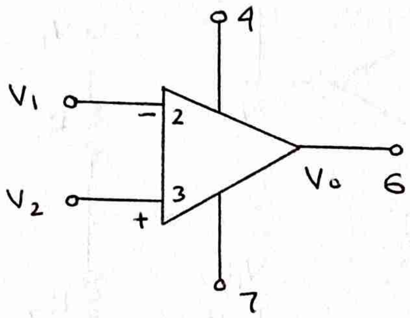
Solid State Physics, Devices & Electronics

Operational Amplifier

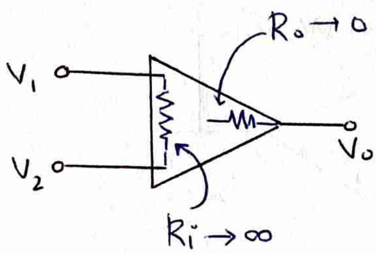
31.07.2024



pin 3: Non inverting terminal
pin 2: Inverting terminal
pin 6: output
pin 4,7: Limitter

$V_{in} = V_2 - V_1$ $\qquad$ $A_V = \frac{V_o}{V_{in}} = \frac{V_o}{V_2 - V_1}$ = Voltage gain

① Ideal OP-AMP:



(a) Input Resistance should be infinite
(b) For maximum output V_o, $R_o \to 0$ i.e output resistance should be zero
(c) $R_i \to \infty$ so that V_1, V_2 not mixed.
(d) No current flow in the OPAMP

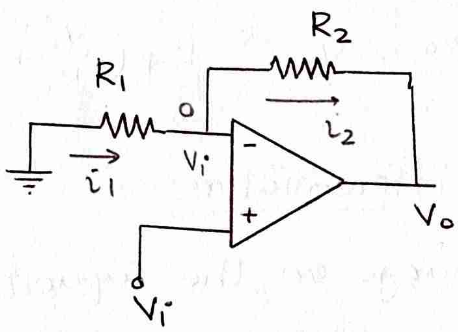
② Non-inverting

From the Concept of Virtual ground Potential at 0 is V_i

Now $i_1 = \frac{0 - V_i}{R_1}$, $i_2 = \frac{V_i - V_o}{R_2}$

As the Currents are same

$$-\frac{V_i}{R_1} = \frac{V_i - V_o}{R_2} \Rightarrow V_o = V_i\left(1 + \frac{R_2}{R_1}\right)$$

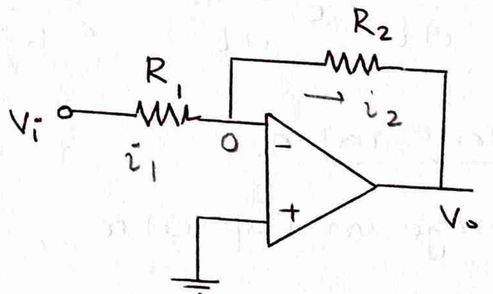


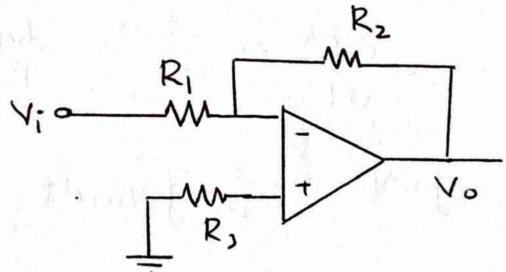
③ Inverting:

As the Currents are Same,

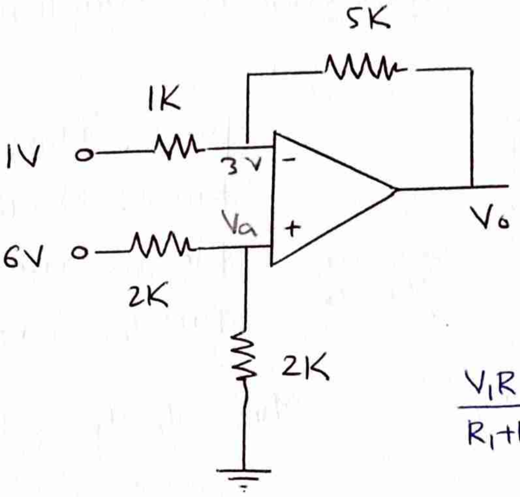
$$\frac{V_i - 0}{R_1} = \frac{0 - V_o}{R_2}$$

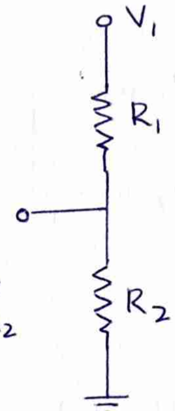
$$V_o = -\frac{R_2}{R_1} V_1$$





④ Differential





$\frac{V_1 R_2}{R_1+R_2}$

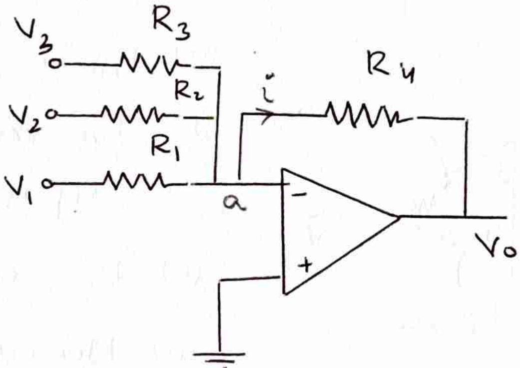
From Potential divider. Potential at a is

$$V_a = \frac{2\times 6}{2+2} = \frac{12}{4} = 3\text{Volt}$$

Now, $\frac{3-1}{1} = \frac{V_o-3}{5}$

$10 = V_o - 3 \Rightarrow V_o = 13\text{Volt}$

⑤ Adder/Summing

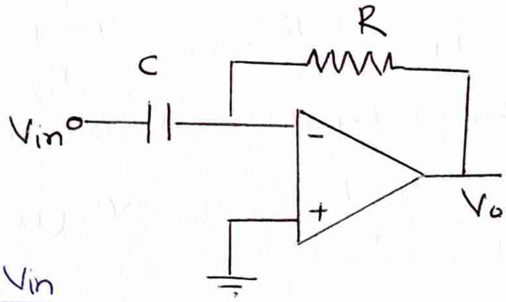


From the concept of Virtual ground. Potential at a. $V_a = 0$

Now $i = \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$ Also $\frac{0-V_o}{R_4} = i$

So, $V_o = -R_4\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$

⑥ Differentiator



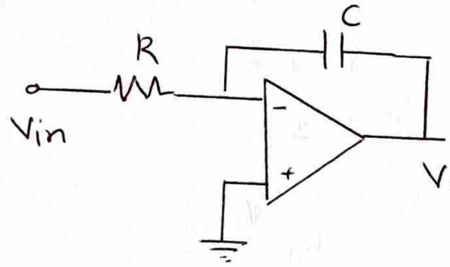
charge on the Capacitor

$q = C(V_{in} - 0) = CV_{in}$

$i = \frac{dq}{dt} = C\frac{dV_{in}}{dt}$ $\frac{0-V_o}{R} = C\frac{dV_{in}}{dt}$

$V_o = -RC\frac{dV_{in}}{dt}$

⑦ Integrator:



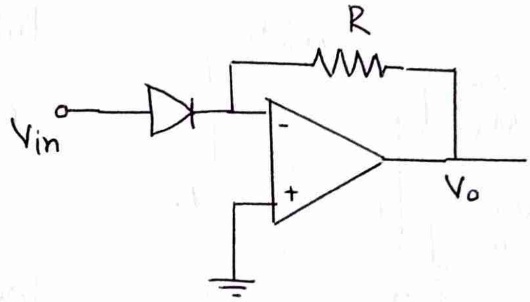
charge on Capacitor

$q = CV = C(0-V_o)$

$\frac{dq}{dt} = -C\frac{dV_o}{dt}$ $i = \frac{V_{in}}{R}$

$\int dV_o = -\frac{1}{RC}\int V_{in}dt$ $V_o = -\frac{1}{RC}\int V_{in}dt$

(8) Exponential/ Antilog

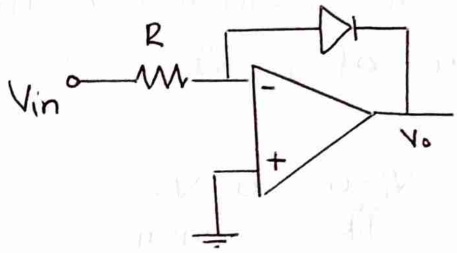


Diode Current

$$i = i_o e^{\frac{qV_{in}}{\eta KT}} = \frac{0 - V_o}{R}$$

$$V_o = - i_o R \exp\left(\frac{qV_{in}}{\eta KT}\right)$$

(9) Logarithmic :



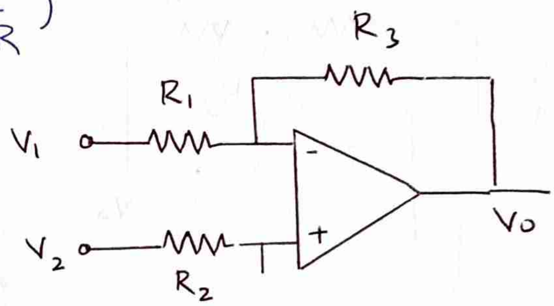
Diode Current

$$i = \frac{V_{in} - 0}{R} = i_o \exp\left(\frac{-qV_o}{\eta KT}\right)$$

$$\frac{V_{in}}{i_o R} = \exp\left(\frac{-qV_o}{\eta KT}\right)$$

$$V_o = - \frac{\eta KT}{q} \ln\left(\frac{V_{in}}{i_o R}\right)$$

(10) At first we have to observe to voltage at Non inverting terminal is V_2



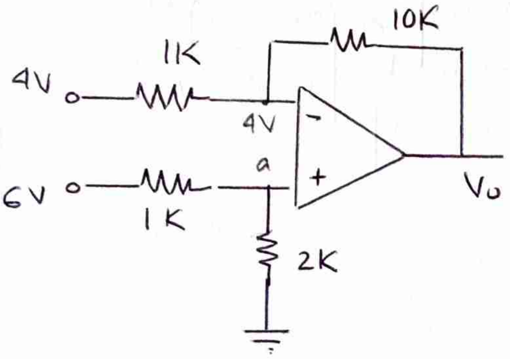
Now $\dfrac{V_1 - V_2}{R_1} = \dfrac{V_2 - V_o}{R_3}$

$$V_2 - V_o = \frac{R_3}{R_1}(V_1 - V_2)$$

$$V_o = V_2 + \frac{R_3}{R_1}(V_1 - V_2)$$

$$V_o = \left(1 + \frac{R_3}{R_1}\right)V_2 - \frac{R_3}{R_1}V_1$$

(11) Find the output Voltage

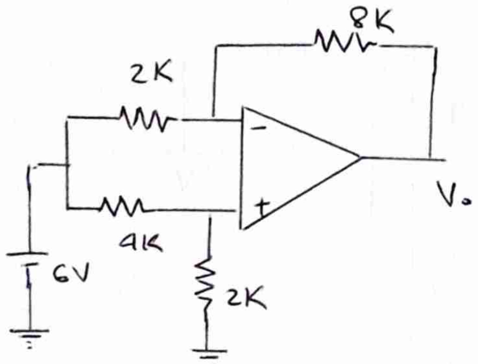


Potential at a $V_a = \dfrac{6 \times 2}{1+2} = 4\text{Volt}$

$$\frac{4-4}{1} = \frac{4 - V_o}{10} \Rightarrow V_o = 4\text{Volt}$$

output Voltage is 4Volt

(12)



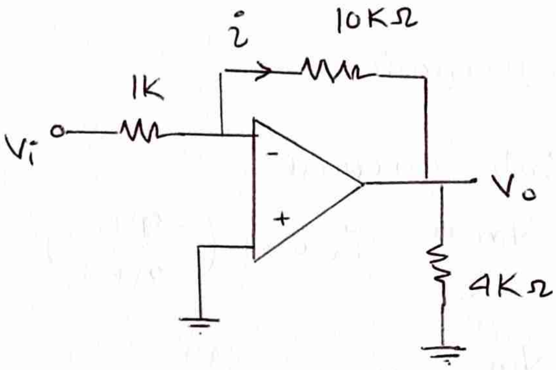
Potential at a, $V_a = \frac{6 \times 2}{4+2} = 2\,\text{Volt}$

$$\frac{6-2}{2} = \frac{2-V_o}{8} \Rightarrow 16 = 2 - V_o$$

$$\Rightarrow V_o = -14\,\text{Volt}$$

The output Voltage is -14 Volt

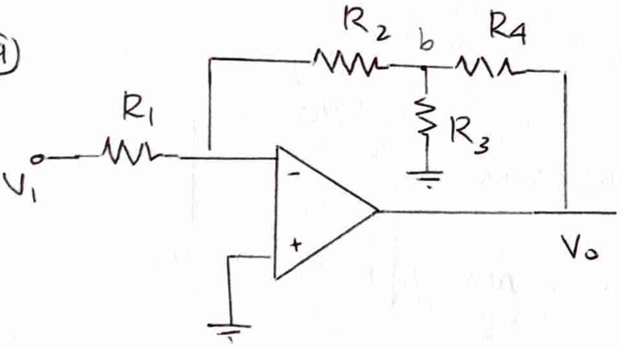
(13) If $V_i = 2\sin\omega t$ mV, the Value of i_o is



$$i = \frac{V_i - 0}{1K} = \frac{0 - V_o}{10K\Omega}$$

$$i = 2\sin\omega t \times 10^{-3} \times 10^{-3} = 2\sin\omega t\,\mu A$$

(14)



Find the output Voltage V_o

let the Potential at b is x

$$\frac{x-0}{R_2} + \frac{x-0}{R_3} + \frac{x - V_o}{R_4} = 0$$

a

$$x\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) = V_o$$

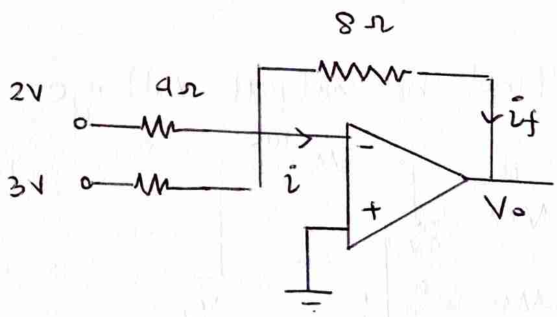
Also $\frac{V_1 - 0}{R_1} = \frac{0 - x}{R_2} \Rightarrow x = -\frac{R_2}{R_1} V_1$

$$-\frac{R_2}{R_1} V_1 \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) = V_o$$

Value of output Voltage is

$$V_o = -\frac{R_2}{R_1} V_1 \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)$$

(15) Find the Value of i

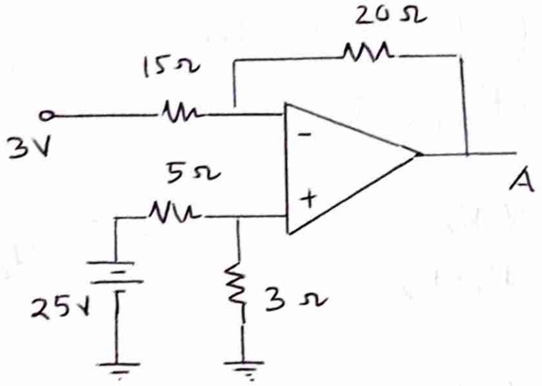


Since no current flow in the OPAMP $i = 0$

(16)

Potential at a

$V_a = \frac{25 \times 3}{3+5} = \frac{75}{8}$ Volt



$$\frac{3 - \frac{75}{8}}{15} = \frac{\frac{75}{8} - V_o}{20}$$

$-47.06 = 9.375 - V_o \Rightarrow V_o = 9.375 + 47.06 = 56.435$ Volt

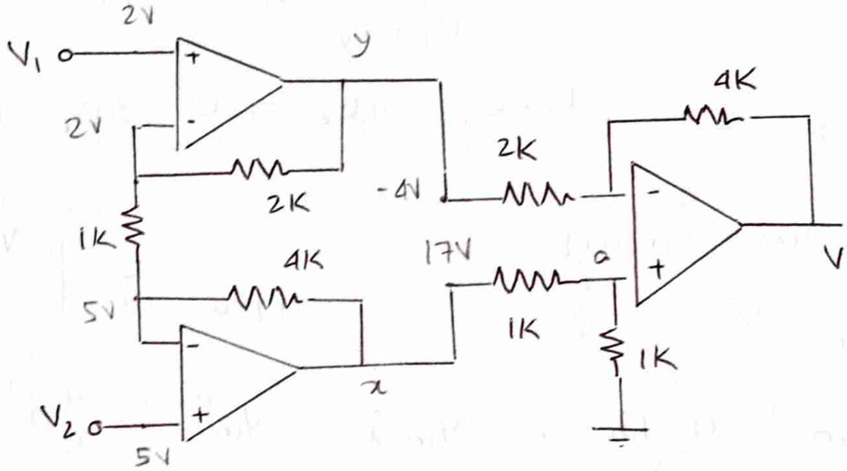
(17)

Given that

$V_1 = 2V$

$V_2 = 5V.$

Find the output Voltage V_o



$\frac{x-5}{4} = \frac{5-2}{1} \Rightarrow x = 17$ Volt $\quad \frac{-y+2}{2} = \frac{5-2}{1} \Rightarrow y = -4$ Volt

Potential at a $\quad V_a = \frac{17 \times 1}{2} = 8.5$ Volt

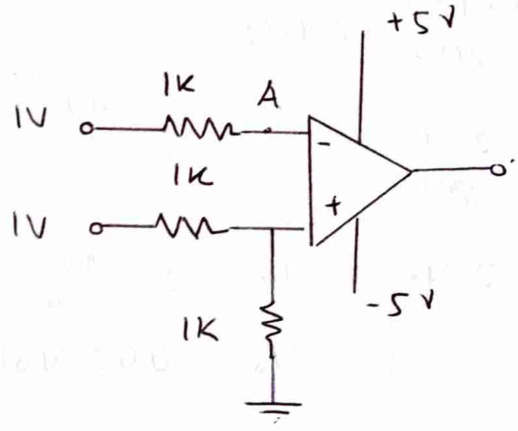
$\frac{-4-8.5}{2} = \frac{8.5 - V_o}{4} \Rightarrow -V_o + 8.5 = -25 \Rightarrow V_o = 33.5$ Volt

(18) In the operational amplifier Voltage at A is

Potential at a

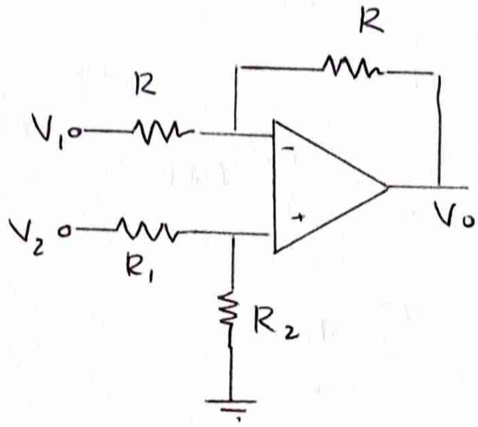
$V_a = \frac{1 \times 1}{1+1} = 0.5$ Volt

Voltage at A is 0.5 Volt



(19)

$V_o = \left(-V_1 + \frac{V_2}{2}\right)$ the ratio R_1/R_2 is



$\Rightarrow$

$$V_a = \frac{V_2 R_2}{R_1 + R_2}$$

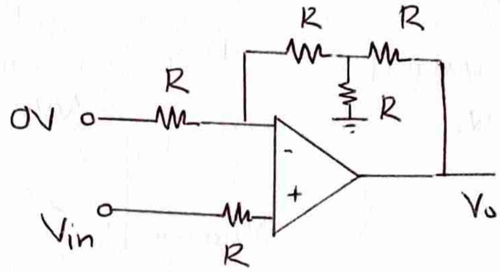
$$\frac{V_1 - V_a}{R} = \frac{V_a - V_o}{R}$$

$V_1 = 2V_a - V_o \Rightarrow V_o = 2V_a - V_1$

$$\Rightarrow V_o = \frac{2V_2R_2}{R_1 + R_2} - V_1 = -V_1 + \frac{V_2}{2}$$

$$\frac{2R_2}{R_1 + R_2} = \frac{1}{2} \Rightarrow R_1 + R_2 = 4R_2 \Rightarrow R_1 = 3R_2 \Rightarrow R_1/R_2 = 3$$

(20) For the circuit $\frac{V_o}{V_{in}} = ?$



$V_a = V_{in}$ $\qquad \frac{0 - V_{in}}{R} = i = \frac{V_{in} - x}{R}$

$2V_{in} = x$

$\frac{x - V_{in}}{R} + \frac{x - 0}{R} + \frac{x - V_o}{R} = 0$

$x - V_{in} + x + x - V_o = 0$

$3x = V_{in} + V_o$

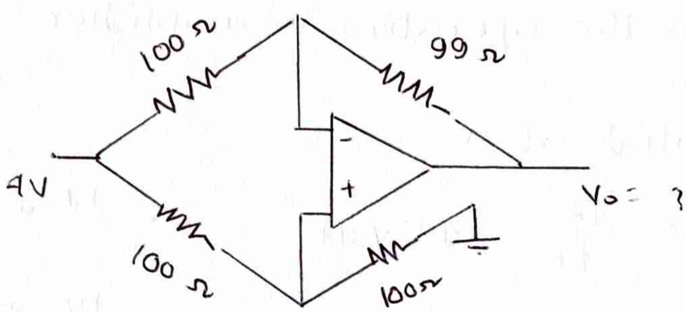
$x = \frac{1}{3}(V_{in} + V_o)$

$2V_{in} = \frac{1}{3}(V_{in} + V_o)$

$6V_{in} = V_{in} + V_o$

$5V_{in} = V_o \Rightarrow \frac{V_o}{V_{in}} = 5$

(21)



$$V_a = \frac{4 \times 100}{200} = 2\text{ Volt}$$

$$\frac{4-2}{100} = \frac{2 - V_o}{99}$$

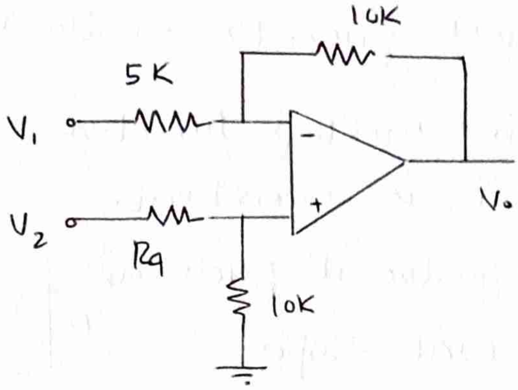
$$\frac{99}{50} = 2 - V_o \Rightarrow V_o = 2 - \frac{99}{50}$$

$\Rightarrow V_o = 0.02$ Volt

(22)

Given, $V_o = \frac{V_2}{3} - 2V_1$

The Value of R_4 is



$\Rightarrow$ $V_a = \frac{V_2 \times 10}{10 + R_4} = \frac{10V_2}{R_4 + 10}$

$\frac{V_1 - V_a}{5} = \frac{V_a - V_o}{10}$

or $2V_1 - 2V_a = V_a - V_o$

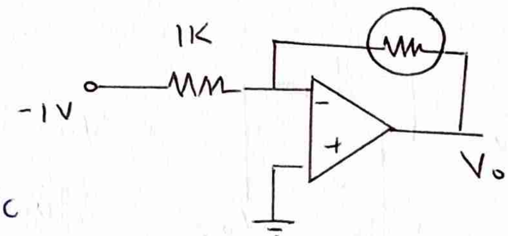
or $V_o = -2V_1 + 3V_a$

$\frac{V_2}{3} - 2V_1 = -2V_1 + \frac{30V_2}{R_4 + 10}$

$\frac{1}{3} = \frac{30}{R_4 + 10}$ $\Rightarrow$ $R_4 + 10 = 90$

$\Rightarrow$ $R_4 = 80\,\Omega$

(23) The thermister has a resistance $3K\Omega$ at $25°c$. Its resistance decrease by $150\,\Omega$ per °c upon heating. The output of the Circuit at $30°c$ will be



Resistance at increase 5c

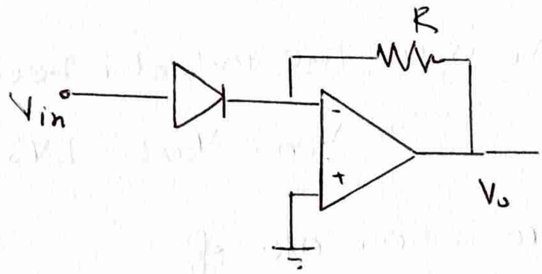
$R_f = R_i - \alpha\Delta t = 3000 - (5 \times 150) = 2250\,\Omega = 2.25K$

$\frac{-1-0}{1} = \frac{0 - V_o}{2.25}$ $\Rightarrow$ $V_o = 2.25$ Volt

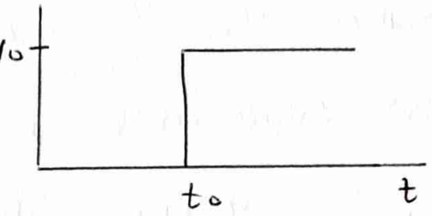
(24) If $y = \log x$. The the circuit that can be used to produce an output Voltage V_o Varying linearly with x is

$\Rightarrow$ $y = \log x$ so we have to use exponential amplifier

$x = e^y = V_o$

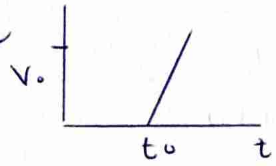


(25) The input given to an ideal OP-AMP integrator circuit is

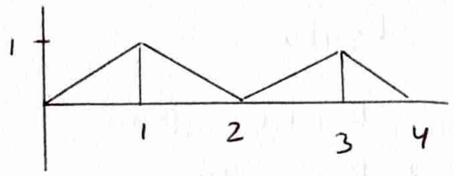


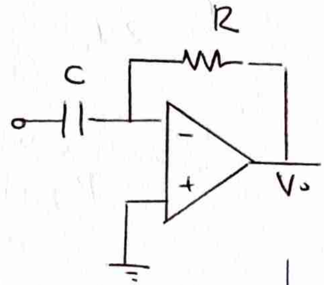
=) This is unistep function and it is constant.

on integrator it gives a Constant slope.



(26)

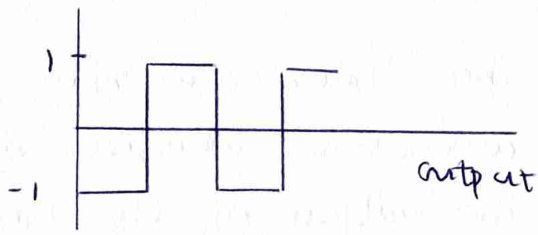




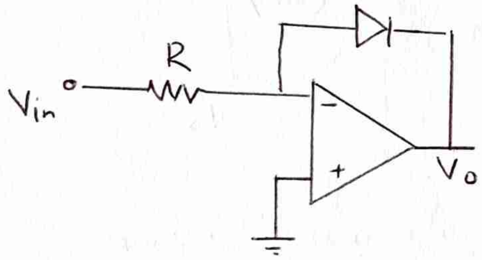
Value of RC is 1

This is a differentiator

$$V_o = -RC\frac{dV_{in}}{dt} = -\frac{dV_{in}}{dt}$$



(27)

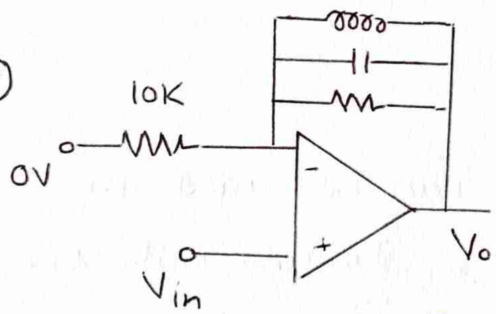


Vo is Proportional to

For Logarithmic amplifier

$V_o \propto \ln|V_{in}|$

(28)



L = 1mH

C = 1 uF

R = 90K

Vin = 1V DC

For inductor

$X_L = \omega L$

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

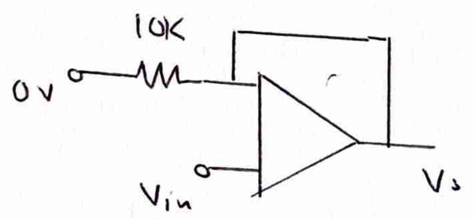
For Pure DC, $\omega \to 0$

AC $\omega \to \infty$

$X_L = 0$

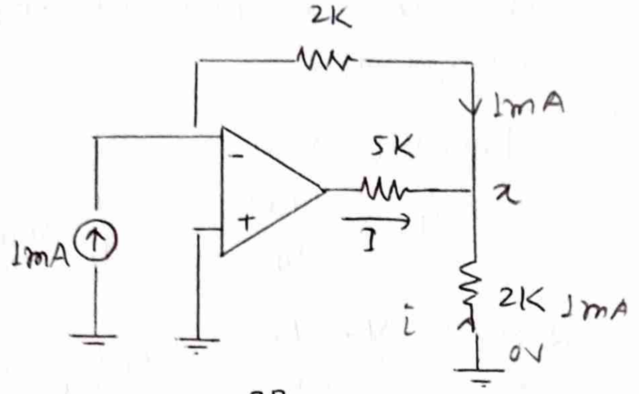
As X_L is 0 the inductor became short circuit

so Vin = Vout = 1 Volt



There is no role of resistor and capacitor

(29) Value of I will be

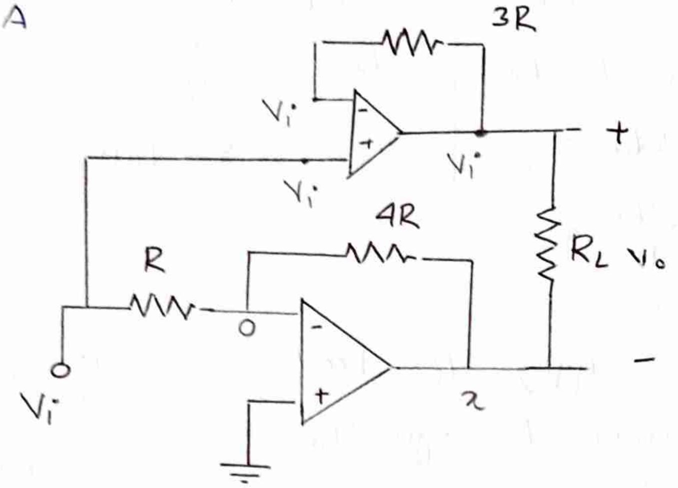


$$\frac{x-0}{2} = -1 \Rightarrow x = -2\text{Volt}$$

$$i = \frac{0-(-2)}{2} = 1mA$$

Value of I is $-2mA$

(30) Value of $\frac{V_o}{V_i}$ is



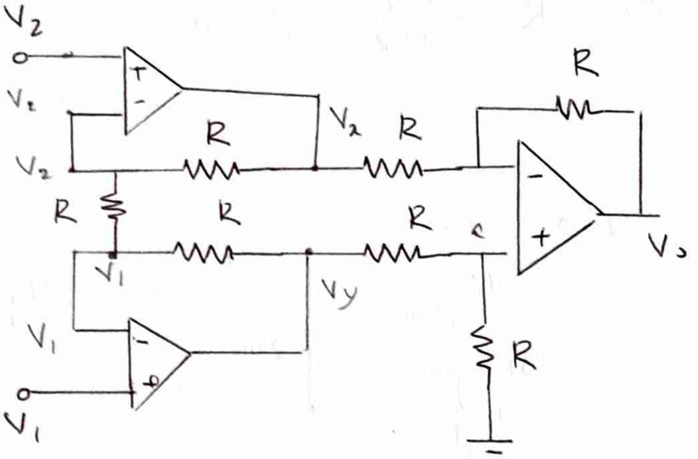
$$\frac{V_i - 0}{R} = \frac{0-x}{4R}$$

$$x = -4V_i$$

Potential difference $V_o = V_i - (-4V_i) = 5V_i$

$$\frac{V_o}{V_i} = 5$$

(31) Value of $\frac{V_o}{V_1 - V_2}$ is



$$\frac{V_2 - V_1}{R} = \frac{V_1 - y}{R}$$

$$V_2 - V_1 = V_1 - V_y$$

$$V_y = 2V_1 - V_2$$

$$\frac{V_x - V_2}{R} = \frac{V_2 - V_1}{R}$$

$$V_x = 2V_2 - V_1$$

$$V_a = \frac{V_y R}{R+R} = \frac{V_y}{2}$$

$$V_x - \frac{V_y}{2} = \frac{V_y}{2} - V_o$$

$$V_x - V_y = -V_o$$

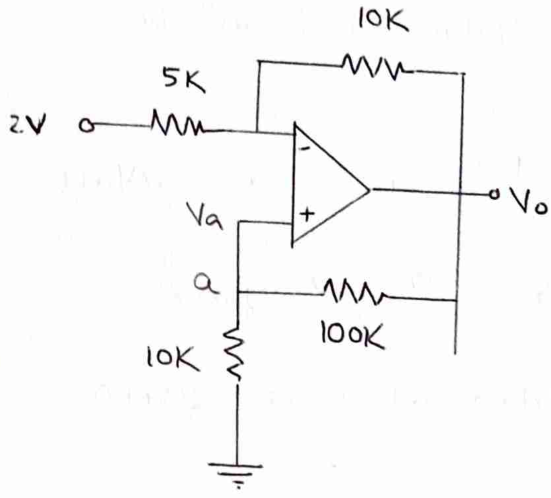
$$V_o = V_y - V_x$$

$$V_o = 2V_1 - V_2 - 2V_2 + V_1$$

$$V_o = 3V_1 - 3V_2$$

$$\frac{V_o}{V_1 - V_2} = 3$$

(32) What will be value of output Voltage V_o



⇒ Potential at a.

$$V_a = \frac{10V_o}{10+100} = \frac{V_o}{11} \text{ Volt}$$

$$\frac{2-V_a}{5} = \frac{V_a - V_o}{10}$$

$$4 - 2V_a = V_a - V_o$$

$$V_o = 3V_a - 4$$

$$V_o = \frac{3V_o}{11} - 4$$

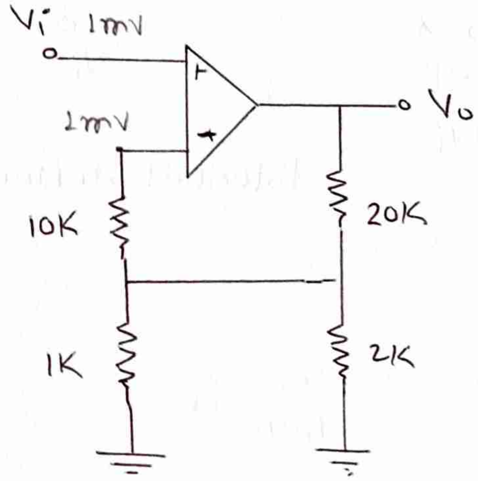
$$V_o\left(\frac{3}{11} - 1\right) = 4$$

$$V_o = -\frac{44}{8}$$

$$V_o = -5.5 \text{ Volt}$$

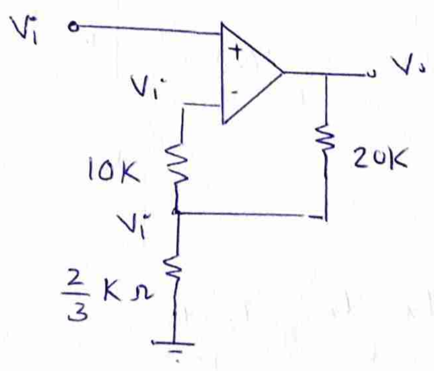
output voltage is -5.5 Volt

(33) Input supply $V_i = 1mV$. The output Voltage $V_o = ?$



⇒ 1K and 2K are in parallel

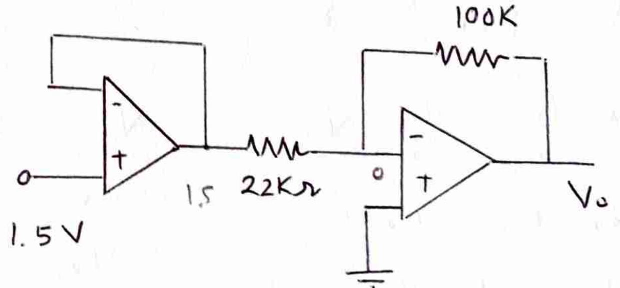
so $R = \frac{1\times 2}{1+2} = 2/3\ \Omega$



$$V_i = \frac{V_o \times \frac{2}{3}}{20 + \frac{2}{3}} = \frac{2V_o}{62} = 1$$

$$V_o = 31\, mVolt$$

(34) The output Voltage will be

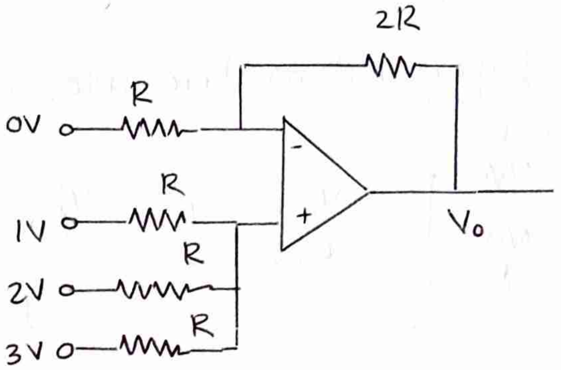


⇒

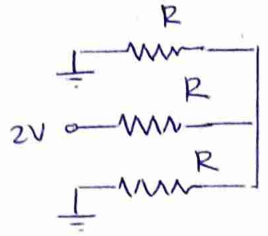
$$\frac{1.5 - 0}{22} = \frac{0 - V_o}{100}$$

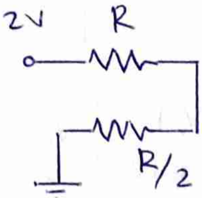
$$V_o = \frac{-1.5\times 100}{22} = -6.818 \text{ Volt}$$

(35) The output Voltage will be

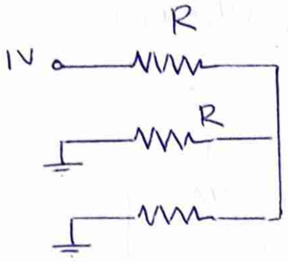


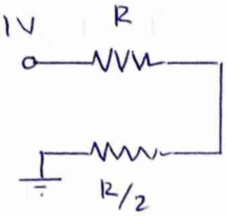
$\Rightarrow$ From superposition Principle



