Unit-1 : Circuit Analysis

Basics

1) Electrical - things operate in greater than 12V (ex: fan)
2) Electronics - things operate in lesser than 12V (ex- phones)

Hardware waste — Software waste (CS)

- important parameters that must be balanced :- power, area, speed to increase its performance.
- diode, BJT[bipolar junction transistors], FET (field effect transistors)
- analog → varies with time instantly (Ex- 29, 30)
- digital → varies with time but not periodical (discrete values, ex- voice over transmission)

Transmission → Channel → Reciever

hacking is possible here

→ Components :

1) Active
- anything that needs power supply

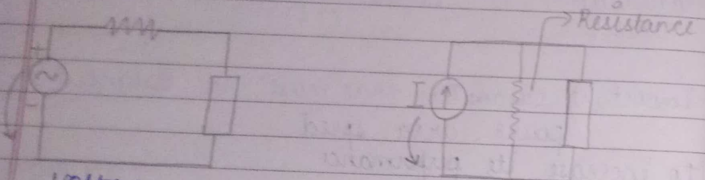
2) Passive
- components that don't require power.

• ex - IC (integrated circuit) • ex (detector, resistor, capacitor)

→ The resistor must be connected in series with voltage source & in parallel with current source.

Relation b/w current & voltage

$V = IR$ → Ohm's law



Voltage source
Series to resistance

Current Source
• parallel to resistance

the circuits are connected to each other too

Kirchoff's Law

KCL: all the incoming current = all the outgoing

KVL: The algebraic sum of all voltages drops & emf sources in any closed path $= 0$

$\Sigma V = 0$

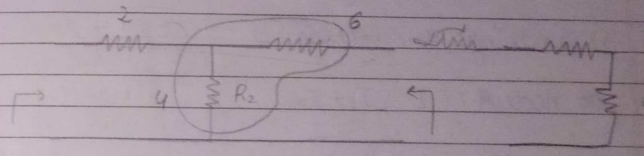
Series & parallel resistance

$R_s = R_1 + R_2 + \dots + R_n$

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}$

$R_p = \frac{R_1 R_2}{R_1 + R_2}$

$\frac{6 \times 4}{6+4}$



voltage → short circuit
current → open circuit

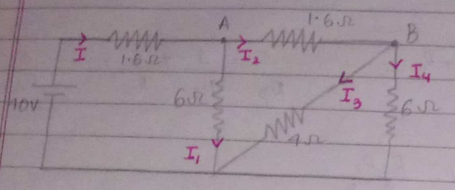
equivalent resistance → $R_1 + (R_2 \parallel R_3)$

→ $R_1 + \frac{R_2 R_3}{R_2 + R_3}$

19/1/24

Nodal Analysis : Use KCL

Ques Find current through the 4Ohm resistor of the following circuit.



earthing

Sol ⇒ at earthing, the voltage = 0

- At node A : $I = I_1 + I_2$

$$\frac{V}{R} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$$

$$\frac{40 - V_A}{1 \cdot 6} = \frac{V_A - 0}{6} + \frac{V_A - V_B}{1 \cdot 6} \quad \text{— (i)}$$

- V_A & V_B kaise decide
- → Jahan se current ... jidhar I gya V_A ...
- → Voltage ke case mein end sign konsa hai

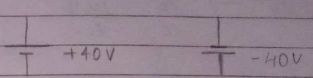
- At node B : $I_2 = I_3 + I_4$

$$\frac{V_2}{R_2} = \frac{V_3}{R_3} + \frac{V_4}{R_4}$$

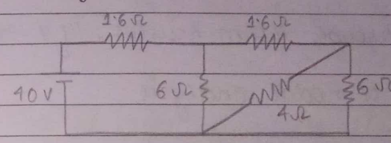
$$\frac{V_A - V_B}{1 \cdot 6} = \frac{V_B - 0}{4} + \frac{V_B - 0}{6} \quad \text{— (ii)}$$

- at the potential 40 V, it is +ve up & -ve down so take it +ve.

→ If it is -ve terminal at top & +ve below, the voltage is -ve.



→ Solving the circuit :-



1) 6 Ω & 4 Ω in parallel = $\frac{6 \times 4}{6+4} = \frac{24}{10} = 2 \cdot 4 \, \Omega$

2) 1·6 Ω & 2·4 in series = 1·6 + 2·4 = 4 Ω

3) 6 Ω & 4 Ω in parallel = 2·4 Ω

4) 1·6 Ω & 2·4 in series = 4 Ω

Ohm's law ($V = IR$) = $40 = I \times R$
$I = 10 A$

From (i) → $\frac{40 - V_A}{1 \cdot 6} = 10$, $40 - V_A = 16$
$V_A = 40 - 16$
$= 24 V$

$I_1 = \frac{24}{6} = 4 A$ $\quad$ $I_2 = I - I_1 = 10 - 4 = 6 A$

- $I = 10A$, $I_1 = 4A$, $I_2 = 6A$

From (ii) $I_2 = I_3 - I_4 \rightarrow \frac{V_A}{6} = \frac{14.4}{6}$

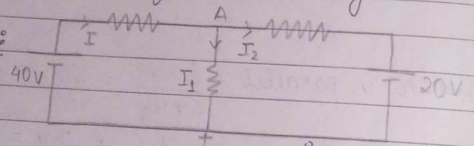
$$\downarrow$$

$$\frac{V_B}{4} = \frac{14.4}{4}$$

ans: current through 4 ohm resistor, $\frac{14.4}{4} = 3.6A$

Different cases of nodal analysis

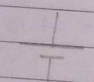
Case 1:



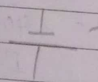
earthing

- connected to earth:

and



$\rightarrow \frac{V_A - 20}{R}$

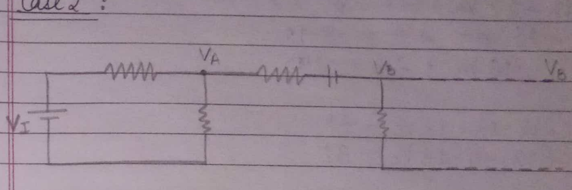


$\rightarrow \frac{V_A + 20}{R}$

i.e. if we come across the +ve terminal first we take -ve. $\frac{V_A - 20}{R}$

but if we come across the -ve terminal first we take +ve $\rightarrow \frac{V_A + 20}{}$

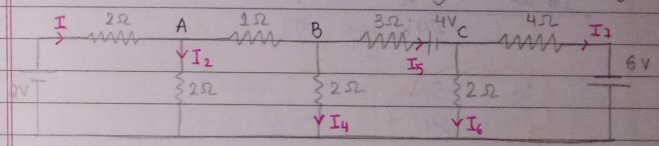
Case 2:



$$\frac{V_A - V_B - V_B}{R}$$

- not connected to earth instead connected to more circuit.

Ques: Find the value of current flowing through 3Ω resistance in given circuit using nodal analysis.



Sol: At node A: $I = I_2 + I_3$

$$\frac{2 - V_A}{2} = \frac{V_A - 0}{2} + \frac{V_A - V_B}{1}$$

$\rightarrow 2 - V_A = V_A + 2V_A - 2V_B$; $2 = 4V_A - 2V_B$

$1 = 2V_A - V_B$

now find V_A, V_B, V_C

$\rightarrow 2V_A - 1 = V_B$

$\rightarrow 6V_A - 11(2V_A - 1) + 2V_C = -8$

$\rightarrow$ $6V_A - 22V_A + 11 + 2V_c = -8$

$-16V_A + 2V_c = -8 - 11$

$-16V_A + 2V_c = -19$

$\rightarrow$ $4(2V_A - 1) - 13V_c = 31$

$8V_A - 4 - 13V_c = 31$

$-16V_A + 2V_c = -19$

$(8V_A - 13V_c = 35) \times 2$

$$\begin{array}{rcl} 16V_A - 26V_c & = & 70 \\ -16V_A + 2V_c & = & -19 \\ \hline -24V_c & = & 51 \end{array}$$

$V_c = \dfrac{-51}{24}$

$\rightarrow$ $-16V_A = -19 - \left(\dfrac{-51}{24}\right) \times 2$

$-16V_A = -19 + \dfrac{51}{12} = \dfrac{-228 + 51}{12} = \dfrac{59}{64}$

$\rightarrow$ $2 \times \dfrac{59}{\cancel{64}\,32} - 1 = V_B \longrightarrow \dfrac{59}{32} - 1 = V_B$

$\dfrac{59 - 32}{32} = V_B$ $\quad\therefore\quad$ $V_B = \dfrac{27}{32}$

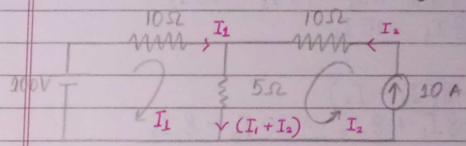
$\therefore$ $V_A = \dfrac{59}{64}$, $V_B = \dfrac{27}{32}$, $V_c = \dfrac{-51}{24}$

Current flowing through I_1

$$\frac{\frac{27}{32} - 4 + \frac{51}{24}}{3} =$$

Loop/ Mesh Analysis :-

Ques Find the current in all the resistive branches of the circuit using loop analysis.



$I_2 = 10$

Loop

$100 = 10I_1 + 5(I_1 + I_2)$

$100 + (-10)I_1 - 5(I_1 + I_2) = 0$

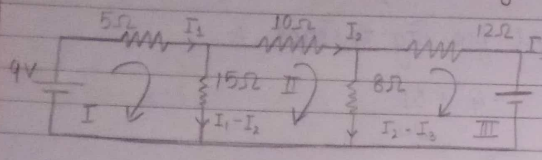
$100 - 10I_1 - 5I_1 - 50 = 0$

$50 - 15I_1 = 0$

$I_1 = \dfrac{50}{15} = \dfrac{10}{3} = 3.33A$

$I_1 = 3.33\,A \qquad I_2 = 10A$

Ques Determine the value of current in 8Ω resistor in the network shown below using mesh method.



loop 1: $9 = 5I_1 + 15(I_1 - I_2)$

$9 = 5I_1 + 15I_1 - 15I_2 = 20I_1 - 15I_2$

loop 2: $0 = 10I_2 + 8(I_2 - I_3) - 15(I_1 - I_2)$

$= 10I_2 + 8I_2 - 8I_3 - 15I_1 + 15I_2$

$= 33I_2 - 8I_3 - 15I_1$

loop 3: $6 = 12I_3 - 8(I_2 - I_3)$

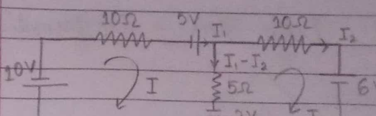
$6 = 12I_3 - 8I_2 + 8I_3 = 20I_3 - 8I_2$

$$I_1 = \frac{9 + 15I_2}{20}$$

Calculations needed to be done

H.W

Ques



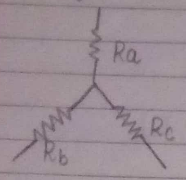
loop 1: $-10V + 5V + 2V = 10I_1 + 5(I_1 - I_2)$

