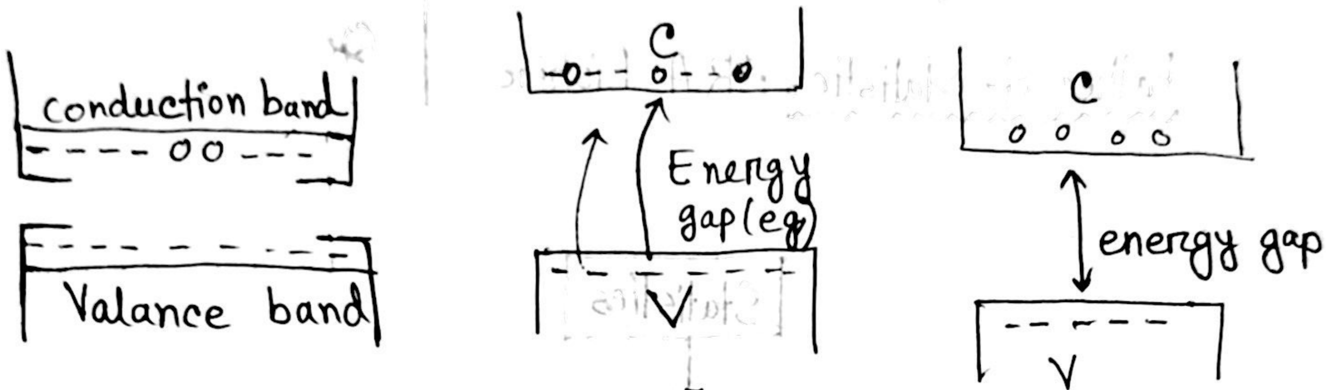
C.W 22/10/2024

CSE251

Diode

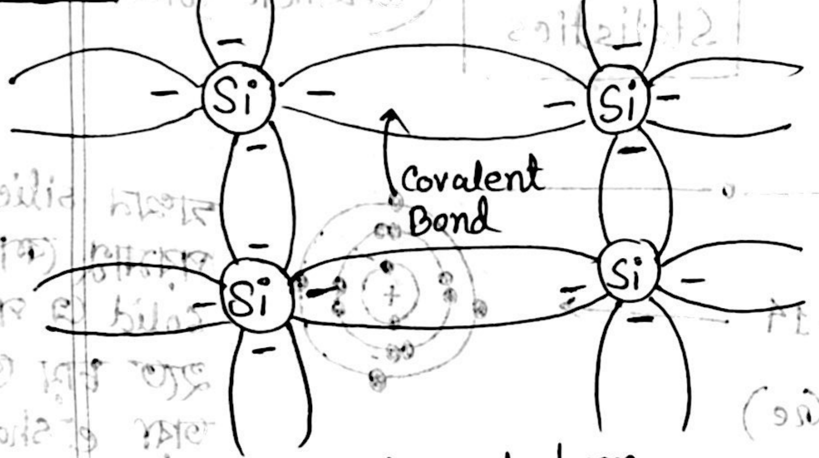
Conductor — Semi-Conductor — Insulator



Ge → 0.67ev

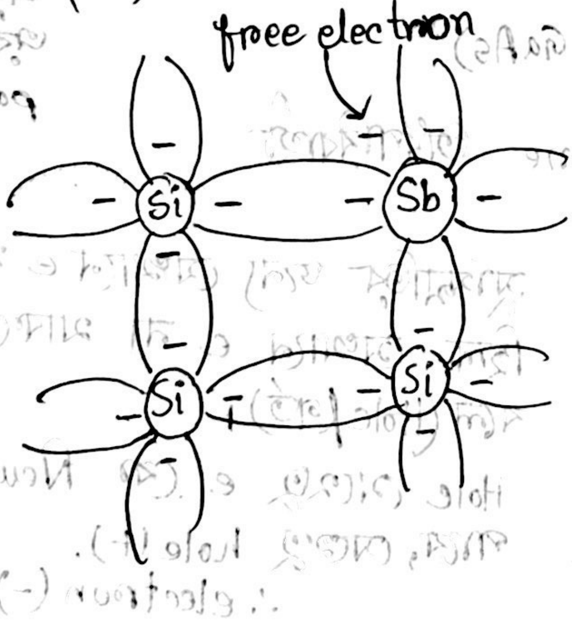
Si → 1.1ev

Si : crystal

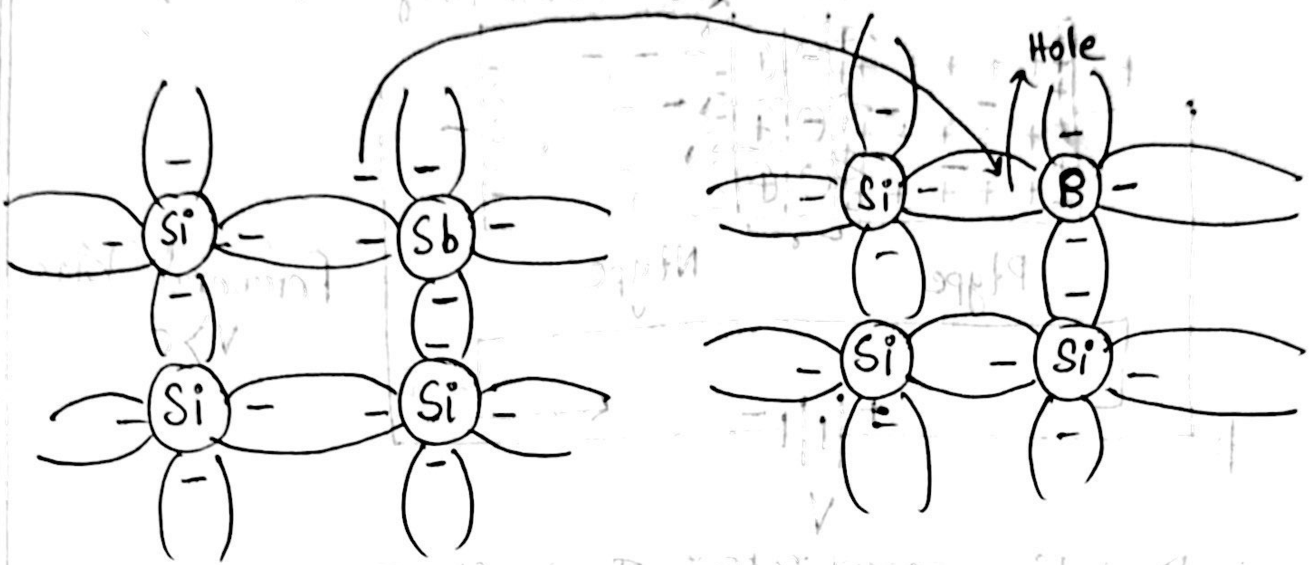


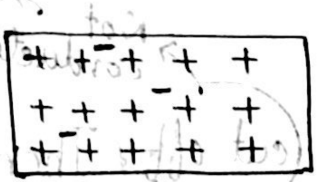
Intrinsic material : No impurity or pure (all silicone)

Dope :

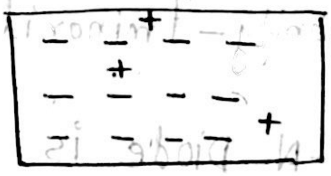


Dope Intrinsic material
↓
Extrinsic material
↓
impure
↓
n type (5 টা)
p type → Al, B, Ga (+3)





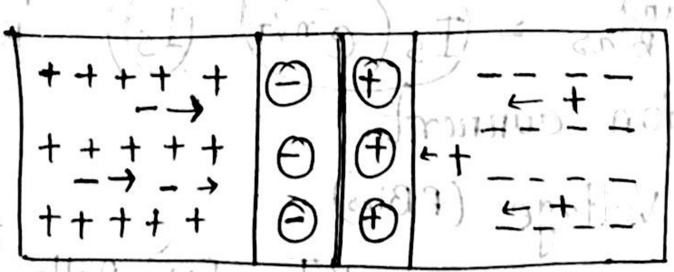
P type ↓



N-type ↓

P type	N-type
Hole → +ve → Majority careerr	Electron → -ve → Majority careerr
electron → -ve → Minority careerr	Hole → +ve → Minority "

P-N Diode :

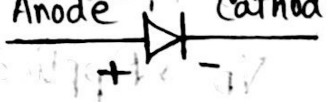


Ptype (Junction) Ntype

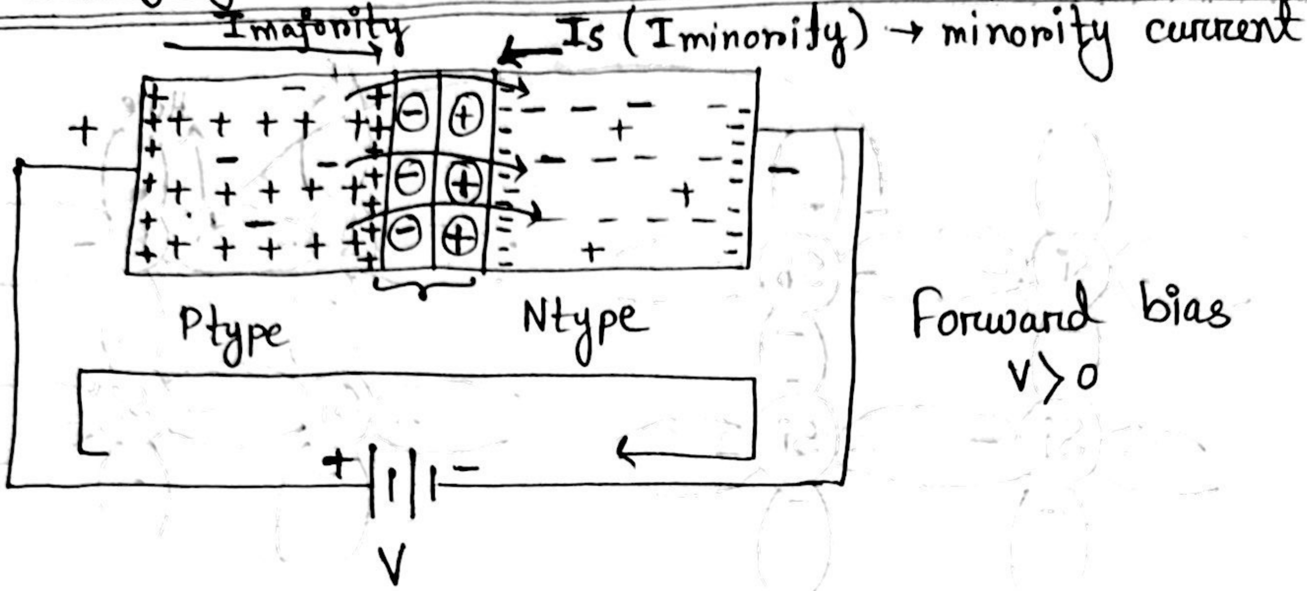
$\underbrace{\text{(Junction)}}$ Depletion region (W)