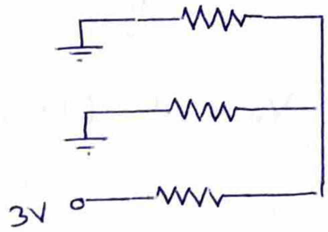


$V_1 = \frac{2}{3}V$





$V_2 = \dfrac{1 \times \frac{R}{2}}{R + \frac{R}{2}} = \frac{1}{3}V$

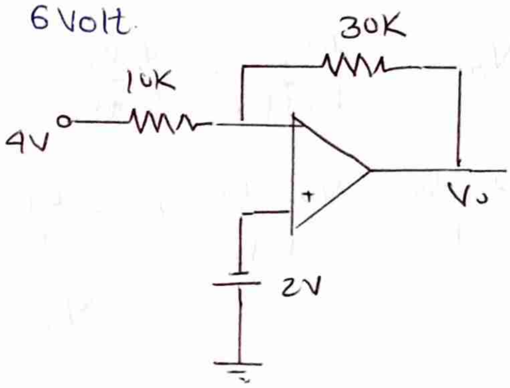


$V_3 = 1\text{Volt}$

$V = V_1 + V_2 + V_3 = \frac{2}{3} + \frac{1}{3} + 1 = 2\text{Volt}$

$\dfrac{0-2}{R} = \dfrac{2-V_o}{2R} \Rightarrow 2 - V_o = -4 \Rightarrow V_o = 6\text{Volt}$

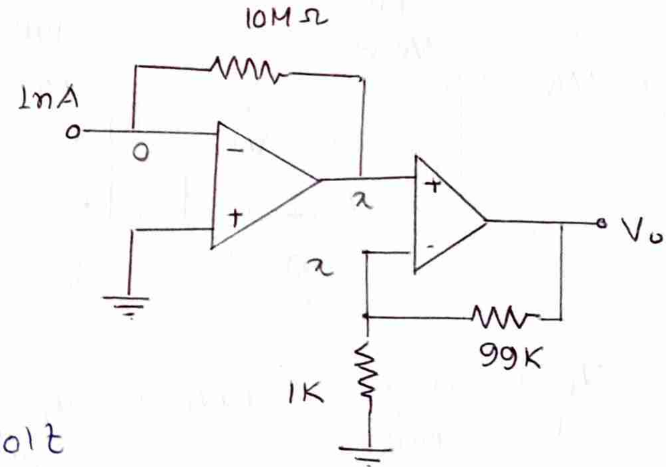
(36) Find the output Voltage V_o



$\Rightarrow$ $\dfrac{4-(-2)}{10} = \dfrac{-2-V_o}{30}$

$18 = -2 - V_o \Rightarrow V_o = -20\text{ Volt}$

(37) The output Voltage will be

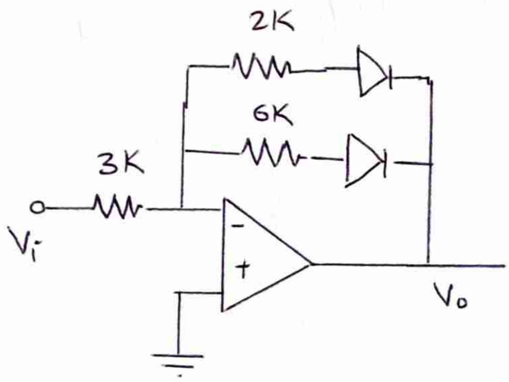


$\dfrac{0-x}{10^7} = 10^{-9} \Rightarrow x = -10^{-2}\text{Volt}$

Also $x = \dfrac{V_o \times 1}{1+99}$

$\dfrac{V_o}{100} = -10^{-2} \Rightarrow V_o = 1\text{Volt}$

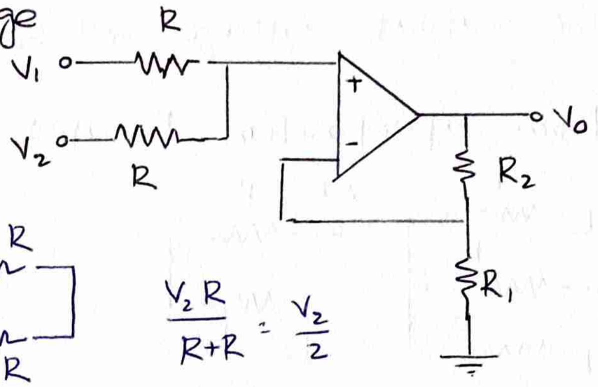
(38) If $V_1 = 2V$ then $V_o = ?$



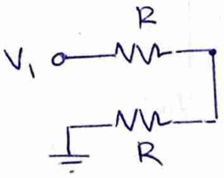
$\Rightarrow$ $\dfrac{V_1 - 0}{3} = \dfrac{0 - V_o}{6}$

$\dfrac{2}{3} = \dfrac{-V_o}{6} \Rightarrow V_o = -4\text{Volt}$

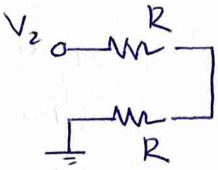
(39) What will be the output Voltage



$\Rightarrow$ By superposition Principle,



$\frac{V_1 \times R}{R+R} = \frac{V_1}{2}$

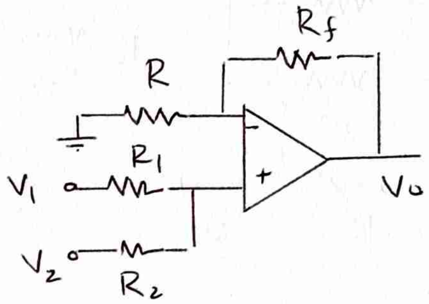


$\frac{V_2 R}{R+R} = \frac{V_2}{2}$

$V_a = \frac{V_1}{2} + \frac{V_2}{2} = \frac{1}{2}(V_1+V_2)$ Also, $\frac{V_o R_1}{R_1+R_2} = \frac{1}{2}(V_1+V_2)$

$V_o = \frac{1}{2}\left(1+\frac{R_2}{R_1}\right)(V_1+V_2)$

(40) What will be the Value of V_o



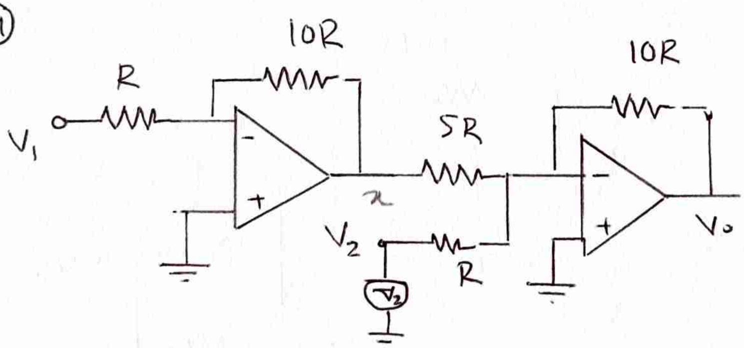
$\Rightarrow$ From superposition Principle

$V_a = \frac{V_1 R_2}{R_1+R_2} + \frac{V_2 R_1}{R_1+R_2} = \frac{V_1 R_2 + V_2 R_1}{R_1+R_2}$

$\frac{0-V_a}{R} = \frac{V_a - V_o}{R_f} \Rightarrow -\frac{R_f}{R} V_a - V_a = -V_o \Rightarrow V_o = \left(1+\frac{R_f}{R}\right) V_a$

$\Rightarrow V_o = \left(1+\frac{R_f}{R}\right)\left(\frac{V_1 R_2 + V_2 R_1}{R_1+R_2}\right)$

(41)

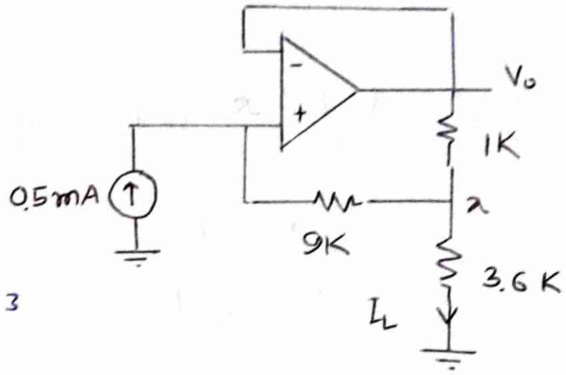


Find the output Voltage V_o

$\Rightarrow \frac{V_1 - 0}{R} = \frac{0-x}{10R}$ $\frac{-10V_1 - 0}{5R} + \frac{V_2 - 0}{R} = \frac{0 - V_o}{10R}$

$x = -10V_1$ $-2V_1 + V_2 = -\frac{V_o}{10} \Rightarrow V_o = 20V_1 - 10V_2$

(42) Find the Value of I_L



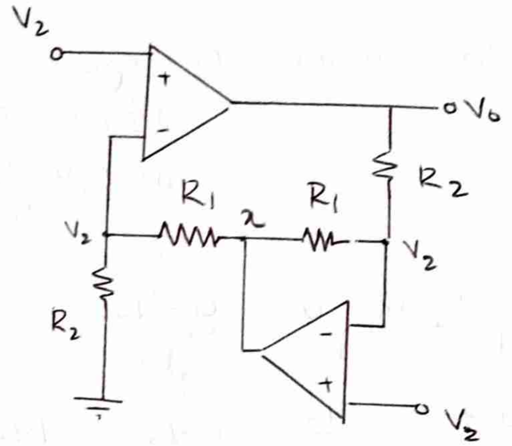
$\Rightarrow$ $\frac{0-x}{9K} = 0.5\times10^{-3}$

$x = -4.5$ Volt

Now Current $I_L = \frac{0-(-4.5)}{3.6}\times10^{-3}$

$I_L = 1.25$ mA

(43) Find the output Voltage V_o



$\frac{x-V_2}{R_1} + \frac{x-V_2}{R_1} = 0$

$2x - 2V_2 = 0$

$x = V_2$

So no Current also flows through R_1 and R_2

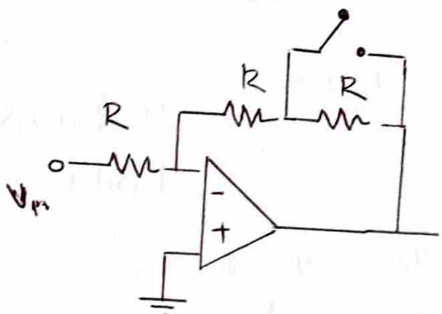
So V_2 is also equal to V_o

$V_o = V_2$

(44) V_{o1} when S open

V_{o2} when S closed

then $\frac{V_{o1}}{V_{o2}}$ is



$\Rightarrow$ when S is open,

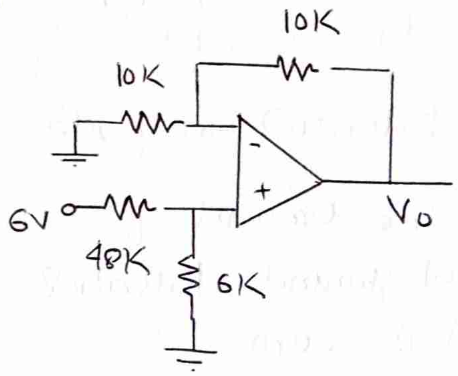
$\frac{V_{in}-0}{R} = \frac{0-V_o}{2R} \Rightarrow V_{o1} = -2V_{in}$

when S is closed

$\frac{V_{in}-0}{R} = \frac{0-V_o}{R} \Rightarrow V_{o2} = -V_{in}$

$\frac{V_{o1}}{V_{o2}} = 2$

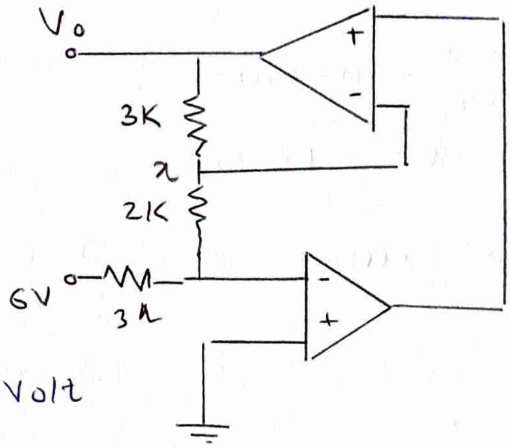
(45) output Voltage V_o



$\Rightarrow$ $V_a = \frac{6\times6}{48+6} = \frac{2}{3}$ Volt

$\frac{0-\frac{2}{3}}{10} = \frac{\frac{2}{3}-V_o}{10} \Rightarrow V_o = 4/3$ Volt

(46) Find the output Voltage



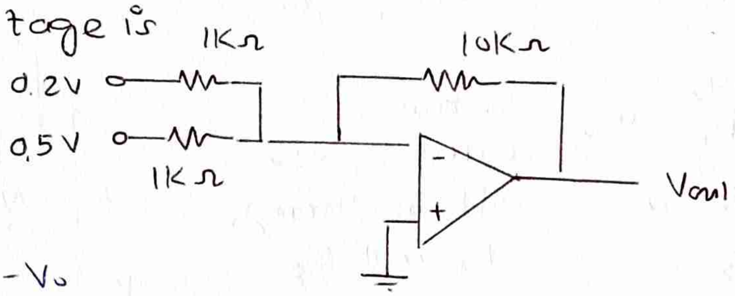
$$\frac{0-x}{2} = \frac{x-V_o}{3} \Rightarrow x - V_o = -\frac{3}{2}x$$

$$\Rightarrow \frac{5}{2}x = V_o$$

$$\Rightarrow x = \frac{2}{5}V_o$$

$$\frac{6-0}{3} = \frac{0-x}{2} \Rightarrow x = -4 \qquad V_o = -10 \text{ Volt}$$

(47) The output Voltage is



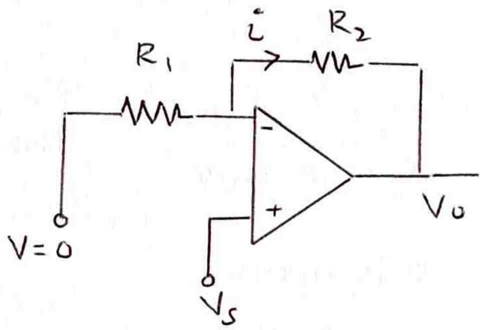
$$\frac{0.2-0}{1} + \frac{0.5-0}{1} = \frac{0-V_o}{10}$$

$$0.7 = \frac{-V_o}{10} \Rightarrow V_o = -7\text{Volt}$$

(48) $R_1 = 120\,\Omega$

$R_2 = 1.5\,K\Omega$ $\qquad V_s = 0.6V$

Find i



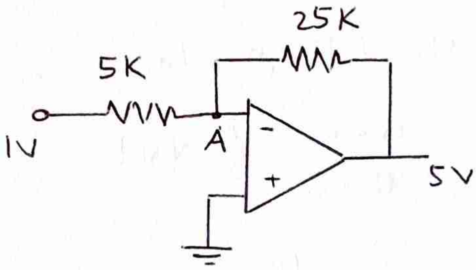
$$\frac{0-V_s}{R_1} = \frac{V_s-V_o}{R_2}$$

$$V_s - V_o = -\frac{R_2}{R_1}V_s \Rightarrow V_o = \left(1+\frac{R_2}{R_1}\right)V_s$$

$$\Rightarrow V_o = \left(1+\frac{1500}{120}\right)\times 0.6 = 8.1 \text{ Volt}$$

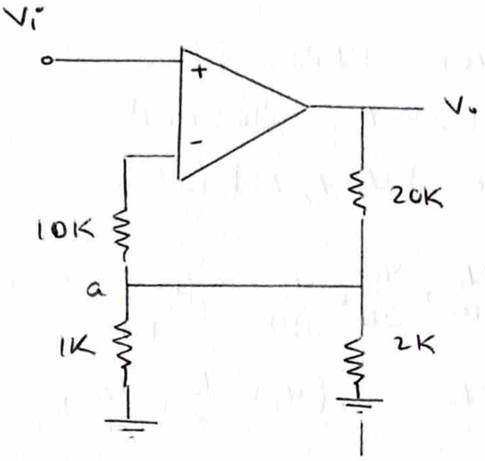
$$i = \frac{V_s-V_o}{R_2} = \frac{0.6-8.1}{1.5} = \frac{7.5}{1.5} = 5\,mA$$

(49) The Potential at node A is



From the concept of Virtual ground, Potential at A is zero.

(50) If $V_i = 1mV$ then value of V_o is



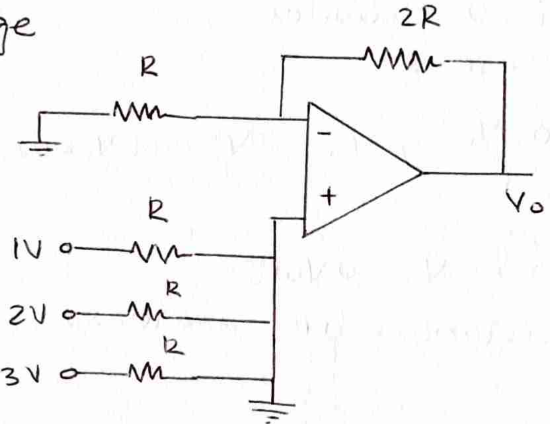
$\Rightarrow$ As no current through $10K\,\Omega$

So potential at a is V_i

Now $V_i = \dfrac{V_o \times \frac{2}{3}}{20 + \frac{2}{3}} = 1$

$\dfrac{2V_o}{62} = 1 \Rightarrow V_o = 31$ Volt

(51) Find the output voltage



$\Rightarrow$ As they are grounded potential

$V_a = 0$ Now

$\dfrac{0-0}{R} = \dfrac{0-V_o}{2R}$

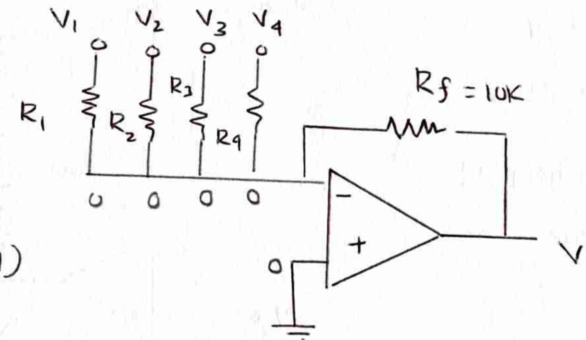
$V_o =$ 0 Volt

(52) If $R_1 = 10K\Omega$, $R_2 = 2R_1$

$R_3 = 2R_2$, $R_4 = 2R_3$ then

if $V_{ref} = 1V$ then for (0001)

V_o is equal to



$\Rightarrow \dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3} + \dfrac{V_4}{R_4} = \dfrac{0 - V_o}{R_f} \Rightarrow V_o = -R_f\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3} + \dfrac{V_4}{R_4}\right)$

$= -10K\left[\dfrac{V_1}{10} + \dfrac{V_2}{2\times10} + \dfrac{V_3}{4\times10} + \dfrac{V_4}{8\times10}\right]$

$V_{ref} = 1V$

$\Rightarrow V_o = -\left[V_1 + \dfrac{V_2}{2} + \dfrac{V_3}{2^2} + \dfrac{V_4}{2^3}\right]$

(0001) $\Rightarrow V_4 = 1$Volt

other 0Volt

$\Rightarrow V_o = -\dfrac{V_4}{8} = -\dfrac{1}{8} = -0.125V$

Case if (1101)

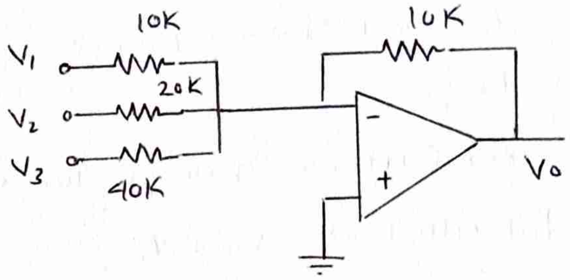
$V_o = -\left(1 + \frac{1}{2} + 0 + \frac{1}{8}\right) = 1.625$

if $V_{reff} = 2$Volt

(1011) $V_1 = 2$Volt $V_3 = 2$Volt

$V_2 = 0$Volt $V_4 = 2$Volt

(53) $V_{ref} = 1$ Volt. if $|V_o| = 1.25V$ is desired then $[V_1 V_2 V_3]$ is



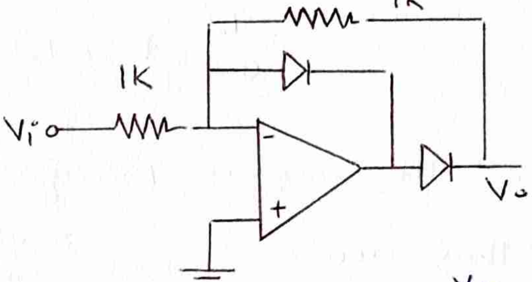
$\Rightarrow \quad \frac{V_1}{10} + \frac{V_2}{20} + \frac{V_3}{40} = \frac{0 - V_o}{10}$

or $V_o = -\left(V_1 + \frac{V_2}{2} + \frac{V_3}{4}\right) = 1.25$

So $V_1 = V_3 = 1$ Volt

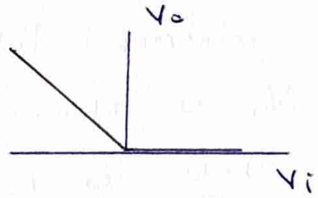
$V_2 = 0$ so $[1 0 1]$

(54) Variation of V_o and V_i



when $V_i < 0$ diodes are useless

$\frac{V_o - 0}{1} = \frac{0 - V_i}{1} \Rightarrow V_o = -V_i \quad (V_i < 0)$



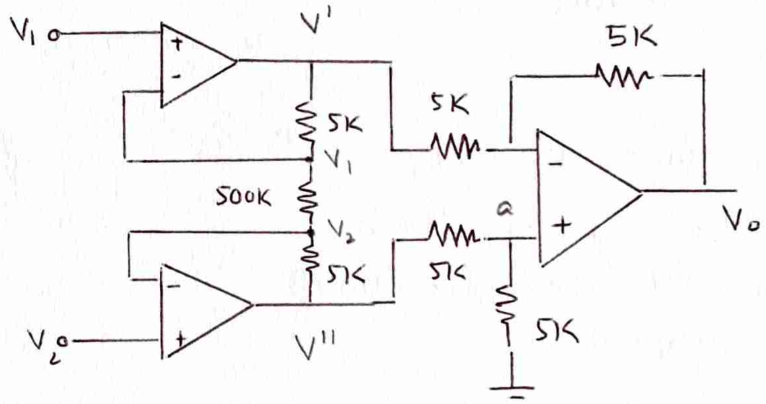
when $V_i > 0$ $V_o = 0$ Volt

(Resistances are useless)

(55) $V_1 = 2.5V$

$V_2 = 2.25V$

Find the output Voltage



$\frac{V' - V_1}{5} = \frac{V_1 - V_2}{500}$ $\qquad$ $\frac{V_1 - V_2}{500} = \frac{V_2 - V''}{5}$

$\frac{V' - 2.5}{5} = \frac{2.5 - 2.25}{500}$ $\qquad$ $\frac{2.5 - 2.25}{500} = \frac{2.25 - V''}{5}$

$V' = 2.5025 V$ $\qquad$ $V'' = -2.2475 V$

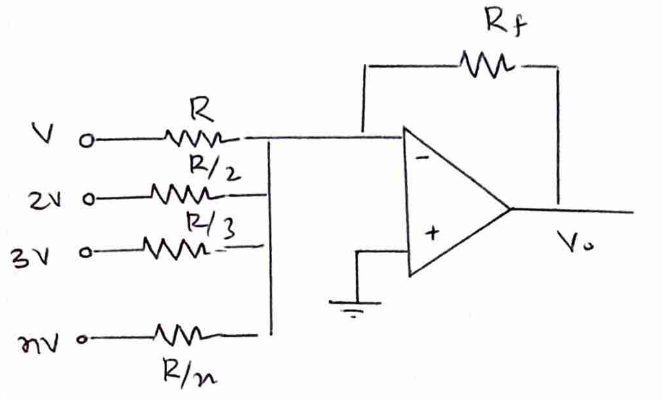
$V_a = \frac{-2.2475 \times 5}{10}$

$V_a = 1.12375$ Volt

$\frac{V' - V_a}{5} = \frac{V_a - V_o}{5} \Rightarrow 2.5025 - 2 \times (1.12375) = -V_o$

$\Rightarrow V_o = -0.255$ Volt

(56) If $V_o = -V$ the Value of R_f is



Current

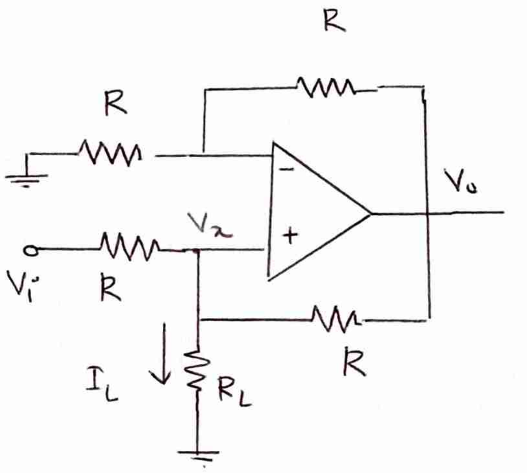
$$i = \frac{V}{R} + \frac{2V}{R/2} + \frac{3V}{R/3} + \cdots + \frac{nV}{R/n}$$

$$= \frac{V}{R}\left(1+2^2+3^2+\cdots+n^2\right) = \frac{0-V}{R_f} \quad (\text{as } V_o = -V)$$

$$R_f = \frac{R}{(1+2^2+3^2+\cdots+n^2)}$$

$$R_f = \frac{6R}{n(n+1)(2n+1)}$$

(57) Find the Value of Current I_L



$$\frac{V_x - V_i}{R} + \frac{V_x - 0}{R_L} + \frac{V_x - V_o}{R} = 0$$

$$V_x\left(\frac{1}{R} + \frac{1}{R_L} + \frac{1}{R}\right) = \frac{V_o}{R} + \frac{V_i}{R}$$

$$V_x = \frac{\left(\frac{V_o}{R} + \frac{V_i}{R}\right)}{\left(\frac{2}{R} + \frac{1}{R_L}\right)} = \frac{V_o}{2}$$

$$\frac{V_o - V_x}{R} = \frac{V_x - 0}{R} \Rightarrow V_x = \frac{V_o}{2}$$

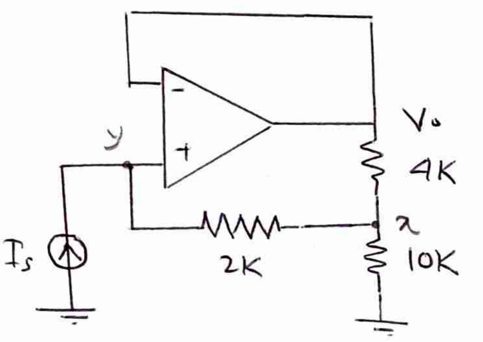
$$\frac{V_o}{R} + \frac{V_i}{R} = \frac{V_o}{R} + \frac{V_o}{2R_L}$$

$$\frac{V_i}{R} = \frac{V_o}{2R_L}$$

$$V_o = \frac{2R_L V_i}{R}$$

$$I_L = \frac{V_x}{R_L} = \frac{V_o}{2R_L} = \frac{V_i}{R}$$

(58) Find the Value $\frac{V_o}{I_s}$



$$\frac{x-y}{2} + \frac{x-y}{4} + \frac{x}{10} = 10 \Rightarrow 13x = 15y$$

$$\Rightarrow y = \frac{17}{15}x$$

$$\Rightarrow x = \frac{15}{17}y$$

$$\frac{x-y}{2} - I_s = 0$$

$$x - y = 2I_s$$

$$x - V_o = 2I_s$$

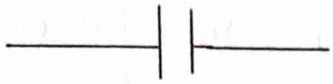
$$\left(\frac{15}{17} - 1\right)V_o = 2I_s$$

$$-\frac{2}{17}V_o = 2I_s$$

$$\frac{V_o}{I_s} = 17$$

Frequency Responses of Filter

① **Capacitor:**



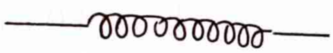
Reactance of capacitor

$X_c = \frac{1}{\omega C}$ if $\omega \to \infty$, $X_c \to 0$

$\omega \to 0$, $X_c \to$ High (DC)

In DC. Capacitor Provide high resistance, blocked DC and Passes the AC signal

② **Inductor:**



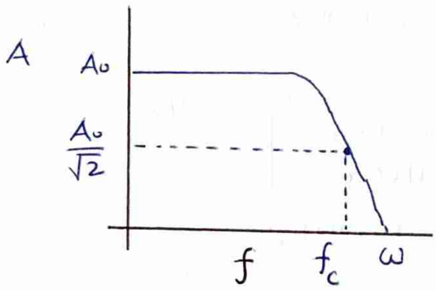
Reactance of inductor $X_L = \omega L$

For DC $\omega \to 0$, $X_L \to 0$ For AC $\omega \to \infty$, $X_L \to \infty$

Inductor block AC signals and Passes DC signals

③ **Low Pass Filters:**

Gain, $A = \frac{V_o}{V_i}$



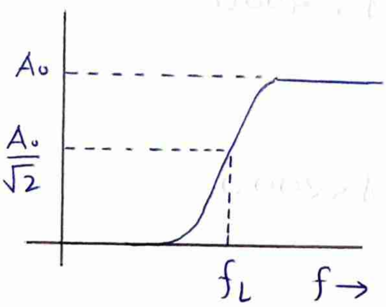
f_c is cut off frequency / Highest frequency

It Passes low frequency and block high frequency ⇒ Low Pass filters.

$f < f_c \Rightarrow$ Passes the signal

$f > f_c \Rightarrow$ Blocked the signal

④ **High Pass Filters:**



$f < f_L \Rightarrow$ Blocked the signal

$f > f_L \Rightarrow$ Passes the signal

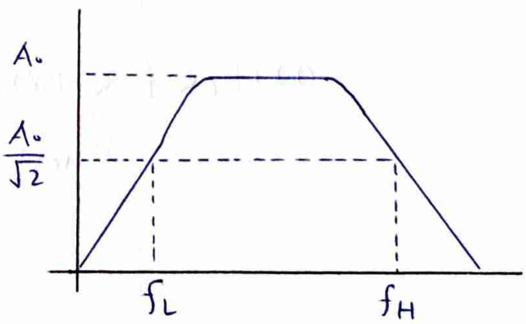
It Passes th high frequency Signals ⇒ High Pass Filters

⑤ **Band Pass Filters**

$0 < f < f_L \Rightarrow$ Blocked

$f_H < f < \infty \Rightarrow$ Blocked

$f_L < f < f_H \Rightarrow$ Passes

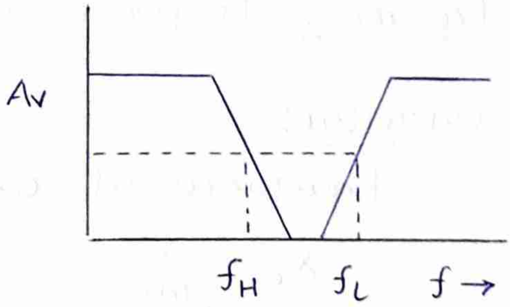


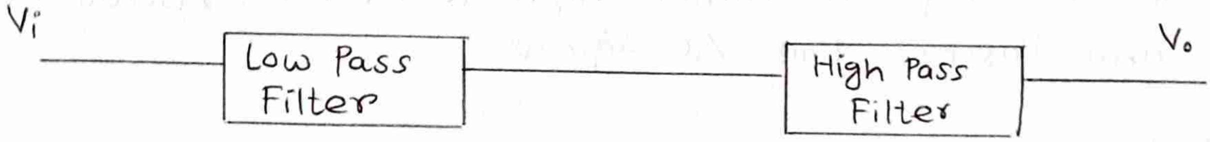
⑥ Band Reject Filter

$0 < f < f_H$ Passes

$f_L < f < \infty$ Passes

$f_H < f < f_L$ Singnal blocked

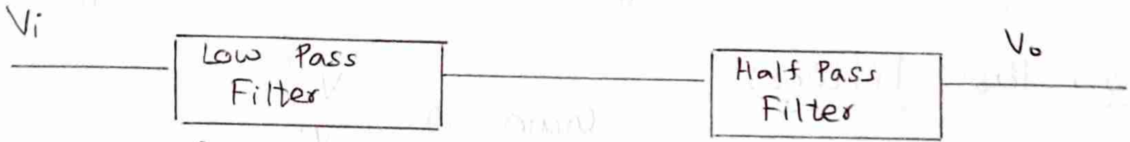




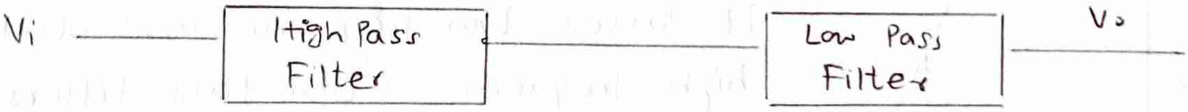
$f_H = 2000\,Hz$ $\Downarrow$ $f < 2000\,Hz$ allowed, $f > 2000\,Hz$ Blocked

$f_L = 4000\,Hz$: $f > 4000\,Hz$ pass, $f < 4000\,Hz$ Blocked

So No output will Pass => No Pass Filter



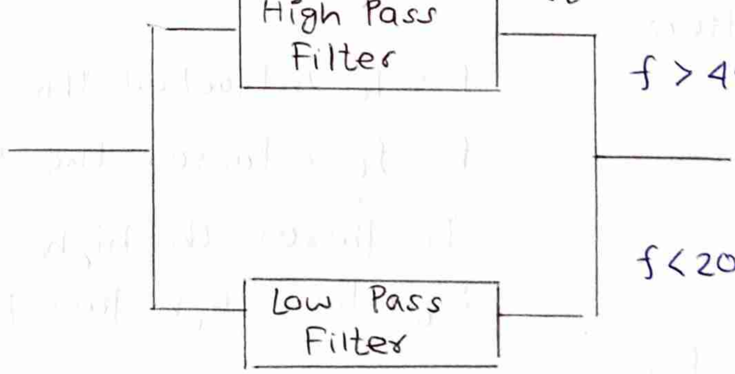
$f_H = 4000\,Hz$ $f_L = 2000\,Hz$



$f_L = 2000\,Hz$ $f_H = 4000\,Hz$

Both are Band Pass Filter.

$f_L = 4000\,Hz$



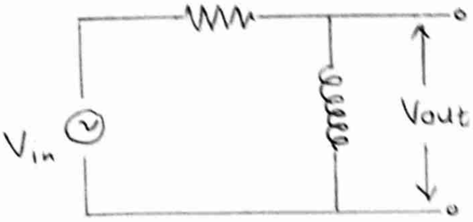
$f > 4000$

$f < 2000$

$f_H = 2000\,Hz$

$2000\,Hz < f < 4000\,Hz$ Be rejected

Band Rejecting Filter

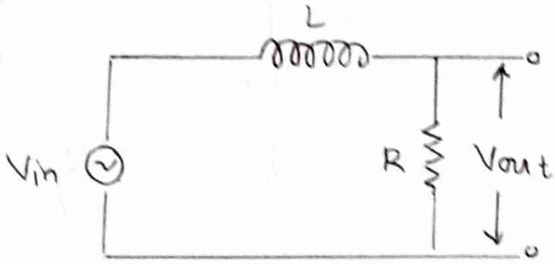


$$V_{in} = i(R + \omega L)$$

$$V_{out} = i\omega L$$

$$A = \frac{i\omega L}{(R+\omega L)i} = \frac{\omega L}{R + \omega L} = \frac{1}{1+\tau\omega}$$

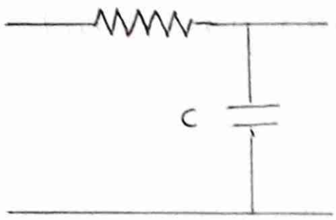
$$\frac{V_o}{V_{in}} = \frac{R}{R + j\omega L}$$

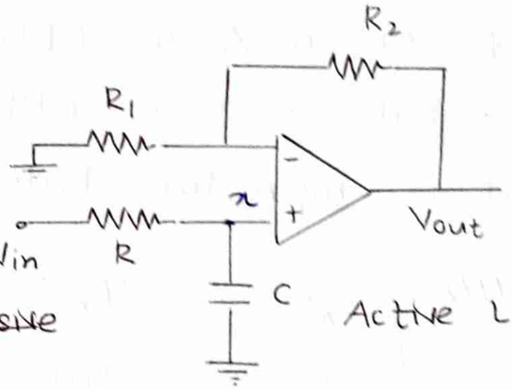


$$\frac{V_o}{V_{in}} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$$

$$A = \frac{1}{\sqrt{1+\omega^2\tau^2}}$$

Passive
~~Active~~
LPF





~~Passive~~

Active LPF

$$x = \frac{V_{in} \cdot \frac{1}{i\omega C}}{R + \frac{1}{i\omega C}} = \frac{V_{in} \cdot \frac{1}{sC}}{R + \frac{1}{sC}}$$

Here $s = i\omega$

$$x = \frac{V_{in}}{sCR + 1} = \frac{V_{in}}{1 + \omega\tau}$$

$$\frac{x - 0}{R_1} = \frac{V_o - x}{R_2}$$

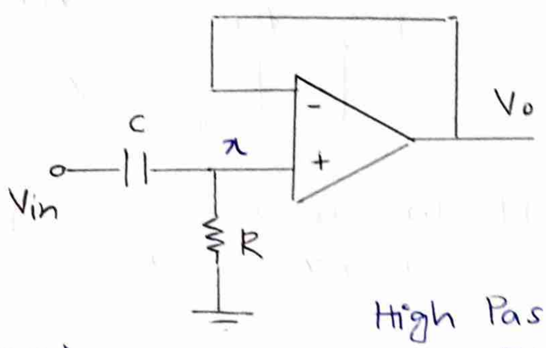
$$V_o = \left(1 + \frac{R_2}{R_1}\right) \frac{V_{in}}{(1+\omega\tau)}$$

$$\frac{V_o}{V_{in}} = \frac{(1 + R_2/R_1)}{(1 + s\tau)}$$

(Low Pass Filter)

HPF:

$$x = \frac{V_{in} \cdot R}{R + \frac{1}{\omega C}} = V_o$$



$$A = \frac{V_o}{V_{in}} = \frac{R + \frac{1}{\omega C}}{R}$$

$$A = 1 + \frac{1}{\omega CR}$$

High Pass Filters

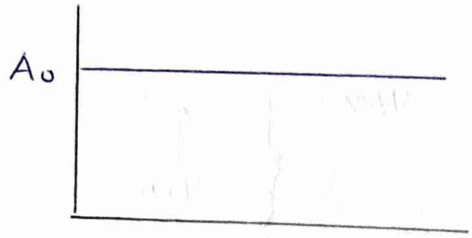
$\omega \to \infty$. $A \to 1$

only Passed High frequency

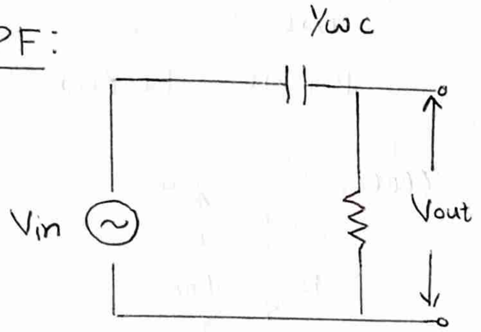
$\omega \to 0$ $A \to \infty$

⑦ All Pass Filter:

Allows are all frequency
Gain is Constant



HPF:



$V_{out} = iR$

$V_{in} = i\left(\frac{1}{\omega c} + R\right)$

$$\frac{V_o}{V_i} = \frac{R}{\frac{1}{\omega c} + R} = \frac{R\omega C}{1 + R\omega C}$$

$$\text{Gain, } A = \frac{V_o}{V_i} = \frac{R\omega C}{1 + R\omega C} = \frac{\tau\omega}{1 + \tau\omega}$$

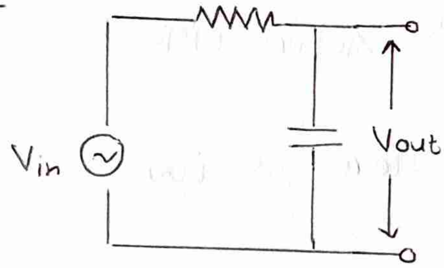
$$\boxed{A = \frac{\omega\tau}{1 + \omega\tau}}$$

If. $\omega \to 0$, $A = 0$ (Blocked low frequency)

$\omega \to \infty$ $A = 1$ (Blocked low, Pass low)

So it is high Pass Filters

LPF



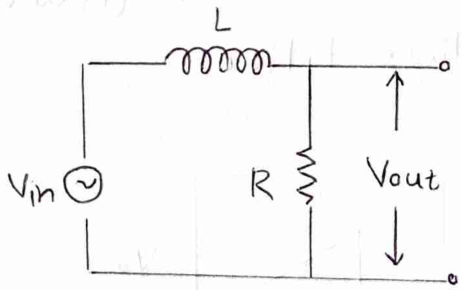
$V_{in} = i\left(R + \frac{1}{\omega c}\right)$

$V_{out} = i \cdot \frac{1}{\omega c}$

$$A = \frac{\frac{1}{\omega c}}{\frac{RC\omega + 1}{\omega c}} = \frac{1}{1 + \tau\omega}$$

$\omega \to \infty$ $A \to 0$ (Blocked High frequency)

Low Pass filters.