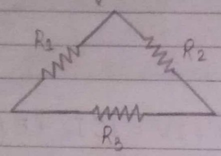
$-3V = 15V_1 - 5I_2$

loop 2: $-6V - 2V = 10I_2 - 5(I_1 - I_2)$

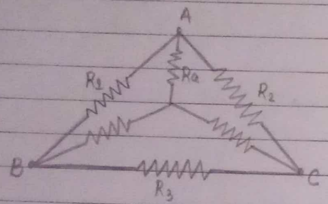
$-8V = 15I_2 - I_1$

Star-Delta, and Delta-Star Trasformation





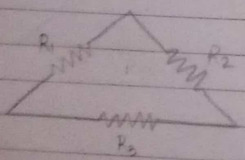
Delta-Star

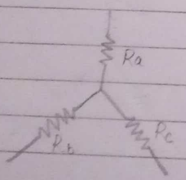


$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3} \qquad R_b = \frac{R_1 R_3}{R_1 + R_2 + R_3}$$

$$R_c = \frac{R_3 R_2}{R_2 + R_2 + R_3}$$

Star-Delta



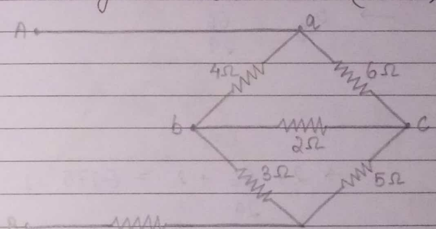


$$R_1 = R_a + R_b + \frac{R_a R_b}{R_c}$$

$$R_2 = R_a + R_c + \frac{R_a R_b}{R_b}$$

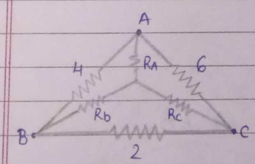
$$R_3 = R_b + R_c + \frac{R_b R_c}{R_a}$$

Ques Find the resistance b/w terminals A & B for the circuit given below use ($Y-\Delta$)



Take First

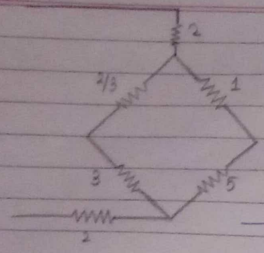
Sol



$$R_A = \frac{R_1 R_2}{R_1 + R_2 + R_3} = \frac{4\times6}{12} = 2$$

$$R_b = \frac{4\times2}{12} = \frac{2}{3}$$

$$R_c = \frac{6\times2}{12} = 1$$



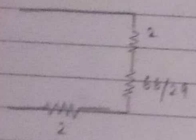
→ $\frac{2}{3} + 3$ (Series) $= \frac{2+9}{3} = \frac{11}{3}$

→ $1+5$ (Series) $= 6$

→ $\frac{11}{3}$ & 6 (parallel)

→ $\frac{1}{11/3} + \frac{1}{6} = \frac{1}{R_{eq}} \rightarrow \frac{3}{11} + 6 = \frac{1}{R} \rightarrow \frac{18+11}{66} = \frac{1}{R_{eq}}$

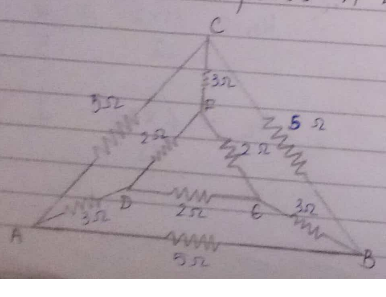
→ $\frac{29}{66} = \frac{1}{R_{eq}} \rightarrow R_{eq} = \frac{66}{29}$



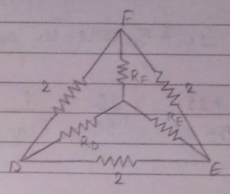
→ $2 + \frac{66}{29} + 2 = 6.275\,\Omega$

• Assignment Questions

Q. Find resistance b/w points A & B.



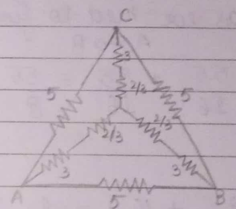
delta to star :-



$R_D = \frac{2+2}{2+2+2} = \frac{2}{3}$

$R_E = \frac{4}{6} = \frac{2}{3}$

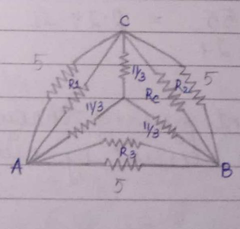
$R_F = \frac{4}{6} = \frac{2}{3}$



→ $3 + \frac{2}{3}$ (series)

→ $9 + 2/3 = 11/3$

→ Convert star into delta

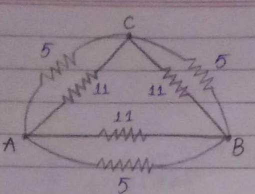


$R_1 = \frac{11}{3} + \frac{11}{3} + \frac{11/3 \times \cancel{11/3}}{\cancel{11/3}}$

$= 3 \times \left(\frac{11}{3}\right) = 11\,\Omega$

$R_2 = 11\,\Omega$ $R_3 = 11\,\Omega$

→

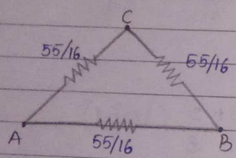


11 & 5 are in parallel

$$\frac{5+11}{55} = \frac{16}{55} = \frac{1}{Req}$$

$$\frac{55}{16} = Req$$

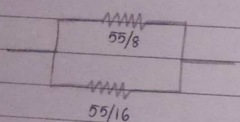
→



as we need to find $A \to B$

$$\frac{55}{16} + \frac{55}{16} = \frac{55}{8}$$

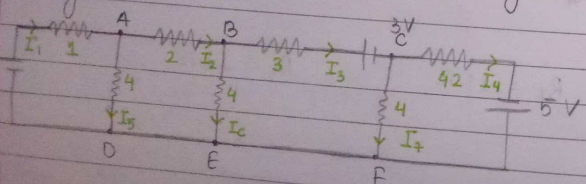
→



$$\frac{8}{55} + \frac{16}{55} = \frac{1}{Req}$$

$$Req = \frac{55}{24} = 2{\cdot}29\ \Omega$$

Find the value of current flowing through 3Ω resistance in the given circuit by using nodal analysis.



Sol Applying KCL :

\# at node A : $I_1 = I_2 + I_5$

$$\rightarrow \frac{4-V_A}{1} = \frac{V_A - V_B}{2} + \frac{V_A - \cancel{0}}{4},$$

$$\rightarrow 4 - V_A = \frac{2V_A - 2V_B + V_A}{4}$$

$$16 - 4V_A = 3V_A - 2V_B \longrightarrow 16 + 2V_B = 7V_A$$

$$\boxed{V_A = \frac{16 + 2V_B}{7}}$$

\# at node B : $I_2 = I_3 + I_6$

$$\frac{V_A - V_B}{2} = \frac{V_B - V_C - 3}{3} + \frac{V_B}{4}$$

$$\frac{V_A - V_B}{\cancel{2}} = \frac{4V_B - 4V_C - 12 + 3V_B}{\cancel{12}\ 6}$$

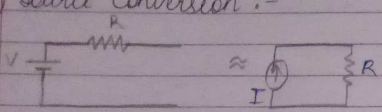
$$\rightarrow 6(V_A - V_B) = 4V_B - 4V_C - 12 + 3V_B$$

$$6V_A - 6V_B = 7V_B - 4V_C - 12$$

$$\Rightarrow 6V_A - 13V_B + 4V_C = -12$$

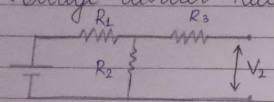
30/1/24

1) Source Conversion :-



Voltage to current & current to source.

2) Voltage divider Rule :-

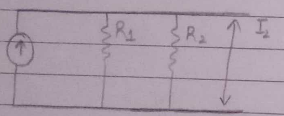


resistance of that voltage

$$V_2 = \frac{R_2}{R_1 + R_2} \cdot V_1$$ Incoming current

total resistance till that voltage

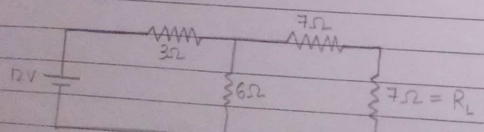
3) Current division Rule :-



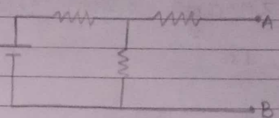
$$I_2 = \frac{R_1}{R_1 + R_2} I_1$$

Thevenin's Theorem

Find the current in load resistance R_L using Thevenin's Theorem.



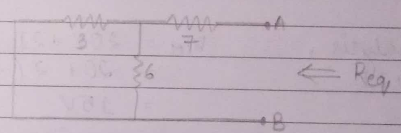
Step 1: Remove the load network & mark the 2 terminals A & B.



Step 2: Calculate the thevenin equivalent voltage (V_{TH}) across terminals A & B.

Using voltage divider case Rule → $V_{TH} = \frac{6}{3+7} \times 12 = 8V$
(only in some cases)

Step 3: Find the thevenin equivalent resistance by short circuiting voltage source & open circuiting current source across the two terminals (A) (B)



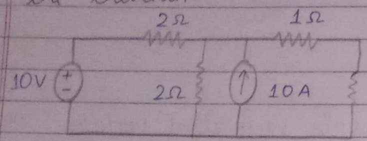
$$R_{eq} = 7 + (6 \text{ Parallel } 3) = 7 + \frac{(6 \times 3)}{6+3} = 7 + \frac{18}{9} = 9\,\Omega$$

Step 4: Replace the network by thevenin equivalent circuit & connect the load resistance back to it.

$$I = \frac{V_{TH}}{R_{eq} + R_L}$$

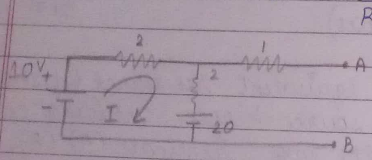
$$\frac{8}{9+7} = \frac{8}{16} = \frac{1}{2} \qquad I = D\cdot S\cdot A$$

Ques Find the current through 3 ohm resistor using the thevenin



Sol ⇒ $V = 10-20 = -10V$; $R = 4V$ $\Big\}$ $V = IR$

$$I = \frac{V}{R} = \frac{-10}{4} = -2.5A$$



Using loop analysis,

$10-20 = 2I + 2I$

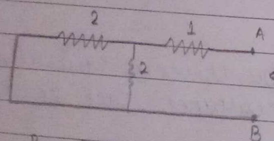
$-10 = 4I$

$I = \frac{-10}{4} = -2.5A$

$V_{TH} = 20V + 2I$

$= 20 + 2(-2.5)$

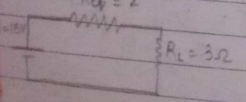
$= 15V$



$= 1 + (2 \text{ parallel } 2)$

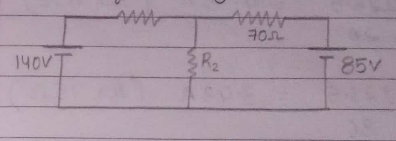
$= 1 + \frac{2\times2}{4} = 1+1$

$= 2\Omega$

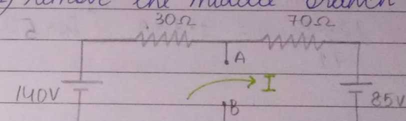


$$\boxed{I = \frac{V_{TH}}{R_{eq} + R_L}} \rightarrow \frac{15}{2+3} = \frac{15}{5} = 3A$$

Ques In the circuit given below find the branch current I_2 which flows through the resistance R_2 where R_2 has following values : 5Ω, 15Ω, 10Ω



Sol → 1) remove the middle branch i.e. short circuit



→ $\frac{1}{R_{eq}} = \frac{1}{70} + \frac{1}{30}$ (they are in ~~⊕~~ // due to 'A' branch)

→ $R_{eq} = \frac{70\times30}{70+30} = \frac{2100}{100} = 21\Omega$

→ according to loop $= I = \frac{V}{R} = I \rightarrow \frac{140-85}{30+70} = \frac{55}{100} = 0.55$

→ $V_A = V_{TH}$

(using nodal analysis)

$I = \frac{140 - V_A}{30}$; $30(0.55) = 140 - V_A$

$16.5 = 140 - V_A$

$V_A = 123.5V$

$I = \frac{V_{TH}}{R_{eq} + R_L}$

$\rightarrow I = \frac{123.5}{21+5} = \frac{123.5}{26} = 4.75A$ (For 5Ω)

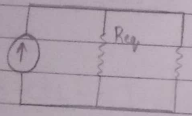
$\rightarrow I = \frac{123.5}{21+15} = \frac{123.5}{36} = 3.43A$ (For 15Ω)

$\rightarrow I = \frac{123.5}{21+50} = \frac{123.5}{71} = 1.73A$ (For 50Ω

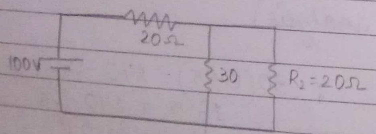
Norton's Theorem

- R_{eq} / I_N

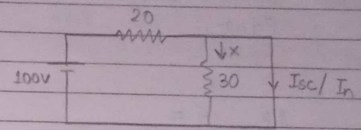
$I_N = I_{sc}$ (short circuit current)



Q Find the current in 20Ω resistor using norton's theorem

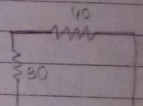


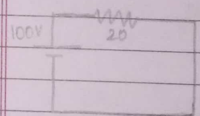
Step 1: Remove the load resistance & short circuit the two terminals & calculate this short circuit current (I_N / I_{sc}).