P-N → Diode

Anode cathode



Applying V on P-N Diode :



Forward bias
$V > 0$

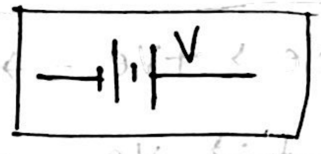
Depletion ভেঙ্গে গেলে I minority হয়।

$I_D = I_{majority} - I_{minority}$

→ Not conducting → less than 0.7 for Si

* if $V = 0$, P-N Diode is called cut off Then, Depletion region will be reformed.

- Reverse bias condition when, $V < 0$.



- Diode current, $I_D = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$

$$\text{Forward Bias} = I_S\left(e^{\frac{V_D}{nV_T}}\right) - (I_S) \quad \text{Reverse Bias}$$

$I_S \to$ Reverse Saturation current

$V_D \to$ Applied Voltage (F-Bias)

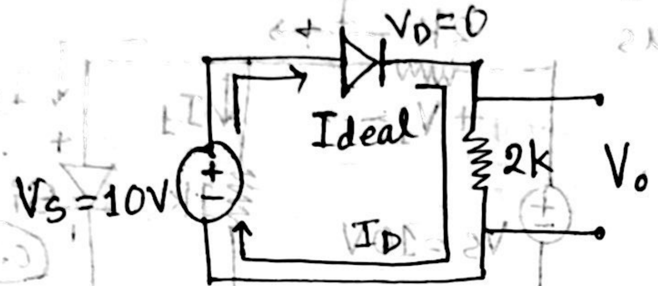
$V_T \to$ Thermal voltage $= \frac{KT}{q}$ [K = Boltzman constant] → 1.38×10^{-23} J/K

$\eta \to$ Identity factor (1 or 2) depends on construction

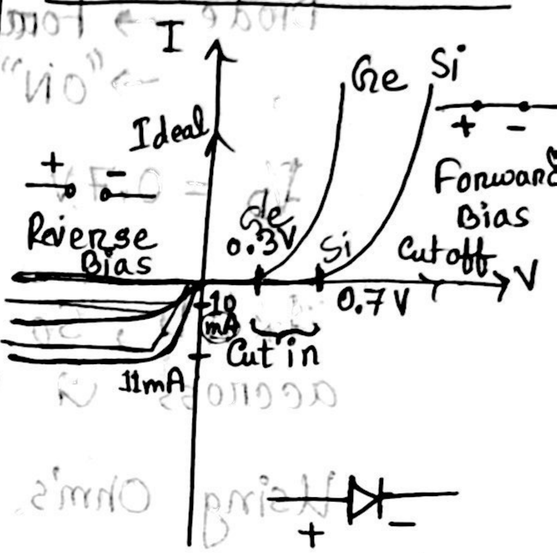
$\eta \to 1$: Ge

$\eta \to 2$: Si

Determine the voltage V_o



I-V characteristic curve



Soln:

Diode → forward bias → "ON"

Ideal Diode, $V_D = 0V$

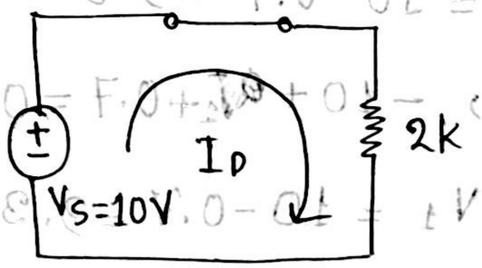
$$I_D = \frac{V_S}{2k} = \frac{10}{2k} \text{ [Ohm's law]}$$

$$= 5mA$$

$$V_o = 2K \times I_D$$

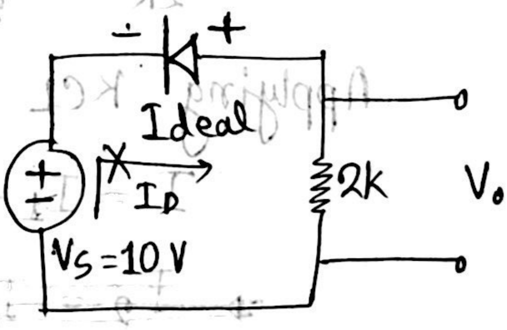
$$= 2k \times 5mA$$

$$= 10V$$



Reverse Diode এর ক্ষেত্রে,

Diode → Reverse bias → "OFF"

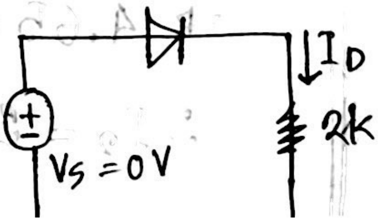


$I_D = 0A$

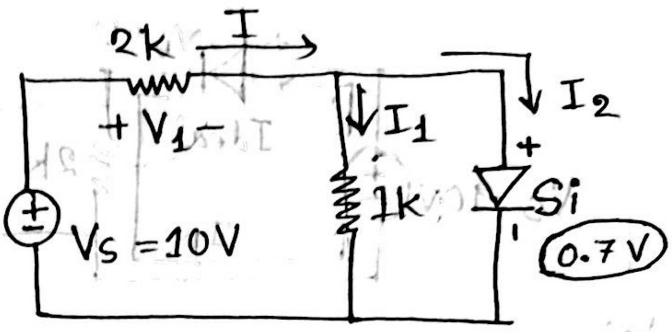
$V_o = 0V$

Diode → cut off

$I_D = 0A$



Determine I, I_1, I_2 & V_1

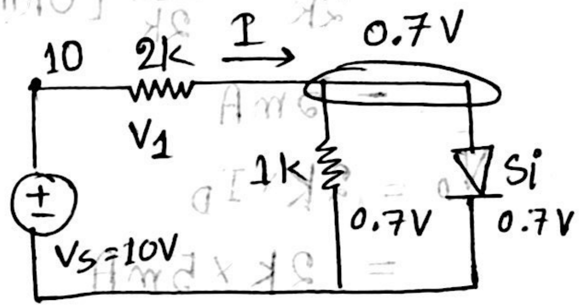


Diode → Forward bias
→ "ON"

$V_D = 0.7V$

$1k \parallel D$, So 1k এর
accross এ $V = 0.7V$

Using Ohm's law, $I_1 = \frac{0.7}{1k} = 0.7\,mA$



$V_1 = 10 - 0.7 = 9.3V$

OR, KVL, $-10 + V_1 + 0.7 = 0$

$\Rightarrow V_1 = 10 - 0.7 = 9.3V$

$I = \frac{V_1}{2k} = \frac{9.3}{2} = 4.65\,mA$

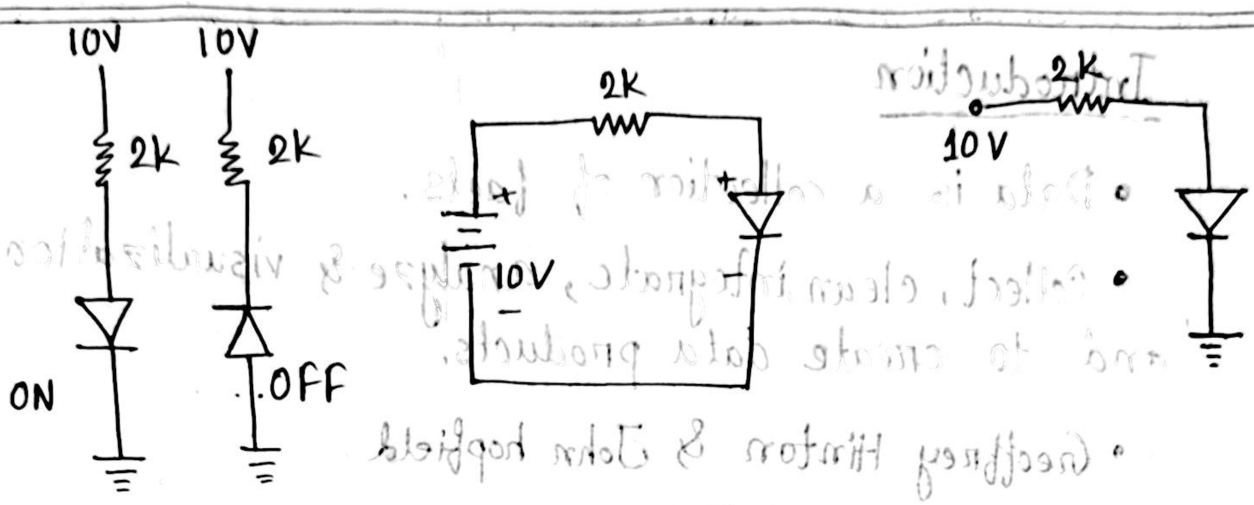
Applying KCL at node A,

$I = I_1 + I_2$

$\cancel{\Rightarrow I_2 = I - I_1}$

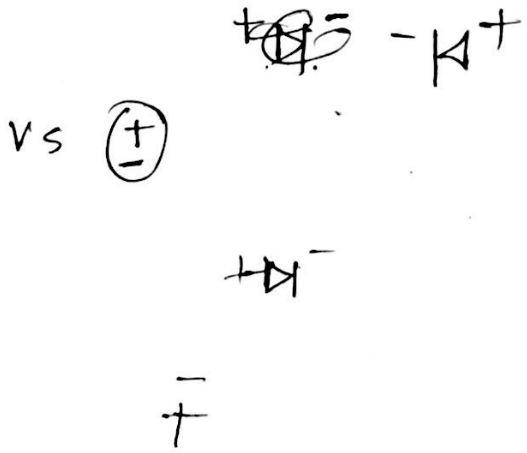
$\Rightarrow 4.65 = 0.7 + I_2$

$\therefore I_2 = 3.9\,mA$ (Ans)