$V_{in} = i(R + \omega L)$

$V_{out} = iR$

$$A = \frac{iR}{iR + \omega L} = \frac{1}{1 + \frac{\omega L}{R}} = \frac{1}{1 + \omega\tau}$$

If $\omega \to 0$ $A = 1$

$\omega \to \infty$ $A = 0$

It is a low Pass Filters

LPF

$$x = \frac{V_{in} R}{R + j\omega L} = V_o$$

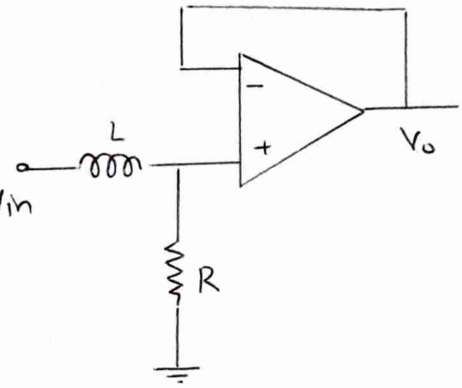
$$\frac{V_{in} R}{R + SL} = V_o$$

$$A = \frac{V_o}{V_{in}} = \frac{1}{1 + \tau s}$$

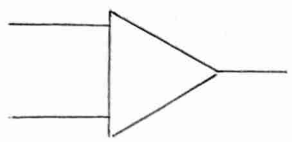
$S \to 0 \quad A = 1$

$S \to \infty \quad A = 0$

Active Low Pass Filter



Slew Rate:



Rate of change of output Voltage with time is Called slew rate

output lags with input

(time 10^{-6} sec)

Number System

Binary to decimal & Decimal to Binary

$(713)_{10} = (1011001001)_2$

2	713	1
2	356	0
2	178	0
2	89	1
2	44	0
2	22	0
2	11	1
2	5	1
2	2	0
	1	

Now 1 0 1 1 0 0 1 0 0 1

$\rightarrow 1\times2^0 = 1$

$\rightarrow 0$

$\rightarrow 0$

$\rightarrow 1\times2^3 = 8$

$\rightarrow 1\times2^6 = 64$

$\rightarrow 1\times2^7 = 128$

$\rightarrow 1\times2^9 = 512$

By adding them. we get $(713)_{10}$

Octal System

$(01234567)_8$

$(713)_{10} = (1311)_8$

8	713	1
8	89	1
8	11	3
	1	

1 3 1 1

$1\times8^0 = 1$

$1\times8^1 = 8$

$3\times8^2 = 192$

$1\times8^3 = 512$

By adding them $(713)_{10}$

Hexadecimal

$(0\ 1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9\ A\ B\ C\ D\ E\ F)_{16}$

$(713)_{10} = (2C9)_{16}$

Binary of $(713)_{10}$

$(0010\ 1100\ 1001)_2$

16	713	9
16	44	12
	2	

① If $7_n \times 8_n = (38)_n$ then the Value of n is

$\Rightarrow$

$(7)_n = 7\times n^0 = 7$

$(8)_n = 8\times n^0 = 8$

$(7)_n \times (8)_n = 7\times8 = 56$

38

$\hookrightarrow 8\times n^0 = 8$

$\hookrightarrow 3\times n^1 = 3n$

$56 = 3n + 8$

$3n = 48$

$n = 16$

② The binary no of $(2^{11}-1)$ is

$\Rightarrow$ $(0111\ \ 1111\ \ 1111)_2$

$2^1-1=1 \quad 1$

$2^2-1=3 \quad 11$

$2^3-1=7 \quad 111$

③ $(21)_3=\sqrt{(100)_x}$ the Value of x is

$\Rightarrow$ $(21)_3 = (2\times3^1)+(1\times3^0) = 6+1=7$

$49=(100)_x \Rightarrow x=7$

④ Binary equivalent of 9.625

$\Rightarrow$ $(9)_{10}=(1001)_2$

$0.625\times2 = 1.250$

$0.250\times2 = 0.500$

$0.500\times2 = 1.000$

$0.000\times2 = 0.$

$(9.625)_{10}=(1001.101)_2$

⑤ The octal equivalent of $(49.5)_{10}$ is

$\Rightarrow$

$0.5\times8=4.0$

$(49.5)_{10}=(61.4)_8$

$$\begin{array}{c|c|c} 8 & 49 & 1 \\ \hline & 6 & \end{array}$$

⑥ If $(211)_x=(152)_8$ the Value of x is

$\Rightarrow$

211

$\rightarrow 1\times x^0=1$

$\rightarrow 1\times x = x$

$\rightarrow 2\times x^2=2x^2$

152

$\rightarrow 2\times8^0=2$

$\rightarrow 5\times8^1=40$

$\rightarrow 1\times8^2=64$

$(152)_8=(106)_{10}$

$(211)_x=(2x^2+x+1)_{10}$

$2x^2+x+1=106$

$2x^2+x-105=0$

$x=\dfrac{-1\pm\sqrt{1+840}}{2\times2}=\dfrac{-1+\sqrt{840+1}}{2\times2}$

$=\dfrac{28}{4}=7.$

7. In a particular no system a cubic equation $x^3+bx^2+cx-190=0$ has roots $x=5$, $x=8$ and $x=9$ on a base of 10. The base of the number system is

$\Rightarrow$

product of roots $= -\frac{d}{a}$

sum of roots $= \frac{c}{a}$

$5 \times 8 \times 9 = (190)_r$

or $360 = r^2 + 9r$

or $r^2 + 9r - 360 = 0$

or $r^2 + 24r - 15r - 360 = 0$

$r(r+24) - 15(r+24) = 0$

or $(r+24)(r-15) = 0$

$r = -24, 15$

$r = 15$ Base of the system is 15

8. Consider the equation $(43)_x = (y3)_8$ the no of possible solution is

$\Rightarrow$

$(43)_x = (4x+3)$ $\quad (y3)_8 = 3 + 8y$

$8y + 3 = 4x + 3 \Rightarrow x = 2y$ $\quad (43)_x \Rightarrow x > 4$

$(y3)_8 \Rightarrow y < 8$

$x > 4$	$y < 8$	
2	1	(No)
4	2	(No)
6	3	(yes)
8	4	(yes)
10	5	(yes)
12	6	(yes)
14	7	(yes)

Their are 5 possible solutions

9. Given $\sqrt{41} = 5$ is correct in at least one no system is the base of the no

$\Rightarrow$

$(41)_r = (5 \times 5)_r$

$4r + 1 = 25$

$4r = 24$

$r = 6$

Base of the no system is 6

(10) $(-64)_{10} + (64)_8 = (x)_{10}$ the value of x is

$\Rightarrow$ $-64 + (48+4) = x \Rightarrow x = -12$

(11) Value of $\sqrt{(121)_r} = (11)_r$ Value of r is

$\Rightarrow$ $(121)_r = (11)_r (11)_r$ So the value doest depend on r.

$r^2 + 2r + 1 = (r+1)^2$ Any value greater than 2

(12) $(123)_5 = (x8)_y$. x and y are unknown possible value of solution are

$\Rightarrow$

$25 + 10 + 3 = xy + 8$

$xy = 30$ $y > x$

$y > 8$

x	y
3	10
2	15
1	30

Three value is possible

(13) The no N of base r is represented as $(N)_r$

$(10)_{16}^3 = (X)_{10}^2$ The value of x is

$\Rightarrow$ $(10)_{16}^3 = [1\times16^1 + 0\times16^0]^3 = 16^3$ $X^2 = 16^3$

$(X)_{10}^2 = [X\times10^0]^2 = X^2$ $X = 64$

(14) $(125)_R = (203)_5$. The value of R is

$\Rightarrow$ $(125)_R = R^2 + 2R + 5$ $(203)_5 = 50+0+3 = 53$

$R^2 + 2R + 5 = 53$ $R^2 + 8R - 6R - 48 = 0$

$R^2 + 2R - 48 = 0$ $R(R+8) - 6(R+8) = 0 \Rightarrow R = 6$

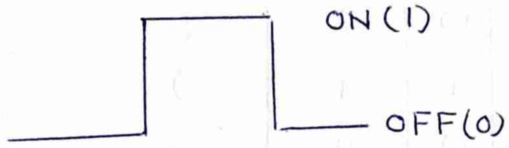
(15) Find the value of b $\frac{(54)_b}{(4)_b} = (13)_b$

$\frac{5b+4}{4} = b+3 \Rightarrow 5b+4 = 4b+12$

$\Rightarrow b = 8$

Digital Electronics

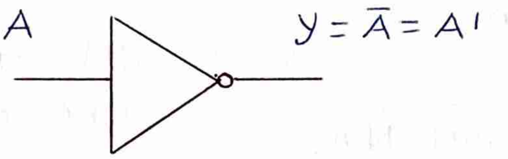
Based on digital signal

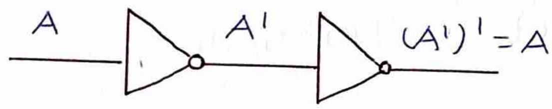


Logic Gates

① NOT Gate:

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



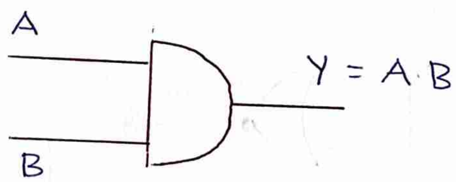


(It has single input)

$(\bar{\bar{A}}) = A$

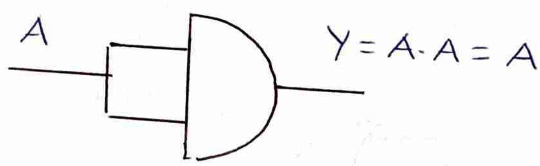
② AND Gate:

A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1



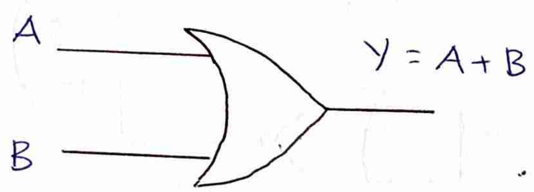
If any of input is low, output will be low.

A	A	$Y = A \cdot A$
0	0	0
1	1	1

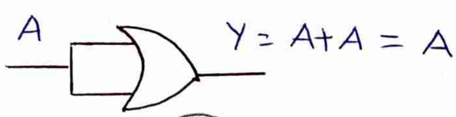


③ OR Gate:

A	B	$Y = A+B$
0	0	0
0	1	1
1	0	1
1	1	1

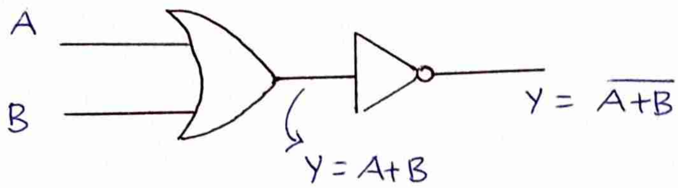


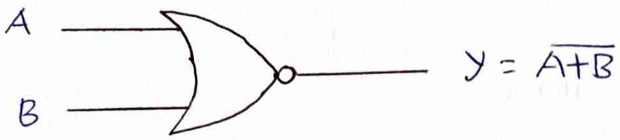
If any input is high, the output will be high.



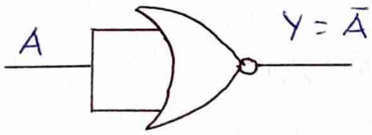
④ NOR Gate:

A	B	A+B	$Y = \overline{A+B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

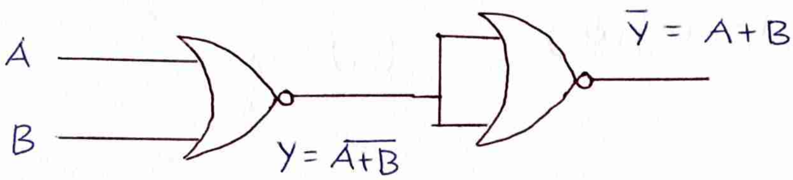




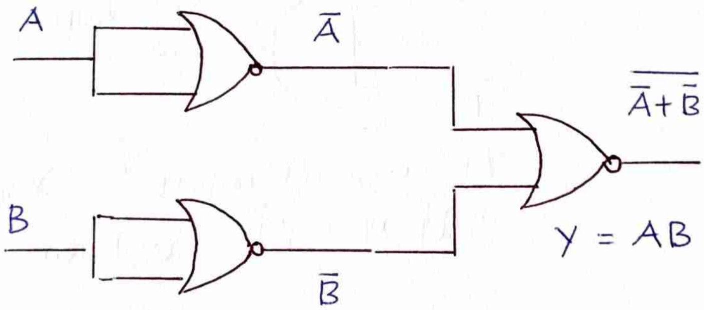
If any of the input is high the output will be low



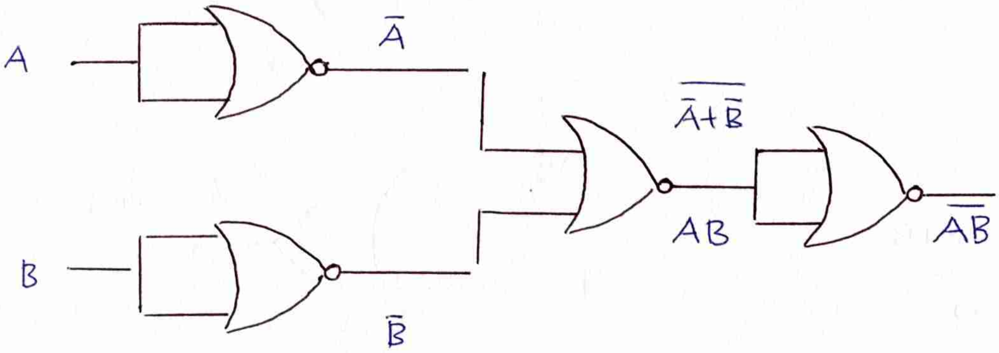
For same input NOR act as NOT Gate.



OR Gate by using NOR Gate



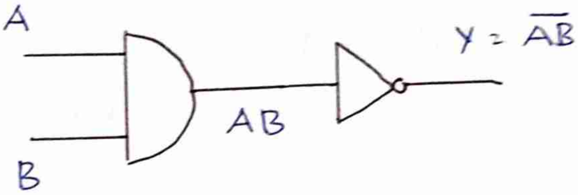
AND Gate by using NOR Gate

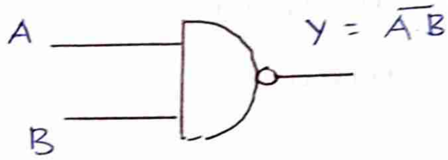


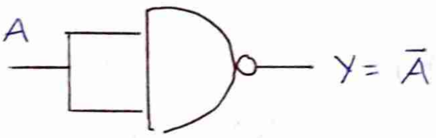
NAND Gate by using NOR Gate

⑤ NAND Gate

A	B	AB	$\overline{AB}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

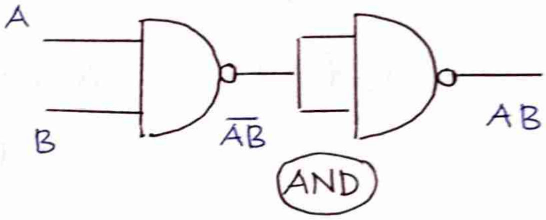




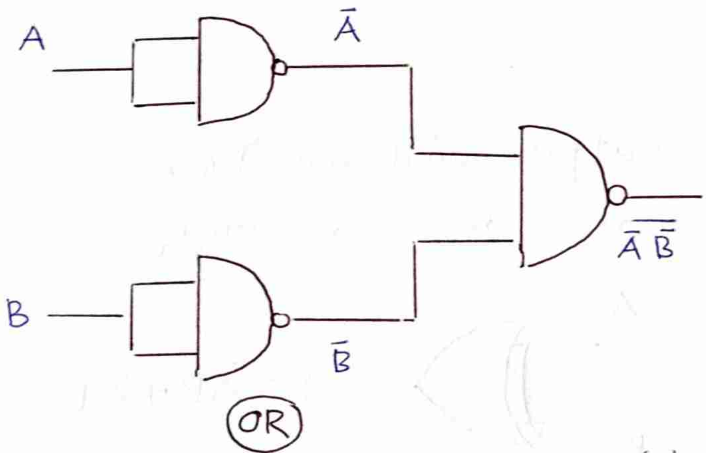


NOT by NAND Gate

If any of the input is low output will be high



AND by NAND



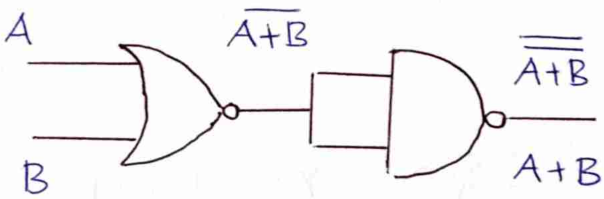
OR Gate by using NAND Gate.

$A+B = \overline{\bar{A}\,\bar{B}}$

$A \cdot B = \overline{\bar{A}+\bar{B}}$

(De-Morgan's Law)

(Break the line & change the sign)



The logic circuit is equivalent to OR Gate

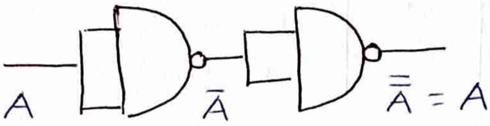
② To design $A + A\bar{B} + A\bar{B}C$ what should be the minimum number is required

$\Rightarrow$

$$A + A\bar{B} + A\bar{B}C$$

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

So 2 NAND Gate is required:



③ $y = \overline{(X \cdot \bar{Y}) + (\bar{X} \cdot Y)}$ is equivalent to

$X\bar{X} = 0$

$Y\bar{Y} = 0$

$\Rightarrow$

$$= \overline{(X \cdot \bar{Y})}\ \overline{(\bar{X} \cdot Y)}$$

$$= (\bar{X} + Y)(X + \bar{Y}) = \bar{X}X + \bar{X}\bar{Y} + XY + Y\bar{Y}$$

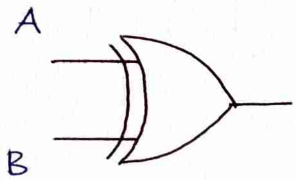
$$= XY + \bar{X}\bar{Y}$$

⑥ Ex-OR Gate

If no of 1 are even output will be low

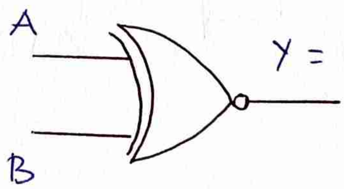
1 are odd " " " High

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



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

⑦ Ex-NOR Gate



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

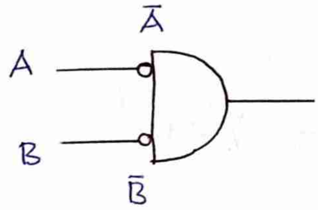
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

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

If no of 1 = even: output = 1

1 = odd: output = 0

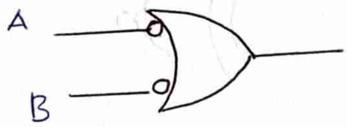
⑦ Bubbled AND Gate



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

(NOR Gate)

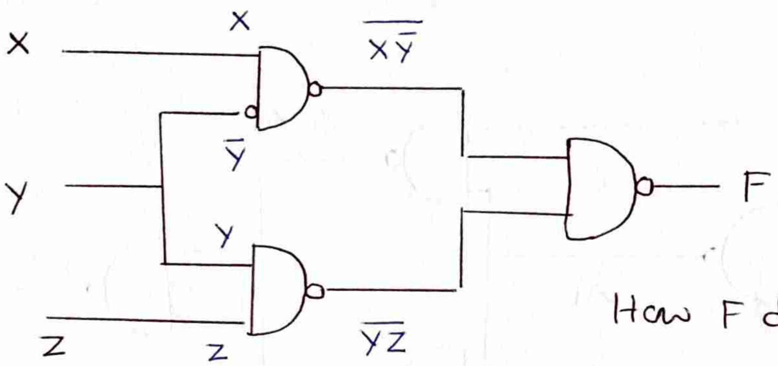
⑧ Bubbled OR Gate



$Y = \bar{A} + \bar{B} = \overline{AB}$

(NAND Gate)

Q



How F depends on XYZ

$F = \overline{\overline{YZ}\cdot\overline{X\bar{Y}}} = \overline{\overline{YZ}} + \overline{\overline{X\bar{Y}}} = YZ + X\bar{Y}$

(they all dependent)

Q $(X \oplus Y) \oplus XY$

$= (X\bar{Y} + \bar{X}Y) \oplus XY$

$= (X\bar{Y} + \bar{X}Y)\cdot\overline{XY} + \overline{(X\bar{Y} + \bar{X}Y)}\, XY$

$= (X\bar{Y} + \bar{X}Y)(\bar{X} + \bar{Y}) + (\overline{X\bar{Y}})(\overline{\bar{X}Y})\, XY$

$= X\bar{Y} + \bar{X}Y + (\bar{X} + Y)(X + \bar{Y})XY$

$= X\bar{Y} + \bar{X}Y + (\bar{X}\bar{Y} + XY)XY$

$= X\bar{Y} + \bar{X}Y + XY$

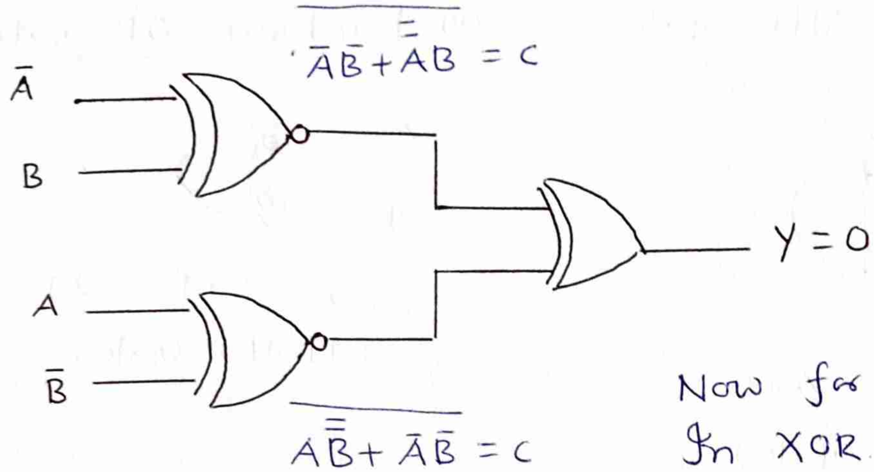
$= X\bar{Y} + Y(X + \bar{X}) = X\bar{Y} + Y = (Y + X)(Y + \bar{Y}) = (X + Y)$

⊛ $(A+B)(A+C)$

$= A + AC + AB + BC = A(1 + C + B) + BC = A + BC$

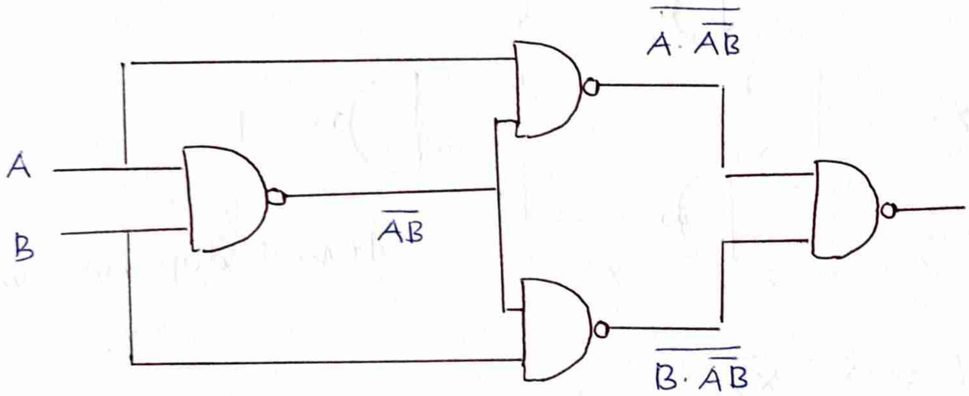
So. $(A+B)(A+C) = A + BC$

(4)



Now for same input In XOR output will became zero

(5)



$$Y = \overline{\overline{A\cdot\overline{AB}}\cdot\overline{B\cdot\overline{AB}}} = \overline{\overline{A\cdot\overline{AB}}} + \overline{\overline{B\,\overline{AB}}}$$

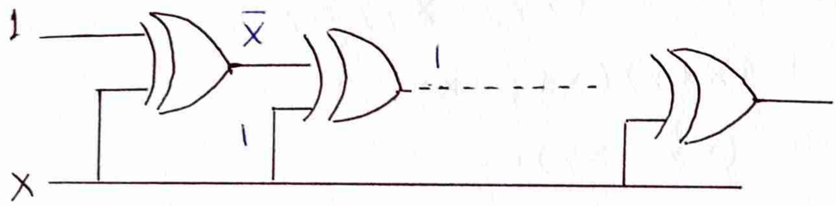
$$= A\cdot\overline{AB} + B\cdot\overline{AB}$$

$$= A(\bar{A}+\bar{B}) + B(\bar{A}+\bar{B})$$

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

(We can constract any gate by NAND/NOR so universal gate.)

(6)



20 XOR gate

$X\bar{1} + 1\bar{X} = \bar{X}$

$\bar{X}\bar{X} + XX$
$= X + \bar{X} = 1$

20 is even number
In 2nd $Y = 1$ at 20 $Y = 1$ (also)

Karnaugh Map

Bar means 0

$\bar{A} = \bar{B} = \bar{C} = 0$

① 3 Input K Map

A	B	C	Y	
0	0	0	0	0
0	0	1	1	1
0	1	0	1	2
0	1	1	1	3
1	0	0	0	4
1	0	1	1	5
1	1	0	1	6
1	1	1	1	7

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	0	1: 1	3: 1	2: 1
A	4	5: 1	7: 1	6: 1

OR

Both are possible

oct → quard → Pair (Prefrence)

	$\bar{C}$	C
$\bar{A}\bar{B}$	0	1: 1
$\bar{A}B$	2: 1	3: 1
AB	6: 1	7: 1
$A\bar{B}$	4	5: 1

② 4 Input K Map

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	0	1	3	2
$\bar{A}B$	4	5	7	6
AB	12	13	15	14
$A\bar{B}$	8	9	11	10

> Remove what changes and take which does't change there

A, B changes but C not

> A, C change but B not

$Y = C + B$

So K-Map is Verified Here. (using SOP Method)

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

Q $Y = A\bar{B}\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}CD + \bar{A}BCD + A\bar{B}\bar{C}D$

⇒

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$		1	1	
$\bar{A}B$		1	1	
AB				
$A\bar{B}$	1	1		

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

we can get the same result by using SOP Method.

Q. $\bar{A}BC + \bar{A}\bar{B}C + AB\bar{C} + A\bar{B}\bar{C}$ is Equivalent to

⇒

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1	1	
A	1			1

$Y = \bar{A}C + A\bar{C}$

$Y = A \oplus C$

Q. $AB + ABC + \bar{A}B + A\bar{B}C$ is equivalent to

⇒ $AB(C+\bar{C}) + ABC + \bar{A}B(C+\bar{C}) + A\bar{B}C$

$= ABC + AB\bar{C} + ABC + \bar{A}BC + \bar{A}B\bar{C} + A\bar{B}C$

$= ABC + AB\bar{C} + \bar{A}B\bar{C} + A\bar{B}C$

$= AC(B+\bar{B}) + B\bar{C}(A+\bar{A})$

$= AC + B\bar{C}$

Q. $ABC + \bar{A}BC + A\bar{B}C + \bar{A}B\bar{C} + \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C}$

⇒

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	1	1
A		1	1	

$Y = \bar{A} + C$

$= (\bar{A}+C)(C+\bar{C})$

$= \bar{A}\bar{C} + C$

Q The Boolean expression $Y = \overline{PQ}R + Q\bar{R} + \bar{P}QR + PQR$ Simplifies to (JAM 2022)

⇒ $Y = (\bar{P}+\bar{Q})R + (P+\bar{P})Q\bar{R} + \bar{P}QR + PQR$

$Y = \bar{P}R + \bar{Q}R + PQ\bar{R} + \bar{P}Q\bar{R} + \bar{P}QR + PQR$

$Y = \bar{P}(Q+\bar{Q})R + (P+\bar{P})\bar{Q}R + PQ\bar{R} + \bar{P}Q\bar{R} + \bar{P}QR + PQR$

$Y = \bar{P}QR + \bar{P}\bar{Q}R + P\bar{Q}R + \bar{P}\bar{Q}R + PQ\bar{R} + \bar{P}Q\bar{R} + \bar{P}QR + PQR$

	$\bar{Q}\bar{R}$	$\bar{Q}R$	QR	$Q\bar{R}$
$\bar{P}$		1	1	1
P		1	1	1

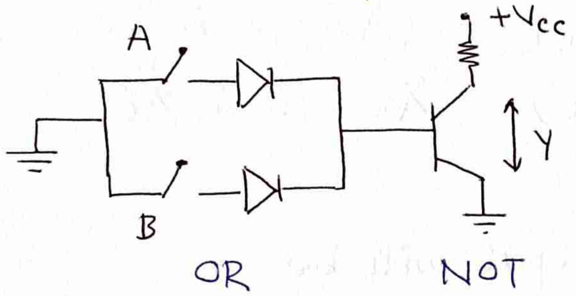
$Y = Q + R$

Q Simplify $F = (X+Y)(X+\bar{Y}) + \overline{(\bar{X}\bar{Y})+\bar{Y}}$

$\Rightarrow$ $F = X + Y\bar{Y} + (\overline{\bar{X}\bar{Y}})\bar{\bar{X}}$

$= X + (X+Y)X = X + XX + XY = X + X + XY$

$= X(1+Y) = X$

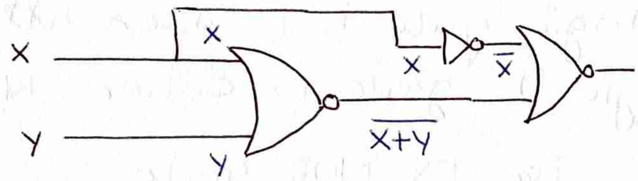
Q. 

Boolean relation at the output stage is

NOR Gate

$Y = \overline{A+B} = \bar{A}\cdot\bar{B}$

Q. This gate is equivalent to

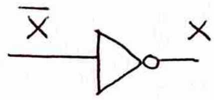


$Y = \overline{\bar{X} + \overline{X+Y}}$

$Y = \bar{\bar{X}} \cdot \overline{\overline{X+Y}} = X(X+Y)$

$Y = XX + XY = X(1+Y)$

$Y = X$



Q The dual of $\bar{A}B + A\bar{B}$ is

$\Rightarrow$

DUAL Means
+ replaced by ·
· replaced by +

$\bar{A}B + A\bar{B}$

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

$= A\bar{A} + \bar{A}\bar{B} + AB + B\bar{B} = \bar{A}\bar{B} + AB$

Q The dual of $AB + BC + AC$ is

$\Rightarrow$ $(A+B)(B+C)(A+C)$

$= (AB + AC + BB + BC)(A+C)$

$= (AB + AC + BC)(A+C)$

$= \{B(A+C) + AC\}(A+C)$

$(B + AC)(A+C)$

$AB + BC + AAC + CAC$

$AB + BC + AC + AC$

$= AB + BC + AC$

So it is self dual

Q check wheather

$\bar{A}\bar{B}+\bar{B}\bar{C}+\bar{A}\bar{C}$ is self dual or not

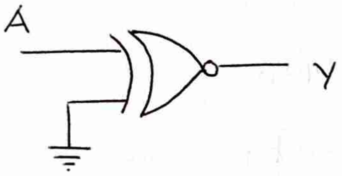
$\Rightarrow$ $(\bar{A}+\bar{B})(\bar{B}+\bar{C})(\bar{A}+\bar{C})$ Yes it is self dual

$= (\bar{B}+\bar{A}\bar{C})(\bar{A}+\bar{C})$

$= \bar{B}\bar{A}+\bar{B}\bar{C}+\bar{A}\bar{A}\bar{C}+\bar{A}\bar{C}\bar{C}$ $(\bar{A}\bar{A}=\bar{A}$ & $\bar{C}\bar{C}=\bar{C})$

$= \bar{B}\bar{A}+\bar{B}\bar{C}+\bar{C}\bar{A}(\bar{A}+\bar{C}) = \bar{A}\bar{B}+\bar{B}\bar{C}+\bar{A}\bar{C}$

Q



The output will be

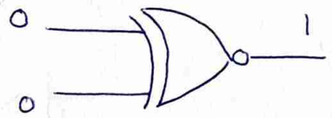
$Y = \overline{A\oplus B} = \overline{A\bar{B}+\bar{A}B}$

$A = A$
$B = 0$

$= \overline{A\bar{0}+\bar{A}0} = \overline{A1} = \bar{A}$

Q The output of a logic gate is 1 when all its inputs are at logic 0. gate is either NOR/EX-NOR

$\Rightarrow$



For EX-NOR Gate

$Y = \overline{A\bar{B}+\bar{A}B} = \bar{0} = 1$

Q $Z = PQ + PQR + PQRS + PQRST + PQRSTU$ then $\bar{Z}$ is

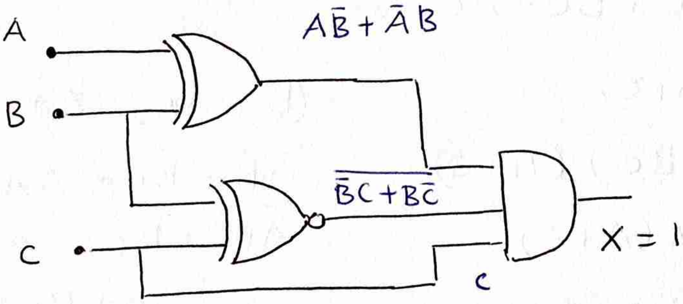
$\Rightarrow$ $Z = PQ + PQR + PQRS + PQRST(1+U)$

$= PQ + PQR + PQRS(1+T)$ $\bar{Z} = \overline{PQ} = \bar{P}+\bar{Q}$

$= PQ + PQR + PQRS$

$= PQ + PQR(1+S) = PQ + PQR = PQ$

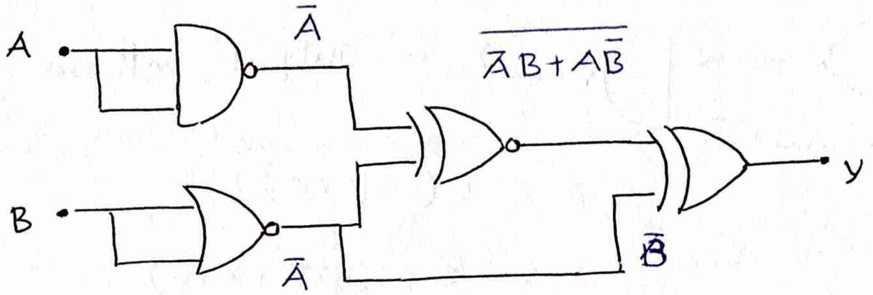
Q.