$\rightarrow$ Current doesn't flow through 30Ω as there is better path which doesn't have any resistance i.e. directly to path of short circuit.

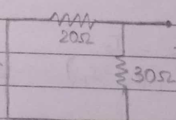
If resistance is there on other branches ex: then it flows through both the resistor.





$V = IR \rightarrow I_n = \frac{V}{R} = \frac{100}{20} = 5A$

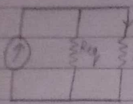
Step 2: $\rightarrow$ Find the value of R_{eq} across the terminal



$\frac{1}{R_{eq}} = \frac{1}{20} + \frac{1}{50}$

$R_{eq} = \frac{30 \times 20}{50} = \frac{600}{50} = 12\Omega$

Step 3 → Find the norton equivalent circuit

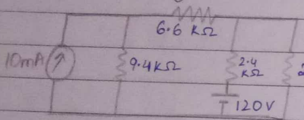


Use current division law

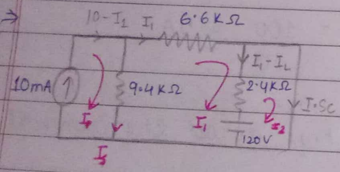
$$I_L = \frac{R_{eq}}{R_{eq}+R_2} \cdot I_N = \frac{12}{12+20} \times 5$$

$$= \frac{12}{32} \times 5 = \frac{60}{32} = 1.87\ A$$

Ques For the network shown in the figure derive the norton equivalent circuit & find the current through 24 KΩ resistor.



Sol →



$I_n = I_{sc}$ $\qquad I_{sc} = I_2$

$R_{eq} = 6.6 I_1 + 2.4(I_1 - I_2) - 9.4(10 - I_1) = -120$

(I) → $6.6 I_1 + 2.4 I_1 - 2.4 I_2 - 94 + 9.4 I_1 = -120$

$18.4 I_1 - 2.4 I_2 = -120 + 94$

$18.4 I_1 - 2.4 I_2 = -26$

(II) → $-2.4(I_1 - I_2) = 120$

$-2.4 I_1 + 2.4 I_2 = 120$

$-18.4 I_1 - \cancel{2.4 I_2} = -26$

$-2.4 I_1 + \cancel{2.4 I_2} = 120$

$16 I_1 = 94$

$\therefore I_1 = 5.875\ mA$

Maximum Power Transfer :-

1) Maximum power transfer theorem is used to determine the conditions under which maximum power can be transferred from source to load

2) Maximum power will be transferred if equivalent resistance = load resistance. ($R_{eq} = R_L$)

3) For the Thevenin equivalent circuit is given

$$I_L = \frac{V_{TH}}{R_{eq} + R_L}$$

- & for max power $I_{2\,max} = \frac{V_{TH}}{2 R_{eq}}$ } max current

4) Maximum power is given by

$$P_{max} = I^2_{max} R_{eq}$$

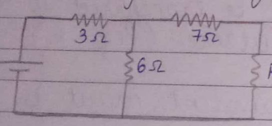
$$P = \frac{V_{TH}}{2R_{eq}} \times \frac{V_{TH}}{2R_{eq}} \times R_{eq} = \boxed{\frac{V_{TH}^2}{4R_{eq}}}$$

→ Total power delivered from source under this condition is :

$$P_T = V_{TH} \cdot I_{max}$$

$$P_T = \frac{V_{TH}}{2R_{eq}} \times \frac{V_{TH}}{2R_{eq}} \times 2R_{eq} = \boxed{\frac{V_{TH}^2}{4R_{eq}}}$$

Ques Find the current in load resistance. What is max power of R_2 if it varies. Also find power absorbed by load if $R_2 = 7$ & 11



• consider R_{eq} only, don't use R_L's value

Sol (i) 1) Remove load resistance

$$V_{TH} = \frac{6}{3+6} \times 12 = \frac{\cancel{6}^2}{\cancel{9}_3} \times \cancel{12}^4 = 8V.$$

2) $R_{eq} = 7 + (6 \| 3) = 7 + \left(\frac{6 \times 3}{6+3}\right) = 9\Omega$

3) $I_L\ max = \frac{8}{9+9} = \frac{8}{18} = 0.44\ A$
$(R_{eq} = R_L)$

(ii) $R_L = 7\Omega$ & $R_L = 11\Omega$

→ $I_L\ max = \frac{8}{9+7} = \frac{8}{16} = 0.5A$

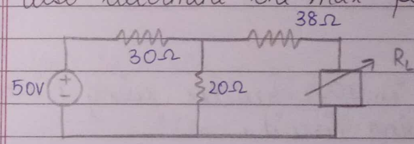
→ $P_L\ max = I_L^2\ max \times R_L$
$= \frac{0.5}{10_2} \times 7 \times \frac{0.5}{10_2} = \frac{7}{4} = 1.75\ A$

▷ $R_L = 11\Omega$

$I_L\ max = \frac{8}{9+11} = 0.4\ A$

$P_L\ max = I_L^2\ max \times R_L$
$= 0.4 \times 0.4 \times 11 = 1.76A$

Ques Find the value of R_L for max power transferred also determine the max power transfered.



→ $V_{TH} = \frac{20}{20+30} \times 50 = \frac{20}{\cancel{50}} \times \cancel{50} = 20V$

→ $R_{eq} = 38 + \left(\frac{30 \times 20}{30+20}\right) = 38 + \left(\frac{\cancel{600}^{12}}{\cancel{50}}\right) = 50\Omega$

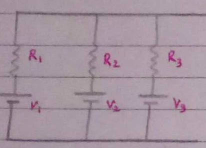
$R_{eq} = R_L$

$\rightarrow I_{L max} = \frac{20}{50+50} = \frac{20}{100} = 0.2A$

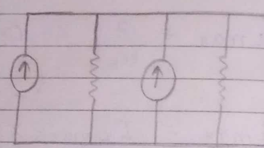
$P_{L max} = 0.2 \times 0.2 \times 50 = 2V$

$= \frac{\cancel{0.2}}{\cancel{10}} \times \frac{\cancel{0.2}}{\cancel{10}_5} \times \cancel{50}10$

Millman's Theorem :-

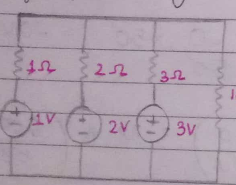


OR



$$V_m = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}}{1/R_m} \qquad R_m = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Ques Calculate current in 10Ω resistor using Millman's Theorem for following circuit.



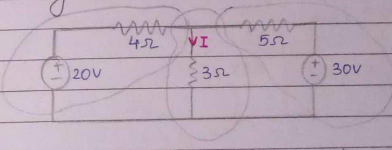
Sol ⇒ $R_m = \frac{1}{\frac{1}{1} + \frac{1}{2} + \frac{1}{3} + \frac{1}{10}} = \frac{1}{1 + 0.5 + 0.3 + 0.1}$

$= 0.52\,\Omega$

$V_m = \frac{1 + \frac{2}{2} + \frac{3}{3} + 0}{1/0.52} = \frac{1+1+1}{\frac{1}{0.52}} = \frac{3}{1.94} = 1.54V$

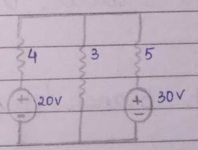
7/12/24

Ques Calculate the current I shown in the figure below using millman's theorem.



* convert into millman form.

Sol ⇒ $V_m = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}}{1/R_m}$ $\qquad R_m = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$



$R_m = \frac{1}{\frac{1}{4} + \frac{1}{3} + \frac{1}{5}} = \frac{1}{0.783}$

$= 1.277$

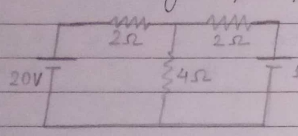
$$V_m = \frac{\frac{20}{4} + \frac{30}{5}}{1/1.277} = \frac{5+6}{1} \times 1.277 = \frac{11}{0.783} = 14.048$$

$V_m = IR$ (R = Jo resistance question mein nikalne ko bola hai)

$$\frac{14.048}{3} = I \rightarrow \boxed{4.68\ A}$$

Super Position Theorem (V.V. Imp)

Ques Calculate the current in each branch in the figure given below using super position theorem.



Step1: ▷ S.P.T is applicable to circuit having more than one source (ya I ya voltage)

▷ Short voltage source / open the I source, one at a time.

2: ▷ Calculate the current in each branch / required branch.

$I_3 = 3A$

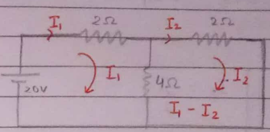
$I_4 + 1.11 = 0$

$I_4 = 2A$

$I_B = (I_1 - I_2) + (I_3 - I_4)$ $I_c = I_2 - I_3$

$I_a = I_1 - I_4$

Step 1



apply loop analysis

$$2I_1 + 4(I_1 - I_2) = 20$$
$$2I_1 + 4I_1 - 4I_2 = 20$$
$$6I_1 - 4I_2 = +20$$
$$3I_1 - 2I_2 = +10$$

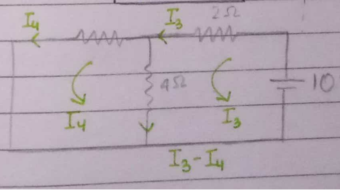
$$2I_2 - 4(I_1 - I_2) = 0$$
$$2I_2 - 4I_1 + 4I_2 = 0$$
$$6I_2 - 4I_1 = 0$$
$$3I_2 - 2I_1 = 0$$

$$(3I_1 - 2I_2 = 10) \times 2$$
$$(-2I_1 + 3I_2 = 0) \times 3$$

$$\cancel{6I_1} - 4I_2 = 20$$
$$-\cancel{6I_1} + 9I_2 = 0$$
$$5I_2 = 20$$
$$\boxed{I_2 = 4\ A}$$

$$3(4) - 2I_1 = 0$$
$$\frac{12}{2} = I_1$$
$$\boxed{I_1 = 6A}$$

#



$2I_4 - 4(I_3 - I_4) = 0$
$2I_4 - 4I_3 + 4I_4 = 0$
$-2I_4 = 4I_3$
$-2I_4 - 4I_3 = 0$
$-2(I_4 + 2I_3) = 0$

$(I_4 + 2I_3 = 0) \times 2$

$2I_3 + 4(I_3 - I_4) = 10$
$2I_3 + 4I_3 - 4I_4 = 10$
$6I_3 - 4I_4 = 10$
$2(3I_3 - 2I_4) = 10$

$3I_3 - 2I_4 = 5$

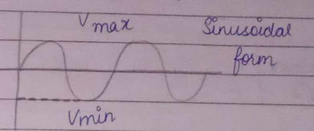
$3I_3 - 2\cancel{I_4} = 5$
$4I_3 + \cancel{2}I_4 = 0$
$7I_3 = 5$

$\boxed{I_3 = \frac{5}{7}}$

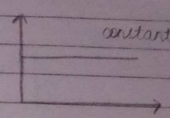
Unit-2 : A.C. Circuits & CRO

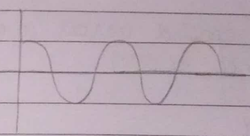
Notes :

- AC (alternating current)

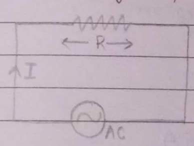


- Direct Current



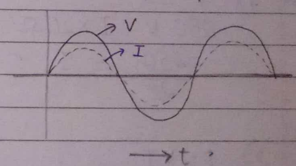


AC through pure Resistor :-



→ wave form

always in pure resistor

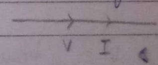


$\boxed{V = V_{max} \sin \omega t}$

$\boxed{I = I_{max} \sin \omega t}$

$\boxed{\omega = 2\pi f}$

→ Phasor form



$V = V_m \angle 0$
$I = I_m \angle 0$

(inline)

▷ Voltage & current are inline & the angle b/w them is zero

★ $\boxed{V = IR}$, power absorbed is given by $\boxed{P = VI}$

$\boxed{V_{rms} = \frac{V_{max}}{\sqrt{2}}}$ $\boxed{I_{rms} = \frac{I_{max}}{\sqrt{2}}}$

Ques At 250V, 50 Hz voltage is applied across a circuit consisting of pure resistance of 20Ω.
Determine the following :-
1) Current through the circuit
2) Power absorbed by circuit
3) Give expression for voltage & current
4) Give the wave & phasor diagram.

