and current will lead the voltage.

This is again illustrated in the vector diagrams of Fig.

Q25. Establish hybrid equivalent circuit of a transistor. (2018)

Ans. Equivalent circuit of a transistor

The methods of circuit analysis recognize only the current or voltage sources and the circuit constants like impedance, admittance. Therefore, in order to be able to analyze a transistor circuit, one must have an electrical equivalent of the transistor in terms of these parameters. This can be found out by using the two-port network equations in any representation. The hybrid-parameter representation, in which the input current and output voltage are taken as independent variables while the input voltage and output current are expressed as their functions, is most widely used in transistor application. In this representation, the network equations relating the input and output variables are

$$\begin{cases} V_i = h_i I_i + h_r V_o, \\ I_o = h_f I_i + h_o V_o, \end{cases}$$

where h_i , h_r , h_f and h_o are, respectively, the input impedance, the reverse voltage amplification factor, the forward current gain and the output admittance. It is easy to verify that these same equations hold good for a very simple circuit shown in Fig. This circuit, therefore, gives an electrical equivalent for the transistor: a voltage source $h_r V_o$ in series with an impedance equal to h_i for the input of the transistor and a current source $h_f I_i$ in parallel with an admittance h_o for the

output of the transistor. This is the general hybrid-parameter equivalent circuit. For a specific configuration, appropriate values of the parameters and the input output variable have to be used.

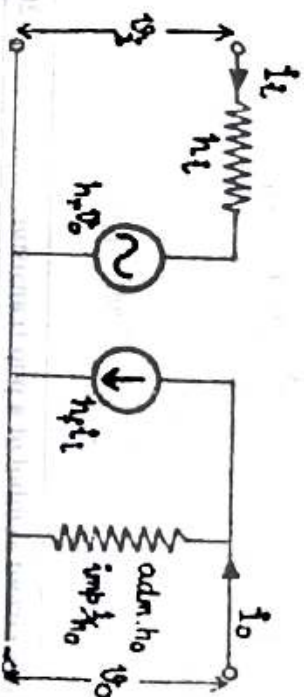


Fig. Equivalent circuit for a BJT in the hybrid parameter representation

Q26. A load resistance of $5.0k\Omega$ is connected in a R-C coupled CE amplifier. Calculate mid-frequency voltage gain of the amplifier considering $h_{ie} = 1k\Omega$ and $h_{fe} = 120$. (2018)

Ans. $A_{ve} = -\frac{h_{fe}}{h_{ie}} \cdot R_L$

$$A_{ve} = \frac{120}{100} \times 5000$$

$$A_{ve} = 6000$$

Q27. What is modulation index? Obtain minimum & maximum amplitudes of amplitude modulated wave for 50% modulation. (2018)

Ans. The ratio of maximum change in amplitude to the carrier amplitude known as modulation index. The maximum value that m can have unity corresponding to 100 percent modulation.

$$m = \frac{KE_m}{E_c}$$

$$E_{\max} = E_c(1+m) = E_c(1+0.5) = 1.5E_c$$

$$E_{\min} = E_c(1-m) = E_c(1-0.5) = 0.5E_c$$

Q28. A transistor connected in single stage common-emitter amplifier has h-parameters $h_{ie} = 125$, $h_{re} = 2 \times 10^{-4}$, $h_{fe} = 5 \times 10^{-6}$ mho and $h_{oe} = 5k\Omega$. Considering h-parameter approximation, calculate current gain, voltage gain, power

Ans.

Current gain, $A_{v_e} = h_{fe} = 125$
Voltage gain,

$$A_{v_e} = \frac{-h_{fe}}{h_{ie}} R_L = \frac{-125}{5 \times 10^3} \times 2000 = -50$$

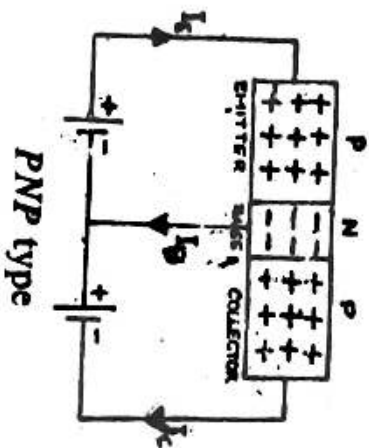
Power gain,

$$A_{p_e} = \frac{h_{fe}^2}{h_{ie}} R_L = \frac{(125)^2}{5 \times 10^3} \times 2000 = 6250$$

Q29. Give circuit symbol of a pnp transistor.