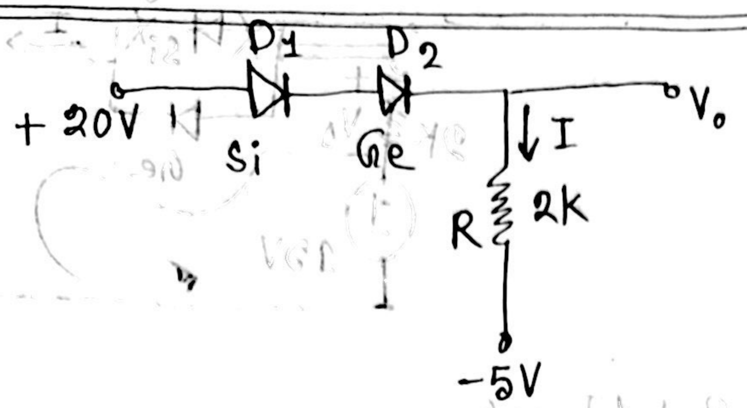
Forward Bias → Short circuit

Reverse Bias → Open circuit



C.W
27/10/2024

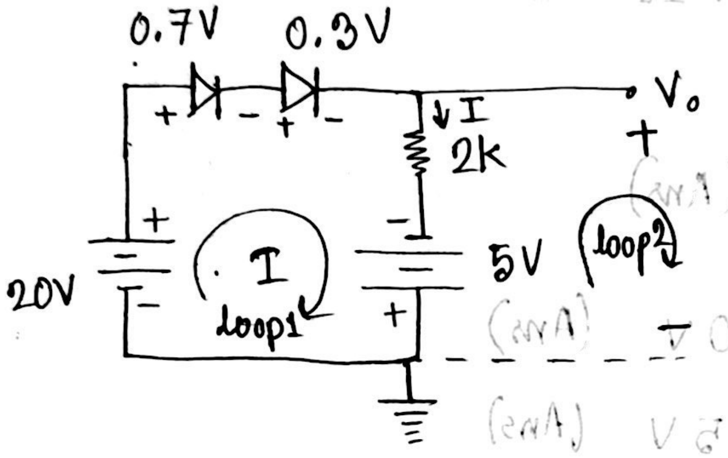
Determine the current I & the voltage V_o



Si = 0.7 V

~~Ge = 0.6~~

Ge = 0.3 V



Forward Bias

∴ D1 & D2 → "ON"

KVL,

$-20 + 0.7 + 0.3 + 2I - 5 = 0$

$\Rightarrow 2I = 24$

$\Rightarrow I = 12\ mA$ (Ans)

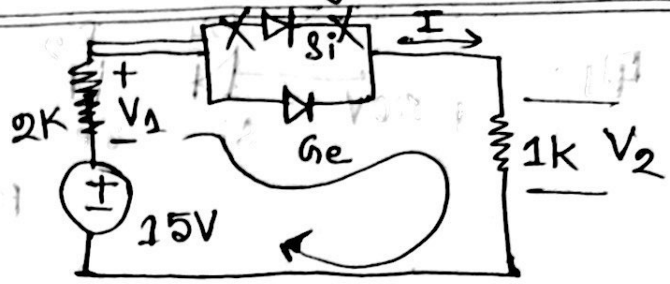
KVL in loop 2, $+5 - 2I + V_o = 0$

$\Rightarrow 5 - 24 + V_o = 0$

$\Rightarrow V_o = 19\ V$ (Ans)

Scanned with CamScanner

Determine the current I & the voltage V_1 & V_2



$D_1 \rightarrow$ "OFF"

$D_2 \rightarrow$ "ON"

Applying KVL,

$$-15 + 2I + 0.3 + 1I = 0$$

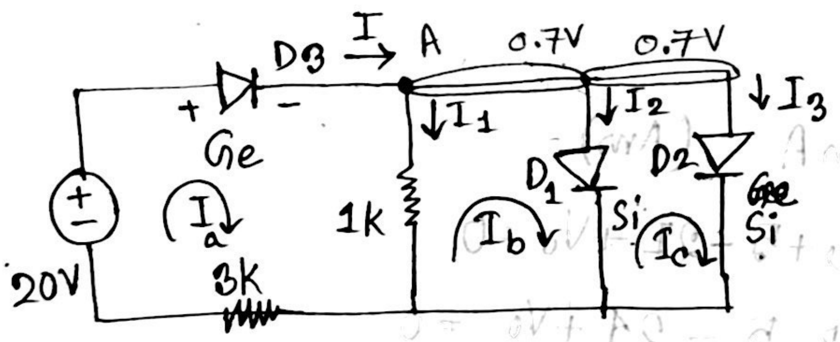
$$\Rightarrow 3I = 14.7$$

$$\Rightarrow I \approx 5\,mA \text{ (Ans)}$$

$$\therefore V_1 = 2 \times 5 = 10\,V \text{ (Ans)}$$

$$\therefore V_2 = 1 \times 5 = 5\,V \text{ (Ans)}$$

Determine the voltage V_1 & the currents I_1, I_2, I_3



Applying mesh analysis in loop 1,

$$-20 + 0.3 + I_a - I_b + 3I_a = 0$$

$$\Rightarrow 4I_a - I_b = 19.7$$

Applying mesh analysis in loop 2,

$I_b - I_a + 0.7 = 0$

$\Rightarrow I_a - I_b = 0.7$

~~Applying mesh analysis in loop 3,~~

Wrong Answer

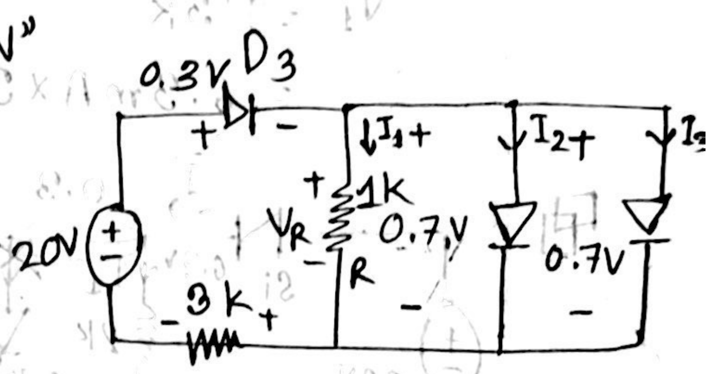
$4I_a - I_b - I_a + I_b = 19.7 - 0.7$

$\Rightarrow 3I_a = 19$

$\therefore I_a = 6.33\ mA$

Soln:

D_1, D_2 & $D_3 \longrightarrow$ "ON"



$V_{D_3} = 0.3V$

$V_{D_1} = V_{D_2} = 0.7V$

Since, $R \| D_1 \| D_2$

$V_R = V_{D_1} = V_{D_2} = 0.7V$

Applying KVL, $-20 + V_{D_3} + V_R + V_1 = 0$

$\Rightarrow -20 + 0.3 + 0.7 + I' 3k = 0$

$\therefore I' = 6.3\ mA = I$

(Ans)