Ans ⇒ 1) $V = IR$

$250\ V = I \times 20\Omega$

$\frac{25\cancel{0}}{2\cancel{0}} = I \rightarrow I = 12.5 A$

2) $P = VI$

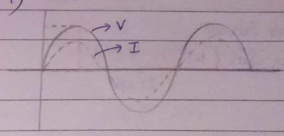
$= \frac{25\cancel{0} \times 125}{1\cancel{0}} = 3125$

3) ▶ $V = \frac{V_{max}}{\sqrt{2}} \rightarrow V_{max} = V \times \sqrt{2}$

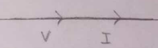
$V_{max} = 250 \times \sqrt{2}$
$= 353.553\ V.$

▶ $I_{max} = I \times \sqrt{2} = 12.5 \times \sqrt{2}$
$= 17.67 A$

4) V_{max}



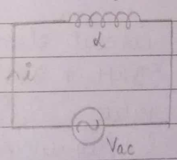
$\omega = 2\pi f$
$= 2 \times 3.14 \times 50 = \frac{\cancel{2} \times 314 \times \cancel{50}}{\cancel{100}} = 314$

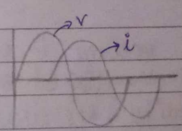


13th Feb

AC through pure Indicator

$V - I = DC$
$V - i = AC$
V_{ac}

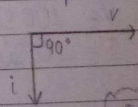




→ phasor form

$\boxed{\begin{array}{l} V = V_{max} \sin \omega t \\ i = I_{max} \sin(\omega t - 90°) \end{array}}$

lags

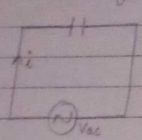


Pa = 0

$V = I\textcircled{R} \rightarrow X_L \quad \therefore \quad V = I X_L$

$\boxed{X_L = \omega \times L}$ $\boxed{\omega = 2\pi f}$

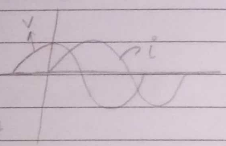
AC through pure capacitor



$\boxed{\begin{array}{l} V = V_{max} \sin \omega t \\ I = I_{max} \sin(\omega t \,\textcircled{+}\, 90^\circ) \end{array}}$

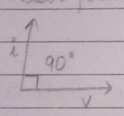
leads

$\boxed{X_c = \frac{1}{\omega C}, \ \omega = 2\pi f}$ → wave form



$V = I X_C$

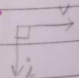
→ Phasor form



The voltage & current through circuit elements are $V = 100 \sin 314t$ and $I = 10 \sin(314t + 315^\circ)$. Identify the circuit element. Find value of inductive reactance, value of inductance & frequency.

$V = 100 \sin 314t$
$I = 10 \sin(314t + 315^\circ)$

angle = 315°
lies in 4th quad
∴ inductor



→ $\omega = 314$, $V_{max} = 100$, $I_{max} = 10$

- $X_L = \omega \times L$
  $10 = 314 \times L$
  $\frac{10}{314} = L$
  $L = 0.031$

- $V_{max} = I_{max} \times X_L$
  $100 = 10 \times X_L$
  $\frac{100}{10} = X_L \rightarrow 10$

- $\omega = 2\pi f \rightarrow 2 \times 3.14 \times f = 314$
  $f = \frac{\cancel{314}}{\cancel{2} \times 3.14} \times \cancel{100}\ 50$

  $f = 50\ Hz$

m	← 10^{-3}	10^3	→ kilo
(micro) μ	← 10^{-6}	10^6	→ M
(nano) n	← 10^{-9}	10^9	→ G
pico	← 10^{-12}	10^{12}	→

Ques 50 Hz / 230 V is applied across a pure capacitive circuit having capacitance of 26.5 μF. Show voltage & I in a time diagram (wave form), also calculate the reactive capacitance in circuit.

Sol ⇒ $f = \cancel{10}\ 50\ Hz$, $V_{rms} = 230\,V$, $C = 26.5\ \mu F$
$= 26.5 \times 10^{-6}\ F$

→ $\omega = 2 \times \pi \times f$

$= \frac{2 \times 3.14}{100} \times 50 = 314$

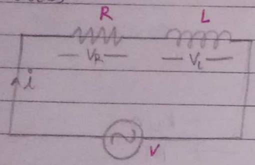
→ $X_c = \frac{1}{\omega \times C} \rightarrow \frac{1}{314 \times 26.5 \times 10^{-6}} = \frac{10^6 \times 10}{314 \times 265}$

$= 120.177$

14th Feb

AC through R, L circuit

→ Series



$Z = R + jX_L$ (j → imaginary term)

$$\boxed{Z = \sqrt{R^2 + X_L^2}}$$

$$\boxed{\phi = \tan^{-1}\left(\frac{X_L}{R}\right)}$$

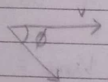
$$\boxed{V^2 = V_R^2 + V_L^2}$$

$V = V_{max} \sin \omega t$

$I = I_{max} \sin(\omega t - \phi)$

$V = IZ$ → impedence

→ phasor diagram :



- Power Factor $= \cos\phi = \frac{R}{Z}$ (R → resistance, Z → impedance)
- apparent power (Pa) $= VI$
- P_T (True/Real Power) $= VI \cos\phi$
- P_R (reactive power) $= VI \sin\phi$
- Q-Factor $= \frac{1}{\text{power factor}} = \frac{Z}{R}$ or $\frac{1}{R}\sqrt{\frac{L}{C}}$

Ques A 4Ω resistor is connected to a 10mH inductor across a 100 volts/50 Hz voltage source. Find input current, voltage drop across resistor & inductor, power factor of the circuit & the real power consumed in the circuit?

Sol ⇒ $R = 4\Omega$, $L = 10 \times 10^{-3}$, $V_{rms} = 100$, $F = 50\,Hz$,
$I = ?$, $V_R = ?$ (IR), $V_L = ?$ (IX_c), p.f. = ?, p.t = ?

→ $V = IZ$

$Z = \sqrt{R^2 + X_L^2}$

$V = IZ$

$100 = I$

5.08

→ $X_L = \omega \times L$

$\omega = 2\pi f = \frac{2 \times 3.14 \times 50}{100} = 314$

→ $X_L = \frac{314 \times 10}{1000} = 3.14$

$Z = \sqrt{(4)^2 + (3.14)^2} = \sqrt{16 + 9.859} = \sqrt{25.859}$

$= 5.08$

$V_R = I \times R = \overset{19.68}{19.6} \times 4 = 78.4$

$V_L = I \times X_L = 19.6 \times 3.14 = 61.79$

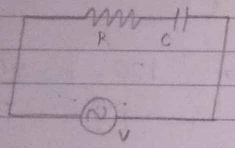
$p.f = \frac{R}{Z} = \frac{4}{5.08} = 0.78$

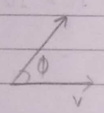
$p.t = VI \cos\phi = \cancel{100} \times \frac{19.68}{100} \times \frac{0.78}{\cancel{100}}$

AC through RC circuit

→ phasor diagram (wrt I)

→ phasor diagram of voltage in opposite direction.





phasor diagram

$\boxed{V = IZ}$

$\phi = \tan^{-1}\left(\frac{-X_c}{R}\right)$

$\boxed{Z = \sqrt{R^2 + (X_c)^2}}$

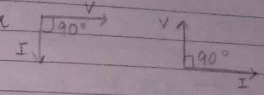
$z = R - jX_c$

$\boxed{\begin{aligned} V &= V_{max} \sin \omega t \\ I &= I_{max} \sin(\omega t + \phi) \end{aligned}}$

$V^2 = V_R^2 + V_C^2$

Phasor diagram for voltage is exactly opposite to the phasor diagram we have drawn.

ex: Inductor



16th Feb

Ques A supply of 400V, 50 Hz is applied to a series RC circuit. Find the value of capacitor if the power absorbed by the resistor is 500 W at 150V. Also find what is energy stored in the capacitor.

Sol ⇒

$V = 400V$

$F = 50\ Hz$

$C = ?$

$P_a = V_R I \rightarrow V_R = 150V$

(resistor)

$I = \frac{P_a}{V_R} = \frac{500}{150} = 3.33A$

$V^2 = V_R^2 + V_c^2$

$(400)^2 = (150)^2 + V_c^2$

$V_c = \sqrt{137500} = 370.80$

$V_c = I X_c$

$370.80 = 3.33 \times X_c$

$$\frac{370.80}{3.33} = X_c$$

$\rightarrow X_c = 111.35$

$\rightarrow X_c = \frac{1}{\omega \times C} \rightarrow 111.35 = \frac{1}{2 \times 3.14 \times 50 \times C}$

$\rightarrow 111.35 = \frac{1}{314 \times C}$

$\rightarrow 111.35 \times 314 \times C = \frac{1}{111.35 \times 314}$

$C = 0.0000286009$

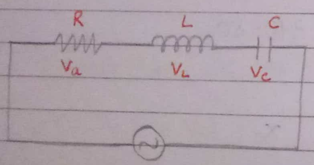
$C = 0.286 \times 10^{-3}$ m uF

$= 28.60$ uF

▷ Energy stored in capacitor is = $\boxed{\frac{1}{2} C V_c^2}$

$= \frac{1}{2} \times (370.8)^2 \times 0.0000286009 = 1.966$ J

AC through RLC Circuit



⇐ RLC circuit

$V = V_{max} \sin \omega t$

$i = I_{max} \sin(\omega t \pm \phi)$

$\boxed{Z = \sqrt{R^2 + (X_L - X_c)^2}}$ $\phi = \tan^{-1}\left(\frac{X_L - X_c}{R}\right)$

$\boxed{V^2 = V_R^2 + (V_c - V_c)^2}$

* Note

1) If X_L is greater than $X_c \rightarrow$ lags

$X_L < X_c \rightarrow$ leads

$X_L = X_c \rightarrow$ in-line

Ques (Imp) A coil of resistance 20Ω and inductance 100 mH is connected in series with a capacitance of 40 micro fared across 100V, 50 Hz AC supply.

Calculate :

(a) Current in the circuit

(b) Power factor

(c) Phase angle

(d) Voltage across each element.