Ans.

(2019)

**Q30. Write short note of (h)-parameter.**

(2019)

Ans. In this representation, input current and output voltage are taken as independent variable and the input voltage and output current are given in terms of them by the equations

$$\begin{cases} v_i = h_{11} i_i + h_{12} v_o, \\ i_o = h_{21} i_i + h_{22} v_o, \end{cases}$$

(A 5.5)

In this case, the network parameters have different dimensions : h_{11} has that of impedance, h_{12} and h_{21} are dimensionless while h_{22} has the dimensions of admittance. They are given by

$$\begin{cases} h_{11} = \left(\frac{\partial v_i}{\partial i_i} \right)_{v_o}, & h_{12} = \left(\frac{\partial v_i}{\partial v_o} \right)_{i_i}, \\ h_{21} = \left(\frac{\partial i_o}{\partial i_i} \right)_{v_o}, & h_{22} = \left(\frac{\partial i_o}{\partial v_o} \right)_{i_i}. \end{cases} \quad (A 5.6)$$

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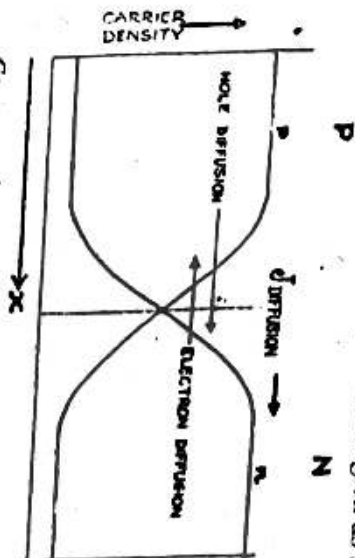
h_{11} is, clearly, the input impedance and is also denoted by h_i . h_{12} gives the ratio of change in the input voltage to the corresponding change in the output voltage. It is, therefore, known as the reverse voltage amplification factor and is also denoted by h_r or μ_r . h_{21} is the ratio of a change in the output current to the corresponding change in the input current, it is, therefore, known as the forward current gain and is also denoted by h_f or α_f . h_{22} gives the output admittance and is also denoted by h_o .

Q31. What is diffusion of charge carriers? Explain the formation of depletion layer in P-N-junction diode?

(2019)

Ans. **P-N junctions : diffusion of charge carriers**

If a junction of formed between a P-type and an N-type semiconductor, the electron density changes by several orders of magnitude as we go from the N-side having electrons as the majority charge carriers to the P-side, where the electrons are in the minority. The statement is true for hole density also as we go from the P-side to the N-side. Thus there exist steep concentration gradients dp/dx and dn/dx in the junction region as shown in



Concentration gradients in a P-N junction.

This sets in a diffusion process from the regions of higher concentration to the regions of lower concentration. Thus electrons diffuse from N side to P side and the holes diffuse from P side to N side resulting in diffusion currents through the junction. The rate of diffusion is proportional to the magnitude of the concentration gradient. This rate multiplied by the charge of the carrier gives the diffusion current density. Thus,

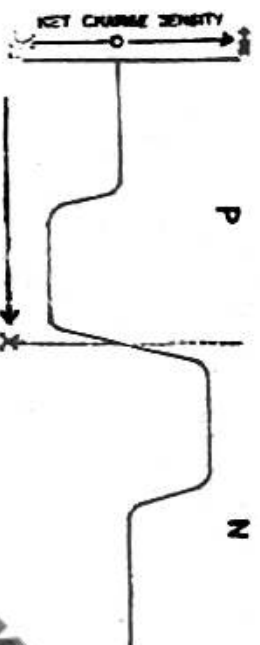
$$J_n = -eD_n \frac{dn}{dx}, \quad J_p = eD_p \frac{dp}{dx},$$

hole and the electron, respectively. Since the electron and hole movements are in opposite directions, their current add up to give the net diffusion current through the junction as