Applying KCL, at node A

$$I = I_1 + I_2 + I_3$$

Using Ohm's law,

$$I_1 = \frac{0.7}{1K} = 0.7\,mA$$

$$\Rightarrow I_2 + I_3 = I - I_1$$

$$= 6.3\,mA - 0.7\,mA$$

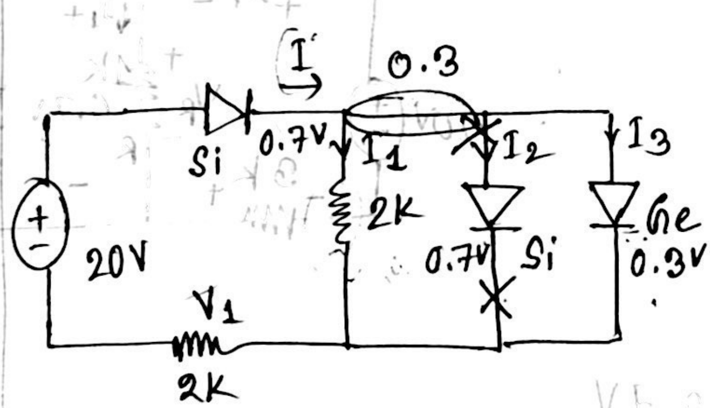
$$= 5.6\,mA$$

$$I_2 = I_3 = \frac{5.6}{2}\,mA = 2.8\,mA \text{ (Ans)}$$

$$V_1 = I' 3K$$

$$= 6.3\,mA \times 3 = 18.9\,V \text{ (Ans)}$$

V_1, I_1, I_2 & I_3



KVL,

$$-20 + 0.7 + 0.3 + 2I = 0$$

$$\Rightarrow 2I = 19$$

$$\therefore I = 9.5\,mA$$

$$\frac{I_s \times}{R}$$

As D_2 = "OFF", $I_2 = 0\,mA$

Ohm's law,

~~KVL in loop~~, ~~CDR~~, $I_1 = \frac{0.3}{2} = 0.15\,mA$

2Ω

Applying KCL, $I = I_1 + I_3$

$\Rightarrow I_3 = I - I_1$

$\therefore I_3 = 9.5 - 0.15 = 9.35\,mA$

$\therefore V_1 = 2 \times I = 2 \times 9.5 = 19\,V$

Slide-11

AND Gate

A	B	Output
0V 0	0V 0	0V 0
0V 0	5V 1	5V 1
5V 1	0V 0	5V 1
5V 1	5V 1	5V 1

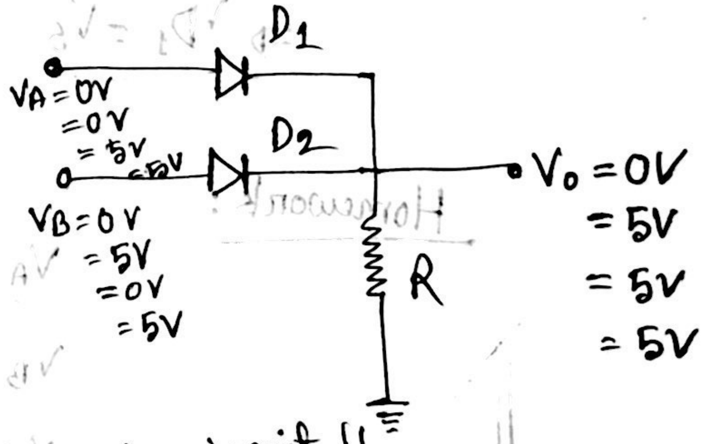
logic "0" → 0V
logic "1" → 5V

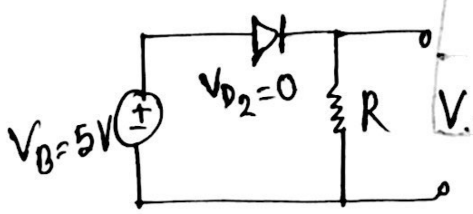
OR Gate

A	B	Output
0V 0	0V 0	0V 0
0V 0	5V 1	0V 0
5V 1	0V 0	0V 0
5V 1	5V 1	5V 1

D_1 & D_2 → Ideal diode

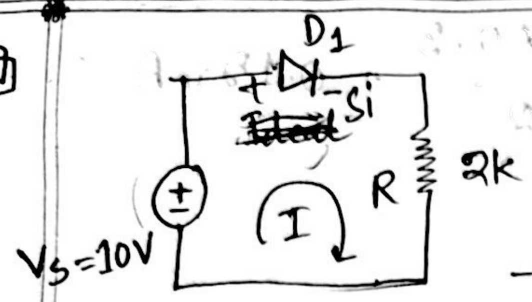
V_{D_1} & $V_{D_2} \rightarrow 0V$





This circuit is representing → OR gate

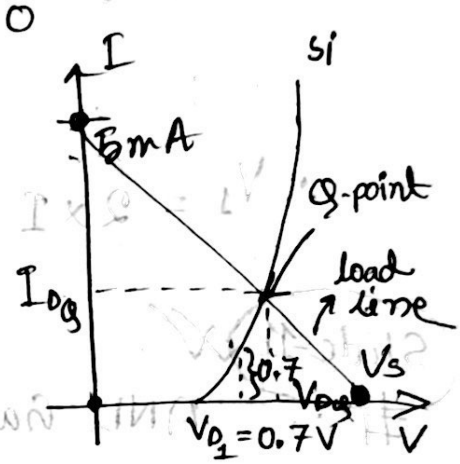
Determine the load line for the following circuit and determine the Q point.



$$-V_S + V_D + V_o = 0$$

<u>Soln:</u> Applying KVL, $-10 + 0.7 + 2I = 0$

$$\Rightarrow I = 4.65 \text{ mA}$$



Let $V_{D_1} = 0V$

$$-V_S + V_R = 0$$

$$\Rightarrow V_R = V_S$$

$$\Rightarrow IR = V_S$$

$$\Rightarrow I = \frac{V_S}{R}$$

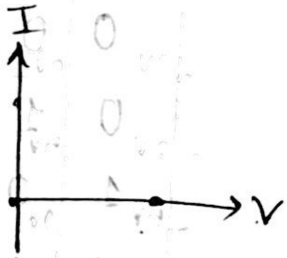
$$= \frac{10}{2} = 5\text{mA}$$

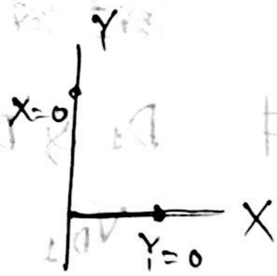
Let, <u>$I = 0A$</u>, From eqn ①

$$-V_S + V_{D_1} + IR = 0$$

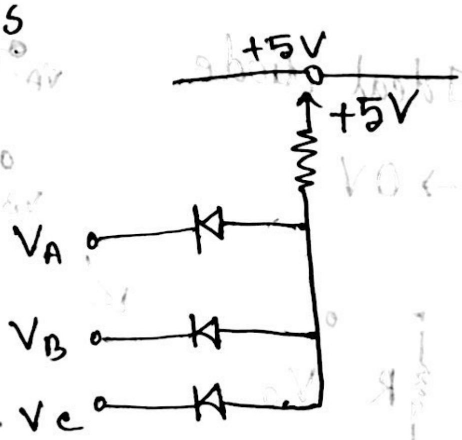
$$\Rightarrow -V_S + V_{D1} = 0 \qquad [IR = 0]$$

$$\Rightarrow V_{D_1} = V_S$$





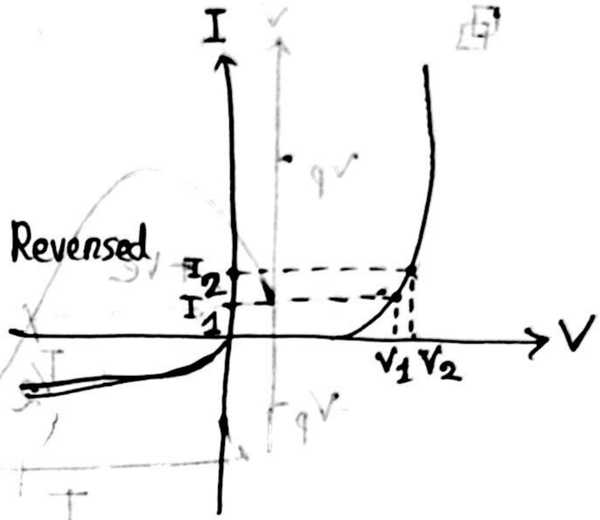
<u>Homework:</u>



29/10/24

$$I = I_s\left(e^{\frac{V_D}{nV_T}} - 1\right)$$

$$= \underbrace{I_s e^{\frac{V_D}{nV_T}}}_{\text{Forward Bias}} \underbrace{- I_s}_{\text{Reverse Bias}}$$



V_T = Thermal Voltage

$$\therefore V_T = \frac{KT}{q} = 25.5 \approx 26\,mV$$

Let, $n = 1$

$$\therefore I_1 = I_s e^{\frac{V_1}{V_T}}, \quad I_2 = I_s e^{\frac{V_2}{V_T}}$$

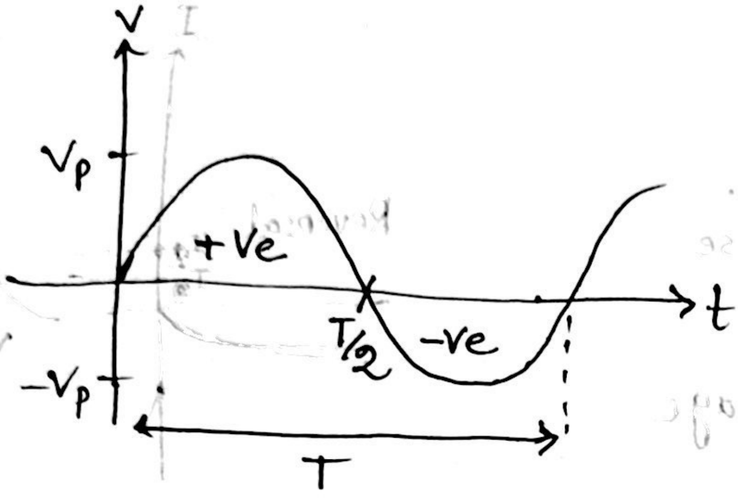
$$\therefore \frac{I_2}{I_1} = \frac{I_s e^{V_2/V_T}}{I_s e^{V_1/V_T}} = \frac{e^{V_2/V_T}}{e^{V_1/V_T}}$$

$$\Rightarrow \frac{I_2}{I_1} = \frac{e^{V_2/V_T}}{e^{V_1/V_T}}$$

$$\Rightarrow \frac{I_2}{I_1} = e^{(V_2 - V_1)/V_T}$$

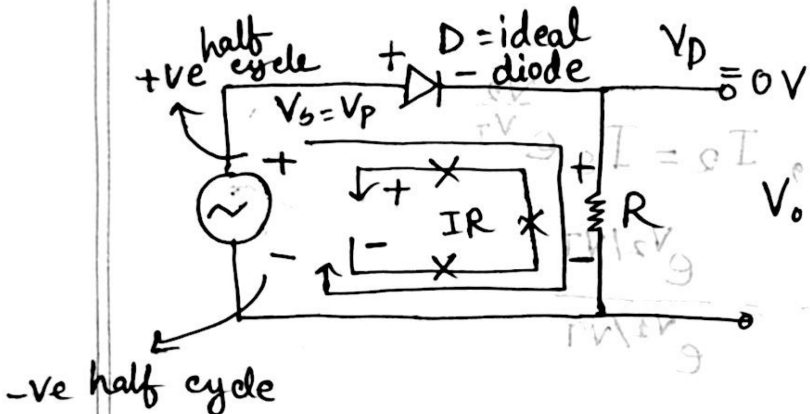
$$\Rightarrow V_2 - V_1 = V_T \ln\left(\frac{I_2}{I_1}\right)$$

$$\Rightarrow \boxed{V_2 - V_1 = \underbrace{2.3\, V_T}_{60\,mV} \log\left(\frac{I_2}{I_1}\right)}$$