Sol →

$V = 100$ V

$f = 50$ Hz

$R = 20\Omega$

$L = 100$ mH $= 0.100$ H

$V = IZ$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$X_L = \omega L$

$X_L = 2\pi f L$

$= \frac{2 \times 22}{7} \times 50 \times 0.100$

$\boxed{X_L = 31.428}$

$X_C = \frac{1}{\omega C}$

$= \frac{1}{2\pi f \times 40}$

$= \frac{1}{2 \times 3.14 \times 50 \times 40}$

$\boxed{X_C = 79.61}$

$Z = \sqrt{(20)^2 + (31.4 - 79.61)^2}$

$= \sqrt{400 + (2323.24)}$

$= \sqrt{2723.24}$

$\boxed{Z = 52.19}$

$V = IZ$

$100 = I \times 52.19$

(a) $\boxed{I = 1.91}$

(b) $\frac{R}{Z} = P.f$

$\frac{20}{52.19} = 0.38$

$\boxed{P.F = 0.38}$

(c) $\cos\phi = P.F$

$\cos^{-1}(0.38) = 67.66^\circ$

$\boxed{\phi = 67.66^\circ}$

(d) $V_R = I \times R$

$= 1.91 \times 20 = \boxed{38.2\,V}$

$V_L = I \times X_L$

$= 1.91 \times 20 = \boxed{59.97\,V}$

$V_C = I \times X_C$

$= 1.91 \times 79.61 = \boxed{152.05\,V}$

→ Solve later

Ques A coil with resistance 50 ohms is connected with capacitor in series across 220 volt supply. The circuit has the capacitance of 20 pF, (20×10 inductive reactance of 3·5. Calculate :

a) Frequency in the circuit if $\omega = 75$.
b) The voltage across capacitor if voltage across inductor is 100 volts ($V_L = 100V$).
c) power factor

23rd Feb 2024

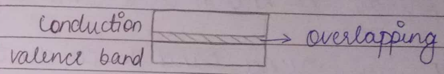
Date
Page

Unit-3 : Semi Conductor

Energy band gap in materials :-
conductor, insulators, semi-conductor

▷ $\boxed{\text{Conductor}}$

→ The valence band & conductor band overlap each other & has no band gap energy & thereby has maximum conduction.



→ The electrons are free to move without any external energy source

→ Ex: metals

▷ $\boxed{\text{Insulator}}$

→ The valence bond & conduction band has a large energy band gap (generally >5ev) such that electr from valence band can't jump to conduction whatsoever is possible.

conduction band

greater than 5ev — E.G = energy band gap / Forbidden energy gap.

valence band

→ Ex: wood

▷ Semi-Conductor

→ A material which acts as an insulator as well as a conductor depending upon certain parameters like external energy is known as a semi-conductor.

→ Energy band gap b/w valence band & conduction band is less than (< 1.1 eV).

→ By applying some external energy electrons from valence band can jump to the conduction band & the material can act like a conductor.

conduction band

↕ < 1.1 eV

valence band

A semi-conductor acts as an insulator at absolute zero temperature i.e. $\boxed{0°K}$

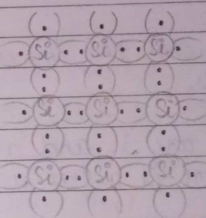
Ex – silicon, germanium etc.

Types of semi-conductors.

▷ Intrinsic Semi-Conductor

1) A semi conductor which is ~~pretty~~ formed purely from the carbon family (group 4 elements) without any mixture is an intrinsic s.c.

2) Silicon is the most used semi-conductor because of it's vast & free availability then germanium.



▷ Extrinsic Semi Conductor

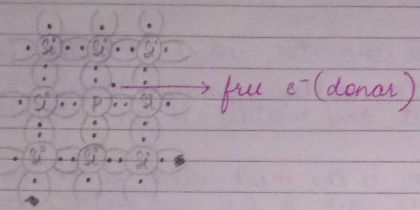
~ Doping = The process of adding impurity is known as doping.

1) → There are 2 types of extrinsic semiconductor :

a) n-type extrinsic semi conductor

→ In N-type extrinsic semi conductor the impuri[ty] is added from group 5 elements.

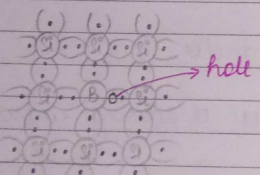
→ The valence e⁻s are 5 and are known as penta-valent. Therefore, an extra electron is available (extra e^- ↑es conductivity).



b) p-type semi conductor

→ in p-type semi conductor the impurity is added from group 3 elements.

→ The valence electrons are 3 and are known as trivalent. Therefore there is a free space.



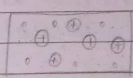
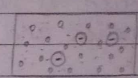
* hole is the free space

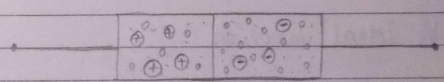
* it is an acceptor

Elemental Vs Compound Semi Conductor

Elemental	Compound Semi Conductor
→ Semi conductor made of single elemental such as silicon, germanium are known as elemental semi-conductors.	→ Semi Conductors made of several elements such as the combination of group 3 or 5 / group 2 & 6 elements are known as compound semi-conductors. Eg – GaAs

N-type / P-type

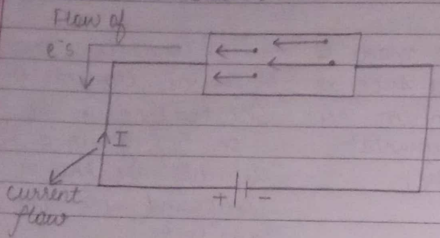
N-type	P-type
	
Majority → · (-ve)	Majority → (+ve)
Minority → o (+ve)	Minority → (-ve)
⊕ → Donor ions (fixed) (In mobile)	⊖ → Acceptor ions



p-n junction

Flow of e^- / Current in semi conductor

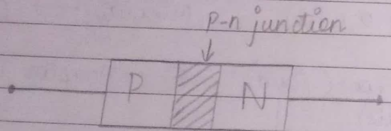
① The flow of e^- is always opposite to the conventi current direction.



P-N Junction

① When a p & n-type material are brought together a junction is formed between the two known as p-n junction and a basic diode is created.

② A diode is a device that conducts current in only one direction.



★ Practical Vs Ideal Junction

① Ideal diode draws no current when reverse biased.	① Practical diode draws very low current when reverse biased.
② Ideal diode offers infinite resistance when reverse biased.	② Practical diode offers very high resistance when reverse biased.

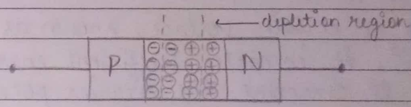
Formation of depletion region

① Free electrons near the junction begin to defuse with holes.

② The N-region loses electrons and creates a positively charged layer near the junction.

③ The P-region loses holes and creates a negatively charged layer near the junction.

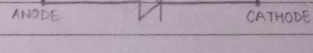
④ The two layers forms the depletion region.



⑤ The depletion layer acts as a potential barrier for further movement of electrons across the junction.

→ The barrier potential for $\boxed{Si = 0.7V \;\&\; Ge = 0.3V}$

⑥ The component form is known as a p-n junction diode

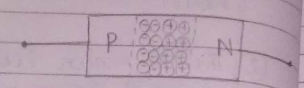


DIODE SYMBOL

Biasing a diode

→ No-Bias

Add equilibrium or no-bias :



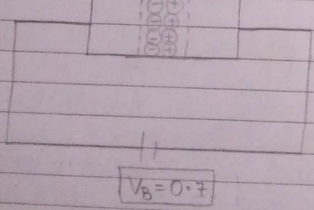
→ ~~Forw~~ Forward-Bias

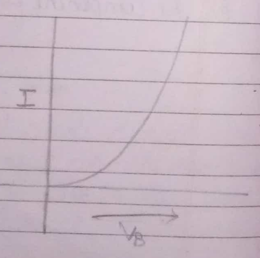
① In forward bias condition P-type is connected to +ve terminal & N-type to -ve terminal of the battery.

② On applying a certain voltage, known as bias voltage 'V_B', it imparts sufficient energy to free electrons to overcome the barrier potential and move through their p-region.

③ The depletion region narrows.

④ On increasing the voltage, huge current flows through the diode.



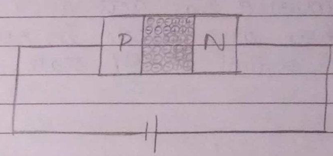


→ Reverse Biasing

① In reverse bias condition, n-type is connected to to positive terminal & p-type is connected to negative side of battery.

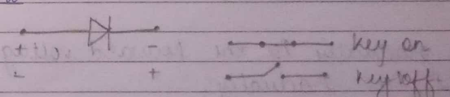
② On applying voltage, diode exhibits negligible energy & the ~~moment of~~ movement of e^-'s are Ideally blocked.

③ The depletion region widens

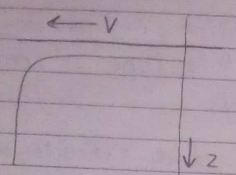


④ There are few thermally generated minority carries in both p and n region.
These minority carriers are drifted towards p-n junction & a very small amount of current flows through a diode.

This current is known as reverse saturation current.



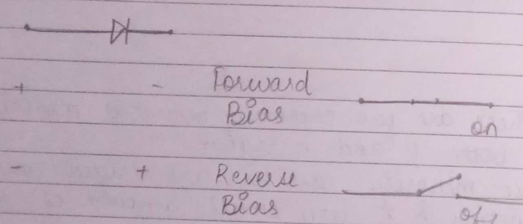
→ Reverse characteristics



* Note:

Diode as a switch.

A diode in forward bias acts as a switch In on state where as a diode in reversed bias acts as a switch in off state.



Effect of temperature on VI characteristics of diode

(1) Forward Characteristics

a) As we gradually ↑se the forward voltage, a forward current ↑ses gradually.

b) When the forward voltage is increased to a value known as knee voltage, the forward current begins to increase rapidly.

Knee Voltage : The voltage at which the current starts to increase rapidly or the minimum voltage applied to a diode for which it starts conducting.

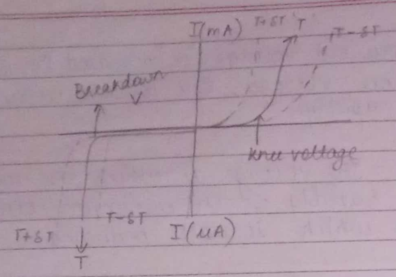
(2) Reverse Characteristics

a) As we gradually ↑se the reverse bias voltage, a very small reverse current flows across the diode.

b) When the applied reverse bias voltage is ↑sed to a value where the reverse voltage across the diode reaches breakdown value, the reverse current ↑ses rapidly.

(3) Effect of Temperature

a) If temperature ↑ses, the conductivity also ↑se and the resistance of diode ↓ses, whereas if the temperature ↓ses the conductivity ↓ses and the resistance of the diode ↑ses.



Diode equation (Shockley's Equation)

The diode equation:

$$I_D = I_S\left(e^{\frac{V_D}{\eta V_T}} - 1\right)$$

where,

$I_D = I \rightarrow$ It is the diode current

$I_S = I_0 \rightarrow$ It is the reverse saturation current

$V_D = V \rightarrow$ It is the diode voltage (applied voltage)

$\eta \rightarrow$ It is the Ideality factor

For Silicon $\eta = 2$
Germanium $\eta = 1$

$V_T \rightarrow$ It is the thermal voltage given by

$V_D = +$ (forward bias)
$V_D = -$ (reverse bias)

$$\boxed{V_T = \frac{KT}{q}}$$

where K is the Boltzman's Constant and it's valu is $K = 1.38 \times 10^{-23}\ J/K$.

T is the temperature and q is the charge given by $q = 1.61 \times 10^{-19}\ C$

* Note
At room temperature $V_T = 26\ mV$

*Ques 1 A Germanium diode carries a current of one mA at room temperature, when a forward bias voltage of 0.15 is applied. Estimate the reverse saturation current at room temperature.

Sol ⇒ Germanium

$\eta = 1$
$I_D = 1 \times 10^{-3}$
$V_T = 26 \times 10^{-3}$
$V_D = 0.15$
$I_0 = ?$

$$I_D = I_S\left(e^{V_D/\eta V_T} - 1\right)$$

$$1 \times 10^{-3} = I_S\left(e^{0.15/1 \times 26 \times 10^{-3}} - 1\right)$$

$\Rightarrow \dfrac{1\times10^{-3}}{(e^{0.15/1\times26\times10^{-3}}-1)} = I_s$

$\Rightarrow \dfrac{1\times10^{-3}}{319.291} = I_s$

$\Rightarrow 3.13\times10^{-6} = I_s$

Ques For what voltage will the reverse current of a Germanium diode reach 99% of its saturation value at room temperature.