$A = 1$
$B = 0$
$C = 1$

$Y = (A\bar{B}+\bar{A}B)(\overline{\bar{B}C+B\bar{C}})C$

Q



A	B	y
0	1	y_1
1	1	y_2

Value of y_1 and y_2 is

$y_1 = 0$

$y_2 = 1$

Q Simplify $ABC + \bar{A}BC + A\bar{B}C + \bar{A}B\bar{C} + \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C}$

=>

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	1	1
A		1	1	

$Y = \bar{A} + C$

Also $C + \bar{A}\bar{C} = (C + \bar{C})(C + \bar{A})$

$C(A + \bar{A}) + \bar{A}\bar{C}$

$CA + C\bar{A} + \bar{A}\bar{C}$

$Y = \bar{A} + C$ $\quad Y = C + \bar{A}\bar{C}$

Q Equivalent in SOP for K Map

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$		1	1	
$\bar{A}B$	1			1
AB	1			1
$A\bar{B}$		1	1	

$Y = \bar{B}D + B\bar{D}$

$Y = B \oplus D$

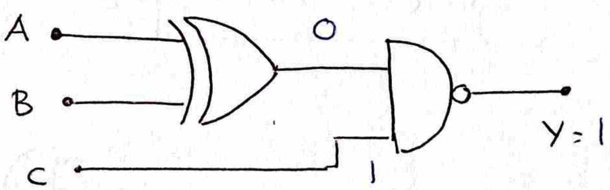
Q The minimal boolean Expression is

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1			1
A	1			1

$Y = \bar{C}$

Q If $A = B = C = 1$

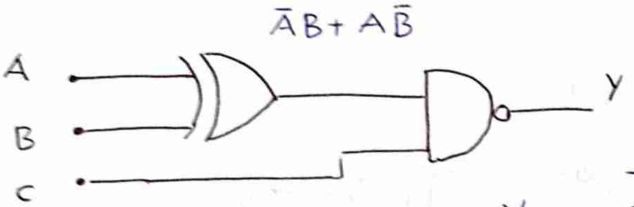
then $Y = ?$



=> $Y = 1$

/1

Q



output will be

$$Y = \overline{C(\bar{A}B + A\bar{B})}$$

$$Y = \bar{C} + (\overline{\bar{A}B + A\bar{B}})$$

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

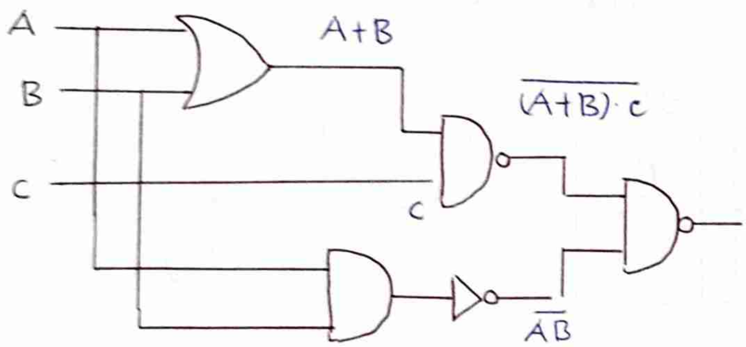
$$Y = \bar{C} + (A+\bar{B})(\bar{A}+B)$$

$$Y = \bar{C} + AB + \bar{A}\bar{B}$$

$$Y = \bar{A}\bar{B} + AB + \bar{C}$$

output

Q The output will be



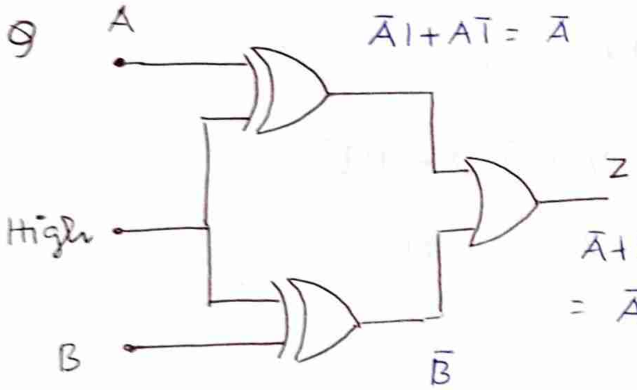
$$Y = \overline{(A+B)\cdot C \cdot \overline{AB}}$$

$$Y = \overline{(A+B)C} + AB$$

$$Y = \overline{(A+B)} + \bar{C} + AB$$

$$Y = \bar{A}\bar{B} + \bar{C} + AB$$

Q



Q $P + \bar{P}Q$ represents

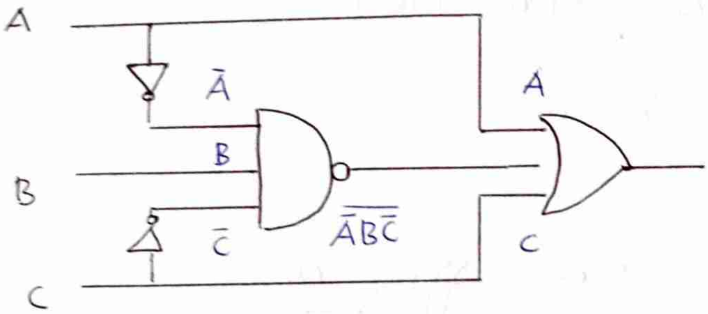
$\Rightarrow$ $P + \bar{P}Q$

$$= (P+\bar{P})(P+Q)$$

$$= P+Q$$

(OR Gate)

Q



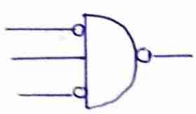
The Circuit is Equivalent to

$$Y = A + \overline{\bar{A}B\bar{C}} + C$$

$$= A + (\bar{\bar{A}} + \bar{B} + \bar{\bar{C}}) + C$$

$$= A + (A + C + \bar{B}) + C$$

$$= A + \bar{B} + C$$



(Equivalent gate)

Don't Care Condition

Here we take a truth table

A	B	C	Y
0	0	0	0
0	0	1	X 0
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	X 1
1	1	0	0
1	1	1	0

Now from Karnaugh Map

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		X	1	1
A	1	X		

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

We can use x pair with 1 but if 1 engaged then no pair between x and 1

Q Find the Simplified form of

$$y = \sum(0,2,4,5,8,10) + \sum_d (6,12,13)$$

$\sum_d$ means don't Care

⇒ $Y = \bar{C}B + \bar{C}\bar{D} + \bar{B}\bar{D} + \bar{A}\bar{D}$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1 (0)	(1)	(3)	1 (2)
$\bar{A}B$	1 (4)	1 (5)	(7)	X (6)
AB	X (12)	X (13)	(15)	(14)
$A\bar{B}$	1 (8)	(9)	(11)	1 (10)

Folding of Corner also Gives Squard Here All element of $\bar{C}\bar{D}$ Engangeд

So $Y = \bar{C}B + \bar{B}\bar{D} + \bar{A}\bar{D}$

Q Expression for 3 input Ex-OR Gate

⇒

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

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1		1
A	1		1	

$Y = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

(check the TT)

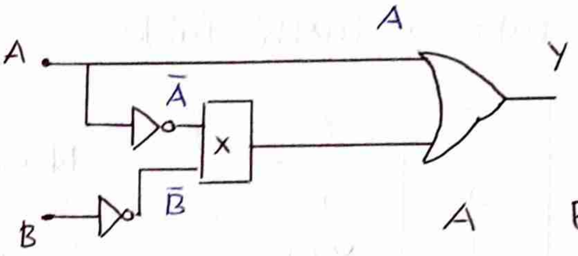
① Simplify

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	X	X	1	X
AB		1	1	
$A\bar{B}$		1	1	

$Y = CD + AD$

$Y = D(A+C)$

② unknown gate should be XOR or NAND



$\bar{A}$	$\bar{B}$	X
1	1	0
1	0	1
0	1	X
0	0	X
(C)	(D)	

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

	$\bar{D}$	D
$\bar{C}$	X	X
C	1	

$Y = \bar{D} = B$

③ Find the simplified form

$$f = \sum 5,7,8,10,13,15 + \sum_d (0,1,2)$$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	X	X		X
$\bar{A}B$		1	1	
AB		1	1	
$A\bar{B}$	1			1

$\Rightarrow f = BD + \bar{D}\bar{B}$

④ Simplify $Y = ABC + \bar{A}BC + A\bar{B}C + \bar{A}B\bar{C} + \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C}$

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	1	1
A		1	1	

$Y = \bar{A} + C$

$C + \bar{A}\bar{C} = (C + \bar{A})(C + \bar{C}) = \bar{A} + C$

⑤

A	B	C	Y
			1
			0
			1
			1
			1
			0

Find Y.

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 (0)	(1)	1 (3)	1 (2)
A	1 (4)	(5)	X (7)	X (6)

$Y = B + \bar{C}$

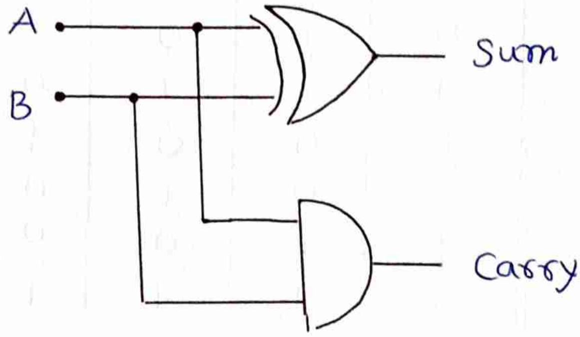
① Half Adder

By this adder we can add 2 bit

A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

$S = \bar{A}B + A\bar{B} = A \oplus B$

$C = AB$



Sum: Ex-OR Gate

Carry: AND Gate

② Full Adder

A	B	C	S	C'
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1		1
A	1		1	

$$S = A\bar{B}\bar{C} + \bar{A}\bar{B}C + ABC + \bar{A}B\bar{C}$$

$$= \bar{C}(\bar{A}B + A\bar{B}) + C(AB + \bar{A}\bar{B})$$

$$= \bar{C}(A \oplus B) + C(\overline{A \oplus B})$$

$$= (A \oplus B) \oplus C$$

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$			1	
A		1	1	1

$$C' = AC + BC + AB$$

③ Half Substractor

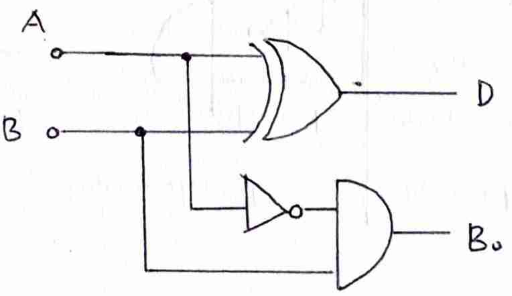
By the electronic device we substract 2 single bit

A	B	B_o	D
0	0	0	0
0	1	0	1
1	0	1	1
1	1	0	0

$D = A\bar{B} + \bar{A}B$

$= A \oplus B$

$B_o = \bar{A}B$



④ Full Substractor

INPUT			OUTPUT	
A	B	Bin	D	BOUT
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

$$D = \bar{A}\bar{B}B_{in} + \bar{A}B\bar{B}_{in} + A\bar{B}\bar{B}_{in} + ABB_{in}$$

$$= (\bar{A}\bar{B} + AB)B_{in} + (\bar{A}B + A\bar{B})\bar{B}_{in}$$

$$= (\overline{A \oplus B})B_{in} + (A \oplus B)\bar{B}_{in}$$

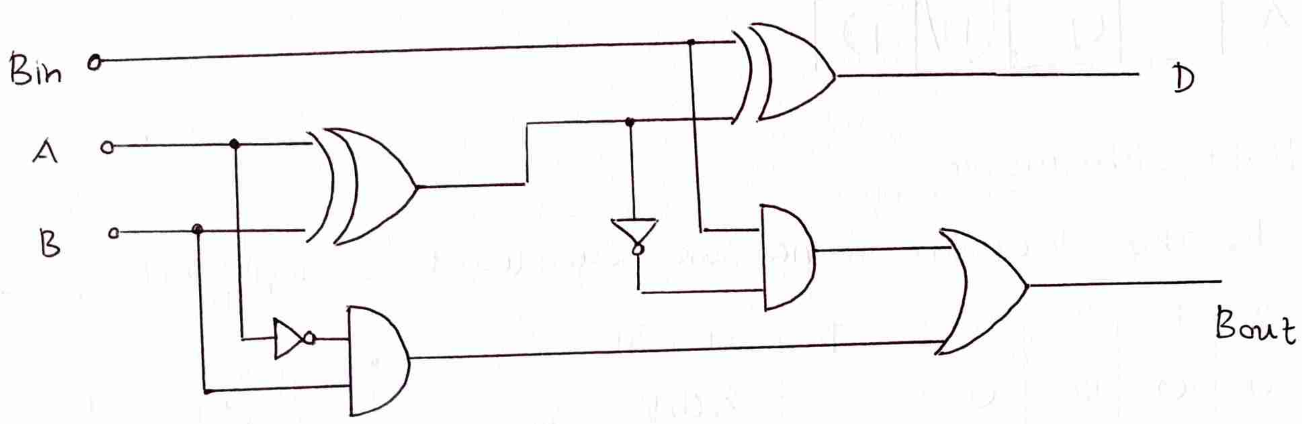
$$= (A \oplus B)\ B_{in}$$

$$B_{out} = \bar{A}\bar{B}B_{in} + \bar{A}B\bar{B}_{in} + \bar{A}BB_{in} + ABB_{in}$$

$$= (\bar{A}\bar{B} + AB)B_{in} + \bar{A}B(B_{in} + \bar{B}_{in})$$

$$= (\overline{A \oplus B})B_{in} + \bar{A}B$$

The logic circuit can be designed by using two Half Substractor.



① Crystal Structure

There are 3 states of matter —

	Solid	Liquid	Gas
Intermolecular Force	Strong	Intermediate	Weak
Moleculer distance	Very less	Intermediate	Most

> Some characteristics of Solid:

(a) They have definite mass, volume and density
(b) Intermolecular distances are short
(c) Intermolecular forces are strong
(d) They are incompressible and rigid have fixed Positions

Solid

Crystaline Solid	Amorphous Solid
(a) Regular shape	(a) Regular shape
(b) Sharp MP, BP	(b) Range of MP & BP
(c) Definite heat of fusion	(c) They have not it
(d) Anisotrophic in nature	(d) Isotrophic in nature
(e) They are True Solids	(e) Pseudo Solids

> Unit Cell:

Smallest unit that repeats itself to form a Crystal is called unit cell

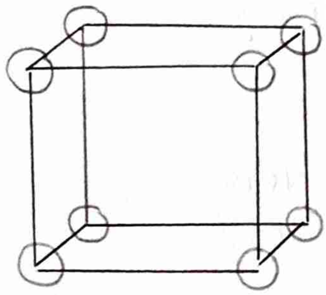
> Lattice Points: Imaginary Points in Space

Types of unit cells:

① Primitive unit cell (Atoms are at Corners only) Simple Cubic

② Non Primitive cell (FCC, BCC, ECC)

(a) Simple Cubic unit Cell



> 8 atoms at Corners
> Contribution of each atom in the unit cell is 1/8
> No of atom = $8 \times \frac{1}{8} = 1$ $N_{eff} = 1$
> Co-ordination no is 6

Actually the atom touch each other
$a = 2r$

> Nearest neighbour distance = a
Second nearest distance = $\sqrt{2}a$

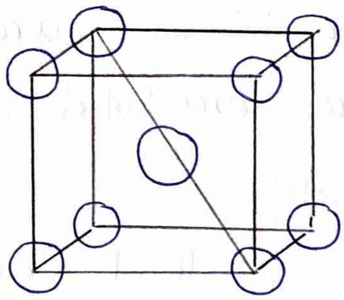
> Volume of unit cell is a^3
of atom is $1 \times \frac{4}{3}\pi r^3$ $a = 2r$

$$\% \text{ Packing fraction} = \frac{\text{Volume of atom}}{\text{Volume of unit cell}} \times 100$$

$$= \frac{1 \times \frac{4}{3}\pi r^3}{a^3} \times 100 = 52.3\%$$

> Void fraction = (100 - 52.3) = 47.6%

(b) Body Centred Cubic



> 8 atoms at Corners $(8 \times \frac{1}{8} = 1)$
> 1 atom at centre
> $N_{eff} = 2$
> Nearest Neighbour distance $\frac{\sqrt{3}}{2}a$
> Second Nearest is a
> Coordination no is 8

Here $2r = \frac{\sqrt{3}}{2}a$

$r = \frac{\sqrt{3}}{4}a$

Packing fraction

$$= \frac{2 \times \frac{4}{3}\pi r^3}{a^3}$$

$$= \frac{8}{3} \times \pi \times \frac{3\sqrt{3}}{64} = 68\%$$

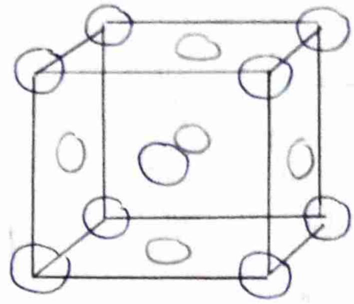
Void fraction = 32%

(c) Face Centred Cubic Cell

> At Corner $8 \times \frac{1}{8} = 1$

Face Centre $6 \times \frac{1}{2} = 3$

> $N_{eff} = 1 + 3 = 4$



> Nearest Neighbour distance $\frac{a}{\sqrt{2}}$

$2r = a/\sqrt{2}$

> Second nearest is a

> Coordination number $CN = 4 + 4 + 4 = 12$

> Packing fraction =

$$\frac{N_{eff} \times \frac{4}{3}\pi r^3}{a^3} \times 100 = 74\%$$

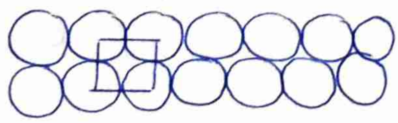
> Void fraction = 100 - 74 = 26%

② closed Packing:

(a) 1D closed Packing

(b) 2D closed Packing

Square closed Packing



AAA Type

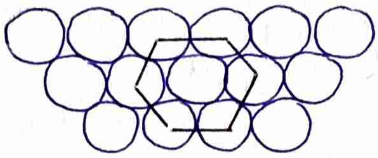
$2r = a$

$Z_{eff} = \frac{1}{4} \times 4 = 1$

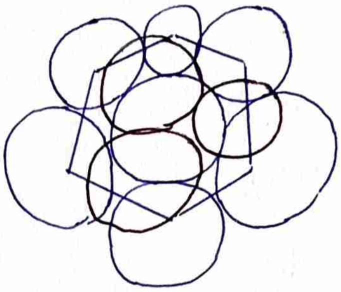
Coordination No is 4

$$Pf = \frac{\pi R^2}{a^2} = \frac{\pi}{4} \times 100 = 78.5\%$$

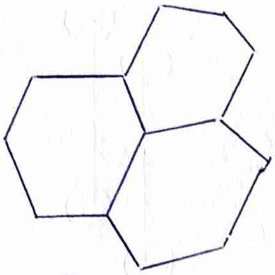
Hexagonal closed Packing



HCP in 3D

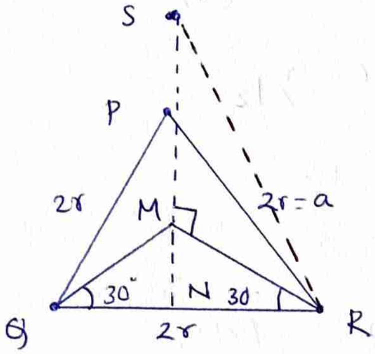


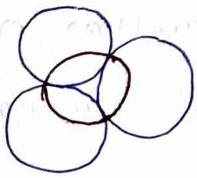
ABAB layering



$N_{eff} = (12\times\frac{1}{6})+(\frac{1}{2}\times 2)+3 = 2+1+3 = 6$

Here also, $a = 2r$





S is centre of Black atom

P, Q, R is for white atoms

M is centre of Void PQR

$\triangle MNR$, $NR = \frac{a}{2}$

$\cos 30 = \frac{a/2}{MR} \Rightarrow MR = \frac{a}{2}\times\frac{2}{\sqrt{3}} = \frac{a}{\sqrt{3}}$

$\Rightarrow MR = \frac{a}{\sqrt{3}}$

From $\triangle SMR$

$SR = a$, $MR = a/\sqrt{3}$

$SM = \sqrt{(SR)^2-(MR)^2}$

$\frac{c}{2} = \sqrt{a^2-\frac{a^2}{3}} = \sqrt{\frac{2}{3}}\,a$

$c = \sqrt{\frac{8}{3}}\,a$

Volume of unit cell

= Area ~~Volume~~ of hexagon × height

$= 6\times\frac{\sqrt{3}}{4}a^2\times c$

$$\text{Packing fraction} = \frac{N\times \text{Volume of atom}}{\text{Volume of unit cell}} = \frac{6\times\frac{4}{3}\pi r^3}{\frac{6\sqrt{3}}{4}\times(2r)^2+(\sqrt{\frac{2}{3}}\times 4r)}$$

$= 74\%$

① An ionic compound has a unit cell consisting of A ions at the corners of a cube and B ions on the centres of the faces of the cube. The emperical formula is

$\Rightarrow$ $A = 8 \times \frac{1}{8} = 1$ Emperical formula is AB_3

$B = 6 \times \frac{1}{2} = 3$

② A diatomic molecule X_2 has a bcc structure with a cell edge of 300pm. The density of the molecule is 6.17 g/cm³. The number of molecule in 200 g of X_2 is

$\Rightarrow$ $$\rho = \frac{W N_{eff}}{a^3 N_A} \Rightarrow 6.17 \times 10^3 = \frac{W \times 2 \times 10^{-3}}{(300 \times 10^{-12})^3 N_A} \Rightarrow W = 50$$

In 50 g $\rightarrow$ N_A

200 g $\rightarrow$ $4N_A$

③ At 373K Copper has FCC unit cell structure with cell edge of x Å. The approximate density of Cu is

$\Rightarrow$ $$\rho = \frac{W N_{eff}}{a^3 N_A} = \frac{4 \times 63.5}{(x \times 10^{-8})^3 N_A} = \frac{422}{x^3}$$

④ Nearest neighbour distance in Na crystal is 1.83 Å. Density of electrons in Na crystal

$\Rightarrow$ Na is BCC

Nearest neighbour distance

$$\frac{\sqrt{3}}{2} a = 1.83 \times 10^{-10} \Rightarrow a = 2.11 \times 10^{-10} m$$

$$\text{Density of atom} = \frac{\text{No of atom}}{\text{Volume}} = \frac{2}{(2.11 \times 10^{-10})^3} = 2.12 \times 10^{29} /m$$

⑤ Consider 2 types of space lattice. SC & FCC. Ratio of nearest neighbour distance

$\Rightarrow$ $1 : \frac{1}{\sqrt{2}}$

Miller Indices

① Take intercepts (3a 2b 6c)

② Remove Constant (3 2 6)

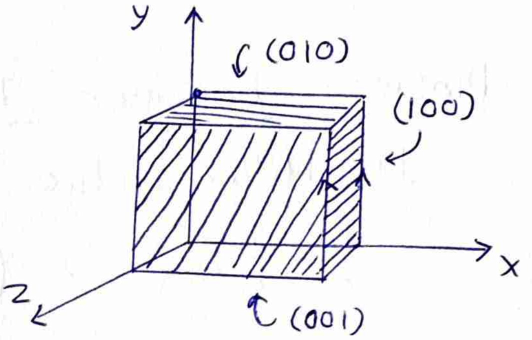
③ Reciprocate $\left(\frac{1}{3}\ \frac{1}{2}\ \frac{1}{6}\right)$

④ LCM Multiplied $\left(\frac{1}{3}\times 6\ \ \frac{1}{2}\times 6\ \ \frac{1}{6}\times 6\right)$

Miller indices of (3a 2b 6c) is [2 3 1]

> If intercepts are $(a\ \infty\ \infty)$

the Miller indices (1 0 0)

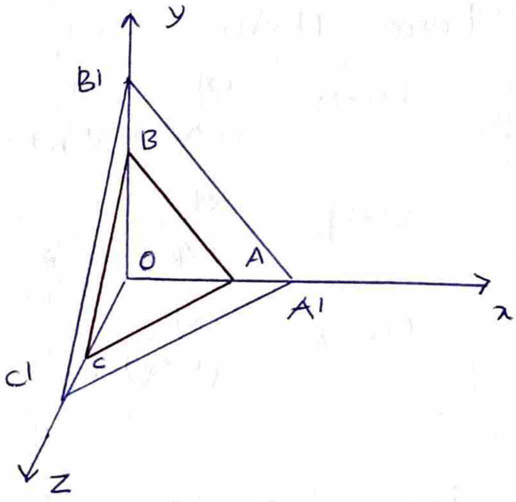


Law of Rational Indices

If OA = a OA' = na

OB = b OB' = mb

OC = c OC' = Ka



The features of Miller indices -

① Represent direction of a plane

② It won't be infinite ever

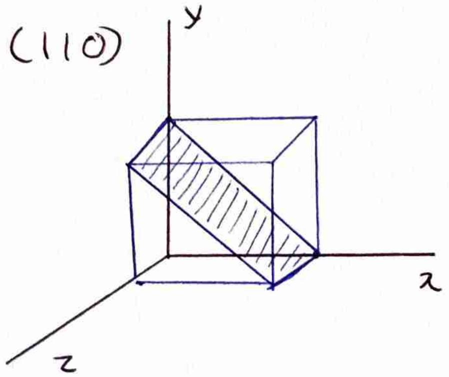
③ Only integral Value.

④ Plane is never Considered to be Passing through origin

⑤ Receprocal of intercepts.

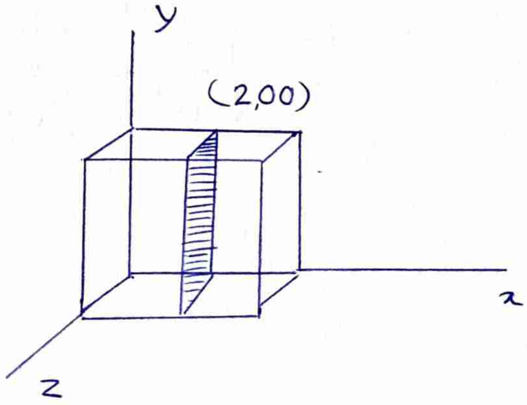
> For (2a, 3b, 5c) ⟹ 2 3 5 ⟹ $\frac{1}{2}\ \frac{1}{3}\ \frac{1}{5}$ ⟹ (15 10 6)

> (110)



> (200)

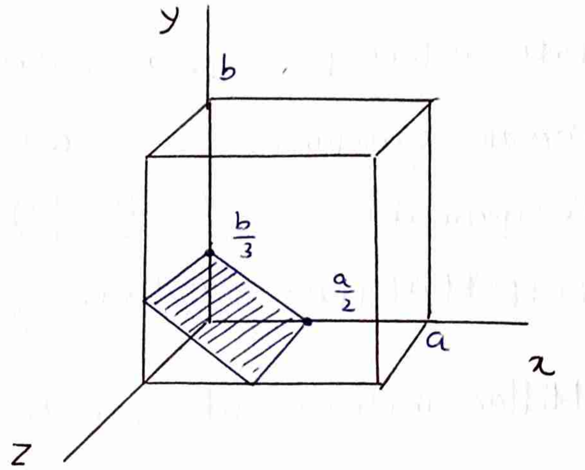
$\left(\frac{1}{2}\ \infty\ \infty\right)$



MI of 2 3 0

$(\frac{1}{2}, \frac{1}{3}, \infty)$

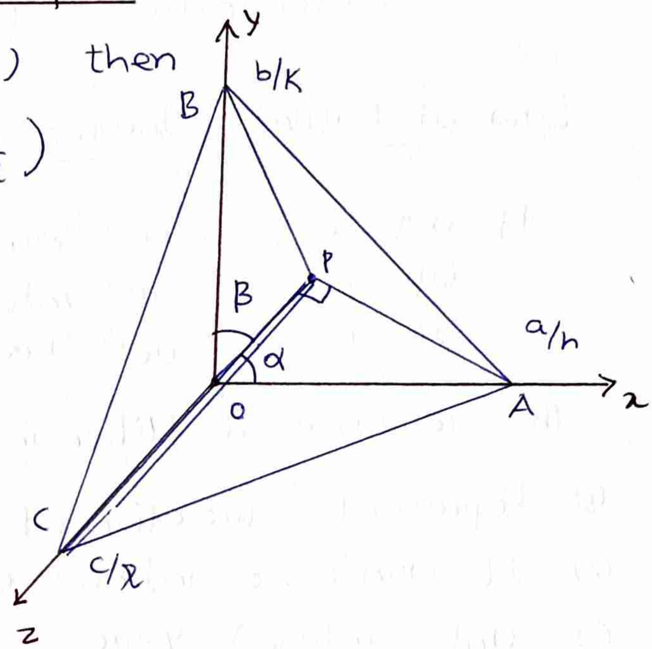
$(\frac{a}{2}, \frac{b}{3}, \infty)$



Distance between Interplanner space:

If Miller indices are $(h\ k\ l)$ then

$\frac{1}{h}, \frac{1}{k}, \frac{1}{l} \Rightarrow \left(\frac{a}{h}\ \frac{b}{k}\ \frac{c}{l}\right)$



From $\triangle PAO$

$$\cos\alpha = \frac{OP}{OA} = \frac{d}{(a/h)}$$

$$\cos\beta = \frac{d}{(b/k)}$$

$$\cos\gamma = \frac{d}{(c/l)}$$

From the law of direction cosine we have

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

$$\frac{d^2}{(a/h)^2} + \frac{d^2}{(b/k)^2} + \frac{d^2}{(c/l)^2} = 1$$

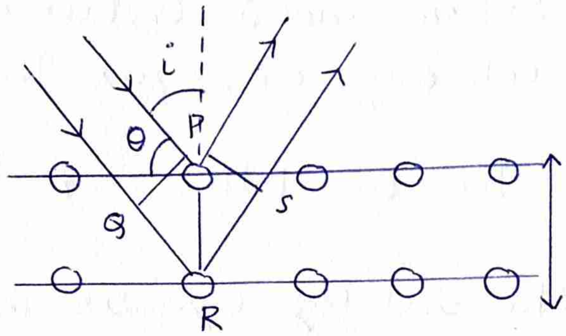
$$d = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$$

So distance between interplanner plane

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$$

> For cubic: $a = b = c$ $\quad d_{hkl} = \dfrac{a}{\sqrt{h^2+k^2+l^2}}$

X-ray Diffraction / Bragg's Law

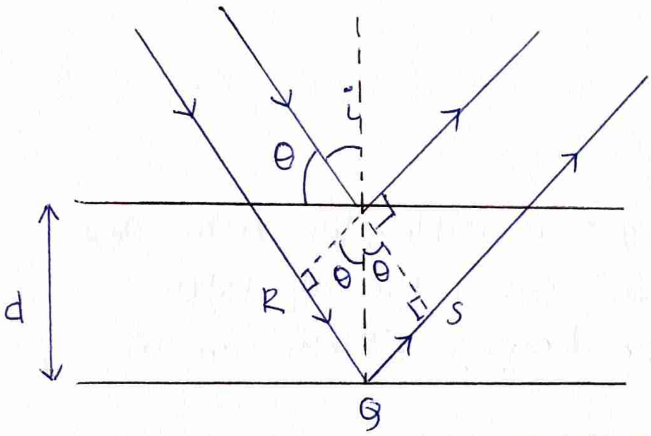


Constructive interference will be form if the Path difference. $\Delta = n\lambda$

$$\Delta = QR + RS = n\lambda$$

θ is Glancing angle
i is incident angle

$$\theta + i = \pi/2$$



Path difference. $\Delta x = RQ + QS$

$$RQ = d\sin\theta$$

$$QS = d\sin\theta$$

$$2d\sin\theta = n\lambda \rightarrow \text{Bragg's law}$$

$$n\lambda = 2d_{hkl}\sin\theta$$

For Cubic Crystal, $d_{hkl} = \dfrac{a}{\sqrt{h^2+k^2+l^2}}$

$$n\lambda = \frac{2a}{\sqrt{h^2+k^2+l^2}}\sin\theta$$

n is the order of diffraction
d is interference spacing

(If order is not mention take n=1)

① Bragg's angles for the first and second order reflection by a Crystal are θ_1 and θ_2 respectively $\frac{\sin\theta_1}{\sin\theta_2}$ is

$\Rightarrow$ $2d\sin\theta = n\lambda \Rightarrow \sin\theta \propto n$

$\Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{1}{2}$

② Sodium metal Crytallizes in a BCC lattice with a unit cell edge of 3.29Å. The radius of Sodium atom

$\Rightarrow$ For BCC lattice $r = \frac{\sqrt{3}}{4}a = \frac{\sqrt{3}}{4} \times 3.29 = 1.42\text{Å}$

③ Na and Mg Crystalize in BCC and FCC type crystal. then the number of atoms of Na and Mg present -

$\Rightarrow$ For BCC, $N_{eff} = 2$

FCC $N_{eff} = 4$

④ An X-ray beam of wavelength 1.54 Å is diffracted from the (100) planes of a Solid with a Cubic lattice of lattice Constant 3.08Å. The first order Bragg diffraction at -

$\Rightarrow$ $2d\sin\theta = n\lambda$

$n\lambda = \frac{2a\sin\theta}{\sqrt{h^2+k^2+l^2}}$

$\lambda = \frac{2\times 3.08\sin\theta}{\sqrt{1}}$

$2\times 3.08\sin\theta = 1.54 \Rightarrow \theta = \sin^{-1}\left(\frac{1}{4}\right)$

⑤ 0.71 Å wavelength of X-ray is diffracted with Simple Cubic Crystal having $a = 2.814$ Å for plane (110) then

$\Rightarrow$ $2d\sin\theta = n\lambda$

$\frac{2a\sin\theta}{\sqrt{h^2+k^2+l^2}} = n\lambda$

$\frac{2\times 2.814\times\sin\theta}{\sqrt{1+1+0}} = 0.71$

$\sin\theta = \frac{\sqrt{2}\times 0.71}{2.814}$

$\theta = \sin^{-1}(0.357)$

Simple Cubic: Reflection through every plane is possible like (100) (010) (210) (200) ...

BCC: Reflection is possible if $h+K+l$ = Even

(100) ✗ (110) ✓ (111) ✗ (210) ✗

FCC: They shold be unmixed

(0 is consider as even)

All odd ✓

All even ✓

(100) ✗ (201) ✗

(101) ✗ (200) ✓

(h, K, l) should be unmixed.

⑥ Consider a monoatomic FCC solid with lattice constant $\sqrt{3}$ Å. which of the following is correct ($\lambda = 1$ Å)

$$\Rightarrow \frac{2a\sin\theta}{\sqrt{h^2+K^2+l^2}} = n\lambda \Rightarrow \frac{2\sqrt{3}\sin\theta}{\sqrt{1+1+1}} = 1 \qquad (111)$$

$$\Rightarrow \sin\theta = \frac{1}{2} \Rightarrow \theta = \frac{\pi}{6}$$

Interplaner distance $d = \frac{a}{\sqrt{h^2+K^2+l^2}} = \frac{\sqrt{3}}{\sqrt{3}} = 1$ Å

⑦ For a single Cubic Lattice $d_{100} : d_{110} : d_{111}$ is

$$\Rightarrow \frac{a}{\sqrt{1+0+0}} : \frac{a}{\sqrt{1+1+0}} : \frac{a}{\sqrt{1+1+1}}$$

$$a : \frac{a}{\sqrt{2}} : \frac{a}{\sqrt{3}} \Rightarrow \sqrt{6} : \sqrt{3} : \sqrt{2}$$

(8) In a powder diffraction pattern recorded from a FCC Sample using X-ray. The first peak appears at 30°. The second peak will appear at angle

=) For FCC. first peak at (111)

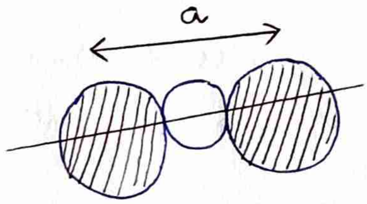
Second peak at (200)

$$\frac{2a\sin\theta_1}{\sqrt{h^2+k^2+l^2}} = n\lambda \Rightarrow \frac{\sin 30}{\sqrt{2+1}} = \lambda \Rightarrow \lambda = \frac{2a}{2\sqrt{3}} \Rightarrow \lambda = \frac{a}{\sqrt{3}}$$

$$\lambda = 2 \cdot \frac{a}{\sqrt{4}} \times \sin\theta = \frac{a}{\sqrt{3}} \Rightarrow \theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$$

(9) The maximum radius of the interstitial sphere that can just fit into the void between the body centred atom of BCC structure is

=)



$$4R = \sqrt{3}a$$

$$R = \frac{\sqrt{3}}{4}a$$

$$2R + 2r = a$$

$$\Rightarrow r = \frac{a-2R}{2} = \frac{a}{2} - 2\frac{\sqrt{3}}{4}a = \frac{a}{2} - \frac{\sqrt{3}a}{4}$$

$$r = \frac{a}{2}\left(1 - \frac{\sqrt{3}}{2}\right)$$

(10) The Cube FCC (200) has a lattice Constant 2.814 Å, $\lambda = 0.710$ Å. The glancing angle corresponding to second order reflection

=)

$$\frac{2a\sin\theta}{\sqrt{h^2+k^2+l^2}} = n\lambda$$

$$\frac{2 \times 2.814 \times \sin\theta}{2} = 2\lambda$$

$$2.814\sin\theta = 2 \times 0.710$$

$$\sin\theta = \frac{1}{2}$$

$$\theta = 30°$$

(11) The Miler indices of a plane passing through the three points having (001) (1,0,0) & (0.5, 0.5, 0.25) are

$\Rightarrow$ Equation of plane
$$\begin{vmatrix} x-x_1 & y-y_1 & z-z_1 \\ x_2-x_1 & y_2-y_1 & z_2-z_1 \\ x_3-x_1 & y_3-y_1 & z_3-z_1 \end{vmatrix}$$

$$\Rightarrow \begin{vmatrix} x & y & z-1 \\ 1 & 0 & -1 \\ 0.5 & 0.5 & -0.75 \end{vmatrix} \Rightarrow x(0+0.5)+y(-0.5+0.75)+(z-1)(0.5)$$

$$\Rightarrow \frac{x}{2}+\frac{y}{4}+\frac{z}{2}=\frac{1}{2} \Rightarrow 2x+y+2z=2$$

$$\Rightarrow \frac{x}{1}+\frac{y}{2}+\frac{z}{1}=1$$

Intercepts $\quad 1 \quad 2 \quad 1$

$\frac{1}{1} \quad \frac{1}{2} \quad \frac{1}{1}$

$2 \quad 1 \quad 2$

Miler indices are (212)

(12) X-ray of wavelength $\lambda = a$ is reflected from the (111) plane of a Simple Cubic lattice. If the lattice constant is a, Braggs angle will be

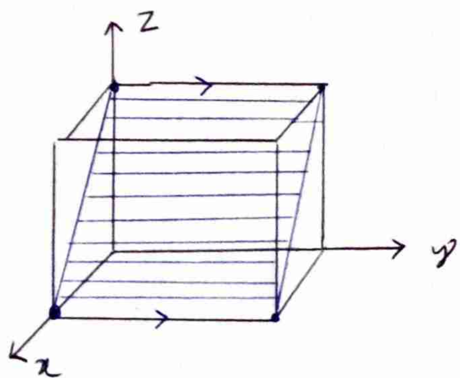
$$\Rightarrow \frac{2a\sin\theta}{\sqrt{h^2+k^2+l^2}} = n\lambda \Rightarrow \frac{2a\sin\theta}{\sqrt{3}} = a \Rightarrow \theta = \sin^{-1}\left(\frac{\sqrt{3}}{2}\right) = \frac{\pi}{3}$$

(13) Consider X-ray diffraction from a Crystal with a FCC. The lattice plane for no diffraction peak is

$\Rightarrow$ (212) $\Rightarrow$ Mixutre of odd & even $\Rightarrow$ No diffraction peak

(14) Crystallographic plane represent (101) miler indices

$a=\frac{1}{1}=1$, $b=\frac{1}{0}=\infty$ $\quad c=\frac{1}{1}=1$



From Bragg's law, $n\lambda = \frac{2a \sin\theta}{\sqrt{h^2+k^2+l^2}}$

Right hand side is constant

$$\frac{\lambda}{2a} = \frac{\sin\theta}{\sqrt{h^2+k^2+l^2}} \quad [\text{for } n=1]$$

$$\frac{\lambda^2}{4a^2} = \frac{\sin^2\theta}{(h^2+k^2+l^2)} = \text{Constant}$$

(11) In an XRD experiment following set of reflections expressed as 2θ (°) 38.40, 44.50, 64.85, 77.90, 81.85, 98.40, 111.20 The crystal structure is

=)

2θ	θ	$\sin^2\theta$	$h^2+k^2+l^2$	$\frac{\sin^2\theta}{h^2+k^2+l^2}$
38.40	19.2	0.108153271	$1^2+0^2+0^2 = 1$	0.108153271
44.50	22.25	0.1433747	$1^2+1^2+0^2 = 2$	0.054076635
38.50	19.2	0.1081532	$1^2+1^2+0^2 = 2$	0.054076635
44.50	22.25	0.1433747	$2^2+0^2+0^2 = 4$	0.0358436
38.40	19.2	0.10815327	$1^2+1^2+1^2 = 3$	0.03605109
44.50	22.50	0.1433747	$2^2+0^2+0^2 = 4$	0.03661652
64.85	32.425	0.287505	$2^2+2^2+0^2 = 8$	0.035938

Values are different so no simple cubic

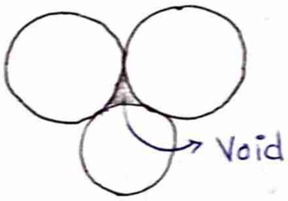
Values are not same so not BCC

Values are same so structure is FCC

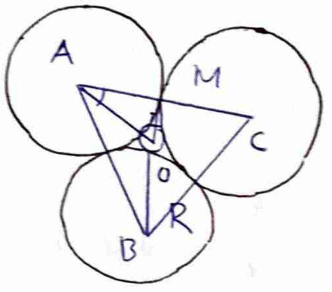
Voids:

① Triangular Voids:

This Vaccany is triangular void ↗ (In 2dim)



Coordination no is 3



$$\frac{AM}{AO} = \cos 30$$

$$\frac{R}{R+r} = \frac{\sqrt{3}}{2}$$

$$2R = \sqrt{3}R + \sqrt{3}r$$

$$(2-\sqrt{3})R = \sqrt{3}r$$

$$\frac{r}{R} = \frac{(2-\sqrt{3})}{\sqrt{3}} = 0.154$$

Radius of inner atom is r

$AM = R$

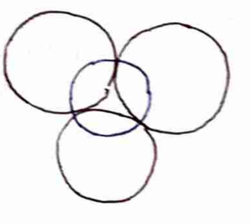
$AO = R+r$

$$\frac{r_+}{r_-} = 0.154$$

Ratio of cation and anion is 0.154.