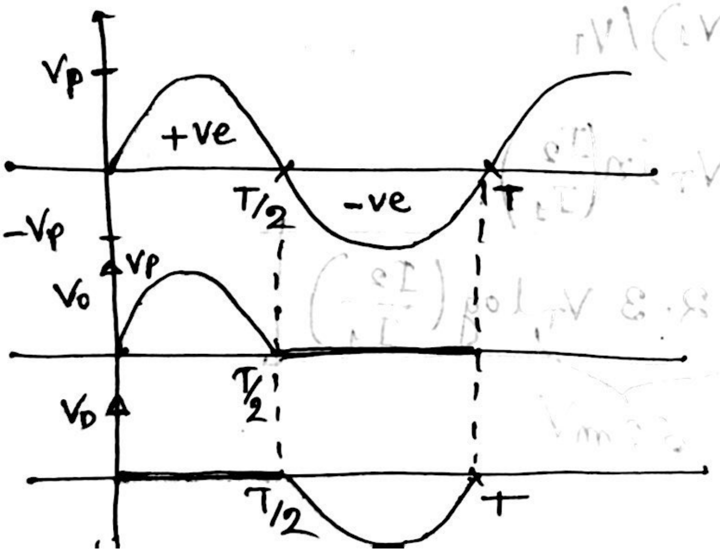


(ω = angular frequency)

* For +ve half cycle
  D ⇒ Forward bias
* For -ve half cycle
  D ⇒ Reverse bias



Halfwave Rectifier:



halfwave Rectifier Circuit

For, +ve half cycle, Applying KVL,

$$-V_P + V_D + V_o = 0$$

$$\Rightarrow V_o = V_P - \cancel{V_D}^{0}$$

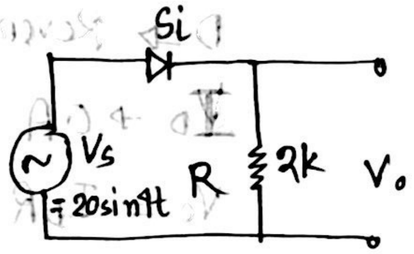
$$\therefore V_o = V_P$$

For, negative (-ve) half cycle, Applying KVL,

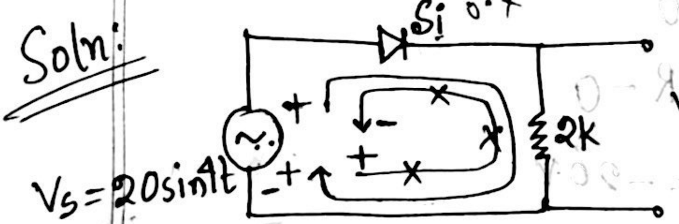
$$\begin{cases} V_S + V_D + V_o = 0 \\ \Rightarrow V_D = -V_S = -V_P \end{cases}$$

Here, $IR = 0, V_o = IR$

Determine the output voltage V_o and sketch the wave forms accross the output resistance and diode

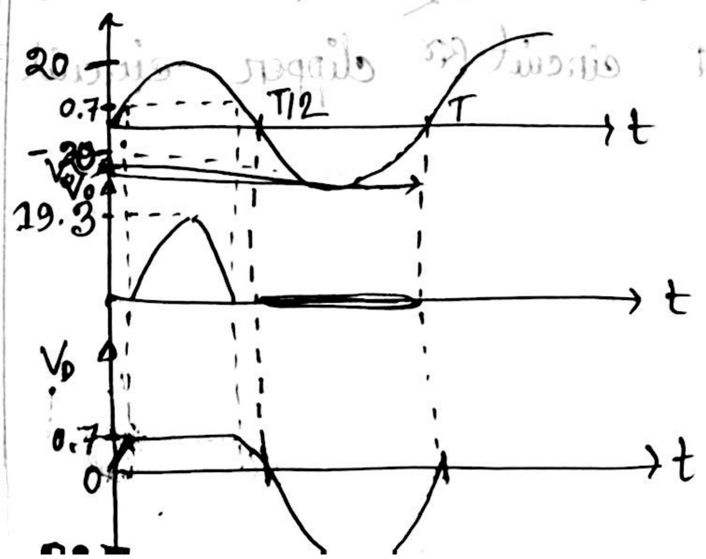


Soln:



Here, $V_S = 20\angle 0^\circ$

$\omega = 4$ rad/sec



Reverse bias fixed voltage drop থাকে না, তাই maximum Voltage থাকে কারণ Reverse bias এ open circuit

For +ve half cycle $(0 - T/2)$

$D \Rightarrow$ Forward bias

$V_D = 0.7V$

$\therefore$ Applying KVL, $-V_S + V_D + V_o = 0$

$\Rightarrow -20 + 0.7 + V_o = 0$

$\therefore V_o = 19.3V$

For (-ve) half cycle $(T/2 - T)$

$D \Rightarrow$ Reverse bias

$I_D \Rightarrow 0A$

$V_o = I_D R = 0 \times 2K = 0V$

$\therefore$ Applying KVL, $V_S + V_D + V_o = 0$

$\Rightarrow V_S + V_D + I_D R = 0$

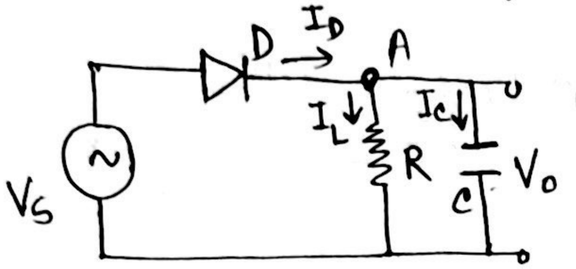
$\Rightarrow V_D = -V_S = -20V$

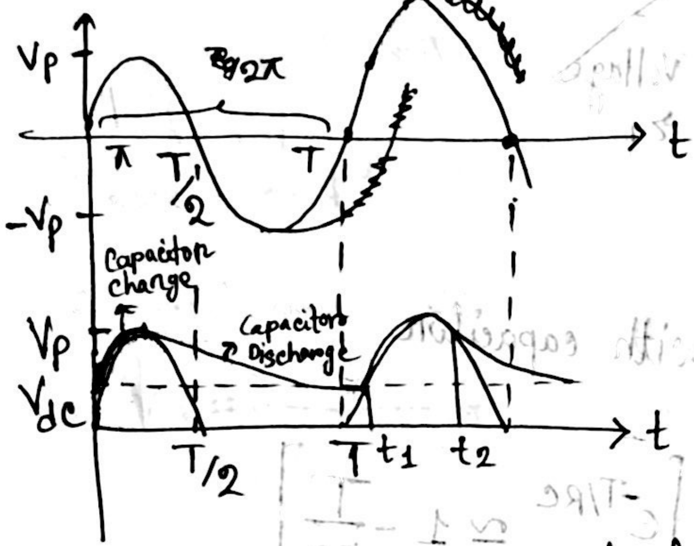
* Diode একটি অংশ কেটে যাচ্ছে আর একটা অংশ থেকে যাচ্ছে এই ধরনের circuit কে clipper circuit বলে।