Sol ⇒ For Ge

$\eta = 1$

$V_T = 26\times10^{-3}$

$I_0 = ?$

$I = 99\%$ of $I_0 = -\dfrac{99}{100}\times I_0$

$\Rightarrow I_D = I_s\left(e^{V_D/\eta V_T} - 1\right)$

$\Rightarrow -\dfrac{99}{100}\times \cancel{I_0} = \cancel{I_0}\left(e^{V_D/1\times26\times10^{-3}} - 1\right)$

$\Rightarrow -\dfrac{99}{100} = e^{V_D/1\times26\times10^{-3}} - 1$

$\Rightarrow 0.01 = e^{V_D/26\times10^{-3}}$

Take log on both sides

$\log(0.01) = \dfrac{V_D}{26\times10^{-3}}$

After taking log on both sides left side wala log reh jayega or right side ka (e) cut jayega

$-2\times26\times10^{-3} = V_D$

$\boxed{V_D = -0.052}$

Ques What is the ratio of current for a forward bias of 0.05 V to the current for the same magnitude of reverse bias.

→ if diode isn't given, assume either germanium or silicon. (Do this question in assignment)

Ques If a silicon diode is operating at a temperature of 35°C & operating voltage of 0.8 V. Calculate the forward current in the diode if the reverse current is 2.5 μA.

Sol ⇒ $I_0 = 2.5\times10^{-6}$

$I = I_0\left(e^{V_D/\eta V_T} - 1\right)$

$I = 2.5\left(e^{0.8/2\times V_T} - 1\right)$

$$V_T = \frac{KT}{q}$$

$$V_T = \frac{1.38 \times 10^{-23} \times 308}{1.61 \times 10^{-19}}$$

$$V_T = 0.0264$$

$$V_T = 2.64 \times 10^{-2}$$

$$\Rightarrow I = 2.5\times10^{-6}\left(e^{0.8/2\times2.64\times10^{-2}} - 1\right)$$

$$\Rightarrow I = 2.5 \times 10^{-6}\,(38{,}03{,}815.315 - 1)$$

$$I = 2.5 \times 10^{-6}\,(38{,}03{,}814.315)$$

$$I = 9.50$$

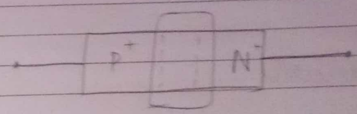
Zener Diode

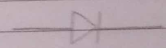
① It is fabricated to be operated in breakdown region.

② When operated in breakdown it maintains a constant voltage.

③ The diode is formed by heavily doping n-type & p-type materials or both. p^{+} n^{+}

④ The depletion region narrows and the electric field is very high by using heavily doped material.





Breakdown Mechanism

Breakdown are of two types:
1) Avalanche breakdown
2) Zener Breakdown

▷ Avalanche Breakdown	▷ Zener Breakdown
a) It is observed in p-n junction diode as well as Zener diode, generally for a reverse voltage of >6 V, ie. $V_R > 6$ V.	a) It is observed in zener diodes at a voltage of ≤ 6 V.
b) The carrier increase is the result of collisions	b) The carrier increase is the result of electric field

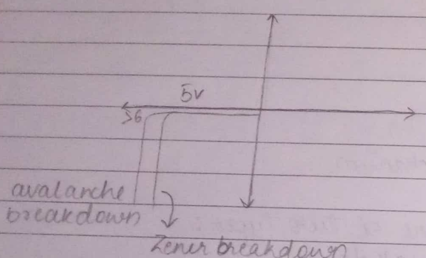
(e⁻ collide with crystal atom and knocks it off, forming/creating e⁻ holes. Carrier multiplication takes place).

strength.

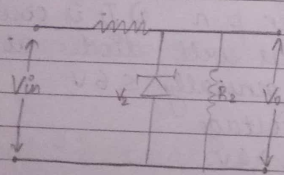
c) It destroys the diode. (burnt off).

c) The diode is discovered.

V- I characteristics



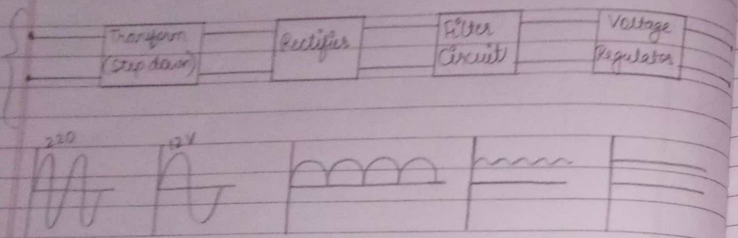
Zener diode as Voltage regulator



$\boxed{V_0 = V_Z}$

~ A Zener diode can be used as a voltage regulator by placing it in parallel to the output and in reverse bias condition.

AC to DC Generator



3rd April

Rectifier

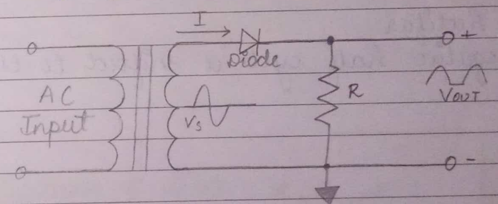
1. Rectifier is a device / circuit which converts AC input to pulsating DC.

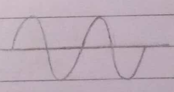
2. All the negative cycles are eliminated either by zero value or by a +ve value.

3. Rectifiers are of two types:

(a) Half Wave Rectifier

i) It uses a single diode.
ii) The negative half cycle is clipped and only the +ve half cycle remains



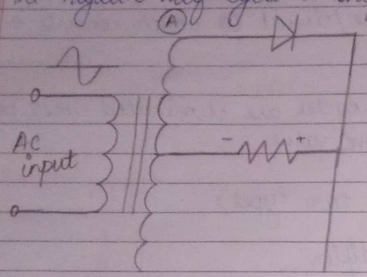


(b) Full Wave Rectifier

They are of two types:

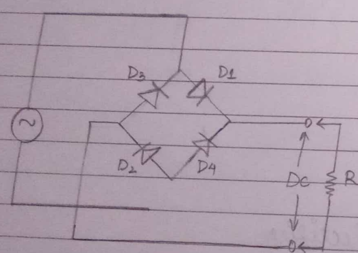
i) Center Tap Full Wave Rectifier

→ The negative half cycle is shifted to the positive half.



ii) Bridge Rectifier

→ The negative half cycle is shifted to the positive half.



→ For positive half cycle, diode D_1 & D_2 conducts, i.e. they are in forward bias and D_3 & D_4 are in reverse bias (OFF).

→ For negative half cycle, D_3 & D_4 conducts, i.e. they are in forward bias and D_1 & D_2 are in reverse bias (OFF).

05/04/24

★ Filter Circuit

→ Generally a capacitive filter circuit is used.

→ The capacitor removes the large ripples & produces an output having small variations.

★ Voltage Regulator

→ The small variations at the output of the filter circuit are removed by using a voltage regulator circuit or IC. (Integrated circuit)

→ The output of this voltage regulator is constant.

09/April/2024

Applications of Diode

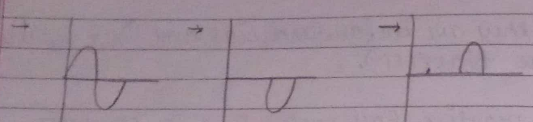
→ Rectifier (already done)

→ Clipper

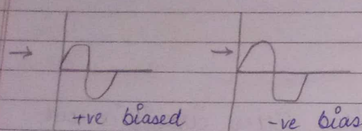
→ Clamper

→ Voltage Multiplier

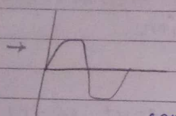
- Clipper : cut some portion of signal
  (saare signal ko ek side either +ve or -



positive negative



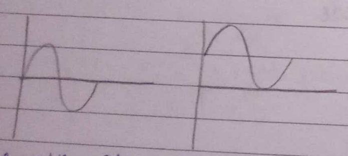
+ve biased -ve biased



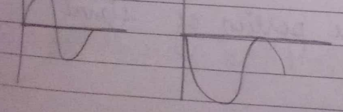
combination biased clipper

- Clamper : The positive & negative peaks of the signal can be placed at any desired value.

Eg : +ve Clamper



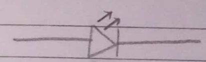
Eg : -ve Clamper



- Voltage multiplier : It converts electrical power from a lower voltage to a higher voltage. Eg: Voltage doubler (x2), voltage tripler (x3) --- etc.

Light Emitting Diode :- (LED)

① When $\bar{e}$ ~~...~~ recombines with a hole, energy is released. In silicon and germanium this energy is in the form of heat. However, for some compound semi-conductors like gallium and arsnyl, the energy released is in the form of light (proton). This happens by the phenomenon known as electro-luminacy



LED

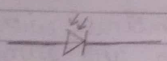
② It is used only in forward bias and the p-n junction is heavily doped.

③ Based on the semi-conductor material used and the amount of doping, an LED will EMIT a specific colored light. Eg: • aluminium Gallium ~~Arsy~~ arsnyl (ALGaAs) - Infrared

- Ga As P = Red, orange, yellow
- Al Ga P = Green
- I Ga N = Blue, Blue-green near UV

→ Applications

1. Electronic Display
2. Remote Controls
3. Lightings

Photo Diode 

*Assignment Ques

Ques What is a Photodiode? Draw it's symbol and explain it's working principle.

Applications :-

1. Infrared remote control receiver
2. Flame Detector
3. Photo detector

10/04/24 Unit-4 Digital Electronics

Bipolar Junction Transistor (BJT)

- Invented by Dr. William Shockley and Dr John Bardeen at Bell labs.
- It is a semi-conductor device formed by sand-wiching either p-type or n-type material between a pair of opposite type.
- The output voltage, current and ~~power~~ power are controlled by input current. Therefore BJT'S are also known as current controlling device.
- The term Bipolar reflects the fact that both e⁻s and holes participate as charge carriers.

Types

BJT are of two types :

1. NPN
2. PNP

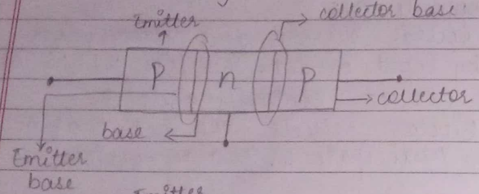
Construction :

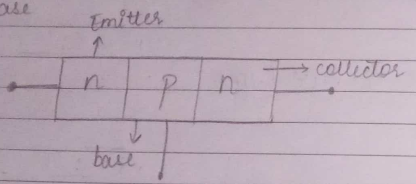
- BJT is a three terminal device. The terminals are : emitter, base, collector.
- Emitter : → heavily doped
  → emitter is charge carriers into base
- Base : lightly doped
- Collector : → intermediate doping (b/w emitter and base)

→ collector region is physically larger as compared to emitter and base.

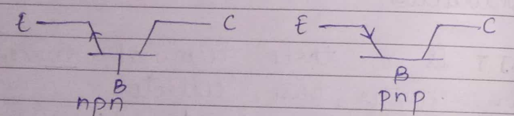
→ collects charge ~~ch~~ carriers.

• BJT has two junctions :
→ Emitter base junction
→ Collector base junction





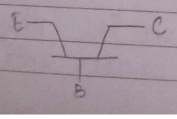
⇒ Symbol :



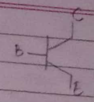
⇒ BJT Configurations :

• BJT can be configurated in 3 different ways.