② Tetrahedral Voids:

Coordination no of tetrahedral Void is 4.

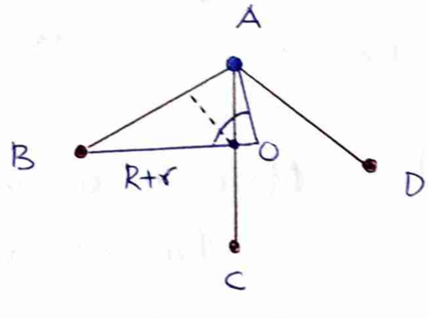


$$\sin 54.75 = \frac{R}{R+r}$$

$$0.816R + 0.816r = R$$

$$0.816r = 0.184R$$

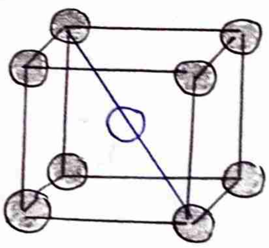
$$\frac{r}{R} = 0.225$$



$AB = 2R$

$AO = R+r$

③ Cubic Void



$$\sqrt{3}a = 2(R+r)$$

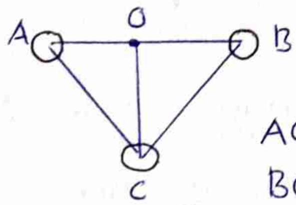
and $a = 2R$

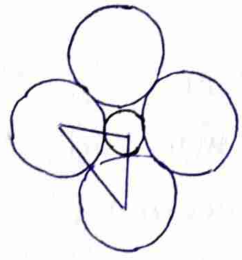
$$2\sqrt{3}R = 2(R+r)$$

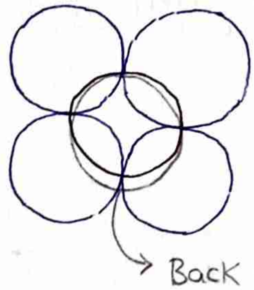
$$\sqrt{3}R = R+r$$

$$(\sqrt{3}-1)R = r \Rightarrow \frac{r}{R} = \frac{r_+}{r_-} = 0.732$$

④ Octahedral Void







$AC = 2R$

$BC = 2R$

$AO = R+r$

$AB = 2(R+r)$

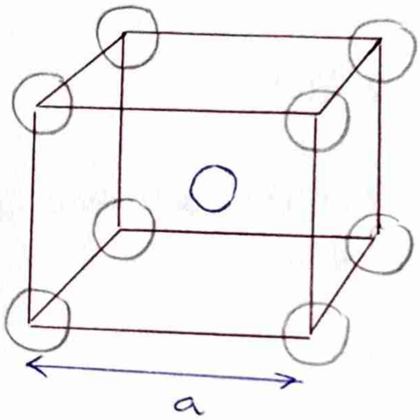
$AC^2 = AO^2 + OC^2 \Rightarrow 4R^2 = 2(R^2 + r^2 + 2Rr)$

$(2R)^2 = 2(R+r)^2 \Rightarrow \frac{r}{R} = \sqrt{2} - 1$

$\frac{r_+}{r_-} = 0.414$

Void	r_+/r_-
Cubic	0.732 – 1
Octahedral	0.414 – 0.732
Tetrahedral	0.225 – 0.414
Triangular	0.155 – 0.225

Caesium chloride (CsCl)

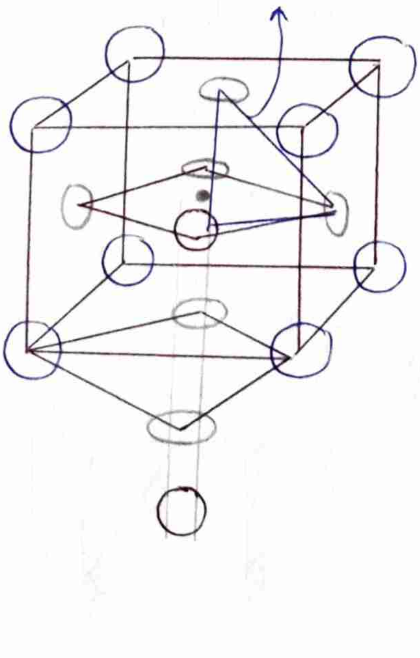


$r_{Cl} + r_{Cs} = \frac{\sqrt{3}}{2} a$

Simple Cubic

Not BCC

Tetrahedral



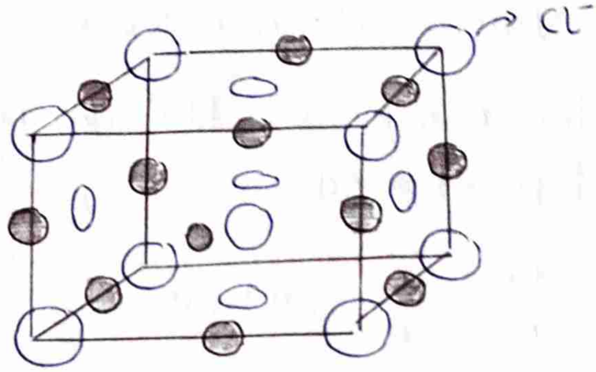
Make an octahedral void and be same for all sides

One edge is shared by 4 edge

At Edge octahedral void formed and Contribution is 1/4

Body diagonal makes tetrahedral (8)

Sodium chloride ($NaCl$)



Octahedral Voids are Occupied by Na^+

$2(r_{Cl^-} + r_{Na^+}) = a$

$r_{Na^+} + r_{Cl^-} = a/2$

No of Cl^- atom 4

Na^+ atom $(12 \times \frac{1}{4}) + 1 = 4$

$Na_4Cl_4 \Rightarrow NaCl$
(Stechometry)

(NaCl makes FCC structure)

(12) The radius of a Calcium ion is 94pm and of the oxide ion is 146pm. The Possible structure is

$\Rightarrow \frac{r_+}{r_-} = \frac{94}{146} = 0.643$ $\quad 0.414 < 0.643 < 0.732$

Structure is Octahedral

(13) CsCl Crystalise in BCC lattice. If a is edge length

$\Rightarrow r_{Cs} + r_{Cl} = \frac{\sqrt{3}}{2}a$

(14) CsBr has BCC type structure with edge length 4.3 Å. The shortest inter ionic distance between Cs and Br

$\Rightarrow$ Inter ionic distance $r_{Cs} + r_{Br} = \frac{\sqrt{3}}{2}a = \frac{\sqrt{3} \times 4.3}{2} = 3.72$ Å

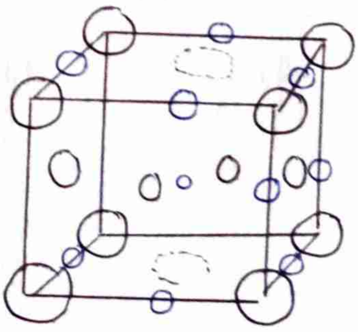
(16) In a Solid AB having NaCl structure A atoms occupy the Corners of unit cell. If all the FCC atoms along one of the axes are removed then the resultant stociometry of the Solid is

$\Rightarrow$ Removed atom,

$Cl = (8 \times \frac{1}{8}) + (4 \times \frac{1}{2}) = 3 \Rightarrow A$

$4 \Rightarrow B$

A_3B_4



(17) Tetrahedral void in a Crystal implies that

=) Void is surrounded by four sphere

(18) The radius of Na^+ ion is 95 pm and that of Cl is 181 pm. type of void

=) $\frac{r_+}{r_-} = \frac{95}{181} = 0.524$ $\quad 0.414 < 0.524 < 0.732$

Direction Indices

[100] represent all parallel indices to it (100). (200). (300)

Family of Planes

{100} $\quad$ (100) ($\bar{1}$00)

(010) (0$\bar{1}$0)

(001) (00$\bar{1}$)

Family of direction Indices

⟨100⟩ → Family of direction

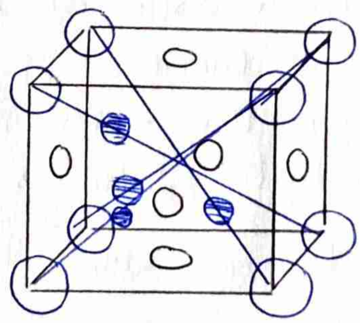
[100] [$\bar{1}$00] [001] [010] [0$\bar{1}$0] [00$\bar{1}$]

Diamond Cubic:

FCC lattice → Principal diagonal has 1 atom

1 → FCC

1 → Half of THV



(Structure of Diamond)

Nearest neighbour distance $= \frac{\sqrt{3}}{4}a = 2r$

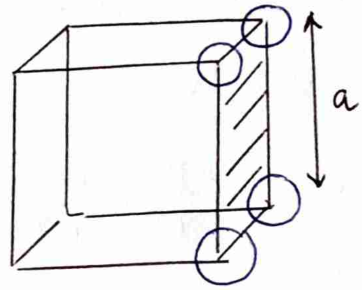
$r = \frac{\sqrt{3}}{8}a$

$N_{eff} = 8$

$Pf = \frac{8 \times \frac{4}{3}\pi r^3}{a^3} = 34\%$

Density of Planes

(100)



No of atom per unit area

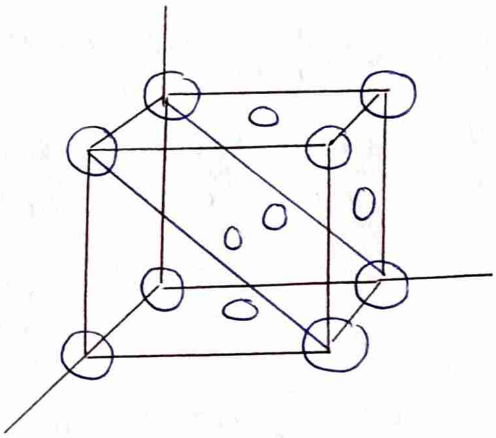
$(4 \times \frac{1}{4}) = 1$

Area $= a^2$

No of atom per unit area $= \frac{1}{a^2}$

$$\% \ pf = \frac{\text{area of atom}}{\text{area of Sphere}} = \frac{\pi r^2}{a^2} = \frac{\pi r^2}{4r^2} = \frac{\pi}{4} = 0.785$$

(110) plane FCC



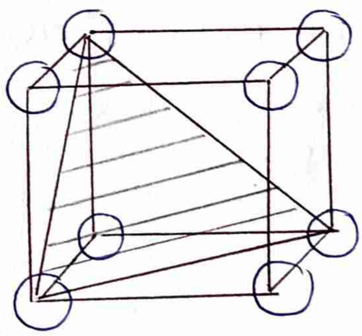
No of atom

$(4 \times \frac{1}{4}) + (2 \times \frac{1}{2}) = 2$

per unit area $= \frac{2}{\sqrt{2}a^2} = \frac{\sqrt{2}}{a^2}$

$$\% \ pf = \frac{2\pi r^2}{\sqrt{2}a^2} = \sqrt{2}\pi \ \frac{1}{8} = \frac{\sqrt{2}}{8}\pi = 0.555$$

(111) Plane BCC



$r = \frac{\sqrt{3}}{4} a$

Atom per unit area

$$= \frac{\frac{1}{6} \times 3}{\frac{\sqrt{3}}{4} a^2} = \frac{0.5 \times 4}{\sqrt{3} a^2}$$

$$= \frac{2}{\sqrt{3} a^2}$$

$$\% \ packing = \frac{\frac{1}{2} \times \pi r^2}{\frac{\sqrt{3}}{4} \times (\sqrt{2} a)^2} = \frac{1}{2} \times \frac{4}{\sqrt{3}} \times \frac{\pi}{2} \times \frac{r^2}{a^2} = \frac{\pi}{\sqrt{3}} \times \frac{3}{16}$$

(19) The Solid phase of an element follows van der waals bonding with inter-atomic potential $V(r) = -\frac{P}{r^6} + \frac{Q}{r^{12}}$. Bond length is

$$\Rightarrow \quad V(r) = -\frac{P}{r^6} + \frac{Q}{r^{12}} \Rightarrow \frac{\partial V}{\partial r} = \frac{6P}{r^7} - \frac{12Q}{r^{13}} = 0$$

$$\frac{6P}{r^7} = \frac{12Q}{r^{13}} \Rightarrow P = \frac{2Q}{r^6} \Rightarrow r = \left(\frac{2Q}{P}\right)^{-6}$$

(20) The potential of a diatomic molecule as a function of r $V(r) = -\frac{a}{r^6} + \frac{b}{r^{12}}$. The Value of potential at eqbm

$$\Rightarrow \quad \frac{\partial V}{\partial r} = \frac{6a}{r^7} - \frac{12b}{r^{13}} \Rightarrow \frac{6a}{r^7} = \frac{12b}{r^{13}} \Rightarrow 6a = \frac{12b}{r^6}$$

$$\Rightarrow r^6 = \frac{2b}{a} \Rightarrow r = \left(\frac{2b}{a}\right)^{1/6}$$

$$V(r) = -\frac{a^2}{2b} + b\frac{a^2}{4b^2} = -\frac{a^2}{2b} + \frac{a^2}{4b} = -\frac{a^2}{4b}$$

(21) α-Co has hcp structure with lattice spacing of $2.51\,\text{Å}$ and height $4.07\,\text{Å}$ and β-Co is FCC with Cube sides $3.55\,\text{Å}$. The ratio of densities

$$\Rightarrow \quad \rho = \frac{Z N_{eff}}{a^3 N_A} \qquad \rho_1 = \frac{6 \times A}{N_A \times 6 \times \frac{\sqrt{3}}{4} a^2 c} \qquad \rho_2 = \frac{4A}{N_A a^3}$$

$$\frac{\rho_1}{\rho_2} = \frac{6 \times 4 \times (3.55)^3}{6 \times \sqrt{3} \times (2.51)^2 \times 4.07 \times 4} = 1.007$$

(25) If relative density of Tungsten is $18.8\ gm/cm^3$ and its atomic weight is 184, assuming that at room temp. there are two free $e^{\ominus}$ per atom. density of free $e^{\ominus}$

$$\Rightarrow \quad \rho = \frac{N_{eff} \times 184 \times 10^{-3}}{a^3 \times N_a}$$

Tugsten is BCC so $N_{eff} = 2$

$a^3 = 3.25 \times 10^{-29}$

1 atom has $2e^{\ominus}$

$$18.8 \times 10^{3} = \frac{2 \times 184 \times 10^{-3}}{a^3 \times N_A}$$

$$e^{\ominus} \text{ density} = \frac{4}{a^3} = \frac{4}{3.25} \times 10^{29}$$

$$= 1.23 \times 10^{29} / cm^3$$

From Bragg's law,

It is a theoritical concept

$$n\lambda = 2d\sin\theta \Rightarrow \lambda = 2d\sin\theta$$

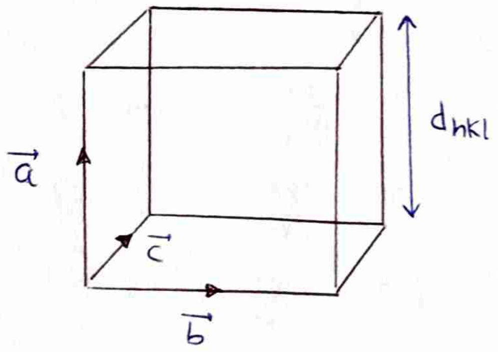
$$\frac{1}{d} = (2\sin\theta)\frac{1}{\lambda} \Rightarrow \frac{2\pi}{d} = (2\sin\theta)\left(\frac{2\pi}{\lambda}\right)$$

$\left(\frac{1}{d} = \sigma \text{ is Reciprocal lattice}\right)$

$$\frac{1}{\text{volume}} = \frac{1}{\text{area}} \times \frac{1}{\text{height}}$$

$$\frac{\text{area}}{\text{Volume}} = \frac{1}{\text{height}}$$

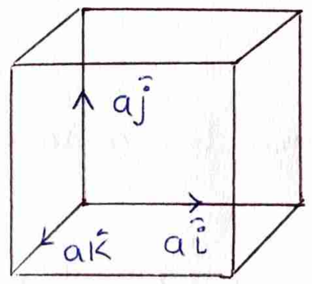
$$\frac{(\vec{b}\times\vec{c})}{\vec{a}\cdot(\vec{b}\times\vec{c})} = \frac{1}{d_{hkl}}$$



$$2\pi\left[\frac{\vec{b}\times\vec{c}}{\vec{a}\cdot(\vec{b}\times\vec{c})}\right] = \sigma_{hkl}$$

Primitive unit cell

$$2\pi\left[\frac{\vec{c}\times\vec{a}}{\vec{a}\cdot(\vec{b}\times\vec{c})}\right] = \vec{b}^*$$



$$2\pi\left[\frac{\vec{a}\times\vec{b}}{\vec{a}\cdot(\vec{b}\times\vec{c})}\right] = \vec{c}^*$$

$$2\pi\left[\frac{\vec{b}\times\vec{c}}{\vec{a}\cdot(\vec{b}\times\vec{c})}\right] = \vec{a}^*$$

$$\left.\begin{aligned}\vec{a} &= a\hat{i}\\ \vec{b} &= a\hat{j}\\ \vec{c} &= a\hat{k}\end{aligned}\right\}\text{Primitive Vectors}$$

Here $\vec{a}^* = \frac{2\pi}{a}\hat{i}$

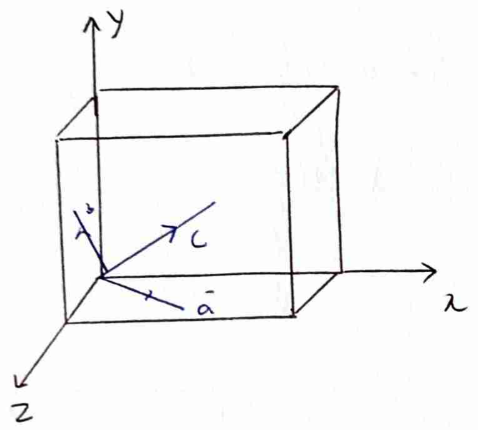
$\vec{b}^* = \frac{2\pi}{a}\hat{j}$

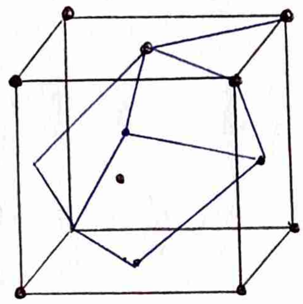
$\vec{c}^* = \frac{2\pi}{a}\hat{k}$

Reciprocal of Simple Cubic is also Simple Cubic

volume $= \left(\frac{2\pi}{a}\right)^3$

Face Centred Cubic





$\vec{a} = \frac{a}{2}\hat{i} + \frac{a}{2}\hat{k}$

$\vec{b} = \frac{a}{2}\hat{j} + \frac{a}{2}\hat{k}$

$\vec{c} = \frac{a}{2}\hat{i} + \frac{a}{2}\hat{j}$

$\vec{a}^* = \frac{2\pi}{a}(\hat{i}-\hat{j}+\hat{k})$

$\vec{b}^* = \frac{2\pi}{a}(-\hat{i}+\hat{j}+\hat{k})$

$\vec{c}^* = \frac{2\pi}{a}(\hat{i}+\hat{j}-\hat{k})$

Reciprocal of BCC $\rightarrow$ FCC
FCC $\rightarrow$ BCC

$\vec{a}\cdot\vec{a}^* = 2\pi$

$\vec{a}\cdot\vec{b}^* = 0$ $\qquad \vec{a}_i\cdot\vec{a}_j = 2\pi\delta_{ij}$

$\vec{b}\cdot\vec{b}^* = 2\pi$

(22) The relation of the reciprocal basis vector $\vec{A}$ to direct basis $\bar{a}$ is given by

$\Rightarrow \quad \vec{A}\cdot\bar{a} = 2\pi$

(23) Given that the edge of diamond is 0.356nm. The number of atoms per meter cube is

No of atom $= \dfrac{8}{(0.356\times10^{-9})^3} = \dfrac{8}{4.5\times10^{-29}} = 1.77\times10^{29}\ m$

(24) FCC is reciprocal of BCC lattice

08.09.2024

Semi Conductors

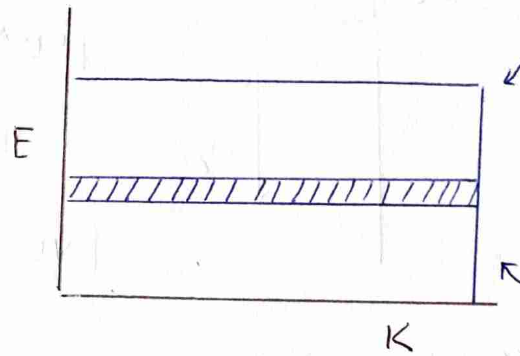
Insulator	Conductors
Conductivity is low	Conductivity is High
Resistivity is High	Resistivity is low.

> Need of Semiconductors

(a) Value of Current (charge) can be Controlled.
(b) Conductivity can be Controlled.
(c) Unidirectional Current flow is possible.
(d) In diode unidirectional flow happen

Examples:

(a) Elemental semi-Conductors: Si, Ge
(b) Compound Semi-Conductors: InP, GaAs



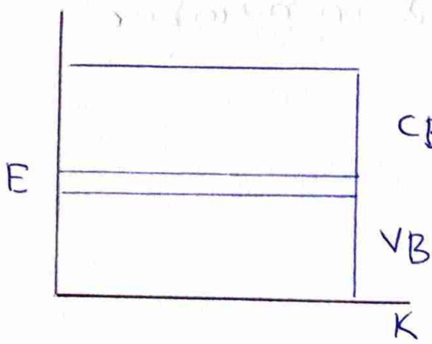
Conduction Band → $e^{\ominus}$ are free to move

Valance Band → $e^{\ominus}$ take participate in chemical reaction

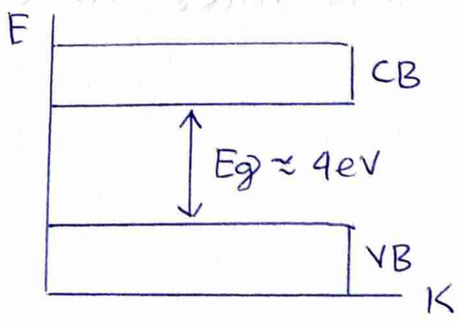
Energy of Valance Band. $-\infty$ to E_v

Conducⁿ Band E_c to ∞

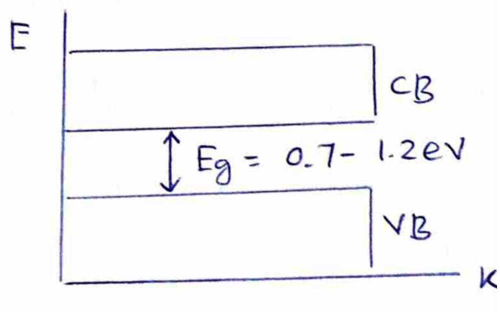
> Gap between the two band is Energy Band Gap E_g



Conductors



Insulators



Semiconductors

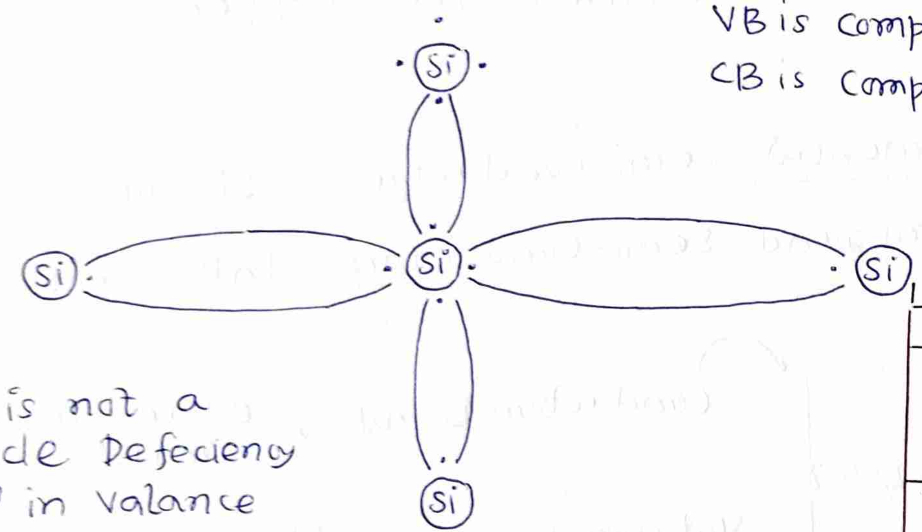
Semi Conductors

- Intrinsic SC (Pure Semiconductor)
- Extrinsic SC (Doaping)
  - p-type
  - N-type

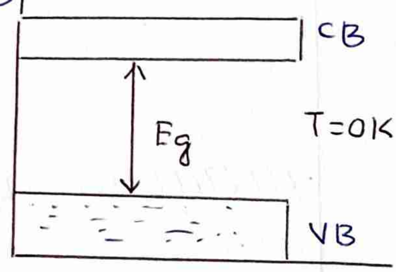
09. 10. 2024

Intrinsic Semiconductor:

At T=0K
VB is completly filled
CB is completly empty



Hole is not a particle Defeciency of $e^{\ominus}$ in valance band is Hole.



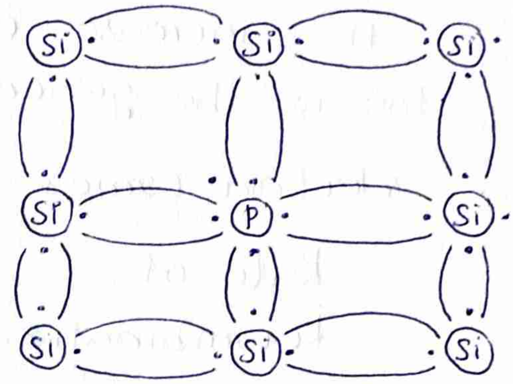
If temperature increase. Some holes created in valance band some hole goes to conduction band At 0K Semiconductor behave like insulator and at high temperature it behave like conductors.

> Direction of movement of $e^{\ominus}$ is just opposite to the Hole.

> Here no of free $e^{\ominus}$ and holes are equal in number

Extrinsic Semiconductor.

(a) N-type SC:



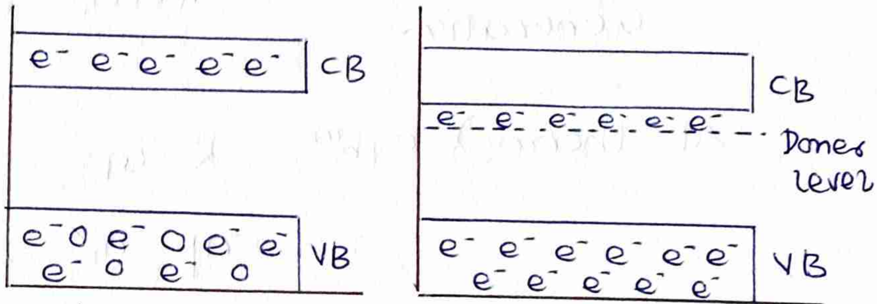
> The extra $e^{\ominus}$ of P is out of bond at even 0K

> Here two types $e^{\ominus}$ —

(a) Thermally generated

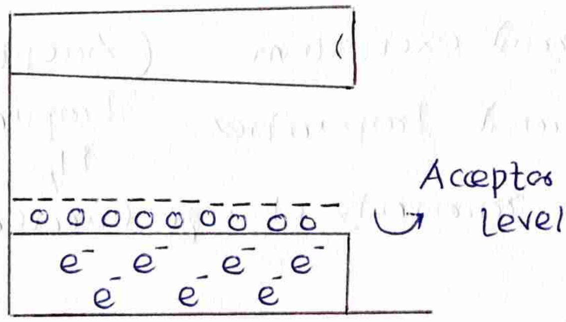
(b) Adding impurity

> Holes are just thermally generated hole.

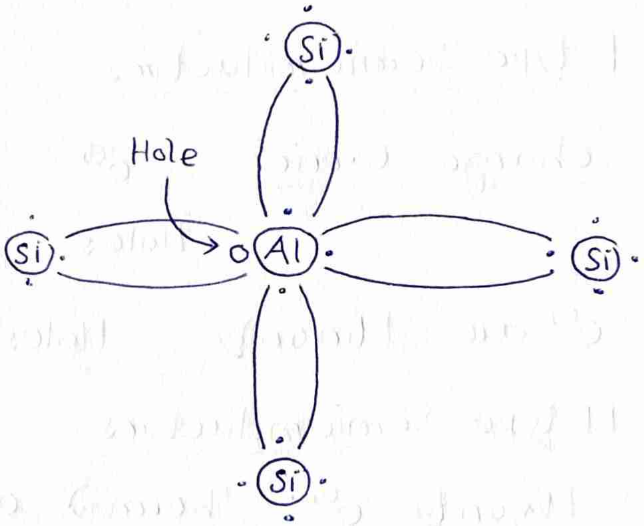


At T>0 | At T=0K

(b) p-type SC:



At T=0



At T=0K, only Holes are present

T ↑. Thermally generated Holes & electrons

Majority ⇒ Hole
Minority ⇒ Electron
(p-type)

Majority ⇒ Electron
Minority ⇒ Hole
(n-type)

> For Intrinsic Semiconductor

if T increase e^- became free and hole created. This is the generation of e^--Hole Pair

> Electron comes to Hole ⇒ Recombination

Rate of Recombination $R, \propto n$ (e^- density)

$\propto p$ (Hole density)

So $R \propto np$

Rate of Generation $G \propto n_i^2$ (Intrinsic Carrier Concentration)

At thermal eqbm $R = G$

$$np = n_i^2 \Rightarrow n_i = \sqrt{np}$$

(This is called laws of mass action)

> P-type Semiconductors

Charge Carrier $e^{\ominus}$: Thermal excitation (Acceptor Impurities) N_A = ~~Positive~~ Neg

Holes : Thermal, Impurities

$e^{\ominus}$ are Minority, Holes are minority charge Carrier

> N-type Semiconductors:

Majority $e^{\ominus}$: Thermal excitation, Impurities

Minority Holes: Thermal excitation

(Doner Impurities) $N_D \rightarrow$ Positive.

> N-type and P-type has no net charge (Neutral)

> From the principle of Electrical Neutrality we have

$$n + N_A = p + N_D$$

> For N-type semiconductor, $N_A = 0$

$$n + N_A = P + N_D \Rightarrow n = P + N_D \Rightarrow N_D = n - p$$

But here $n >> P$. $N_D = n$

From the laws of mass action

$$np = n_i^2 \Rightarrow p = \frac{n_i^2}{N_D}$$

> Simmilarly for p-type semiconductor, $n = \frac{n_i^2}{N_A}$

<u>Electron Concentration in Conduction Band:</u>

Density of state. $g(P)dP = \left(\frac{4\pi p^2 dP}{h^3}\right)V$

Energy. $p^2 = 2mE$

$2pdp = 2mdE$

$dp = \frac{mdE}{\sqrt{2mE}}$

$$g(E)dE = \frac{4\pi V}{h^3} 2mE \frac{mdE}{\sqrt{2mE}}$$

$$g(E)dE = \frac{4\pi V}{h^3}\sqrt{2mE}\, mdE \times 2$$

$$f(E) = \frac{1}{e^{\frac{E-E_f}{KT}}+1} \qquad N = \int f(E)\, g(E)dE$$

$$N = V\int_{E_c}^{\infty} \frac{8\sqrt{2}\pi m^{3/2} E^{1/2} dE}{h^3} \frac{1}{e^{\frac{E-E_f}{KT}}+1}$$

$$= \frac{8\sqrt{2}\pi m^{3/2} V}{h^3}\int_{E_c}^{\infty} \frac{E^{1/2}\, dE}{e^{E-E_f/KT}+1}$$

$$n = \frac{N_F}{V} = \frac{8}{h^3}\sqrt{2}m^{3/2}\pi \int_{E_c}^{\infty} \frac{E^{1/2}\,dE}{e^{\frac{E-E_f}{KT}}+1} \qquad \frac{E-E_f}{K_BT} >> 1$$

or $$n = \gamma \int_{E_c}^{\infty} E^{1/2} e^{-\frac{(E-E_f)}{KT}} dE$$

or $$n = \gamma \int_{E_c}^{\infty} E^{1/2} e^{-\frac{(E-E_c+E_c-E_f)}{KT}} dE$$

or $$n = \gamma \int_{E_c}^{\infty} E^{1/2} e^{-\frac{(E_c-E_f)}{KT}} e^{-\frac{(E-E_c)}{KT}} dE$$

or $$n = \gamma \cdot e^{-\frac{(E_c-E_f)}{KT}} \int_{E_c}^{\infty} E^{1/2} e^{-\frac{(E-E_c)}{KT}} dE$$

or $$n = \gamma \cdot e^{-\frac{(E_c-E_f)}{K_BT}} \int_{E_c}^{\infty} (E-E_c)^{1/2} e^{-\frac{(E-E_c)}{K_BT}} dE$$

or $$n = \gamma \cdot e^{-\frac{(E_c-E_f)}{KT}} \int_{0}^{\infty} (K_BT)^{1/2} x^{1/2} e^{-x} \cdot K_BT\,dx \qquad \text{put } x = \frac{E-E_c}{K_BT}, \quad dx = \frac{dE}{K_BT}$$

or $$n = \gamma \cdot e^{-\frac{(E_c-E_f)}{KT}} \int_{0}^{\infty} (K_BT)^{3/2} e^{-x} x^{1/2} dx$$

or $$n = \gamma \cdot e^{-\frac{(E_c-E_f)}{KT}} (K_BT)^{3/2} \int_{0}^{\infty} e^{-x} x^{1/2} dx$$

or $$n = \frac{8\sqrt{2}\pi m^{3/2}}{h^3} \cdot \frac{1}{2}\sqrt{\pi}(K_BT)^{3/2} e^{-\frac{(E_c-E_f)}{KT}}$$

$$n = 2\left[\frac{2\pi m K_BT}{h^2}\right]^{3/2} e^{-\frac{(E_c-E_f)}{KT}}$$

$$n = N_c e^{-\frac{(E_c-E_f)}{KT}}$$

Electronic Concentration

$$n = 2\left(\frac{2\pi m_e^* K_B T}{h^2}\right)^{3/2} e^{-\frac{(E_c - E_F)}{KT}}$$

$$m^* = \frac{\hbar^2}{\left(\frac{d^2E}{dK^2}\right)}$$

$$p = 2\left(\frac{2\pi m_h^* K_B T}{h^2}\right)^{3/2} e^{-\frac{(E_F - E_V)}{KT}}$$

Intrinsic Semiconductor

Here we have, $n = p$

$$2\left(\frac{2\pi m_e^* K_B T}{h^2}\right)^{3/2} e^{-\frac{(E_c - E_f)}{KT}} = 2\left(\frac{2\pi m_h^* K_B T}{h^2}\right)^{3/2} e^{-\frac{(E_F - E_V)}{KT}}$$

$$e^{-\frac{(E_c - E_f - E_f + E_v)}{K_B T}} = \left(\frac{m_h^*}{m_e^*}\right)^{3/2}$$

$$\boxed{E_f = \frac{E_c + E_V}{2} + \frac{3}{4} K_B T \ln\left(\frac{m_h^*}{m_e^*}\right)}$$

At $T = 0K$

$$m_h^* > m_e^*$$

$$E_f = \frac{E_c + E_V}{2}$$

> From the law of mass action we have

$$n_i^2 = np = N_c e^{-\frac{(E_c - E_F)}{KT}} N_v e^{-\frac{(E_F - E_V)}{KT}}$$

$$= N_c N_v e^{-\frac{(E_c - E_V)}{KT}}$$

$$n_i^2 = N_c N_v e^{-\frac{E_g}{KT}}$$

$$\boxed{n_i = \sqrt{N_c N_v}\, e^{-\frac{E_g}{2K_B T}}}$$

① $I = I_0 \left(1 - \frac{V}{V_0}\right)^2$ The Parameter V_0 and $\sqrt{I_0}$ Can be graphically determined by