$$J_{diff} = e \left(D_e \frac{dn}{dx} - D_h \frac{dp}{dx} \right)$$

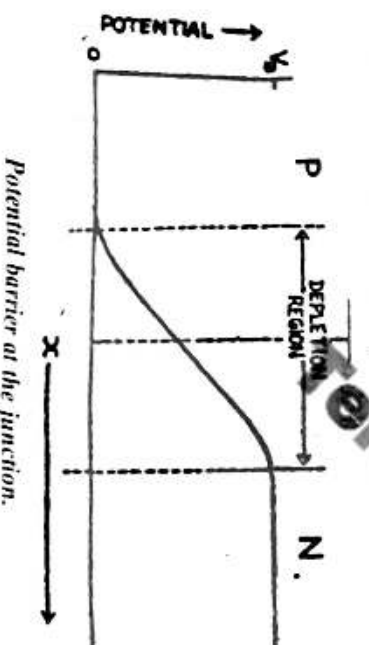
Potential barrier at a P-N junction

The diffusion process discussed in the previous section is a self-limiting process due to the fact that it disturbs the electrical neutrality of both sides of the junction. When electrons cross over from the N side to the P side, they recombine with the excess holes present there and are immobilized. This leaves N side deficient in negative charge and P side having an excess of negative charge. Similarly, the diffusion of holes from P side to N side leaves P side deficient in positive charge and N side having an excess of positive charge. As a result, the two sides of the junction are no longer electrically neutral; P side acquires an excess of negative charge while N side acquires an excess of positive



Effect of diffusion on the net charge density.

charge as shown Fig. 2. This creates a potential difference at the junction as shown in Fig. 3. The potential difference has the right polarity to oppose further diffusion of charge carriers across the junction. Equilibrium is reached when enough number of carriers have diffused so as to create a potential difference that



Potential barrier at the junction.

is just sufficient to stop further diffusion. This potential difference is known as *junction potential barrier* V_B or the *contact potential*. It is of the order of a few tenths of a volt for most P-N junctions.

There is another interesting consequence of the diffusion process. Close to the junction on either side of it, nearly all the mobile free charges diffuse to the other side and are immobilized there by recombination with the carriers of opposite polarity. Thus a narrow region exists at the junction which is depleted of all its mobile charge carriers. It is known as the *depletion region*. Its thickness depends on the impurity concentration in the semiconductors and also on the external voltage, if any, applied across the junction. With no external voltage, the thickness is typically of the order of one micron. Since the depletion region does not have any free charges, it behaves like a dielectric material between the two conducting regions. It, thus, forms a capacitor whose capacitance is known as the *junction capacitance*. Its typical value is of the order of 10 pF. The junction capacitance plays an important role in circuits using high frequency alternating currents.

Q32. The maximum & minimum amplitudes in A.M waves are 3V & 1V respectively. Calculate the modulation percentage. (2019)

Ans.

$$\frac{1+m}{1-m} = \frac{E_{max}}{E_{min}}$$

$$\frac{1+m}{1-m} = \frac{3}{1}$$

$$1+m = 3-3m$$

$$4m = 2$$

$$m = 0.5$$

percentage modulation = $100m = 50\%$.

Q33. Write the relationship between current gain of a transistor in CE - & CB - Configuration. (2019)

Ans. α -current gain in CB
 β -current gain in CE

$$\alpha = \frac{I_c}{I_e} \quad \dots(1)$$

$$\beta = \frac{I_c}{I_b} \quad \dots(2)$$

$$I = I_c + I_b \quad \dots(3)$$

Use (3) in (1).

$$\alpha = \frac{I_c}{I_c + I_\beta}$$

$$\frac{1}{\alpha} = \frac{I_c + I_\beta}{I_c} = 1 + \frac{I_\beta}{I_c}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\frac{1 - \alpha}{\alpha} = \frac{1}{\beta}$$

$$\boxed{\frac{\alpha}{1 - \alpha} = \beta}$$

{from (1)}

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Q1. Why is base in a BJT kept thin & lightly doped? (2019)

Ans. Chapter 2; Question 18.

Q2. Describe Maxwell's Bridge arrangement for obtaining the self inductance of coil. (2019)

Ans. Chapter 1 : Question 29

Q3. Draw the circuit of full wave rectifier and explain its working. Obtain the expression for ripple factor of a full wave rectifier. (2019)

Ans. Chapter 2 : Questions 4.

Q4. What is amplitude modulation? Show that amplitude modulated wave is composed of three waves of different frequencies. (2019)

Ans. Chapter 2 : Question 7 & 8.

Q5. Write short notes on CRO. (2019)

Ans. Chapter 2 : Question 13.

Q6. Write short notes on feedback amplifiers. (2019)

Ans. Chapter 2 : Question 2.

Q7. Give relationship between current, voltage & impedance in a series LCR circuit. Draw vector diagram of current & voltage. Find Q factor of the series LCR Circuit. Explain resonance in series LCR circuit. (2019)

Ans. Chapter 1 : Question 21.