C.W 03/11/24

Capacitor → open circuit
Inductor → Short circuit

Half wave Rectifier circuit





$V_{dc} = 0.318(V_P - V_D)$

$\frac{1}{\pi}$

V_P = Peak Voltage

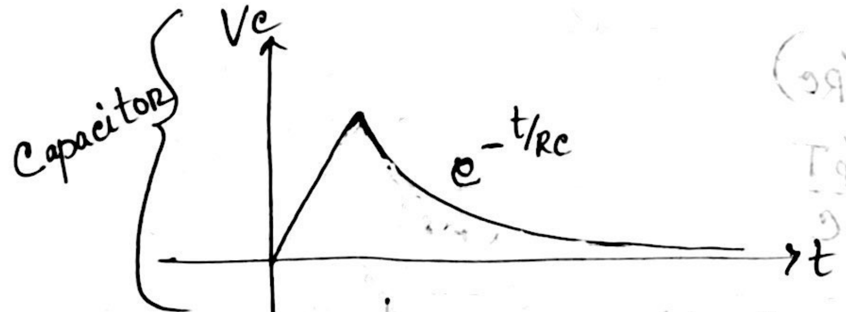
V_D = Diode Voltage

Δt = Conduction Interval $= t_1 \to t_2$

I_L = Load current

$\omega \Delta t$

$RC = \tau$ (tao) = time constant



Applying KVL at node A, $I_D = I_c + I_L$

$$I_D = C\frac{dV_s}{dt} + I_L$$

$$= C\frac{ds}{dt} + \frac{V_0}{R}$$

$$= C\frac{ds}{dt} + \frac{V_P}{R}$$

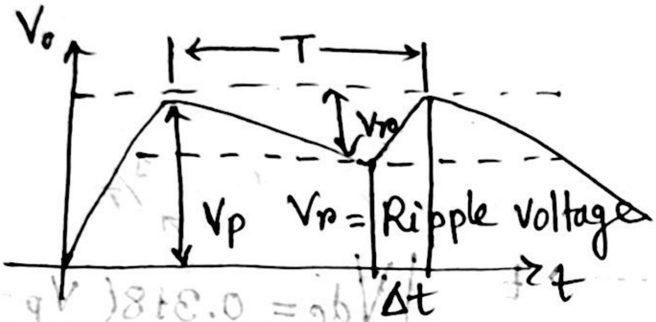
*RC এর Value বাড়ালে Ripple কমবে

Ripple যত কম হবে তত ভালো

KVL in loop 1, $-V_s + V_D + V_o = 0$

$$-V_s + V_D + I_L R = 0$$

$$\Rightarrow V_o = V_s - V_D = V_p - V_D$$



*
$$\boxed{V_o = V_p - \frac{1}{2}V_r}$$

$$V_o = V_p e^{-t/RC} \rightarrow \text{with capacitor}$$

$RC >> T$

$$V_o = V_p e^{-T/RC} \qquad \left[e^{-T/RC} \simeq 1 - \frac{T}{RC}\right]$$

$$V_o = V_p - V_r = V_p e^{-T/RC}$$

$$\Rightarrow V_p - V_r = V_p(1 - T/RC)$$

$$\Rightarrow \cancel{V_p} - V_r = \cancel{V_p} - \frac{V_p T}{RC}$$

$$\Rightarrow V_r = \frac{V_p T}{RC}$$

$$\boxed{\Rightarrow f = \frac{1}{T}}$$

$$\therefore V_r = \frac{V_p}{fRC}$$

$$\Rightarrow V_r = \frac{V_p/R}{fC}$$

$$\Rightarrow \frac{I_L}{fC} \qquad \left[I_L = \frac{V_p}{R}\right]$$

*

$$V_S = V_p \cos(\omega \Delta t)$$

ω = Angular frequency

$\omega = 2\pi f = 2\pi \frac{1}{T}$

Δt = Conduction Interval

$$\cos(\omega \Delta t) = 1 - \frac{1}{2}(\omega \Delta t)^2$$

$$* \boxed{\omega \Delta t = \sqrt{\frac{2V_r}{V_p}}}$$

* Half wave Rectifier

$$i_{D\,avg} = I_L\left(1 + \pi\sqrt{\frac{2V_p}{V_r}}\right) = \text{Average diode current}$$

$$i_{D\,max} = I_L\left(1 + 2\pi\sqrt{\frac{2V_p}{V_r}}\right) = \text{Maximum diode current}$$

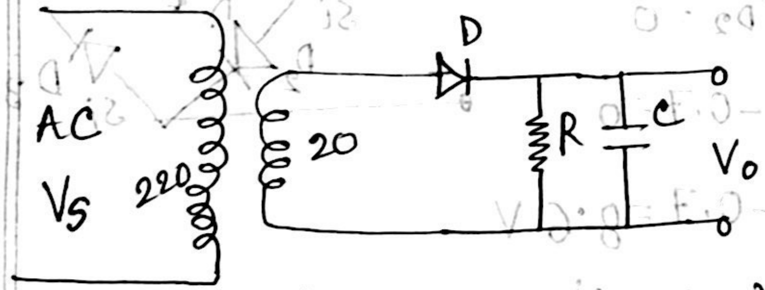
For, full wave Rectifier,

$$V_r = \frac{V_p}{2fRC}$$

$$i_{D_{avg}} = I_L\left(1 + \pi\sqrt{\frac{V_p}{2V_r}}\right)$$

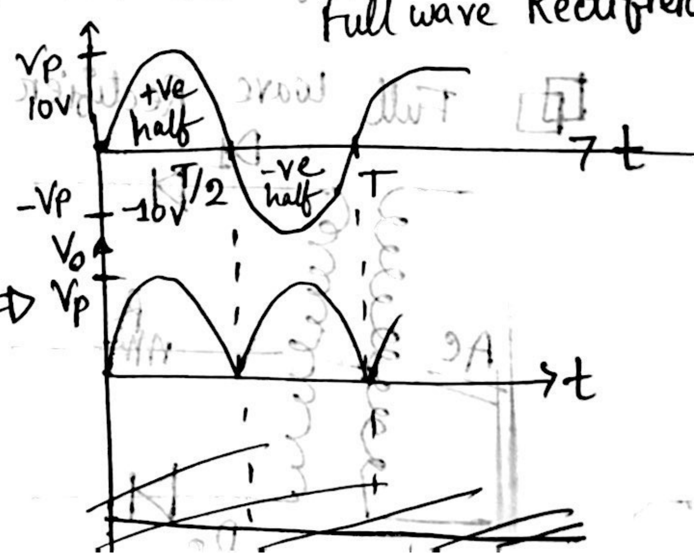
$$i_{D\,max} = I_L\left(1 + 2\pi\sqrt{\frac{V_p}{2V_r}}\right)$$

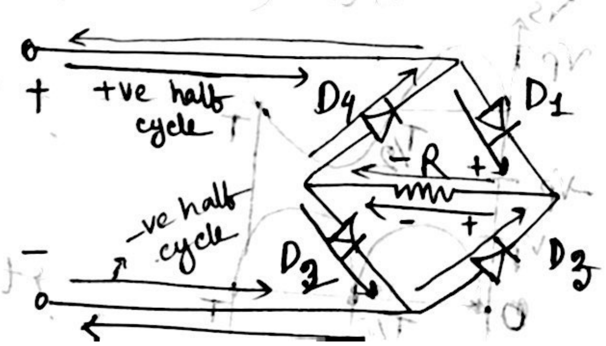
□



X Former / Stepdown transformer

Full wave Rectifier





$V_{dc} = 0.318\,(V_p - V_D)$ — Half

$= (2 \times 0.318)\,(V_p - 2V_D)$ — Full

For +ve half cycle

D_1 & D_2 — ON

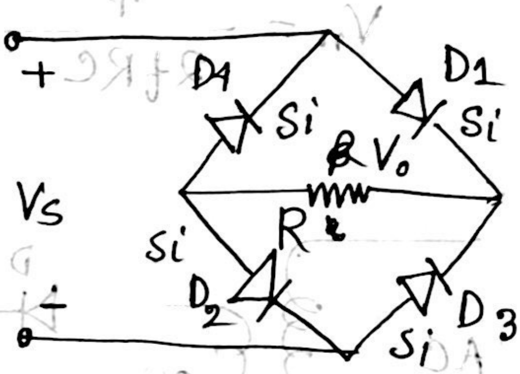
D_3 & D_4 — OFF

For −ve half cycle

D_3 & D_4 — ON

D_1 & D_2 — OFF

$\boxed{}$ Determine V_o



Apply KVL,

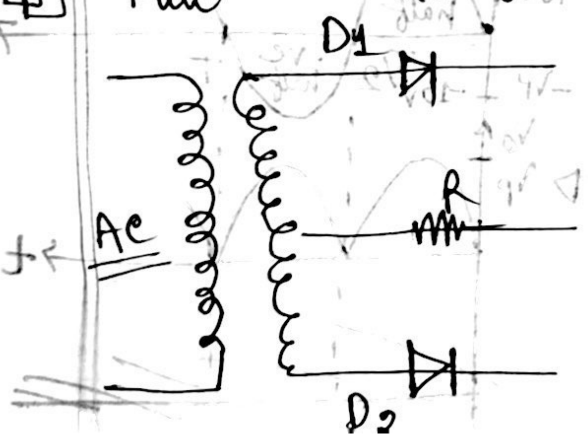
$-V_S + V_{D1} + V_o + V_{D2} = 0$

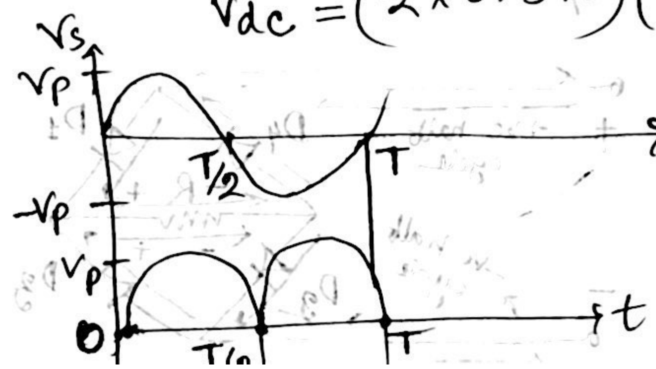
$\Rightarrow V_o = V_S - 0.7 - 0.7 = 0$

$\Rightarrow V_o = 10 - 0.7 - 0.7 = 8.6\ V$

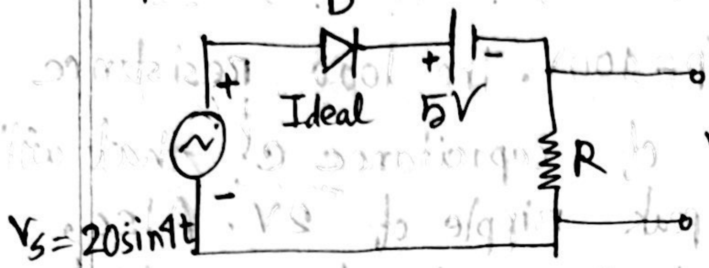
$\boxed{}$ Full wave Rectifier circuit

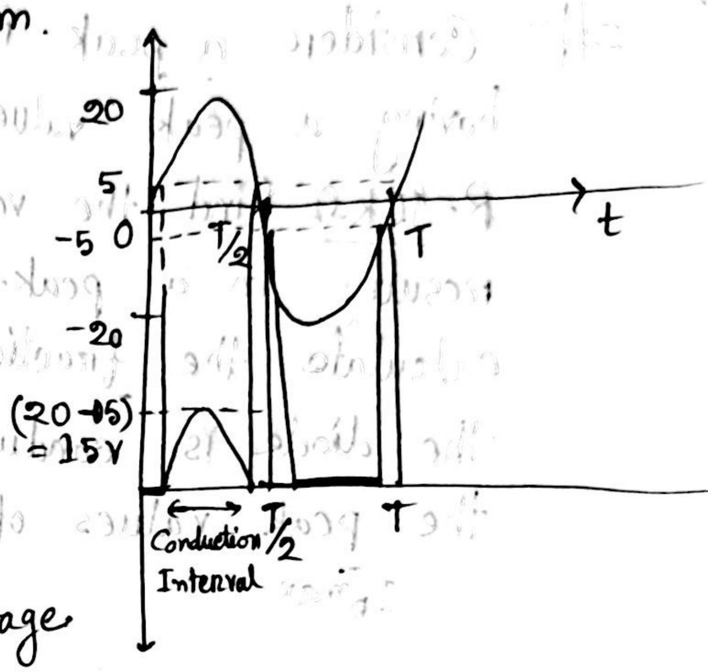
$V_{dc} = (2 \times 0.318)(V_p - V_D)$





Draw the output wave form.