$\Rightarrow$ $I = I_0\left(1 - \frac{V}{V_0}\right)^2$

or $\sqrt{I} = \sqrt{I_0}\left(1 - \frac{V}{V_0}\right)$

or $\frac{\sqrt{I}}{\sqrt{I_0}} = 1 - \frac{V}{V_0}$

or $\frac{V}{V_0} = 1 - \frac{\sqrt{I}}{\sqrt{I_0}}$

or $V = V_0 - \frac{V_0}{\sqrt{I_0}}\sqrt{I}$ $\quad y = V$, $x = \sqrt{I}$

$y = c + mx$

Slope, $m = \frac{-V_0}{\sqrt{I_0}}$

Intercept $c = V_0$

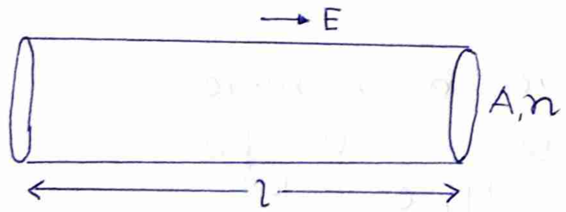
② I-V characteristic of a device $I = I_s\left[\exp\left(\frac{aV}{T}\right) - 1\right]$

The graph between $\log I$ and $\frac{aV}{T}$ will be

$\Rightarrow$ $I = I_s e^{aV/T}$ $\quad e^{\frac{aV}{T}} >> 1$

$\log I = \log I_s + \frac{aV}{T}$

Ohm's Law in Vector Form



$ma = eE$

$a = \frac{eE}{m}$

$V_d = u + at = \frac{eE\tau}{m}$

$i = \frac{(nAl)e}{t}$

$i = \frac{(nAl)eV_d}{l}$

$i = neAV_d$

$\frac{i}{A} = neV_d$

$J = ne \cdot \frac{eE\tau}{m}$

$J = \left(\frac{ne^2\tau}{m}\right)E$

$\vec{J} = \sigma\vec{E}$

Conductivity

$\sigma = \frac{ne^2\tau}{m}$

$\rho = \frac{m}{ne^2\tau}$

Mobility $\mu = \frac{V_d}{E} = \frac{eE\tau}{mE} = \frac{e\tau}{m} \Rightarrow \mu \propto \frac{1}{m^*}$

So $\mu_e >> \mu_h$

$\sigma = \frac{ne^2\tau}{m}$

$\sigma = ne\left(\frac{e\tau}{m}\right)$

$\sigma = ne\mu$

Now in case of Semiconductor

$$J = J_e + J_p = (n_e \mu_e e + n_p \mu_p e)E = \sigma E$$

$$\boxed{\sigma = (n_e \mu_e + n_p \mu_p)}$$

If we remove e^- from doner impurity we get N_d^+

So $N_d^+ = N_d[1 - f(E_d)]$

$E_d \Rightarrow$ Energy of doner level

$f(E) = \frac{1}{1 + e^{\frac{E-E_f}{KT}}}$

or $N_d^+ = N_d\left[1 - \frac{1}{1 + e^{-\frac{(E_f - E_d)}{KT}}}\right]$

$f(E_d) = \frac{1}{1 + e^{\frac{E_d - E_f}{KT}}}$

or $N_d^+ = N_d\left[\frac{1 + e^{-\frac{(E_f - E_d)}{KT}} - 1}{1 + e^{-\frac{(E_f - E_d)}{KT}}}\right]$

or $N_d^+ = N_d\left[\frac{e^{-(E_f - E_d)/KT}}{1 + e^{-(E_f - E_d)/KT}}\right]$

or $N_d^+ = N_d\, e^{-\frac{(E_f - E_d)}{K_B T}}$

For n-type semiconductor

$n = N_d^+$

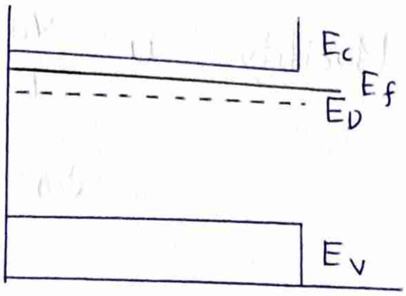
$N_c\, e^{-\frac{(E_c - E_f)}{K_B T}} = N_d\, e^{-\frac{(E_f - E_d)}{K_B T}}$

$e^{(-E_c + E_f + E_f - E_d)/KT} = \frac{N_d}{N_c}$

$2E_f - (E_c + E_d) = KT \ln\left(\frac{N_d}{N_c}\right)$

$$\boxed{E_f = \frac{E_c + E_d}{2} + \frac{K_B T}{2} \ln\left(\frac{N_d}{N_c}\right)}$$

At. $T=0$ $\quad E_f = \frac{E_c+E_d}{2}$



So For n type semiconductor E_f shifted to upward

(For n type sc)

So basically

$$E_f = \frac{E_c+E_d}{2} + \frac{K_B T}{2} \ln\left(\frac{N_d}{N_c}\right)$$

$$N_c = 2\left(\frac{2\pi m^* K_B T}{h^2}\right)^{3/2}$$

If T increase, N_c also decrease, fermi level will be shifted to downward. (For n-type Semiconductor)

> p-type:

$$p = n + N_a^-$$

$$p = N_a^- \quad (N_a^- >> n)$$

$$N_a^- = N_a f(E_a)$$

$$N_a^- = N_a\left[\frac{1}{1+e^{(E_a-E_f)/KT}}\right]$$

$$N_a^- = N_a e^{-(E_a-E_f)/KT}$$

For p type semic $N_a^- = p$

$$p = N_v e^{-(E_f-E_v)/KT}$$

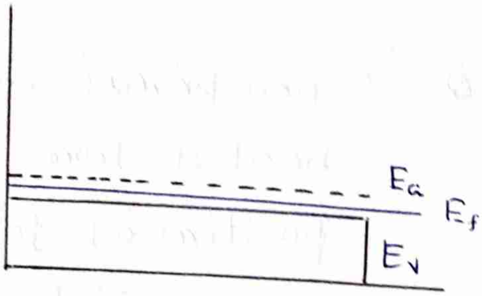
$$\frac{N_a}{N_v} = e^{-(E_a-E_f-E_f+E_v)/KT}$$

$$-\ln\left(\frac{N_a}{N_v}\right) = -(E_a-2E_f+E_v)/KT$$

$$-KT\ln\left(\frac{N_a}{N_v}\right) = 2E_f - (E_a+E_v)$$

$$2E_f = (E_a+E_v) \pm KT\ln\left(\frac{N_a}{N_V}\right)$$

$$E_f = \frac{E_a+E_v}{2} \pm \frac{KT}{2}\ln\left(\frac{N_a}{N_V}\right)$$



Q. The resistivity of an intrinsic semiconductor is $4.5\,\Omega$ at $20^\circ c$ and $2\,\Omega$ at $32^\circ c$. Find E_g

$$\sigma = \frac{1}{\rho} = e n_i \mu_i$$

$$n_i = \sqrt{N_c N_v}\, e^{-\frac{E_g}{2KT}}$$

$$\frac{\rho_1}{\rho_2} = \frac{n_2}{n_1} \Rightarrow \frac{4.5}{2} = \frac{n_2}{n_1} \Rightarrow \frac{n_2}{n_1} = 2.25$$

$$e^{-\frac{E_g}{2KT_1} + \frac{E_g}{2KT_2}} = 2.25$$

$$e^{\frac{E_g}{2K}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)} = 2.25$$

$$\frac{E_g}{2K}\left(\frac{1}{305} - \frac{1}{293}\right) = \ln(2.25)$$

$$-E_g \times (4.86\times10^{18}) = 0.8109 \Rightarrow E_g = 1eV.$$

Q. The Concentration of electrons n and holes p, for an intrinsic Semiconductor at a temp T Can be expressed as $n = p = AT^{3/2}\exp\left(-\frac{E_g}{2K_BT}\right)$ If the mobility of both types of Carrier is proportional to $T^{-3/2}$ then the log of Conductivity is a linear function of T^{-1} with slope

$$\sigma = n_i e\left[\mu_e + \mu_p\right]$$

$$= T^{3/2} e^{-\frac{E_g}{2KT}}\, T^{-3/2}$$

$$\sigma = K' e^{-E_g/2KT}$$

$$\Rightarrow \ln\sigma = \ln K' - \frac{E_g}{2K_BT}$$

Slope is $-\frac{E_g}{2K_B}$

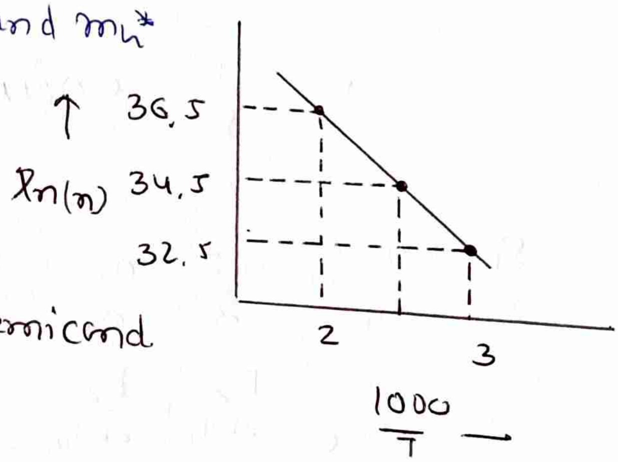
Q. A phosphorus doped silicon (doping density $= 10^{17}/cm^3$) is heated from 100°c to 200°c then

⇒ position of fermi level moves towards middle of energy gap

Q. For an intrinsic semiconductor at finite temperature the Position of fermi level

⇒ depends on both m_e^* and m_h^*

Q. If $K_B = 8.625 \times 10^{-5}$ eV/K



The band gap of the semicond

⇒ $n_i = c\, e^{-\frac{E_g}{2K_BT}}$

$$\ln(n_i) = \ln c - \frac{E_g}{2K_BT} \times \frac{1000}{1000}$$

$$m = \frac{-E_g}{2 \times 1000 \times K_B}$$

$$\text{slope} = \frac{36.5 - 32.5}{2-3} = -4$$

$$E_g = 8000\, K_B = 0.69\,eV$$

Q. In a Crystaline Solid, the energy band structure for an e^- is

$$E = \frac{\hbar^2 K(2K-3)}{2m}$$

The effective mass of the e^- in the Crystal is

⇒ $$m_e^* = \frac{\hbar^2}{\left(\frac{d^2E}{dK^2}\right)} = \frac{m}{2}$$

$$E = \frac{\hbar^2(2K^2 - 3K)}{2m}$$

$$\frac{dE}{dK} = \frac{\hbar^2}{2m}(4K-3)$$

$$\frac{d^2E}{dK^2} = \frac{2\hbar^2}{m}$$

Q. An intrinsic Semiconductor of band gap 1.25 eV has an electron Concentration $10^{10}\ cm^{-3}$ at 300K. If the e^- Concentration at 200K is 4×10^N cm. Find N

$\Rightarrow$

$$\frac{(n_i)_1}{(n_i)_2} = \frac{e^{-E_g/2K_BT_1}}{e^{-E_g/2K_BT_2}}$$

Value of N is 4

$$\frac{10^{10}}{(n_i)_2} = e^{\frac{E_g}{2K_B}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)} = e^{\frac{1.25}{2K_B}\left(\frac{1}{200} - \frac{1}{300}\right)}$$

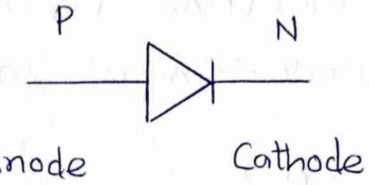
Q. The ratio of e^- densities in the CB of Ge ($E_g = 0.7$ eV) and silicon ($E_g = 1.14$ eV) at 127°c is

$\Rightarrow$

$$n \propto e^{-E_g/2KT}$$

$$\frac{n_1}{n_2} = \frac{e^{-\frac{E_{g_1}}{2KT}}}{e^{-\frac{E_{g_2}}{2KT}}} = e^{\frac{E_{g_2} - E_{g_1}}{2KT}} = 588$$

p-n junction Diode



If doaping Concentration increase depletion layer became decrease

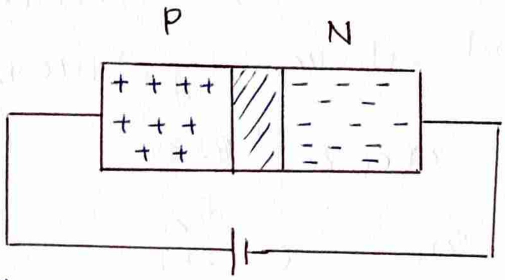
Diode equation is

$$I = I_s \left[e^{\frac{qV}{\eta KT}} - 1 \right]$$

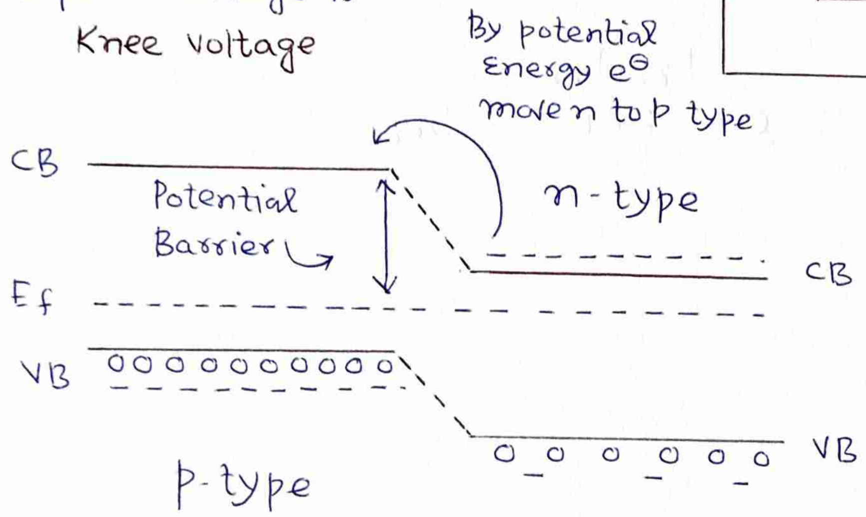
e is electronic charge
V is diode voltage
η is ideality factor
T is temperature

I_s is reverse Saturation Current
I is forward current

$\eta = 1$ (Ge)
$= 2$ (Si)



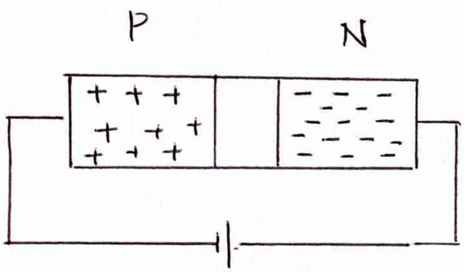
Required Voltage is Knee voltage



$$I = I_s \left[e^{\frac{eV}{\eta KT}} - 1 \right]$$

$$I = I_s \exp\left(\frac{eV}{\eta KT}\right)$$

Reverse Bias



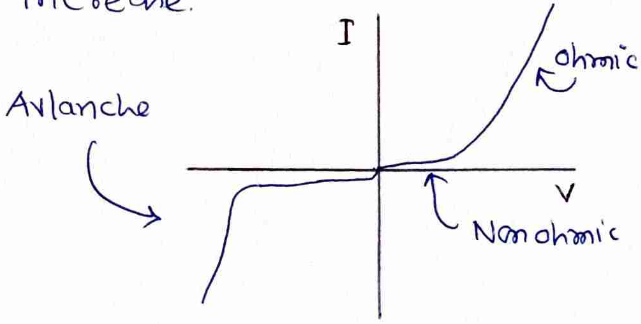
Here Current is very low and

$$I = I_s \left[e^{\frac{eV}{\eta KT}} - 1 \right] \quad V = 0$$

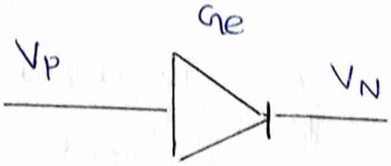
with reverse voltage width of depletion layer increase.

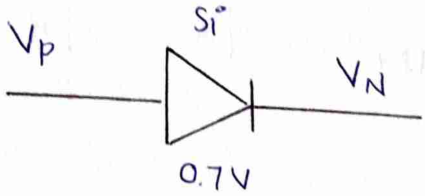
$$I = I_s e^0 = I_s$$

I_s is very low and tends to zero (nA unit)



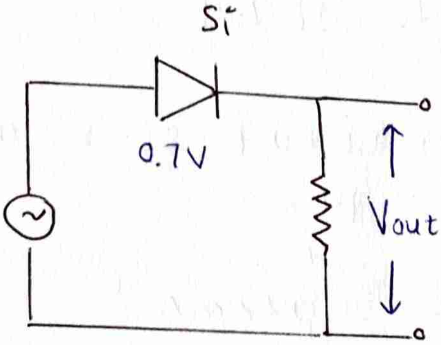
37.

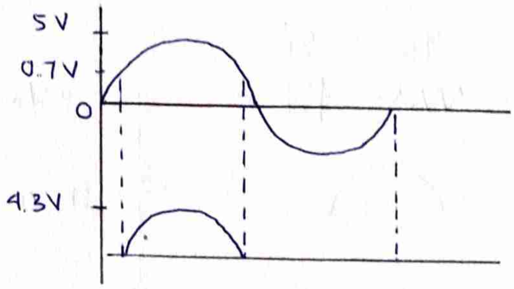


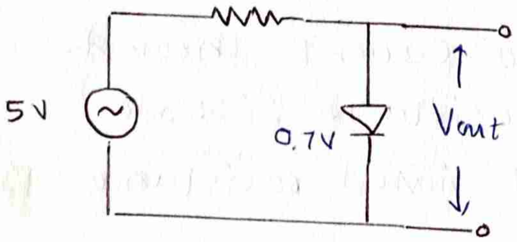


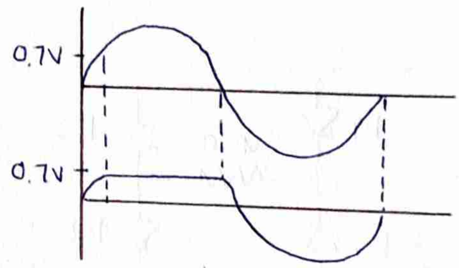
FB: $V_P > V_N + 0.3$

FB: $V_P > V_N + 0.7$

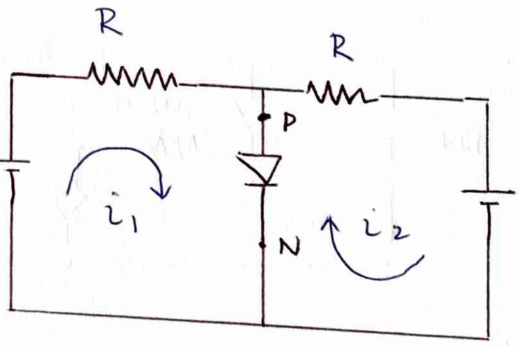




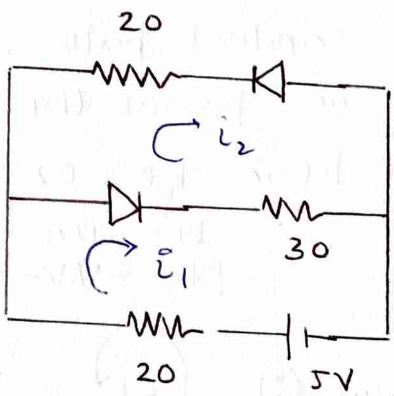




First assume diode is in forward bias. then if the Current through diode is positive then our assumption is Corret



① Find the Current in Circuit



$$-5 + 20 i_1 + 30(i_1 - i_2) = 0$$

$$50 i_1 - 30 i_2 = 5$$

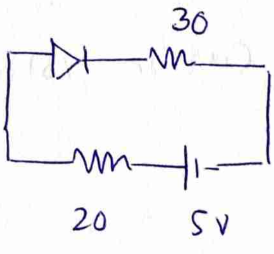
$$20 i_2 + 30(i_2 - i_1) = 0$$

$$i_2 = \frac{3}{5} i_1$$

So assumption is wrong

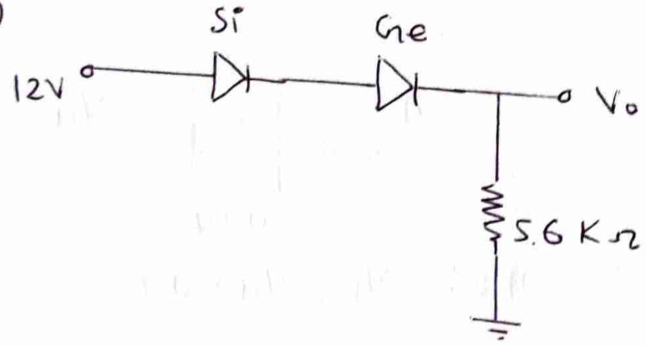
$$i_1 = 5/32 \text{ A}$$

$$i_2 = 3/32 \text{ A}$$



$$i = \frac{5}{50} \text{A}$$

(2)

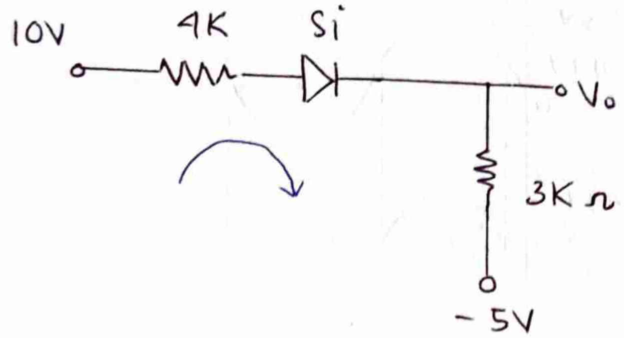


$i = \frac{V}{R} = \frac{12-0.7-0.3}{5.6}$

$V_o = iR = 12-0.7-0.3$

$V_o = 11$ Volt

(3)

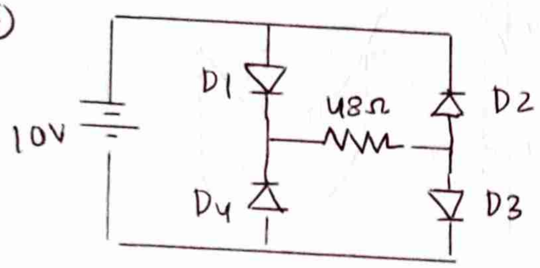


$-10+4i+0.7+3i-5=0$

$i = \frac{14.3}{7}$

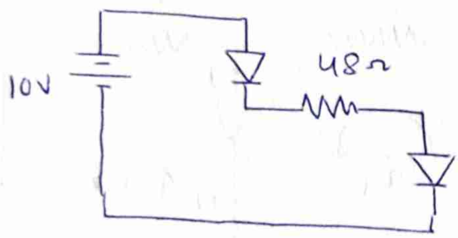
$i = 2.042\,mA$

(4)



Find the Current through 48Ω resistance Si diode, forward biased resistance = 1Ω

→



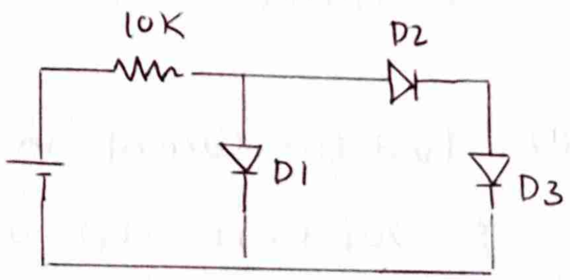
$i = \frac{V}{R} = \frac{10}{48+1+1}$

$i = \frac{10}{50} = 0.2$

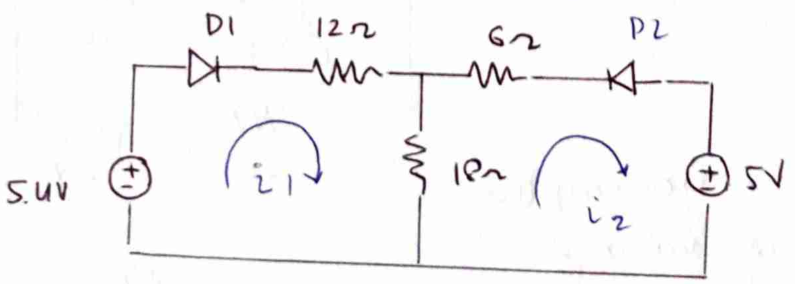
(4)

As the current will follow shortest path so it will be passes through D1

D1 in FB & D2, D3 in RB



(5)



$-5.4+0.6+12i_1+18(i_1-i_2)=0$

$6i_2-0.6+5+10(i_2-i_1)=0$

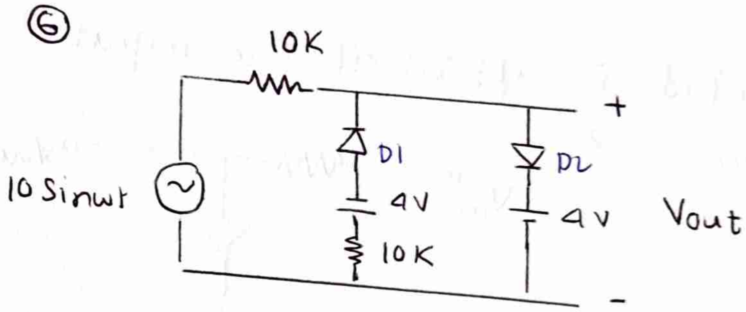
Cut in Voltage 0.6V

$i_1 = 0.49A$

$i_2 = -0.55A$

Both diodes are in Forward Bias

⑥



The max & Min values of the output wave form is

For Positive half cycle . D1 is reverse Bias

0 - 4 Volt   D2 is reverse Bias

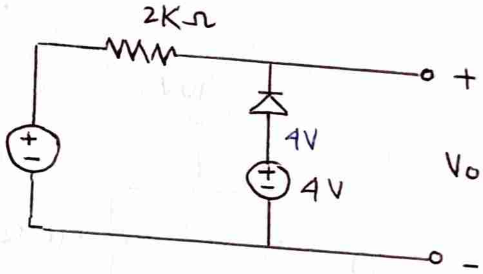
4 - 10 Volt   D2 is forward Bias

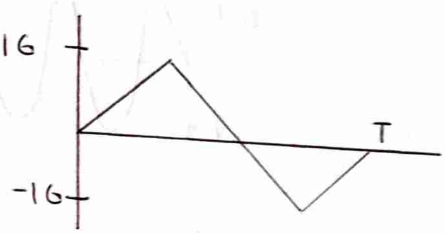
In negative half cycle D2 is reverse Bias

$V_{min} = -7$ Volt

$V_{max} = 4$ Volt

⑦





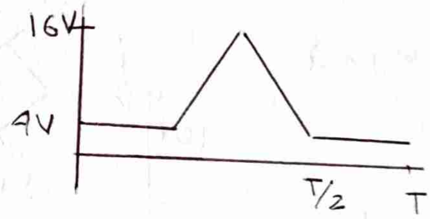
(+) $\frac{1}{2}$ cycle

0 - 4V ⇒ Diode is ~~reverse~~ Forward Bias ⇒ $V_{in} \neq V_{out}$ ⇒ $V_{out} = 4$ Volt

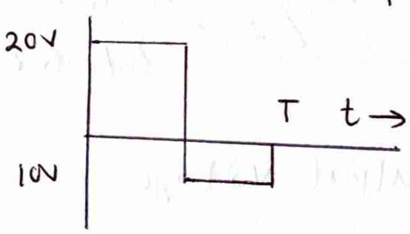
$V_i > 4V$ ⇒ Diode Reverse Bias ⇒ $V_{in} = V_{out}$ ⇒ $V_{in} = V_{out}$

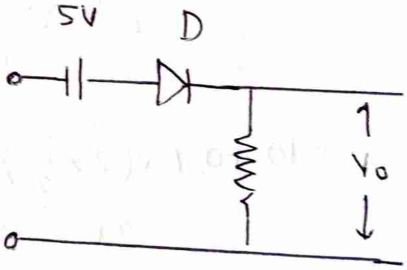
(-) $\frac{1}{2}$ cycle n term is zero volt.

Diode is always forward Bias $V_{out} = 4$ Volt

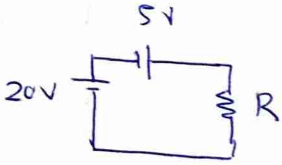


⑧ Determine the output waveform





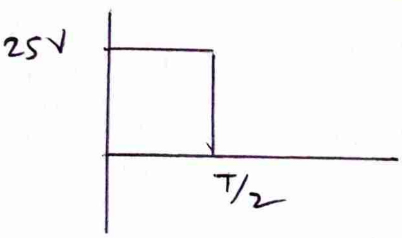
When $V_i = 20$ Volt D is FB



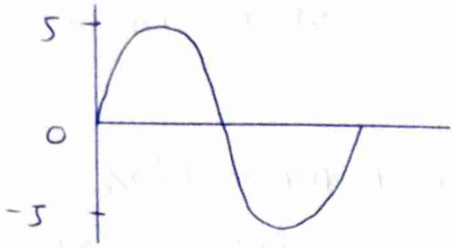
$-25i + R = 0$

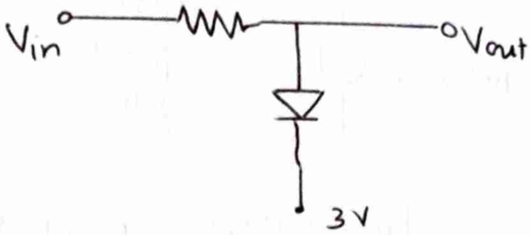
$i = \frac{25}{R}$

$i = 25$ volt



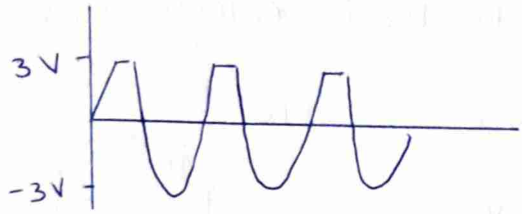
⑨ A Sine wave of 5V amplitude is applied at the input of the Circuit then $V_{out} = ?$



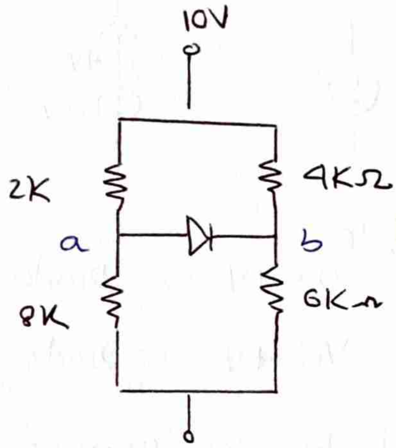


when $V_{in} = 5$ Volt

when 0 - 3 Volt Diode is reverse Bias. $V_{in} = V_{out}$



⑩ The diode is

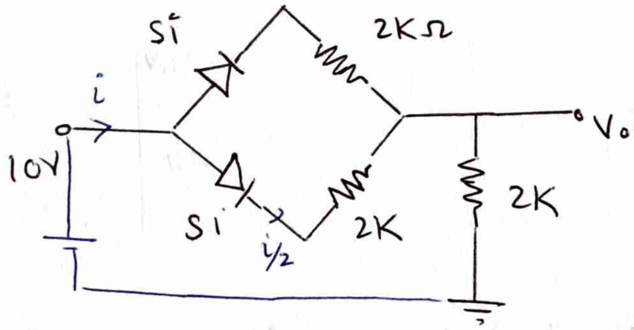


⇒ $V_a = \frac{10 \times 8}{10+0} = 8$ Volt

Reverse Bias

$V_b = \frac{10 \times 6}{10} = 6$ Volt

⑪ The Value of V_o is equal to



⇒ $-10 + 0.7 + 2\frac{i}{2} + 2i = 0$

$4i = 9.3$

$i = \frac{9.3}{4}$ A

$V_o = 2i = \frac{9.3}{2} = 4.65$

~~A.A. 6.2 Volt~~

$-10 + 0.7 + \left(2 \times \frac{i}{2}\right) + 2i = 0$

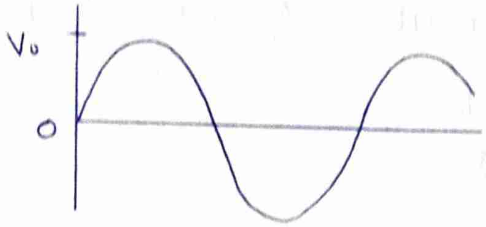
$3i = 9.3$

$i = 3.1$ A

output Voltage

$V_o = 2i = 6.2$A

Rectifiers



Voltage, $V = V_0 \sin\omega t$

and $T = \frac{2\pi}{\omega}$

$$\langle V \rangle = \frac{1}{\int_0^T dt} \int_0^T V\,dt$$

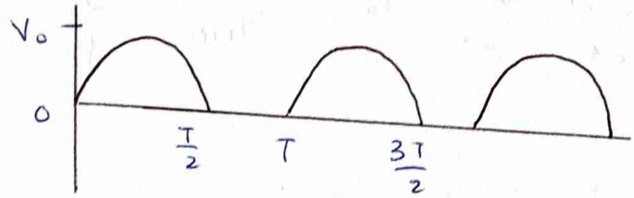
$V_{avg} = 0$

$V_{rms} = V_0/\sqrt{2}$

$$\langle V \rangle = \frac{V_0 \int_0^T \sin\omega t\,dt}{2\pi/\omega} = 0$$

$$\langle V^2 \rangle = \frac{\int V^2 dt}{\int dt} = \frac{\int_0^{2\pi/\omega} V_0^2 \sin^2\omega t\,dt}{\int_0^{2\pi/\omega} dt} = \frac{V_0^2 \cdot \frac{\pi}{\omega}}{2\pi/\omega} = \frac{V_0^2}{2}$$

$$V_{rms} = \sqrt{\langle V^2 \rangle} = \frac{V_0}{\sqrt{2}}$$



$$V(t) = \begin{cases} V_0 \sin\omega t & 0 < t < \pi/\omega \\ 0 & \frac{\pi}{\omega} < t < 2\pi/\omega \end{cases}$$

Average of V,

$$\langle V \rangle = \frac{\int_0^{\pi/\omega} V_0 \sin\omega t\,dt + \int_{\pi/\omega}^{2\pi/\omega} 0\,dt}{\frac{2\pi}{\omega}} = \frac{V_0\omega}{2\pi} \times \frac{1}{\omega} \cos\omega t \Big|_{\pi/\omega}^{0}$$

$$= \frac{V_0}{2\pi}(1+1) = \frac{V_0}{\pi}$$

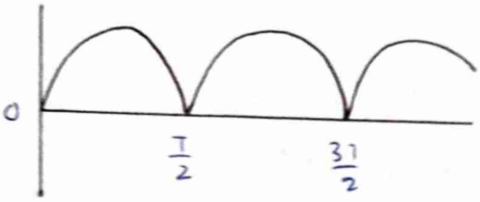
$\langle V \rangle = \frac{V_0}{\pi}$

$$\langle V^2 \rangle = \frac{\int_0^{\pi/\omega} V_0^2 \sin^2\omega t\,dt + \int_{\pi/\omega}^{2\pi/\omega} 0\,dt}{\frac{2\pi}{\omega}} = \frac{V_0^2}{2\pi}\omega \cdot \frac{\pi}{2\omega} = \frac{V_0^2}{4}$$

$$V_{rms} = \sqrt{\langle V^2 \rangle} = \frac{V_0}{2}$$

$V_{avg} = \frac{V_0}{\pi}$

$V_{rms} = \frac{V_0}{2}$



$$V(t) = \begin{cases} V_0 \sin\omega t & 0<t<\pi/\omega \\ -V_0 \sin\omega t & \pi/\omega<t<2\pi/\omega \end{cases}$$

$$\langle V \rangle = \frac{2V_0}{\pi}$$

$$\langle V^2 \rangle = \frac{\int_0^{\pi/\omega} V_0^2 \sin^2\omega t\,dt + \int_{\pi/\omega}^{2\pi/\omega} V_0^2 \sin^2\omega t\,dt}{\frac{2\pi}{\omega}}$$

$$V_{avg} = \frac{2V_0}{\pi}$$

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

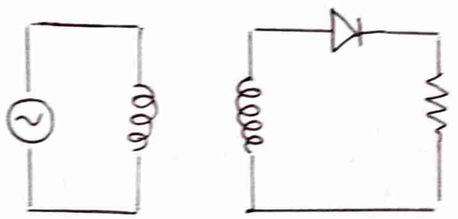
$$= \frac{V_0^2\omega}{2\pi}\left[\frac{\pi}{2\omega} + \frac{1}{2}\int (1-\cos 2\omega t)\,dt\right]$$

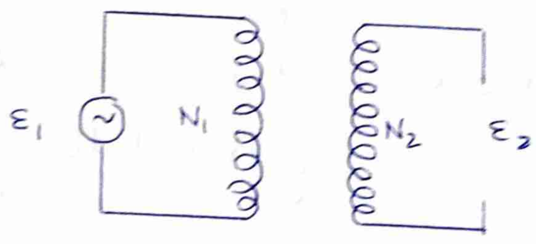
$$= \frac{V_0^2\omega}{2\pi}\left[\frac{\pi}{2\omega} + \frac{1}{2}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_{\pi/\omega}^{2\pi/\omega}\right]$$

$$= \frac{V_0^2\omega}{2\pi}\left[\frac{\pi}{2\omega} + \frac{1}{2}\left\{\left(\frac{2\pi}{\omega} - \frac{\pi}{\omega}\right) - \frac{1}{2\omega}(\sin 4\pi - \sin 2\pi)\right\}\right]$$

$$= \frac{V_0^2\omega}{2\pi}\left[\frac{\pi}{2\omega} + \frac{\pi}{2\omega}\right] = \frac{V_0^2\omega}{2\pi}\cdot\frac{\pi}{\omega} = \frac{V_0^2}{2} \Rightarrow V_{rms} = \frac{V_0}{\sqrt{2}}$$

Half wave Rectifiers





$$V_{DC} = \frac{E_0}{\pi} \qquad V_{rms} = \frac{E_0}{2}$$

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{N_1}{N_2}$$

$$\varepsilon_2 = \frac{N_2}{N_1}\varepsilon_1$$

$$V_{r,rms} = \sqrt{V_{rms}^2 - V_{DC}^2}$$

$\varepsilon_2 > \varepsilon_1 \Rightarrow$ step up

$\varepsilon_2 < \varepsilon_1 \Rightarrow$ step down

$$= E_0\sqrt{\frac{1}{4} - \frac{1}{\pi^2}} = 0.386E_0$$

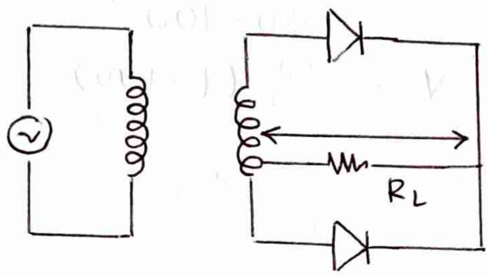
Ripple factor $\gamma = \dfrac{V_{r,rms}}{V_{DC}} = \dfrac{0.386E_0}{E_0/\pi} = 1.21$