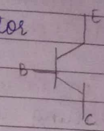
1 Common base



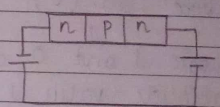
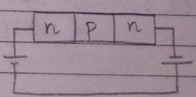
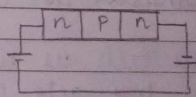
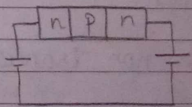
2 Common Emitter



3 Common collector



Biasing a transistor / Transistor action / Region of operation

Cases	Emitter Base Junction	Collector Base Junction	R.O	n-p-n circuit diagram
I	F.B	R.B	Active	
II	F.B	R.B	Saturation	
III	R.B	F.B	Cut-off	
IV	R.B	F.B	Inverted	

Notes

- When a BJT is used in active region, we are dealing with among electronics.
- When a BJT is used in saturation or cut-off region then we are dealing with digital electronics.

Logic

- There are 2 logic levels
  - → Logic High (1)
  - → Logic Low (0)
- Logic 1 and 0 does not neccessarly mean the absolute value 1 and 0.

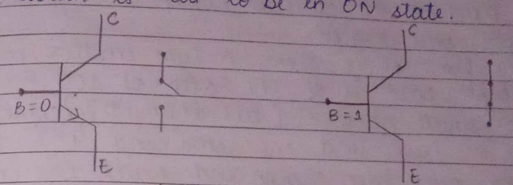
  ex : > 220 V = 1
  < 220V = 0

Transistor BJT as a switch :

- Base tells us whether the switch is on or no.
  → The base acts as an controlling element of the switch.

⇒ For npn transistor, if B = 0 (cut off) OFF
B = 1 (Saturation) ON

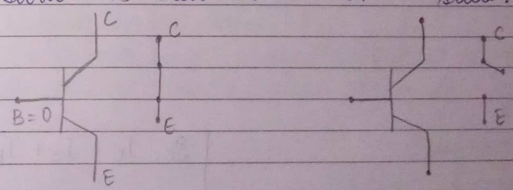
- Base = logic 0, the transistor is in cut off region and switch is said to be in OFF state.
- Base = logic 1, the transistor is in saturation region and switch is said to be in ON state.



OFF (cut-off) ON (Saturation)

⇒ For pnp transistor, if B = 0 (Saturation) ON
B = 1 (Cut off) OFF

- Base = logic 0, the transistor, is in saturation region and switch is said to be in ON state.
- Base = logic 1, the transistor is in cut off region and switch is said to be in OFF state.



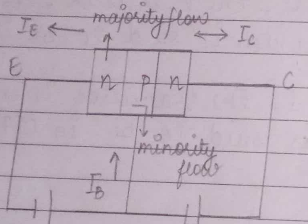
(Saturation) ON (cut-off) OFF

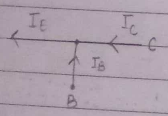
Working Principle (npn transistor)

- A BJT is essentially used as an amplifier

∴ E-B junction in F.B and C.B junction is R.B.

- The F.B of E-B junction causes the emitter current to flow in the collector region through the lightly doped base region.
- The flow of e^- from n-type emitter into the p-type base is of the ratio of 100:5 i.e. 20:1 i.e. small no. of e^- (less than 5%) combine with hole in base and the remaining 95% tend to cross over base region and reach the collector region.
- When active mode/region, the current proportionally ↑ from the collector pin to the emitter pin.
- Conventional current in opposite to flow of e^-.





$$\boxed{\text{So, } I_E = I_C + I_B}$$

Current Eq^n for BJT

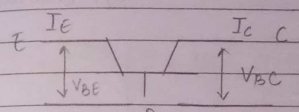
Input / Output (I/O) Characteristics of BJT / Transfer characterstics of BJT.

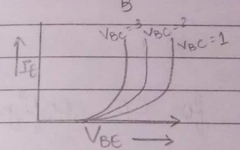
⇒ For input characterstics :-

It is obtained with respect to input current and input voltage for a given value of output voltage.

I/O of npn transistor in CB configuration :-

→ Circuit arrangement





Input parameter

I/P $I = I_E$

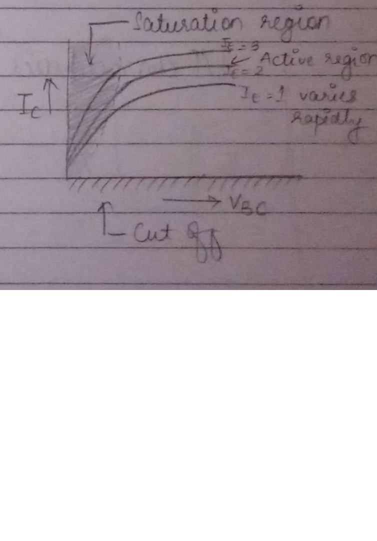
I/P $V = V_{BE}$

O/P $I = I_C$

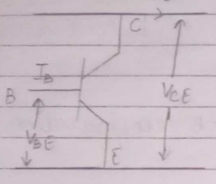
O/P $V = V_{BC}$

⇒ For Output characterstics:

It is obtained with respect to output current and output voltage for a given value of input current.



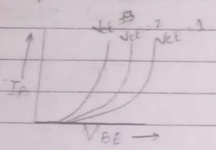
I/O for npn transistor for CE configuration



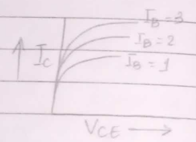
Parameter

I/P	$I = I_B$	
I/P	$V = V_{BE}$	
O/P	$I = I_C$	
O/P	$V = V_{CE}$	

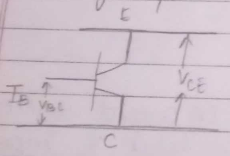
I/P characterstics



O/P characterstics



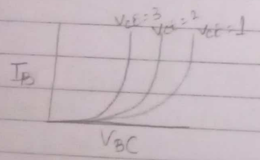
I/O for npn transistor for CC configuration



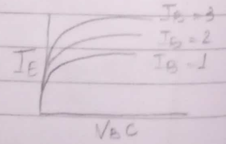
Parameters

I/P	$I = I_B$	
I/P	$V = V_{BC}$	
O/P	$I = I_E$	
O/P	$V = V_{CE}$	

I/P characterstics



O/P characterstics



Current gain:

It is defined as the ratio of output current to input current.

$$CG = \frac{O/P\ I}{I/P\ I}$$

→ For common base configurations : the CG is denoted by 'α' and is given by $\alpha = \frac{I_C}{I_E}$

→ For common emmiter configuration, the CG is denoted by 'β' and is given by $\beta = \frac{I_C}{I_B}$

→ For common collector configuration, the CG is denoted by 'γ' and is given by $\gamma = \frac{I_E}{I_B}$

⇒ Relationship between 'α' and 'β' :-

The current eq^n of BJT is given by →

$$I_E = I_C + I_B \quad \text{--- (1)}$$

divide the eq^n (1) by I_C

$$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$$

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

$$\therefore \alpha = \frac{\beta}{1+\beta} \quad \text{and} \quad \beta = \frac{\alpha}{1-\alpha}$$

⇒ Relationship between 'β' and 'γ'

The current eqⁿ of BJT is given by →

$I_E = I_C + I_B$ — (2)

divide the eqⁿ (2) by I_B

$$\frac{I_E}{I_B} = \frac{I_C}{I_B} + \frac{I_B}{I_B}$$

$$\frac{I_E}{I_B} = \frac{I_C}{I_B} + 1$$

∴ $\gamma = \beta + 1$ and $\beta = \gamma - 1$

Relationship between 'α' and 'γ' :-

The current eqⁿ $I_E = I_C + I_B$ — (3)

Divide the eqⁿ (3) by I_E

$$\frac{I_E}{I_E} = \frac{I_C}{I_E} + \frac{I_B}{I_E}$$

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

$\alpha = -1 + \frac{1}{\gamma}$ and $\gamma = \frac{1}{1-\alpha}$

Ques1 The values for a 'α' of transistor is 0.95. Find the value of 'β' also find value of α if β changes to 100.

$\alpha = 0.95$

$\beta = ?$

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

$$= \frac{0.95}{1-0.95}$$

$$= \frac{0.95}{0.05} \times \frac{100}{100}$$

$$= \frac{95}{5}$$

$\Rightarrow \beta = 19$

$\beta = 100$

$\alpha = ?$

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

$$= \frac{100}{100+1}$$

$$= \frac{100}{101}$$

$\alpha = 0.99$

Ques2 For npn transistor the emmiter current is 10mA (I_E) and the common emmiter current gain is 100 (β). Determine the collector and base current and also determine the value of 'γ'.

$I_E = 10mA$, $\beta = 100$, $I_C = ?$, $I_B = ?$, $\gamma = ?$, $\alpha = ?$

$$\alpha = \frac{\beta}{\beta+1} = \frac{100}{100+1} = \frac{100}{101} = 0.99$$

$\beta = \gamma - 1$ = $100 = \gamma - 1$

$100 + 1 = \gamma$

$\gamma = 101$

$\alpha = \frac{I_C}{10 \times 10^{-3}} = 0.99 = \frac{I_C}{10 \times 10^{-3}}$

$\underline{0.0099 = I_C}$

$I_E = I_C + I_B$

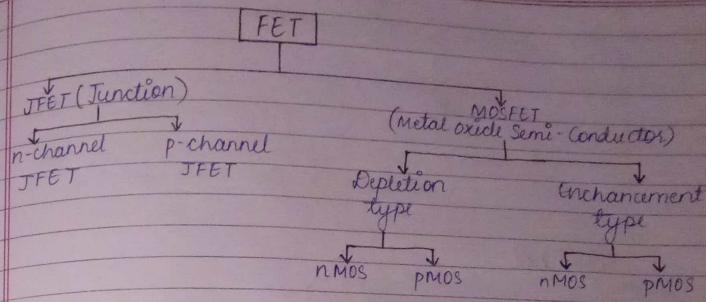
$10 \times 10^{-3} = 0.0099 + I_B$

$10 \times 10^{-3} - 0.0099 = I_B$

$\Rightarrow I_B = 0.0001$

⇒ Difference between FET and BJT

Bipolar Junction ~~Diode~~ Transistor	Field Effect Transistor
• It is a Bipolar device (both majority and minority charge carrier).	• It is a uni-polar device (only majority charge carrier).
• BJT is a current control device.	• FET is a voltage control device.
• Low input resistance	• Very High input resistance
• +ve temp. coefficient.	• -ve temp. coefficient
• less noisy	• Comparitively more noisy.
• Occupies more space	• Occupies less space and is scalable.



Junction FET (JFET)

Construction : It is a 3 terminal device
↳ Gate
↳ Drain
↳ Source

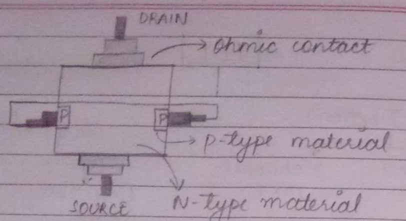
• n-channel

→ Two p-type materials are induced in an n-type substraight.

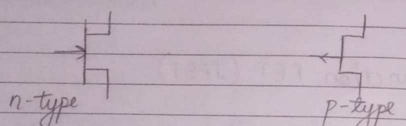
→ Both p-type regions / materials are connected together to form the GATE terminal.

→ Top side forms the DRAIN terminal and bottom side forms the source terminal.

→ The contacts used are OHMIC contacts.