$V_P = 20V$

$D \rightarrow$ Reverse Bias

$V_D \rightarrow PIV \rightarrow$ Peak inverse Voltage

C·W
05/11/2024

Half wave rectifier

Consider a peak rectifier fed by a 60Hz sinusoid having a peak value $V_p = 100V$. The load resistance $R = 10k\Omega$ Find the value of capacitance C? that will result in a peak-to-peak ripple of 2V. Also, calculate the fraction of the cycle during which the diode is conducting and the average and the peak values of diode current. I_D avg

I_D max

$$V_p = 100V, \quad I_L = \frac{V_o}{R} = \frac{V_p}{10} = 10$$

$$i_D\,avg = I_L\left(1 + \pi\sqrt{\frac{2V_p}{V_r}}\right)$$

$$= 10\left(1 + \pi\sqrt{\frac{2 \times 100}{2}}\right)$$

$$= 324.16mA$$

$$i_D\,max = I_L\left(1 + 2\pi\sqrt{\frac{2V_p}{V_r}}\right)$$

$$= 10\left(1 + 2\pi\sqrt{\frac{200}{2}}\right) = \cancel{454.288}$$

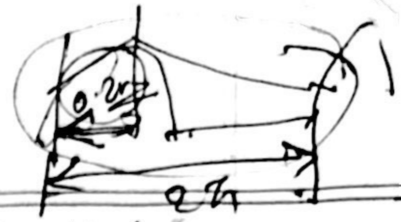
638 mA

(Ans)

$$V_r = \frac{V_p}{fRC}$$

$$\Rightarrow C = \frac{V_p}{fRV_r} = \frac{100}{60 \times 10k \times 2} = \cancel{0.833F}$$

$$= 83.3\mu F \text{ (Ans)}$$



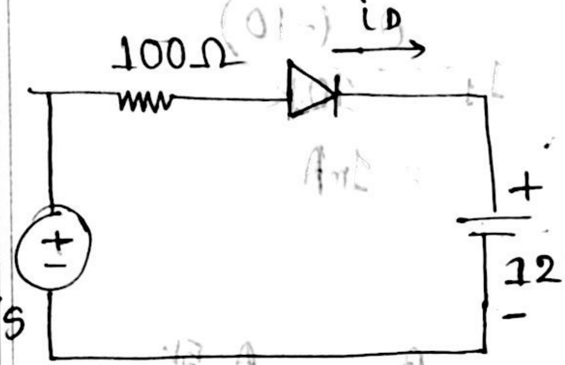
$$\omega \Delta t = \sqrt{\frac{2V_r}{V_p}} = \sqrt{\frac{2\times 2}{100}} = 0.2 \text{ rad}$$

The fraction of the cycle during the diode is conducting,

$$= \frac{0.2}{2\pi} \times 100\%$$

$$= 3.18\% \quad \text{(Ans)}$$

Exam ~~Figure~~



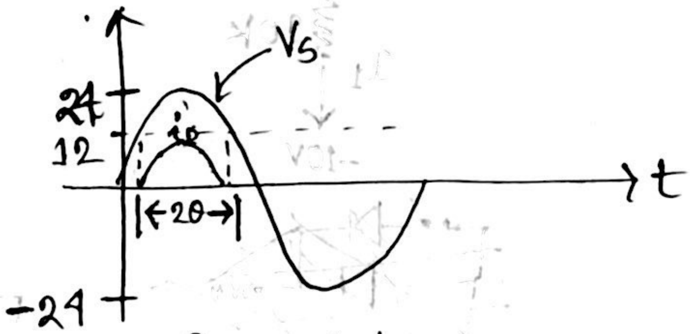


figure 4.4

Q: $i_D = ?$ in forward bias.

$2\theta = ?$

Ans: Applying KVL,

$$-V_S + 100 i_D + V_D + 12 = 0$$

$$\Rightarrow \cancel{124+} -24 + 100 i_D + 0 + 12 = 0 \qquad [V_D = 0] \text{ ideal diode}$$

$$\Rightarrow 100 i_D = 12$$

$$\therefore i_D = 0.12 \text{ A}$$

Again, $24 \cos\theta = 12$

$\Rightarrow \cos\theta = 1/2$

$\therefore \theta = 60°$

$\therefore 2\theta = 2 \times 60 = 120°$ Function of the cycle the diode conducts

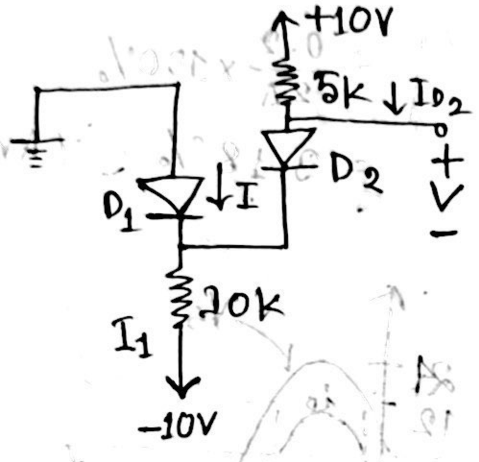
conduction interval

Q: Reverse bias voltage = ?

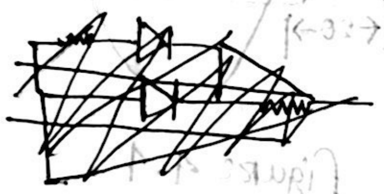
Soln: $24 + 12 = 36\,V = \underline{PIV}$

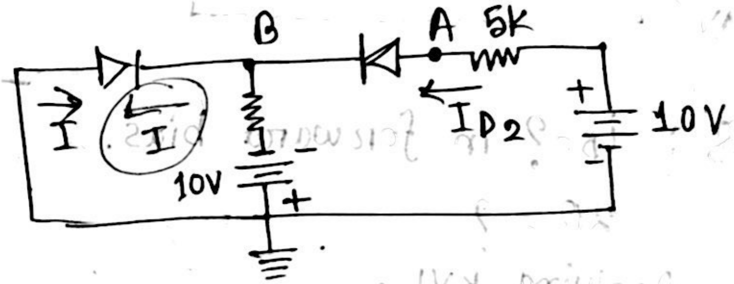
যদি AC, DC দেওয়া থাকে তাহলে সমান ধরবো, নাহলে 0
Previous

#



$$I_1 = \frac{0-(-10)}{10k} = 1mA$$





$$I_{D_2} = \frac{10-0}{5k} = 2mA$$

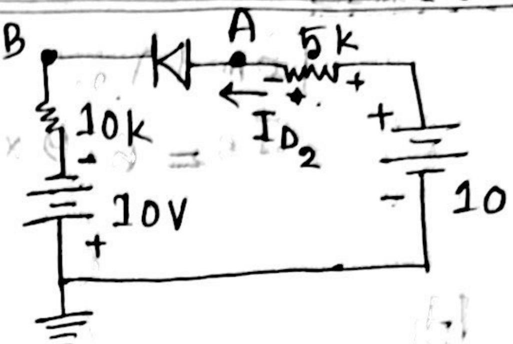
KCL at point B, $I + I_{D_2} = I_1$

$$\Rightarrow I + 2mA = 1mA$$

$$\Rightarrow I = -1mA \quad [D = OFF]$$

This means the diode is in reverse bias condition, To conduct/pass current, the ~~diode~~ current must be $I = 0mA$ & and flow in the opposite direction.

~~+10+10~~



$-10+5I_{D_2}+V_D+10I_{D_2}-10=0$

$\Rightarrow 15I_{D_2}-20=0$

$\Rightarrow 15I_{D_2}=20$

$\therefore I_{D_2}=1.33\ mA$

So, A to Ground Voltage, $V = -10 + I_{D_2}\,10k =$

$= (-10 + 1.33mA \times 10k)$

$= 3.33V$

\# A silicone diode said to be a 1-mA device displays a forward voltage of 0.7V at a current of 1mA. Evalute the junction constant Is. What scaling constants would apply for a 1A diode of the same manufacture that conducts 1A at 0.7V?

$$i = \underbrace{I_s\left(e^{\frac{V_D}{nV_T}} - 1\right)}$$

$$i = I_s\left(e^{\frac{1}{1\times 25}}\right)$$

$V_T = 25.3mV - 26mV$

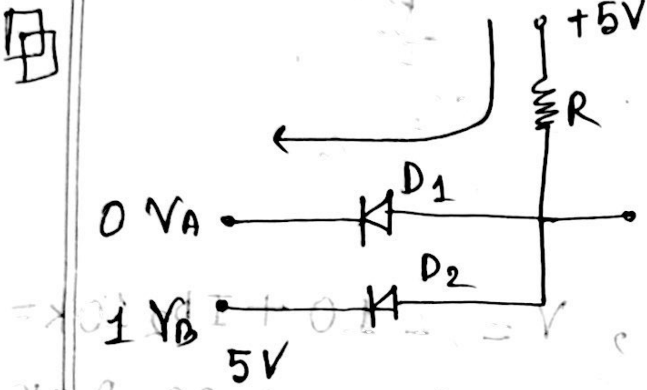
$= 25mV$

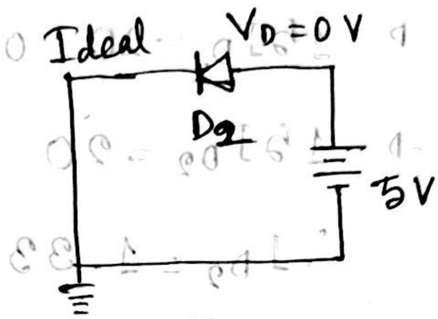
$i = 1mA = 1\times10^{-3}A$

$$I_s = i\,e^{-\frac{V_D}{nV_T}} = 1\times10^{-3}\,e^{\frac{-1}{25}} = 6.9\times10^{-16}A$$