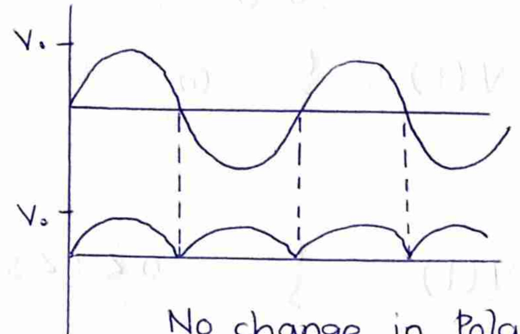
$$\eta = \frac{V_{DC}^2}{V_{rms}^2} = 40.57\%$$

Efficiency $\eta = \frac{V_{DC}^2}{V_{rms}^2} = \left(\frac{2}{\pi}\right)^2 = 40.6\%$

Form factor, $F = \frac{V_{AC}}{V_{DC}} = \pi/2 = 1.57$

Full wave Rectifier





No change in Polarity

$$V(t) = \begin{cases} V_0 \sin\omega t & 0 < t < \pi/\omega \\ -V_0 \sin\omega t & \pi/\omega < t < 2\pi/\omega \end{cases}$$

$V_{DC} = \frac{2V_0}{\pi}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

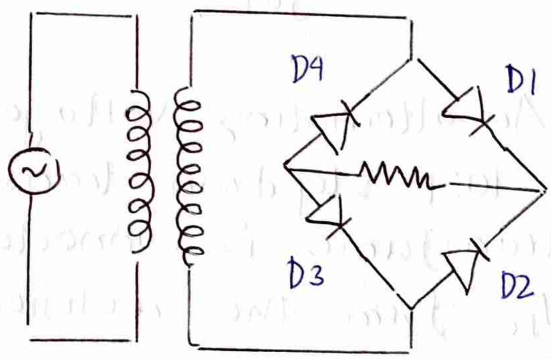
$$V_{r,rms} = \sqrt{V_{rms}^2 - V_{DC}^2} = \sqrt{V_0^2\left(\frac{1}{2} - \frac{4}{\pi^2}\right)} = 0.308V_0$$

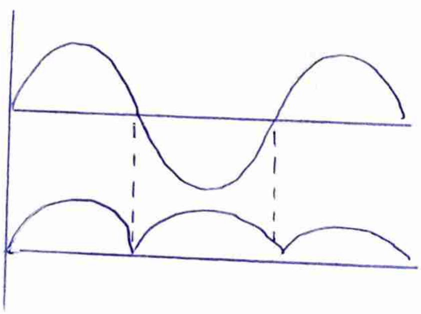
Ripple factor. $\gamma = \frac{V_{r,rms}}{V_{DC}} = \frac{0.308V_0}{\frac{2V_0}{\pi}} = 0.48$

Efficiency $\eta = \frac{V_{DC}^2}{V_{rms}^2} = \left(\frac{2}{\pi} \times \sqrt{2}\right)^2 = 81.2\%$

Bridge Rectifier

1st HF	2nd HF
$D_1 \rightarrow$ FB	$D_2 \rightarrow$ FB
$D_2 \rightarrow$ RB	$D_3 \rightarrow$ RB
$D_3 \rightarrow$ FB	$D_1 \rightarrow$ RB
$D_4 \rightarrow$ RB	D4 $\rightarrow$ FB

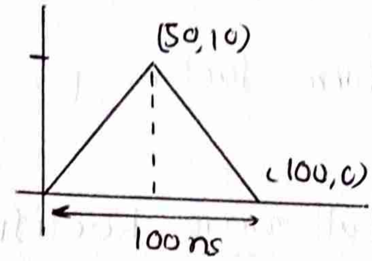




$$V = \begin{cases} V_0 \sin\omega t & 0 < t < \pi/\omega \\ -V_0 \sin\omega t & \pi/\omega < t < 2\pi/\omega \end{cases}$$

Due to PIV, it use over FWR

① Consider a Sawtooth wave form which rises linearly from 0 to 10V. then decays to 0V. linearly to 0V. in 100 ns. The rms voltage is



$\Rightarrow$

$$V - 0 = \frac{10-0}{50-0}(x-0)$$

$$V(t) = \frac{t}{5} \quad — ①$$

$$V - 0 = \frac{100-0}{50-100}(t-100)$$

$$V = -\frac{1}{5}(t-100)$$

$$V(t) = \frac{t}{5} \qquad 0 < t < 50$$

$$-\frac{t}{5} + 20 \qquad 50 < t < 100$$

$$\langle V^2 \rangle = \frac{1}{100}\left[\int_0^{50} \frac{t^2}{25}\,dt + \int_{50}^{100} \left(\frac{t^2}{25} - 8t + 400\right) dt\right]$$

$$= \frac{1}{3 \times 25 \times 100}(50)^3 + \frac{1}{100}\left(\frac{1}{75}t^3 - 4t^2 + 400t\right)_{50}^{100}$$

$$= 16.67 + \frac{1}{100} \times \frac{1}{75} \times 875000 - \frac{1}{25}(7500) + \frac{4}{1} \times 50$$

$$= 16.67 + 116.67 - 300 + 200 = 5.77^2 V$$

$$\langle V^2 \rangle = \frac{\int V^2 dt}{\int dt} \qquad V_{rms} = \sqrt{\langle V^2 \rangle} = 577 \times 10^{-3} \text{ Volt}$$

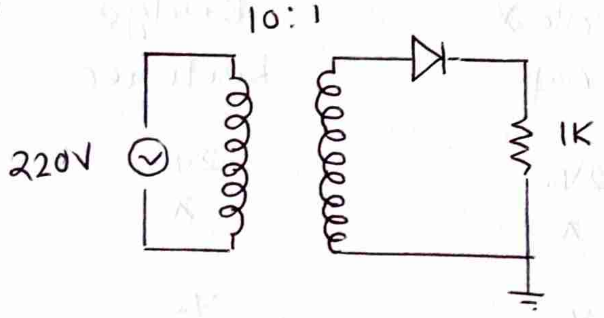
② An alternating voltage $V = 50 \sin 30t$ is applied to a 10:1 stepdown transformer and Secondary of this transformer is connected to the input of a hwr V_{DC} from the rectifier is

$\Rightarrow$

$$V_0 = \frac{50}{10} = 5 \text{ Volt}$$

$$V_{DC} = \frac{V_0}{\pi} = \frac{5}{\pi} \text{ Volt}$$

(3)



The peak secondary voltage and DC load Voltage are respectively

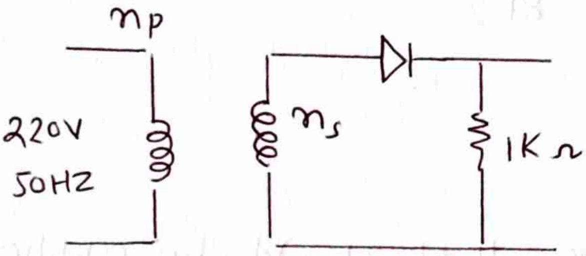
$V_{peak} = V\sqrt{2} = 220\sqrt{2}$ Volt

For HWR

$V_p = \frac{220\sqrt{2}}{10} = 22\sqrt{2} = 31.1V$

$V_{DC} = \frac{V_P}{\pi} = \frac{31.1}{\pi} = 9.9$ Volt

(4)



To develop a dc Voltage of 10V. the ratio $n_p : n_s$ is

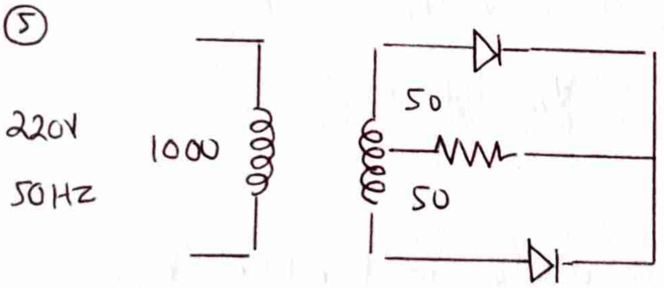
$\Rightarrow$

$V_{DC} = \frac{V_m}{\pi}$ $\quad V_p = 220\sqrt{2} = 311V$

$10 = \frac{V_m}{\pi}$ $\quad \frac{n_p}{n_s} = \frac{311}{10\pi} = \frac{10}{1}$ $\quad n_p : n_s = 10:1$

$V_m = 10\pi$

(5)



DC Voltage obtained from load is

$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{1000}{V_2} = \frac{50+50}{220\sqrt{2}}$

$\Rightarrow V_2 = 31.1$

$V_{DC} = \frac{2V_m}{\pi} = \frac{2\times 31.1}{\pi\times 2} = 10V$

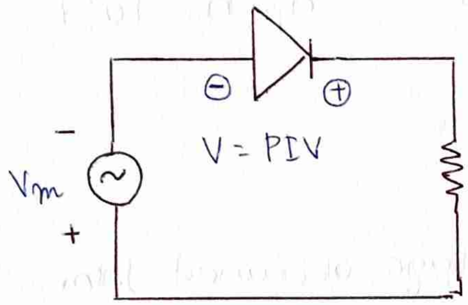
(6) The Peak Value of AC Voltage across the secondary of the transformer in HWR without filter is $9\sqrt{2}$ V. The max dc Voltage across the load

$\Rightarrow$ $V_{DC} = \frac{V_m}{\pi} = \frac{9\sqrt{2}}{\pi} = 4.02$ Volt

	Half wave Rectifier	Central Trap	Bridge Rectifier
V_{DC}	$\frac{V_0}{\pi}$	$\frac{2V_0}{\pi}$	$\frac{2V_0}{\pi}$
V_{rms}/V_{DC}	$\cancel{\frac{2V_0}{\pi}}$ $\frac{V_0}{2}$	$\frac{V_0}{\sqrt{2}}$	$\frac{V_0}{\sqrt{2}}$
γ	1.21	0.482	0.482
η	40.6	81.2	81.2

> peak Inverse Voltage:

Maximum reverse voltage that should be applied across a diode so that it dones't reach the breakdown region.

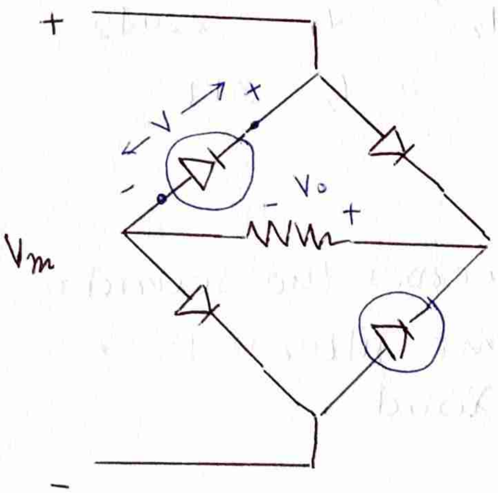


Diode is in off state voltage across diode is PIV

$V_m - V = 0 \Rightarrow V = V_m = PIV$

$V_m \leq PIV$

HWR:



As both the diode in Forward bias we have $V_m = V_0$ — ①

$+V - V_0 = 0$

$V_0 = V = PIV \Rightarrow PIV = V_m$

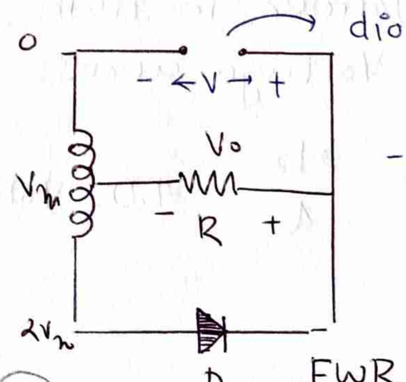
diode in RB

$V = PIV$

$-V + V_0 + V_m = 0$

$V = 2V_m$

$PIV = 2V_m \Rightarrow V_m = \frac{PIV}{2}$



As diode is off

V = PIV

Bridge Rectifier

FWR

Bipolar Junction Transistor

They are basically two types –

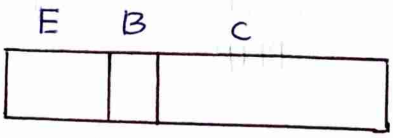
NPN

N	P	N

PNP

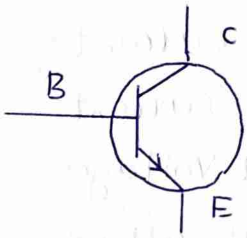
P	N	P

① NPN type transistor



Width of

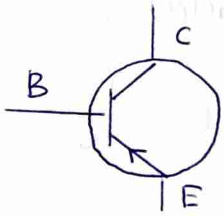
Collector ⇒ Maximum
Base ⇒ Minimum
Emitter ⇒ Moderate



NPN transistor

Doaping of

Emitter ⇒ Maximum
Base ⇒ Minimum
Collector ⇒ Moderate.

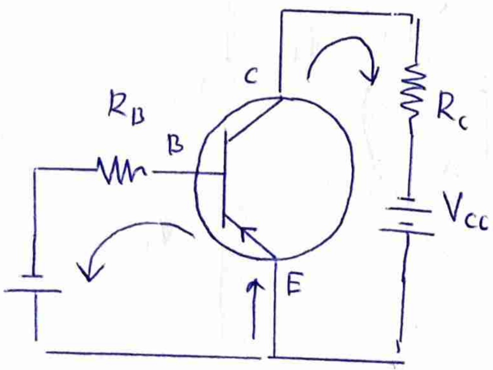


PNP transistor

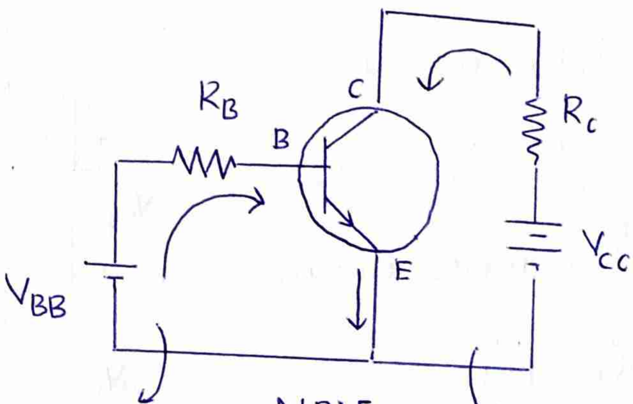
Biasing:

EB Junction is forward Bias
BC Junction is Reverse Bias

② Common Emitter (CE) Configuration



PNP

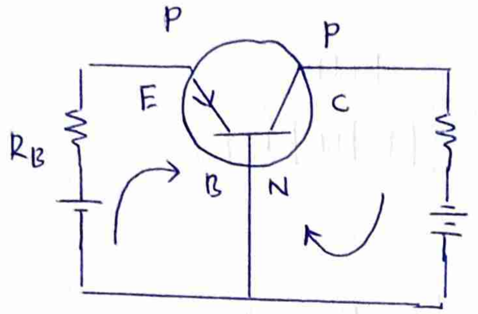


Input

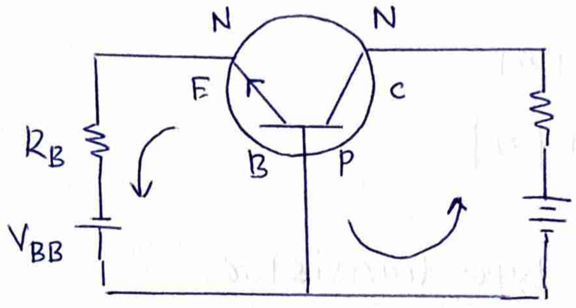
NPN

output

③ Common Base Configuration



PNP



NPN

$$I_E = I_B + I_c$$

I_E is input current
I_c is output current
V_{EB} is input Voltage
V_{CB} is output Voltage
(For CB Mode)

$$\frac{I_c}{I_E} = \alpha \Rightarrow I_E = \frac{I_c}{\alpha}$$

I_B is input current
I_c is output current
V_{CB} is output Voltage
V_{EB} is input Voltage
(For CE Mode)

$$\frac{I_c}{I_E} = \alpha \quad \text{(Current gain)}$$

$$\frac{I_c}{I_B} = \beta$$

Now $\quad I_E = I_B + I_c$

$$\frac{I_c}{\alpha} = \frac{I_c}{\beta} + 1 \Rightarrow \frac{1}{\alpha} = \frac{1+\beta}{\beta} \Rightarrow \alpha = \frac{\beta}{1+\beta} \Rightarrow \beta = \frac{\alpha}{1-\alpha}$$

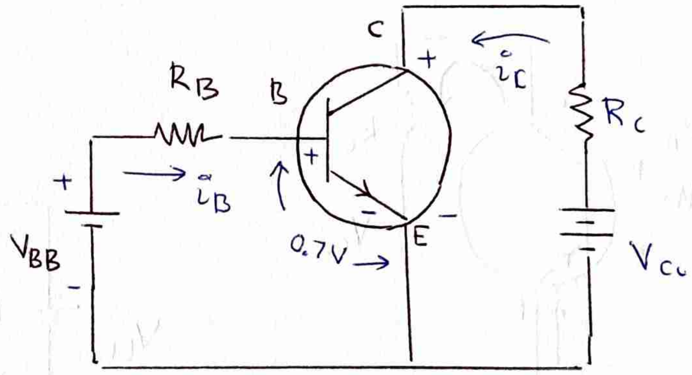
④ Equation of Circuit

$$-V_{BB} + i_B R_B + 0.7 = 0$$

$$\frac{V_{BB} - 0.7}{R_B} = i_B \quad —①$$

Eqn of input circuit

$$i_c = \beta i_B$$

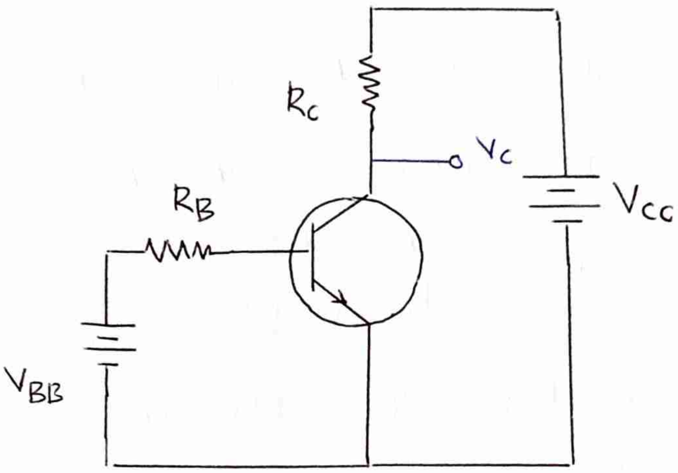


$$-V_{cc} + i_c R_c + V_{CE} = 0$$

$$V_{CE} = V_{cc} - i_c R_c$$

⑤ Circuit Analysis

Ckt:01



$$-V_{BB} + i_B R_B + V_{BE} = 0$$

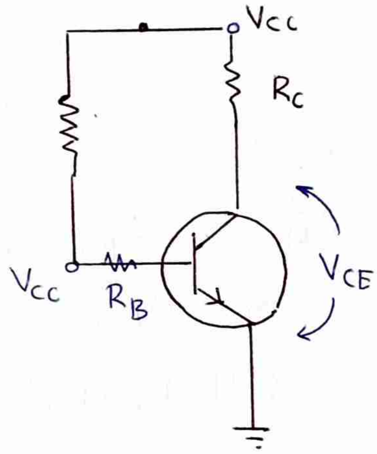
or $$i_B = \frac{V_{BB} - V_{BE}}{R_B}$$

Now. $i_C = \beta i_B$

$$V_{CE} = V_C - V_E = V_C$$

$$i_E = i_C + i_B = \beta i_B + i_B = (1+\beta) i_B \Rightarrow i_E \approx \beta i_B = i_C$$

Ckt:02

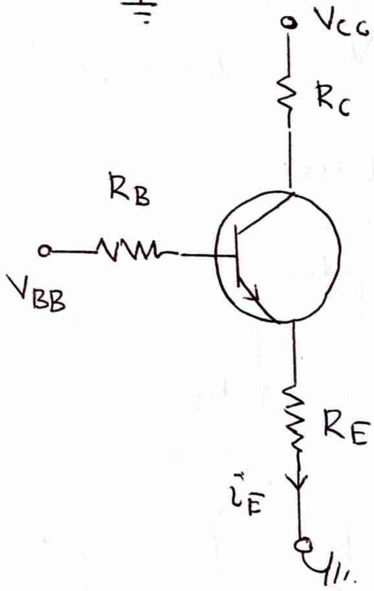


$$i_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$i_C = \beta i_B \Rightarrow V_{CE} = V_{CC} - i_C R_C$$

As $$-V_{CC} + i_C R_C + V_{CC} = 0$$

Ckt:03



$$-V_{BB} + i_B R_B + V_{BE} + i_E R_E = 0$$

$$i_B R_B + i_E R_E = V_{BB} - V_{BE}$$

$$i_B R_B + (1+\beta) i_B R_E = V_{BB} - V_{BE}$$

$$i_B \left[R_B + (1+\beta) R_E \right] = V_{BB} - V_{BE}$$

$$i_B = \frac{V_{BB} - V_{BE}}{R_B + (1+\beta) R_E}$$

As $i_E = (1+\beta) i_B$ and $i_C = \beta i_B$

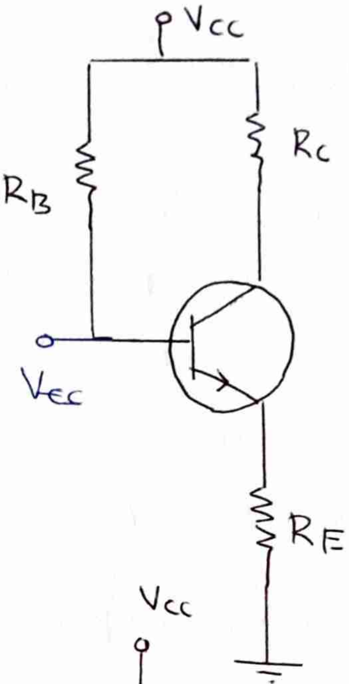
Also $$-V_{CC} + i_C R_C + i_E R_E + V_{CE} = 0$$

$$V_{CE} = V_{CC} - i_C R_C - i_E R_E$$

$i_C = \beta i_B$

$i_E = (1+\beta) i_B$

CKt 04



$$-V_{CC} + i_B R_B + V_{CE} + i_E R_E = 0$$

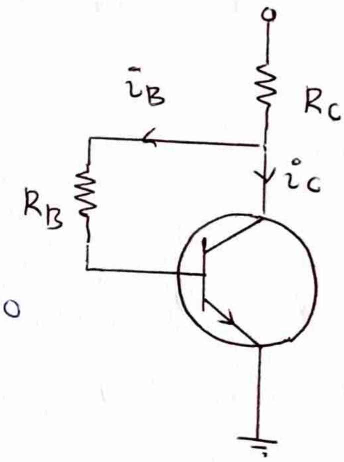
$$i_B R_B + (1+\beta) R_E = V_{CC} - V_{CE}$$

$$i_B = \frac{V_{CC} - V_{CE}}{R_B + (1+\beta) R_E}$$

$$i_C = \beta i_B . \quad i_E = (1+\beta) i_B$$

$$V_{CE} = V_{CC} - i_C R_C - i_E R_E$$

CKt 05:

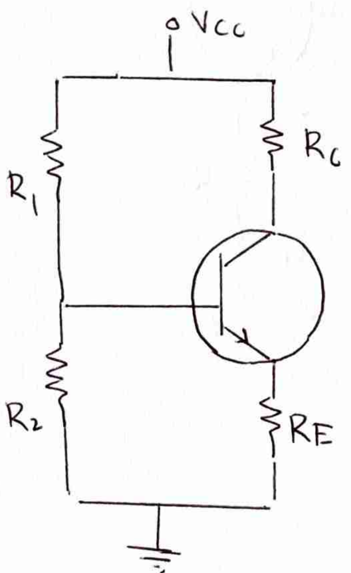


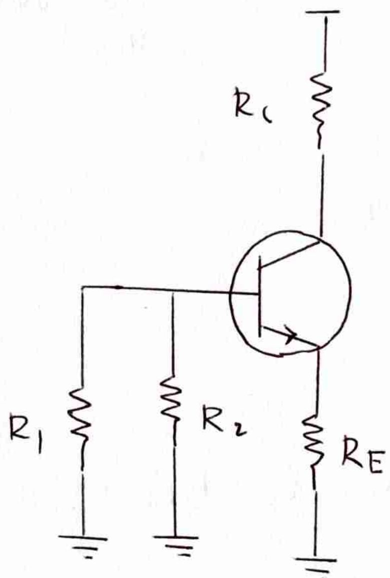
$$-V_{CC} + (i_C + i_B) R_C + i_B R_B + V_{BE} = 0$$

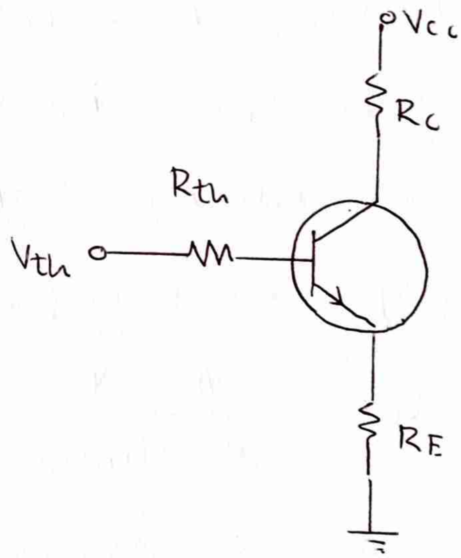
$$i_B = \frac{V_{CC} - V_{BE}}{(1+\beta) R_C + R_B}$$

$$V_{CE} = V_{CC} - (i_C + i_B) R_C$$

CKt 06:







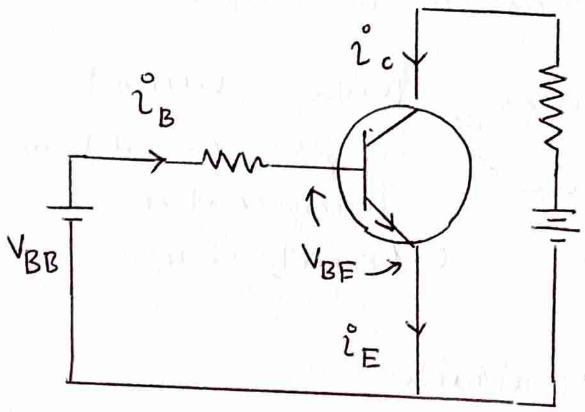
$$V_{th} = \frac{V_{CC} R_2}{R_1 + R_2} \qquad R_{th} = \frac{R_1 R_2}{R_1 + R_2}$$

$$-V_{th} + i_B R_{th} + V_{BE} + i_E R_E = 0$$

$$i_B R_{th} + (1+\beta) i_B R_E = V_{th} - V_{BE}$$

$$i_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}$$

⑥ Common Emitter Configuration

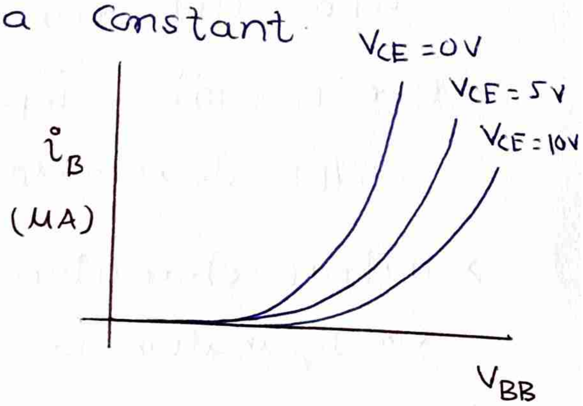


$V_{CE} = V_{CB} + V_{BE}$

V_{BE} is almost Constant

⑦ Input characteristics

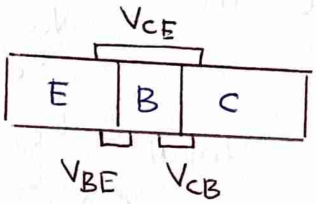
Plot I_B vs V_{BB} by taking V_{CE} as a constant.



output Current i_c

output Voltage V_{CE}

$V_{CE} = V_{CB} + V_{BE}$



If $V_{CE} \uparrow \Rightarrow V_{CB} \uparrow$

V_{BB} remain Constant

As V_{CB} increase (Reverse Bias), base width became decrease and the depletion layer ~~de~~ in creases so base Current i_B became decrease.

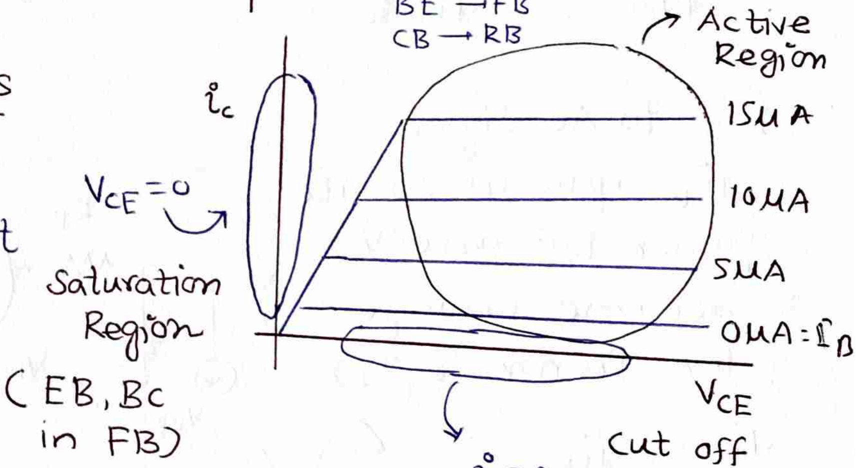
As depletion layer increase the amount of recombination increase So base Current became decrease.

⑧ output characteristics

Plot i_c V/S V_{CE}

taking i_B Constant

$i_c = \beta i_B$ (Almost Constant)



$i_c = \beta i_B + i_{CBO}$ ↳ Due to minority carrier (Leakage current)

$i_E = i_c + i_B$

$\Rightarrow i_c = \alpha (i_c + i_B) + i_{CBO}$

$\Rightarrow i_c = \dfrac{\alpha}{1-\alpha} i_B + \dfrac{1}{1-\alpha} i_{CBO}$

$\Rightarrow i_c = \beta i_B + (1+\beta) i_{CBO}$

Here $i_{CEO} = (1+\beta) i_{CBO}$

i_{CEO} is leakge Current in Common emitter Configuration

⑨ Stabalization In Transistors

The process of making an operating point independent (less dependent) of β and temperature is known as stabalization.

$i_E = \alpha i_c + i_{CBO}$

$i_c = \beta i_B + i_{CEO}$

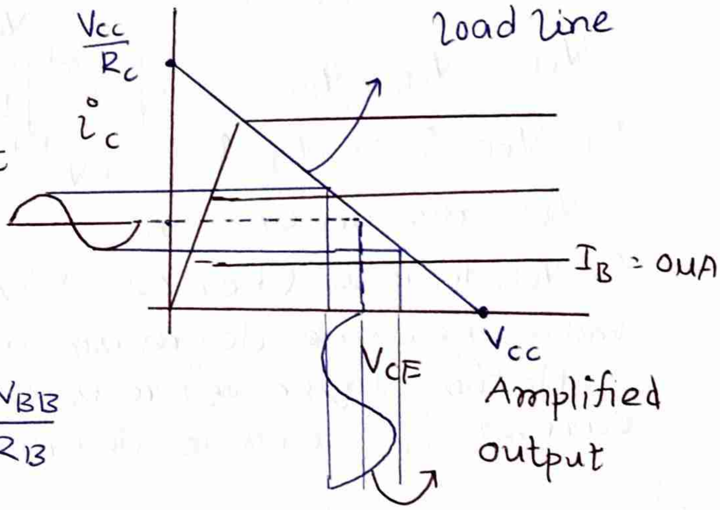
leakege current is generated from Temperature. (Minority charge)

$i_{CEO} = (1+\beta) i_{CBO}$

After $\Delta T \to 10°c$, i_{CBO} became almost double

V_{BE} deacrease 2.5 mV per °c temperature increase.

> output characteristics in configuration is



$$i_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$i_c = \beta i_B \Rightarrow \Delta i_c = \beta \Delta i_B$

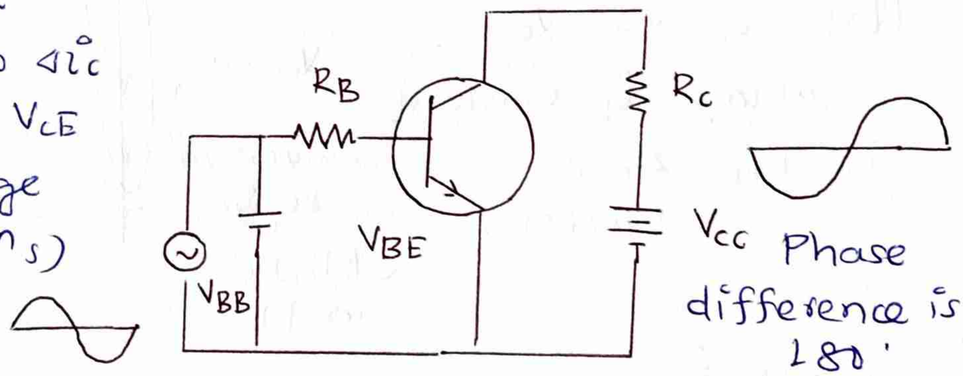
$V_{CE} = V_{cc} - i_c R_c$ $\qquad \Delta i_B = \frac{\Delta V_{BB}}{R_B}$

$\Delta V_{CE} = - \Delta i_c R_c$

Due to AC signal Δi_B appears so Δi_c generated and V_{CE} became change (from Previous eq^n s)

$\Delta i_c = \beta \Delta i_B$

$\Delta V_{CE} = - \Delta i_c R_c$



Phase difference is 180°

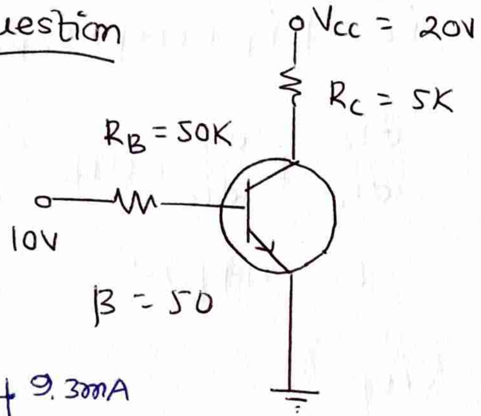
$V_{CE} = V_{cc} - i_c R_c$

$\left.\begin{array}{ll} i_c = 0 & V_{CE} = V_{cc} \\ V_{CE} = 0 & i_c = \frac{V_{cc}}{R_c} \end{array}\right\}$ load line

> (I_c, V_{CE}) is operating point and we have to choose it Very Carefully. For amplification this point should be lies in active region

$$V_{CE} = V_{CC} - i_c R_c$$

Question

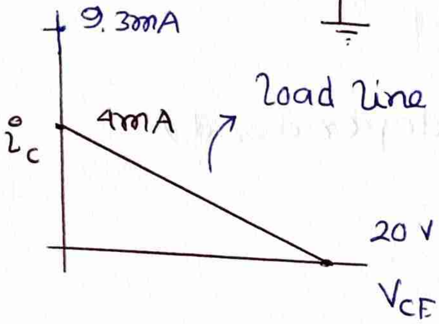


Find the Q - point

$$V_{CC} = i_c R_c + V_{CE}$$

$$V_{CE} = V_{CC} - i_c R_c$$

$$= 20 - i_c \times 5K$$

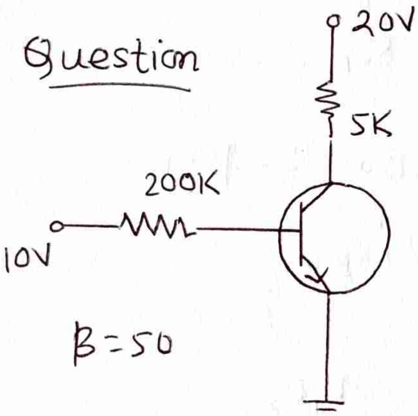


$$i_B = \frac{10 - 0.7}{50} = 0.186 mA$$

$$i_c = \beta i_B = 9.3 mA > (i_c)_{max}$$

(Saturated Region)

Question



$$V_{CE} = V_{cc} - i_c R_c$$

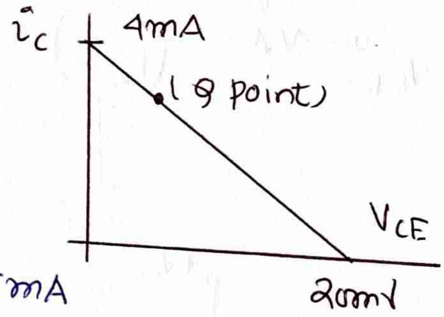
$$= 20 - i_c \times 5K$$

$$i_B = \frac{10 - 0.7}{200} = 0.0465 mA$$

$$i_c = \beta i_B = 2.325 mA$$

$$V_{CE} = 20 - i_c \times 5K$$

$$= 8.375 V$$

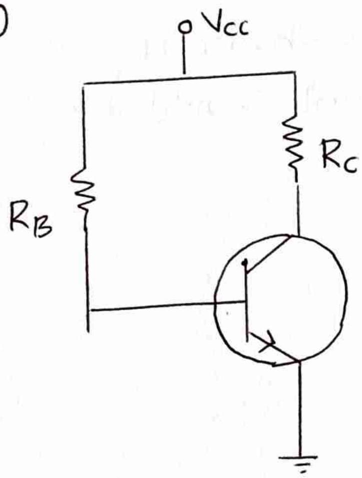


Stability Factor:

$$S = \left(\frac{di_c}{di_{CBO}}\right)_{V_{BE}, \beta} \qquad S = \left(\frac{di_c}{d\beta}\right)_{i_c, V_{BE}}$$

$$S = \left(\frac{di_c}{dV_{BE}}\right)_{\beta, i_{CBO}}$$

①



$$V_{CC} - i_B R_B - V_{BE} = 0$$

$$i_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$i_B = \frac{V_{CC}}{R_B}$$

$$i_C = \beta i_B = \beta \frac{V_{CC}}{R_B}$$

$$i_C = \beta i_B + (1+\beta) i_{CBO}$$

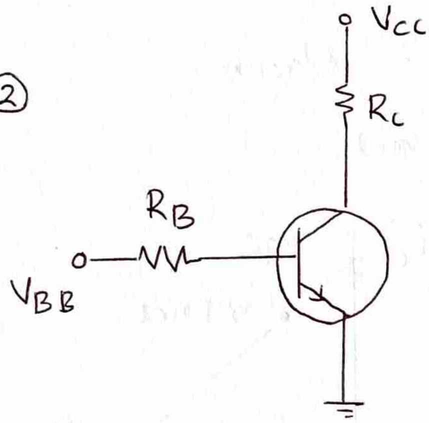
$$\frac{di_C}{di_C} = \beta \frac{di_B}{di_C} + (1+\beta)\frac{di_{CBO}}{di_C}$$

$$1 = (1+\beta)\frac{1}{S}$$

stability, $S = \left(\frac{di_C}{di_{CBO}}\right)_{\beta,\, V_{BE}} \Rightarrow 1/S = \left(\frac{1}{1+\beta}\right)$