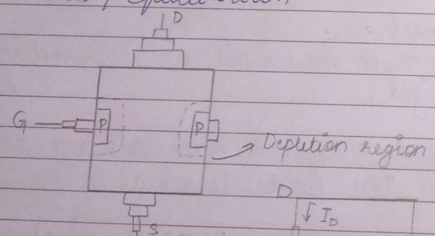


Symbol :

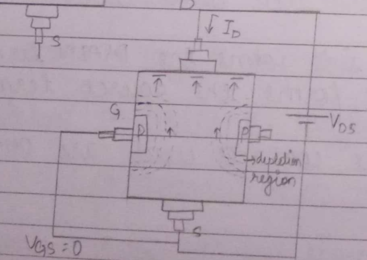


→ Working Principle (n-channel):

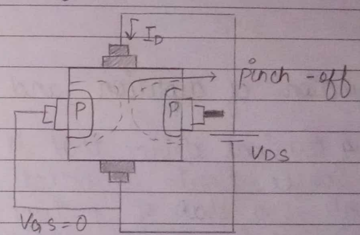
(1) At no bias / Equillibrium



(2) $V_{GS} = 0$
$V_{DS} > 0$

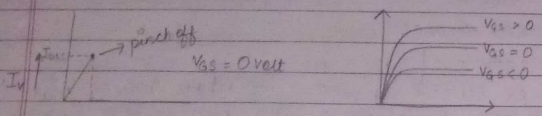


- As V_{DS} is applied, e^- are drawn towards drain terminal and a 'I' → I_D (Drain current) flows through the device.
- Since it is reverse biased depletion region ↑, the width of the depletion region in upper region will be more compared to lower region.
- As we go on ↑ V_{DS}, 2 depletion regions would touch, and condition referred to as pinch-off will result.



- The V_{DS} at this point is known as pinch-off voltage (V_P)
- The I → I_D doesn't drop off at pinch off rather maintains a saturation level defined as Maximum Drain current (I_{DSS}), when at $V_{DS} > V_P$

→ VI characterstics / Transfer characterstics

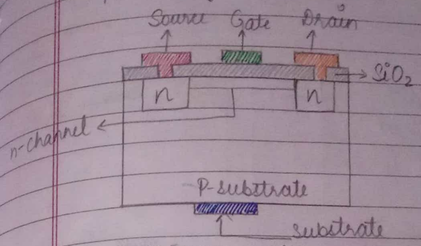


MOSFET / IGFET (Insulated Gate)

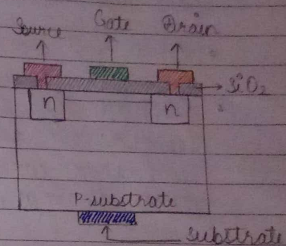
Semi-Conductor (Silicon)
oxide
metal

→ Construction of depletion and enhancement

* It is 4 terminal device that is :
  Gate, Source, Drain, Substrate
* Substrate is a slab of p-type material (for n-mos) and is the foundation on ~~the~~ which the device is constructed.
* Silicon-dioxide (SiO_2) is a type of insulator (di-electric) which sets up opposing electric field with in the dielectric when expose to electric field.
* In depletion type MOSFET an n-channel is present between the drain and source.
* In enchancement type MOSFET the channel is formed.
* Source and drain terminals are connected through metallic contact with diffused dopped regions.



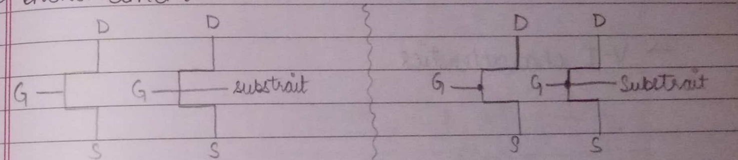
DEPLETION nMOS



ENHANCEMENT nMOS

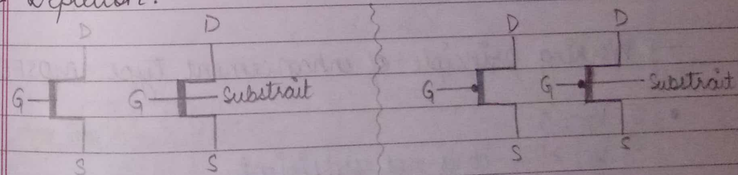
Symbols :

→ Enchancement :-



n-mos p-mos

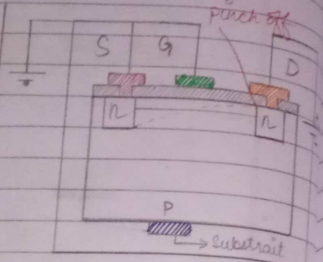
→ Depletion :-



n-mos p-mos

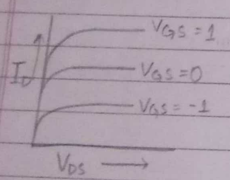
→ Working principle of depletion type (n mos)

- $V_{GS}=0$ and $V_{DS}>0$
- Electrons will attract towards +ve terminal and then current I_D starts flowings.
- As we go on increasing V_{DS}, the voltage can pinch off the channel and therefore drain current saturates and maintains its value



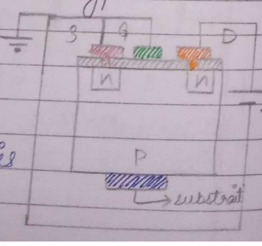
$V_{GS}=0$
$V_{DS}>0$

→ V-I characterstics



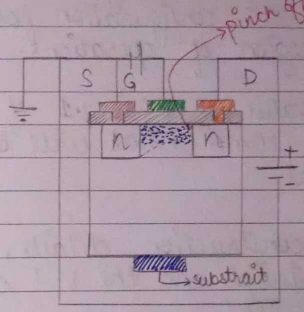
→ Working principle of enhancement type MOSFET

- If $V_{GS}=0$
  $V_{DS}>0$, it is not sufficient to have large accumulation of carriers and hence there is



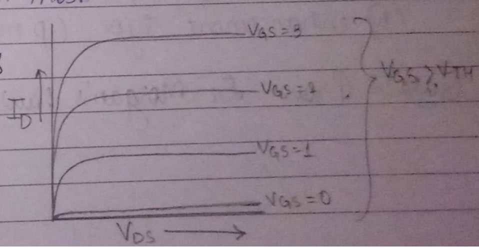
no power between Drain and source. Therefore $I_D=0$ and MOSFET is not conducting.

- $V_{GS}>0$, will pressure holes into p-substrate and electrons will be attracted towards the gate and will accumulate in the region of SiO_2.
- The V_{GS} voltage where channel gets induced (form) is known as threshold voltage. (V_{TH} / V_T)



- $V_{GS}>V_{TH}$ and $V_{DS}>0$ and kept constant conducting and a current I_D starts to flow.
- I_D eventually reach saturation by pinch-off process as that of depletion mos.

→ V-I Characterstics



Assignment Questions

Ques 1: Draw the circuit diagram for the p-n-p junction for: active, saturation, cut-off and inverted junction.

Ques 2: Explain the working principle of pnp transistor in active region.

Ques 3: Draw the circuit arrangement of pnp transistor in CB, CE, CC configuration for all the different region of operations.

Ques 4: The inverse value of 'Y' is 1.1 if the ammeter current is 20mA. What will be the value of base current.

Ques 5: Give the construction details, discuss the working principle and the V-I characterstics of p-channel JFET.

Ques 6: Give the constructional details, symbol and discuss the working principle and V-I characterstics of

(a) depletion type (p mos)
(b) enhancement type (p mos)

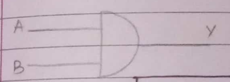
Ques 7: Prove De Morgan's Law for ⇒ $\overline{A \cdot B} = \overline{A} + \overline{B}$

14th May 2024

Logic Gates

- → Basic Gates
  - → AND
  - → OR
  - → NOT
- → Universal Gates
  - → NAND → can be used to design any gates and reduces the no. of hardwares
  - → NOR
- → Special Purpose Gates
  - → Exclusive - OR (XOR)
  - → Exclusive - NOR
  - → Buffer

⇒ AND Gate



$\boxed{Y = A \cdot B}$

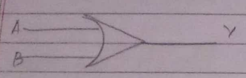
Truth Table

A	B	Y = A·B
0	0	0
0	1	0
1	0	0
1	1	1

2 for input 1 for output

★ 1 I.C. has 4 AND Gates and 1 AND Gate has 3 Pins, ~~therefore~~ total pins = 4 × 3 = 12 pins
+2 more pins are required for power supply.
Hence in total 14 pins are required in 1 I.C.

⇒ OR Gate

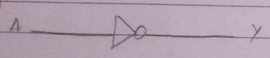


$\boxed{Y = A+B}$

Truth Table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

⇒ NOT Gate

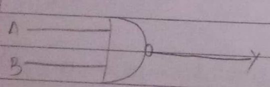


$\boxed{Y = \bar{A}}$

Truth Table

A	Y
0	1
1	0

⇒ NAND Gate (Not AND)

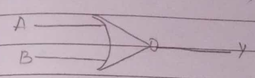


$\boxed{Y = \overline{A \cdot B}}$

Truth Table

A	B	Y	$\bar{Y}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

⇒ NOR Gate (Not OR)

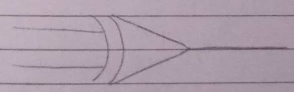


$\boxed{Y = \overline{A+B}}$

Truth Table

A	B	Y	$\bar{Y}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

⇒ XOR Gate (Exclusive OR)



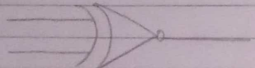
$$\boxed{\begin{aligned} Y &= A \oplus B \\ &= A\bar{B} + \bar{A}B \end{aligned}}$$

Truth Table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

agar inputs same honge toh output 0, and if differ karenge then output will be 1.

⇒ XNOR Gate (Exclusive NOR)



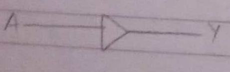
$$\boxed{\begin{aligned} Y &= A \odot B \\ &= AB + \bar{A}\bar{B} \end{aligned}}$$

Truth Table

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

agar inputs same honge toh output = 1, and if different then output = 0.

Buffer



jab input let's say 5V hai and O/P 4.8V and we want it 5V toh we use buffer in that case

$\boxed{Y = A}$

Boolean Algebra

De Morgan's Law

It states that, break the bar and change the sign

ex:

(1) $\overline{A+B} = \bar{A} \cdot \bar{B}$

(2) $\overline{A \cdot B} = \bar{A} + \bar{B}$

→ Prove De Morgan's Law

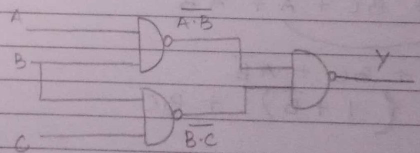
(1) $\overline{A+B} = \bar{A} \cdot \bar{B}$

A	B	A + B	$\overline{A+B}$ (LHS)	$\bar{A}$	$\bar{B}$	$\bar{A} \cdot \bar{B}$ (RHS)
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

⇒ Hence LHS = RHS

Ques Reduce the following using Boolean Algebra / De Morgan's Law

(1)



$\overline{(\overline{A \cdot B} \cdot \overline{B \cdot C})}$

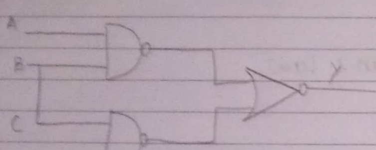
$(\overline{\overline{A\cdot B}\cdot\overline{B\cdot C}})$

→ $\overline{\overline{A\cdot B}} + \overline{\overline{B\cdot C}}$

→ $A\cdot B + B\cdot C$

→ $B\cdot(A+C)$ Ans

(2)



$(\overline{\overline{A\cdot B}+\overline{B\cdot C}})$

→ $(\overline{\overline{A\cdot B}+\overline{B\cdot C}})$

→ $\overline{\overline{A\cdot B}} + \overline{\overline{B\cdot C}}$

→ $A\cdot B\cdot B\cdot C \rightarrow A\cdot B\cdot C$ Ans

Imp

Ques Simplify and solve the following boolean equation

$Y = A + A\cdot B\cdot C + \bar{A}BC + AD + A\bar{D} + A\bar{B}$

$Y = A + BC(A+\bar{A}) + A(D+\bar{D}) + A\bar{B}$

$Y = A + BC(1) + A(1) + A\bar{B}$

$Y = A + BC + A + A\bar{B}$

$Y = A + BC + A\bar{B}$

$Y = A(1+\bar{B}) + BC$

$Y = A(1) + BC$

$Y = A + BC$ Ans

Assi

Ques 8 Minimize the following

(1) $Y = A\bar{B} + ABC + A\bar{B}\bar{C} + A\bar{B} + A\bar{D} + \bar{B}C$

(2)