$S = (1+\beta)$ (But is also β dependend)

②



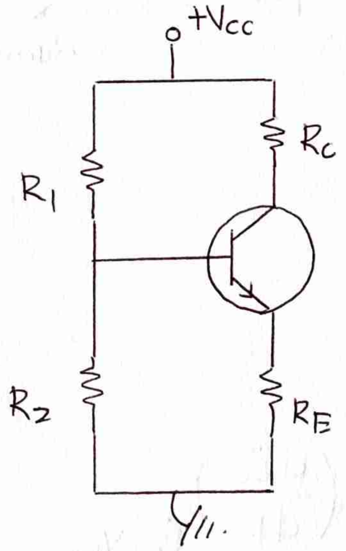
$$V_{BB} - i_B R_B - V_{BE} = 0$$

$$i_B = \frac{V_{BB} - V_{BE}}{R_B} \approx \frac{V_{BB}}{R_B}$$

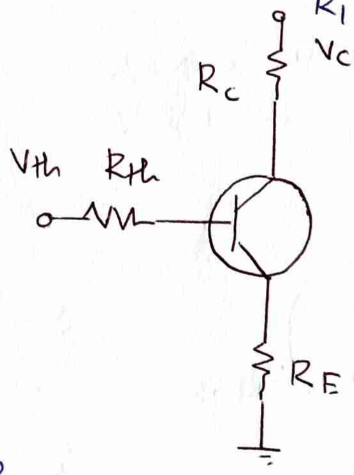
$$i_C = \beta i_B + (1+\beta) i_{CBO} \qquad S = \beta + 1$$

$$i_C = \beta \cdot \frac{V_{BB}}{R_B} + (1+\beta) i_{CBO}$$

③



$$V_{th} = \frac{V_{CC} R_2}{R_1 + R_2} \qquad R_{th} = \frac{R_1 R_2}{R_1 + R_2}$$



$$\cancel{i_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}}$$

But i_B should not written in form of β

$$i_C = \beta i_B + (1+\beta) i_{CBO}$$

$$= \beta\left[\frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}\right] + (1+\beta) i_{CBO}$$

That's why the process is wrong?

stability, $S = (1+\beta)$

Also, $$i_c = \beta\left(\frac{V_{th} - V_{BE} - i_E R_E}{R_{th}}\right) + (1+\beta) i_{CBO}$$

$$i_c = \beta\left(\frac{V_{th} - V_{BE} - (i_c + i_B) R_E}{R_{th}}\right) + (1+\beta) i_{CBO}$$

$$1 = \beta\left(-\frac{R_E}{R_{th}}\right) + (\beta+1)\frac{1}{S} \Rightarrow S = \left(\frac{1+\beta}{1+\beta \frac{R_E}{R_{th}}}\right)$$

so $$S = \frac{(1+\beta) R_{th}}{R_{th} + \beta R_E}$$

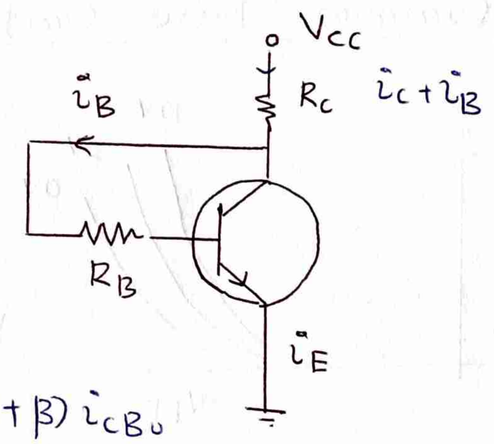
$R_1 \sim R_{th}$ (very less)

$R_{th} << \beta R_E$

$$S = \frac{(1+\beta)}{\beta} \frac{R_{th}}{R_E}$$

$$S = \left(1 + \frac{1}{\beta}\right) \frac{R_{th}}{R_E}$$

③ <u>Collector to Base Bias</u>



$$V_{cc} - i_B R_B - V_{BE} = 0$$

$$i_B = \frac{V_{cc} - V_{BE} - i_c R_c}{R_c + R_B}$$

$$i_c = \beta\left(\frac{V_{cc} - V_{BE} - i_c R_c}{R_c + R_B}\right) + (1+\beta) i_{CBO}$$

$$\frac{di_c}{di_c} = -\frac{\beta R_c}{R_c + R_B} + (1+\beta)\frac{di_{CBO}}{di_c}$$

$$1 + \frac{\beta R_c}{R_c + R_B} = (1+\beta)\frac{1}{S}$$

$$\frac{1}{S} = \frac{1}{(1+\beta)} + \frac{\beta R_c}{(\beta+1)(R_B + R_c)}$$

$$\frac{1}{S} = \frac{R_B + R_c + \beta R_c}{(1+\beta)(R_B + R_c)}$$

$$S = \frac{(\beta+1)(R_B + R_c)}{(\beta+1)\{R_c + R_B\}}$$

$$S = \frac{(\beta+1) R_B}{(1+\beta) R_c + R_B}$$

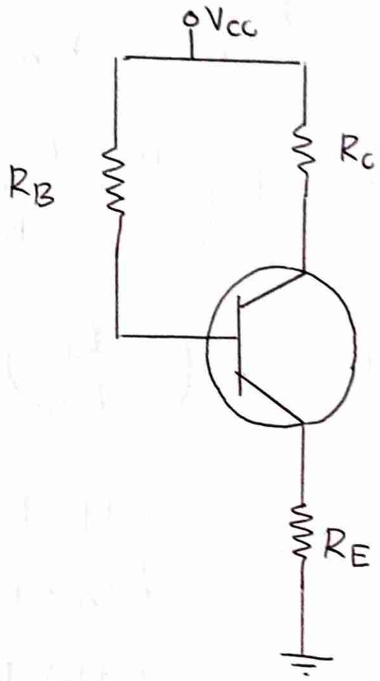
$(R_B >> R_c)$

if $R_c >> R_B$

$$S = \frac{(\beta+1) R_c}{(\beta+1) R_c} = 1$$

$S = 1$

④ Emitter Bias



$$i_B = \frac{V_{CC} - i_E R_E - V_{BE}}{R_B}$$

$$i_B = \frac{V_{CC} - i_C R_E - V_{BE}}{R_B + R_E}$$

$$i_C = \beta i_B + (1+\beta) i_{CB0}$$

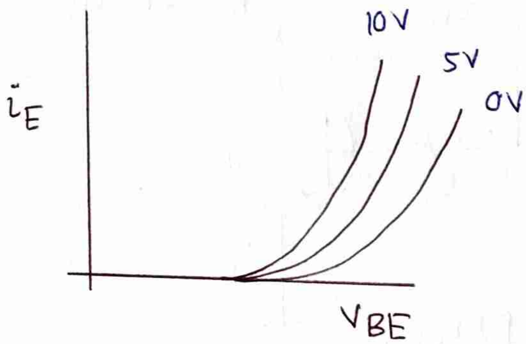
$$S = \frac{(1+\beta)(R_B+R_E)}{R_B + (\beta+1) R_E}$$

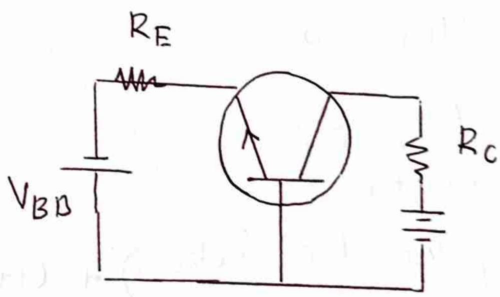
$R_B >> R_E$ $\qquad S = \frac{(1+\beta) R_B}{R_B + (1+\beta) R_E}$

$R_E >> R_B$

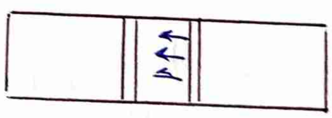
$$S = \frac{(1+\beta) R_E}{(1+\beta) R_E} = 1$$

⑤ Common Base Configuration





(V_{CB} as Constant) Reverse Bias



Base region is narrowed with increase Reverse Bias Early Effect

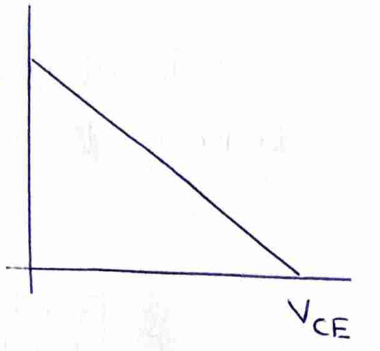
less current is needed for Forward Bias

① For a BJT under Saturation Condition

⇒ $i_c < \beta i_B$

where i_B from Circuit diagram

Here we get i_c



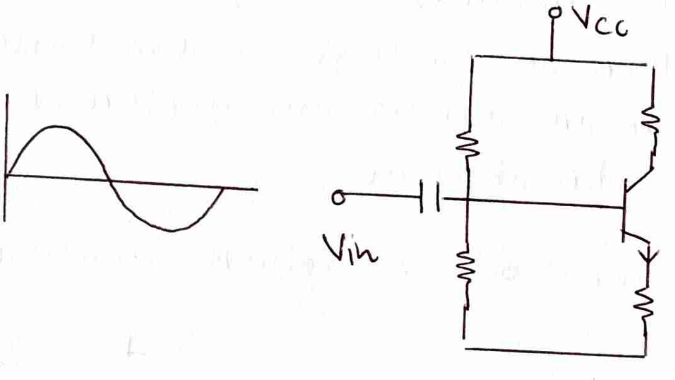
② In a phase shift Oscillator, the frequency determining elements are

⇒ $f = \frac{1}{2\pi\sqrt{6}RC}$ both R and C

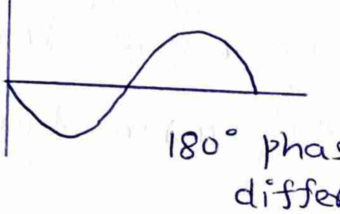
③ In a phase shift Oscillator $R = 1M\Omega$, $C = 68\ pF$. At what frequency does the Circuit Oscillates

⇒ $$f = \frac{1}{2\pi\sqrt{6}RC} = \frac{1}{2\pi\sqrt{6}\times10^{6}\times68\times10^{-12}} = 954\ Hz$$

④



The output is



180° phase difference

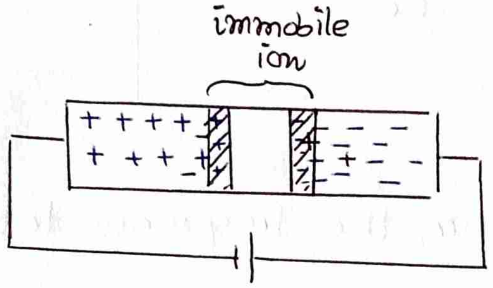
⑤ In a phase shift Oscillator the capacitance of each Capacitor is 5pF. The Value of R so that a frequency of 800 Hz is produced

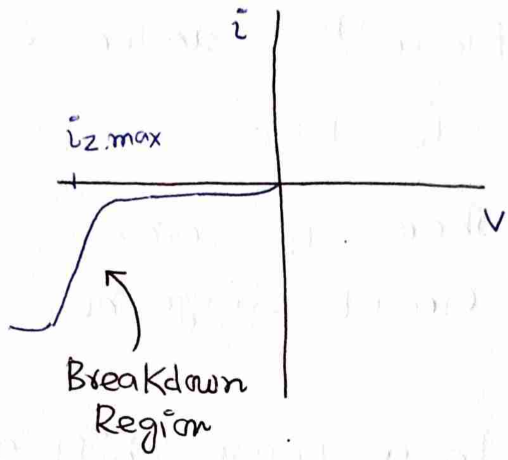
⇒ $$f = \frac{1}{2\pi\sqrt{6}RC} = 800$$

$$\frac{1}{R}\times\frac{1}{5}\times10^{12} = 800\times2\pi\sqrt{6} \Rightarrow R = 16.25\ K\Omega$$

Breakdown

It is always occurs in Reverse Bias.





Zener Diode

By KE, $e^{\ominus}$ will strike at depletion region and knock out the electrons. ⇒ Avalanche Breakdown.

⇓

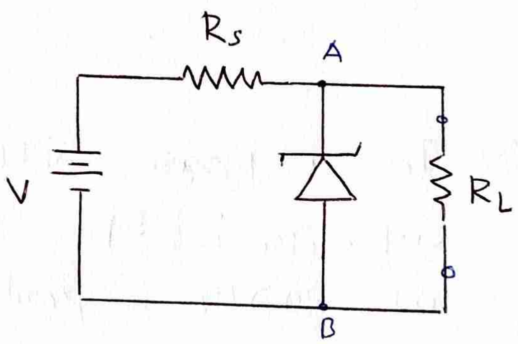
Further strike

That's why current will be increase very fast.

> If we increase ~~breakc~~ impurity (doping) width of the depletion layer will decrease so that we can control Zener voltage. So their are no as such difference between zener and Avalanche Breakdown

> At Forward Bias, Zener diode will behaves like normal diode.

> Voltage across A and B is V_{th}



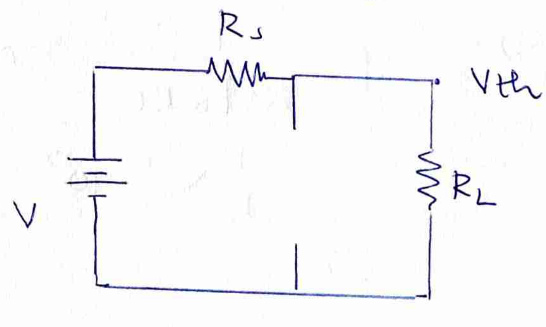
if $V_{th} > V_Z$ ⇒ Zener is On ⇒ $V_o = V_Z$

$V_{th} < V_Z$ ⇒ Zener is off ⇒ $V_o = V_{th}$

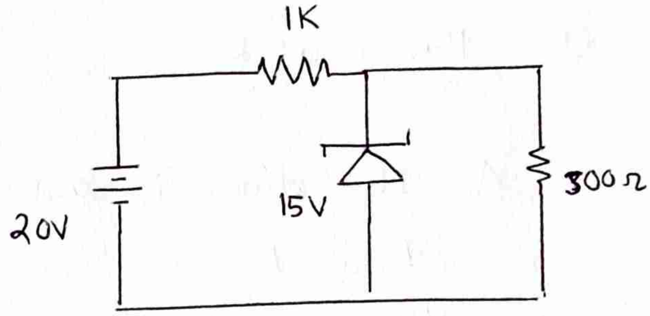
> How to get V_{th}:

Thevinin voltage

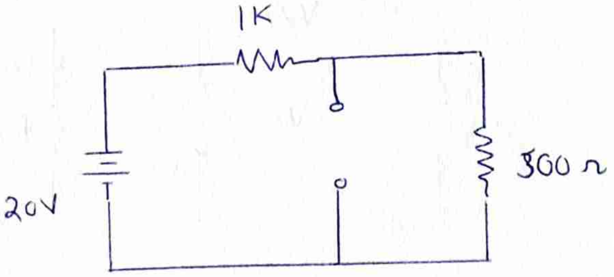
$$V_{th} = \left(\frac{VR_L}{R_S + R_L}\right)$$



① Is the diode ON or OFF



=)



$V_{th} = \frac{20 \times 500}{1500} = 6.67$ Volt

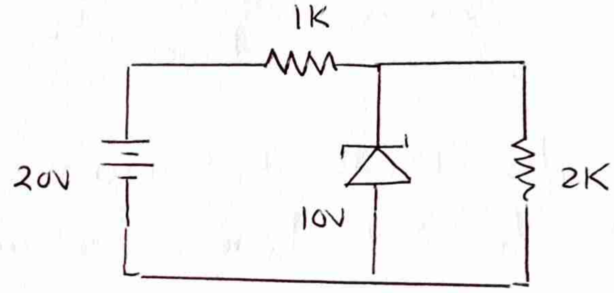
$V_Z = 15V$

$V_Z > V_{th}$

Zener diode is off.

So output voltage $V_o = V_{th} = 6.67$ volt

② check the zener diode



=)

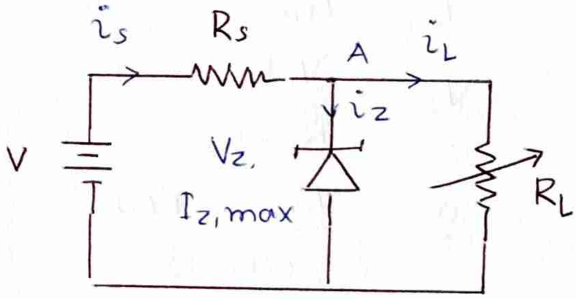
$V_{th} = \frac{2 \times 20}{3} = 13.33$ Volt

$V_Z = 10V$ so $V_{th} > V_Z$

Diode is ON.

So $V_{out} = V_Z = 10$ Volt

③ V, R_s is Given:



Minimum voltage to make ON of the Zener diode

$V_{th} \geq V_Z$ (ON)

Minimum $V_{th} = V_Z$

$$\frac{VR_L}{R_L + R_s} = V_Z$$

⇓

we get $R_{L,min}$

As the diode is ON. Voltage at point A is V_Z

$i_s = \frac{V - V_Z}{R_s}$ is constant

$i_s = i_Z + i_L$

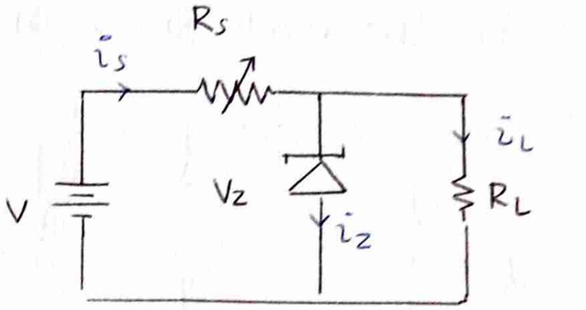
As $R_L \uparrow$, $i_L \downarrow$, $i_Z \uparrow$ as i_s is constant

But i_Z has a maximum value

$i_s = i_{L,min} + i_{Z,max}$

we get $R_{L,max}$ ⇐ $i_s = \frac{V_Z}{R_{L,max}} + i_{Z,max}$

④ <u>Range of R_s</u>



As the diode is ON

$V_{th} = V_z$

$$\frac{V R_L}{R_L + R_s} = V_z \Rightarrow R_s \text{ max}$$

$$i_s = \frac{V - V_z}{R_s} \qquad i_L = \frac{V_z}{R_L} = \text{Constant}$$

$$i_s = i_z + i_L \Rightarrow i_L = i_s - i_z$$

i_s, i_z maximum

i_z, i_s minimum

$$i_L = \frac{V - V_z}{R_s} - i_{z,max}$$

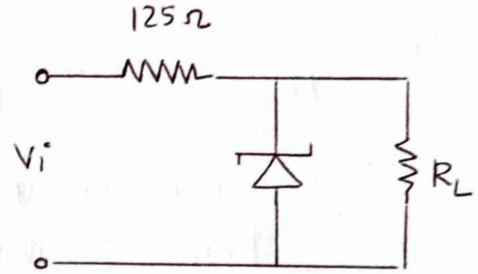
$R_s \downarrow, i_s \uparrow$

$$i_{z,max} = \frac{V - V_z}{R_{s,min}} - i_L$$

⑤ $R_s = 125\Omega$, $R_L = 470\ \Omega$,

$V_z = 9V$. $I_{z,max} = 65\ mA$

Find V_i^{max} and V_i^{min}



$\Rightarrow$ $V_z = V_{th}$

$$V_z = \frac{V_i R_L}{R_L + R_s}$$

$$i_L = i_s - i_z = \frac{V_z}{R_L}$$

$$9 = \frac{V_{i\,min} \times 470}{470 + 125}$$

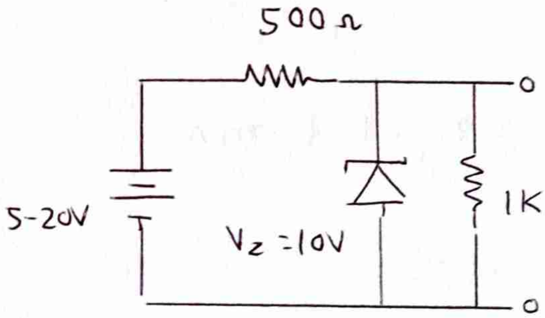
$$\frac{V_{max} - V_z}{R_s} - (65 \times 10^{-3}) = \frac{9}{470}$$

$$\frac{V_{max} - 9}{125} = 0.084 \Rightarrow V_{max} = 19.5$$

$V_{min} = 11.4$ Volt

⑥ The ratio of max to min Power dissipated will be

$\Rightarrow$ At 5V, Diode off



$$V = \frac{5 \times 1000}{1000 + 500} = \frac{10}{3} = 3.33 \text{ Volt}$$

$$P = \frac{V^2}{R_L} = \frac{(3.33)^2}{1000} \text{ watt (Min)}$$

To ON the diode

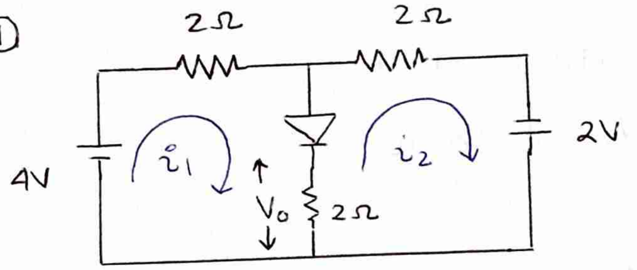
$$P = \frac{10^2}{1000} = 0.1 \text{ watt}$$

(Maximum)

$$10 = \frac{V \times 1000}{15000}$$

$V = 15$ Volt

① Find the Value V_o



$$-4+2i_1+2(i_1-i_2)=0$$
$$4i_1-2i_2=4$$
$$2i_1-i_2=2 \quad \text{— ①}$$

$$2i_2-2+2(i_2-i_1)=0$$
$$4i_2-2i_1=2 \quad \text{— ②}$$

$$2i_1-i_2=2$$
$$-2i_1+4i_2=2$$
$$3i_2=4 \Rightarrow i_2=4/3\ A$$

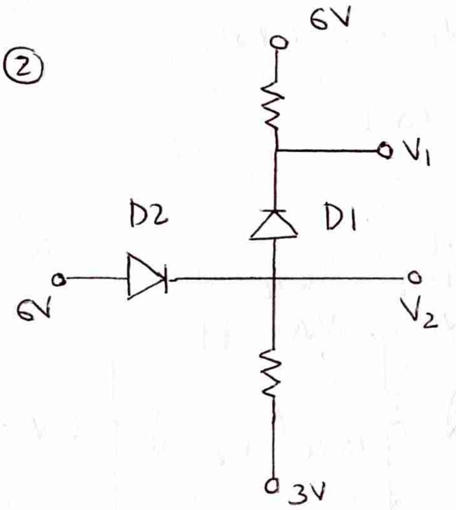
$$2i_1=2+i_2=2+\frac{4}{3}=\frac{10}{3}$$
$$i_1=\frac{5}{3}\ A$$

Current through the diode

$$i=(i_1-i_2)=\frac{1}{3}\ A$$

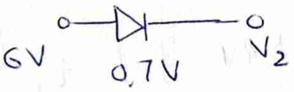
Voltage across the resistance $V_o=2i=2/3$ volt

② Voltage across diode is 0.6 Volt. Find the Values of V_1 and V_2



⇒ As diode D_1 is in reverse Bias, $V_1=6$ Volt

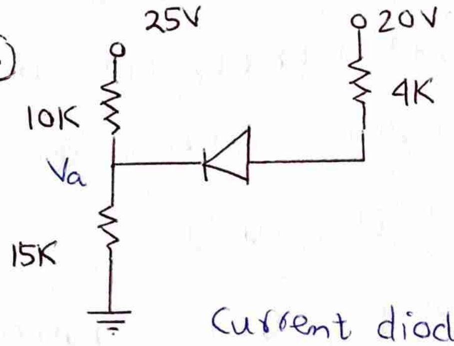
Now voltage across D_2



$V_2=6-0.6=5.4$ Volt

$V_1=6$ Volt, $V_2=5.4$ Volt

③ Find the current across Diode



⇒ By Node analysis

$$\frac{V_a-25}{10}+\frac{V_a-0}{15}+\frac{V_a-20}{4}=0$$

$$6V_a-150+4V_a+15V_a-300=0$$
$$25V_a=450 \Rightarrow V_a=18\ \text{Volt}$$

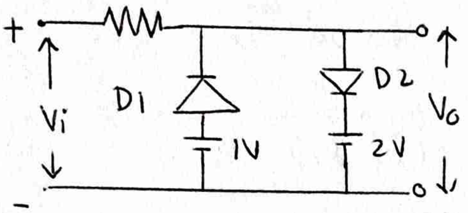
Current diode

$$i_d=\frac{20-18}{4}=0.5\ A$$

④ A particular LED emits light of $\lambda=5490$ Å. the energy band gap of semiconductor material

⇒ $$\Delta E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\times3\times10^{8}}{5490\times10^{-10}}=2.26\ eV.$$

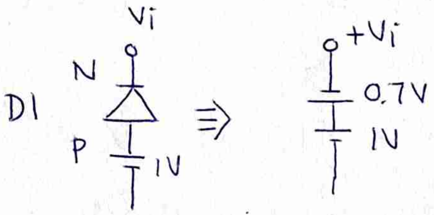
⑤



Voltage drop = 0.7V.

if $V_o = V_i$ then

⇒ Input Voltage is equal to output voltage if both the diode are in reverse Bias.



D1 will be in Forward Bias

if $V_P - V_N > 0.7$

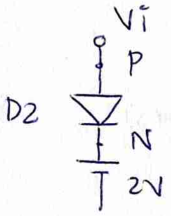
$1 - V_N > 0.7$

$1 - V_i > 0.7$

$V_i \leq .3$ Volt

For Reverse Bias

$V_i > 0.3$ Volt



D2 will be in Forward Bias

$V_P - V_N > 0.7$

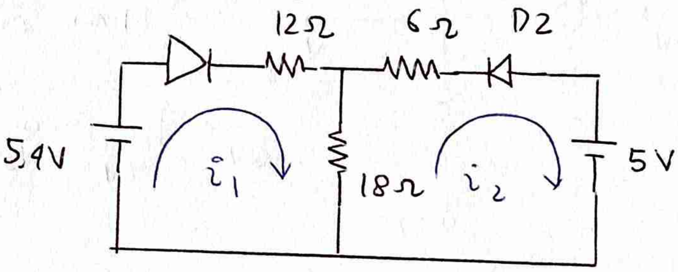
$V_P - 2 > 0.7 \Rightarrow V_P > 2.7$ Volt

For Reverse Bias $V_P < 2.7$ Volt

$0.3 < V_i < 2.7$

⑥ check D1, D2 are in Forward Bias or not

(Given $V_\gamma = 0.6$ Volt)



⇒

$-5.4 + 0.6 + 12i_1 + 18(i_1 - i_2) = 0$

$30i_1 - 18i_2 = 4.8$

$5i_1 - 3i_2 = 0.8$ — ①

$6i_2 - 0.6 + 5 + 18(i_2 - i_1) = 0$

$-18i_1 + 24i_2 = -4.4$ — ②

$40i_1 - 24i_2 = 6.4$

$-18i_1 + 24i_2 = -4.4$

$22i_1 = 2$

$i_1 = \frac{1}{11}$

$i_2 = \frac{1}{3}(5i_1 - 0.8)$

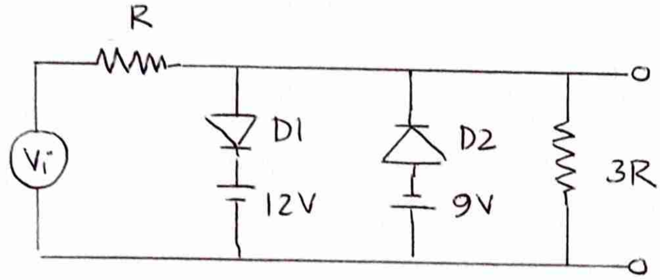
$= \frac{1}{3}\left(\frac{5}{11} - 0.8\right) = -0.09A$

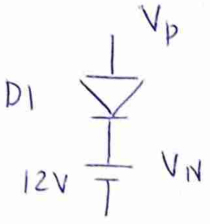
$i_1 = 0.09A \quad i_2 = -0.09A$

Both D_1 and D_2 is in Forward Bias.

(7) Draw the transfer characteristic

$\Rightarrow$





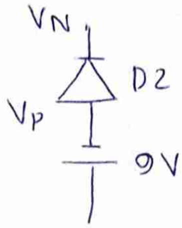
$V_P - V_N > 0$

$V_P > V_N$

$V_{P_1} \geq 12$ Volt

(Forward Bias)

$V_i \leq 12$ Volt (RB)



For Forward Bias

$V_P - V_N > 0$

$-9 - V_N > 0$

$V_i \leq -9$

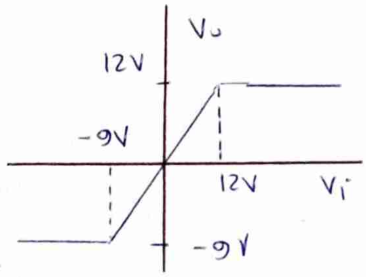
$V_i > -9V$ (RB)

$D1, D2 \Rightarrow FB \Rightarrow V_o = -9V$

$D1\ FB,\ D2\ RB \Rightarrow V_o = -12V$

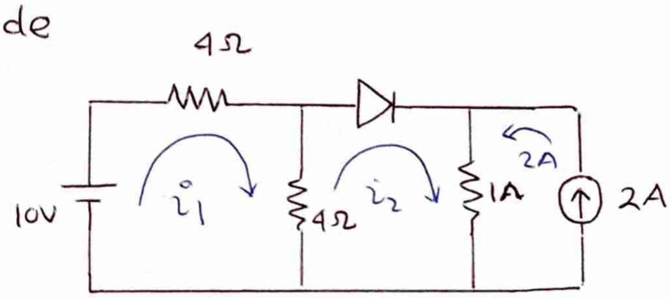
$D1\ RB\ D2\ FB \Rightarrow V_o = -9V$

$D1.\ D2\ RB \Rightarrow V_o = V_i$



(8) Find the current through diode

$\Rightarrow$



$-10 + 4i_1 + 4(i_1 - i_2) = 0$

$8i_1 - 4i_2 = 10$

$4i_1 - 2i_2 = 5 \quad \text{— (I)}$

$1(i_2 + 2) + 4(i_2 - i_1) = 0$

$5i_2 - 4i_1 = -2$

$3i_2 - 2i_1 = -1 \quad \text{— (II)}$

$$\begin{array}{r} 4i_1 - 2i_2 = 5 \\ -4i_1 + 5i_2 = -2 \\ \hline 3i_2 = 3 \end{array}$$

$i_2 = 3/3 = 1$

$i_2 = 1$

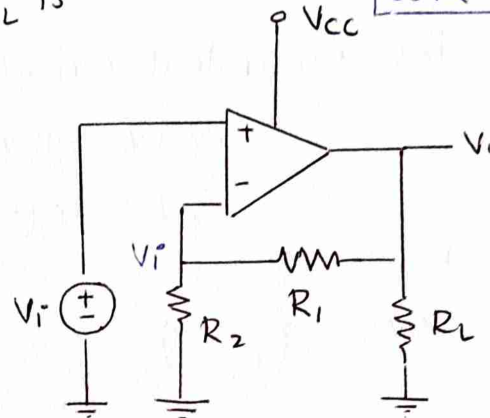
$4i_1 = 5 + 2i_2 = 5 + \frac{3}{2} = \frac{13}{2}$

$i_1 = 13/8$

Current through diode is 1A.

① In the Circuit the input Voltage V_i is 2V, $V_{cc} = 16V$, $R_2 = 2K\Omega$ and $R_L = 10K\Omega$. The Value of R_1 required to deliver 10mW of power across R_L is

CSIR-2016



⇒ By KCL

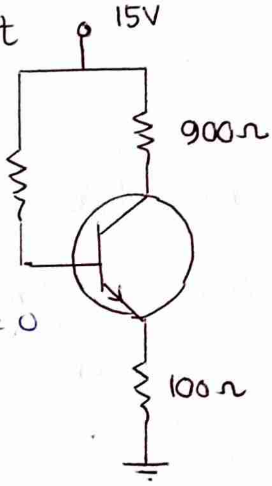
$$\frac{0-V_i}{R_2} = \frac{V_i - V_o}{R_1} = \frac{V_o - 0}{R_L}$$

$$P_L = \frac{V_o^2}{R_L} = 10mW \Rightarrow V_o = 10 \text{ Volt}$$

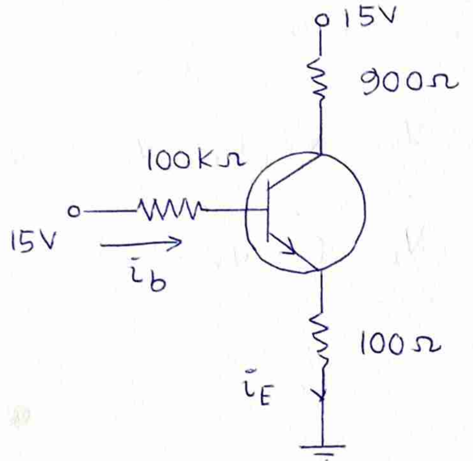
$$\frac{0-2}{2} = \frac{2-10}{R_1} \Rightarrow R_1 = 8K\Omega$$

② Consider the Circuit. $\beta = 100$. Find the Q point

GATE-2012



⇒



$$-15 + 100 i_b + 0.7 + 100 i_E = 0$$

$$100 i_b + 0.1 i_E = 14.3$$

$$i_b = \frac{14.3}{100} mA$$

$$i_c = \beta i_b = 14.3 mA$$

$$V_{CE} = V_{cc} - i_c (R_C + R_E)$$

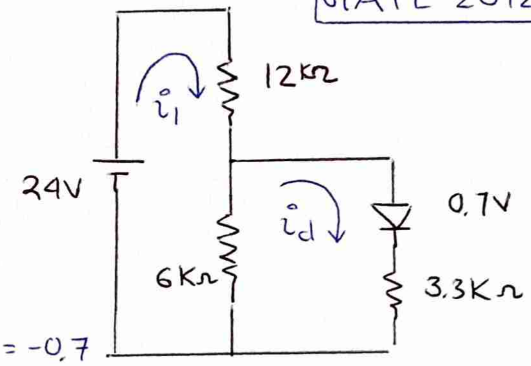
$$= 15 - (900+100) \times 13 \times 10^{-3} = 2V$$

$$i_c = \frac{V_{cc}}{R_c + R_E} = \frac{15}{1000} = 15mA$$

Q point. (2, 13mA)

GATE-2012

③ Current Passing through the diode



⇒

$$-24 + 12 i_1 + 6(i_1 - i_d) = 0$$

$$18 i_1 - 6 i_d = 24$$

$$3 i_1 - i_d = 4 \quad \text{— ①}$$

$$-2 i_d + 6 i_1 = 8$$

$$0.7 + 3.3 i_d + 6(i_d - i_1) = 0$$

$$9.3 i_d - 6 i_1 = -0.7 \quad \text{— ⑪}$$

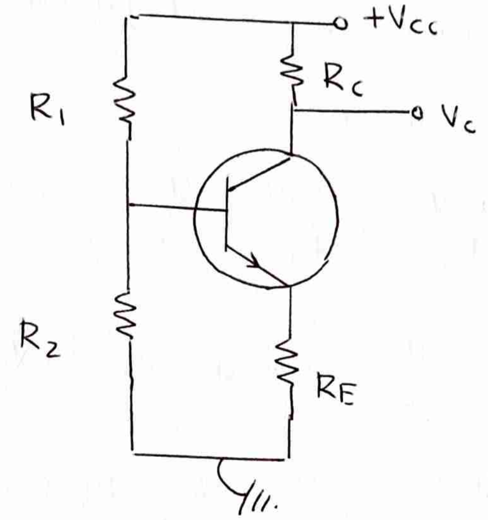
$$9.3 i_d - 6 i_1 = -0.7$$

$$-2 i_d + 6 i_1 = 8$$

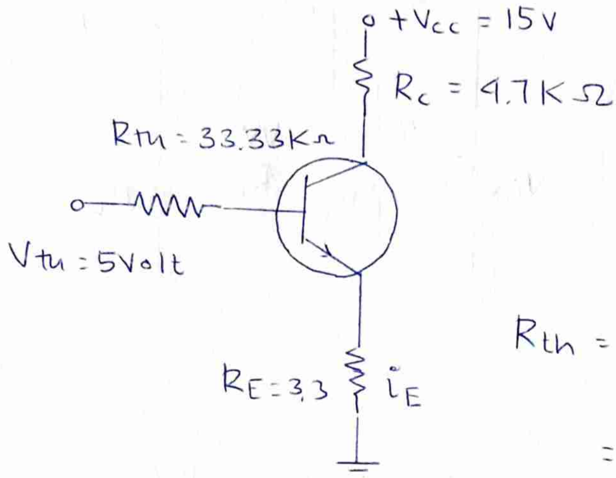
$$7.3 i_d = 7.3 \Rightarrow i_d = 1mA$$

(9) In the following circuit. $\beta = 100$, $V_{BE} = 0.7V$ what will be the Collector voltage. $V_{cc} = 15V$, $R_1 = 100K\Omega$, $R_2 = 50K\Omega$, $R_c = 4.7K\Omega$. $R_E = 3.3K\Omega$

JAM 2023



=) The equivalent circuit



$$R_{th} = \frac{V_{cc}R_2}{R_1+R_2}$$

$$= \frac{15\times50}{150} = 5 \text{ K}\Omega \text{ Volt}$$

$$R_{th} = \frac{R_1R_2}{R_1+R_2} = \frac{100\times50}{150} = 33.33\ K\Omega$$

$$-V_{th} + i_bR_{th} + V_{BE} + i_ER_E = 0$$

$$-5 + 33.3\,i_b + 0.7 + i_b 101\times3.3 = 0$$

$$i_b = \frac{5-0.7}{366.6} = \frac{4.3}{366.6}\ A$$

$$V_{cc} - i_cR_c = V_c - i_ER_E$$

$$V_c = 8.9 \text{ Volt}$$