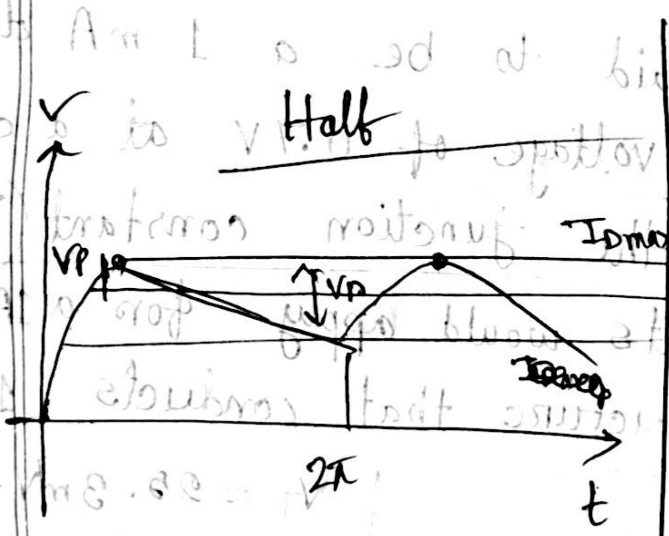
For 1A,

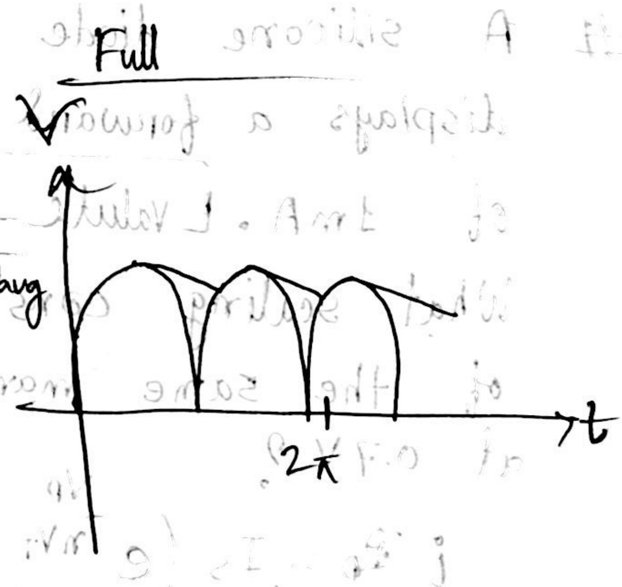
$I_s = 6.9 \times 10^{-13}$ A





x



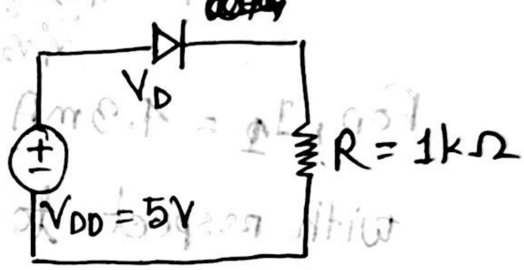


~~Ckt~~

C.W
10/11/24

Determine the current I_D and the diode voltage V_D for the following circuit with $V_{DD} = 5V$ and $R = 1k\Omega$. Assume that, the diode has a current of $\underset{I_1}{1mA}$ at a voltage of $\underset{V_1}{0.7V}$. Draw the load line and find V_{DQ} & I_{DQ}.

Soln: $I_D = \frac{V_{DD} - V_D}{R} = \frac{5-0.7}{1k}\ mA = 4.3mA$



$\Rightarrow I_D = \frac{5}{1} = 5mA$

Applying KVL, $-V_{DD} + V_D + IR = 0$

$\Rightarrow -5 + V_D + (5 \times 1) = 0$

$\Rightarrow V_D = 0V$

$\therefore$ Ideal diode

Again: Let, current 1mA, $V_D = 0.7V$

KVL, $-V_{DD} + V_D + I_D R = 0$ ---- (1)

$\therefore I = \frac{V_{DD} - V_D}{R}$

When, $I_1 = 1mA$

Then $V_1 = 0.7V$

$$V_2 - V_1 = 2.3\, V_T \log\left(\frac{I_2}{I_1}\right)$$

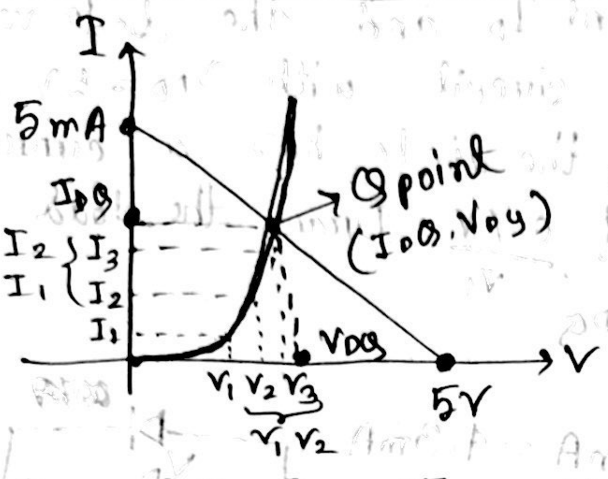
$$\Rightarrow V_2 = V_1 + \underbrace{2.3\, V_T}\log\left(\frac{I_2}{I_1}\right)$$

$$= 0.7 + 0.06 \log \left(\frac{4.3}{I_1}\right)$$

$$= 0.738\ V$$

Assumption
$[V_1 = 0.7V]$

$2.3\, V_T = 60mV$
$I_2 = 10 I_1$



For, $I_1 = 4.3mA$, Then $V_1 = 0.738V$

with respect to I_1, V_1,

$$I_D = \frac{V_{DD} - V_D}{R} = \frac{5 - 0.738}{1K} = 4.262 \rightarrow V_2$$

$$V_2 = V_1 + 2.3 V_T \left(\frac{I_2}{I_1}\right)$$

$$= 0.738 + 0.06 \left(\frac{4.262}{4.3}\right)$$

$$V_2 = 0.737 V$$

∴ Cutting voltage $0.738V = V_D$.

Current rate is changing but the voltage is same.

let, $I_D = 0$

$V_D = V_{DD} = 5V$

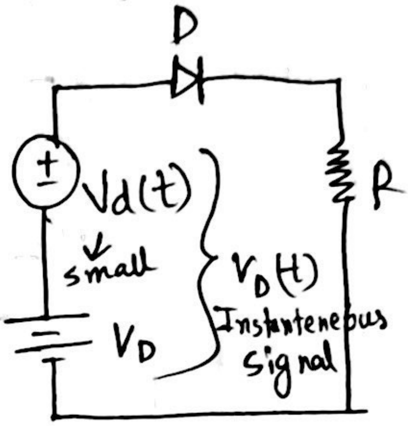
$V_D = 0$

$$I = \frac{V_{DD} - V_D}{R} = \frac{5}{1} = 5mA$$

$V_d = AC$

$V_D = DC$

Small Signal Model (AC+DC)



$$V_D(t) = V_d(t) + V_D$$

For forward bias,

$$I_D = I_S e^{\frac{V_D}{nV_T}}$$

$$i_D = I_S e^{V_D / nV_T}$$

$$= I_S e^{(V_d + V_D)/V_T}$$

$$= I_S e^{\left(\frac{V_d}{V_T} + \frac{V_D}{V_T}\right)}$$

$$= I_S \left[e^{\frac{V_d}{V_T}} \cdot e^{\frac{V_D}{V_T}}\right]$$

$$= \underbrace{I_S e^{\frac{V_D}{V_T}}}_{I_D} \cdot e^{V_d/V_T}$$

$$= I_D e^{V_d/V_T}$$

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

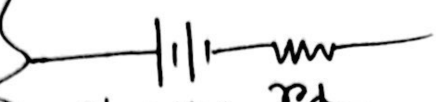
$1 + x$

$$\frac{V_d}{V_T} << 1$$

$\therefore$ Let, $x = \frac{V_d}{V_T}$

$$\boxed{*** \; i_D(t) = I_D \left[1 + \frac{V_d}{V_T}\right]}$$

যখন DC ও AC কে একসাথে রাখবে



AC তে শুধু r_d কে রাখতে হবে

$$i_D(t) = I_D\left[1 + \frac{V_d}{V_T}\right]$$

$$= I_D + \frac{I_D V_d}{V_T}$$

$$= \underbrace{I_D}_{DC} + \underbrace{V_d \frac{I_D}{V_T}}_{\text{Small signal AC}}$$

$\frac{V}{I} = R$

$V \frac{1}{R} = I$

$\Rightarrow VG = I$

A.14

$R = 10K$

$V^+ = 10V$

$f = 60Hz$

$V_{ac} = 1\text{-}V_{peak} = V_d(t)$

We know,

$i_D(t) = I_D + I_D \frac{V_d}{V_T}$

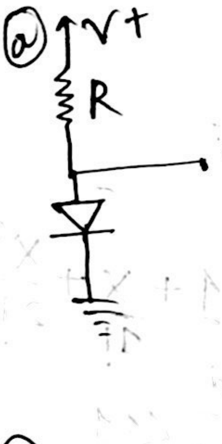
$G_d = \frac{I_D}{V_T}$

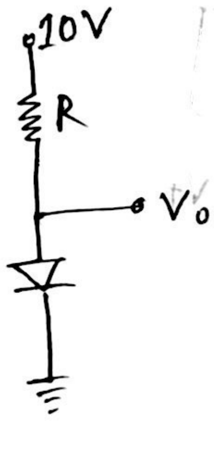
$r_d = \frac{V_T}{I_D}$

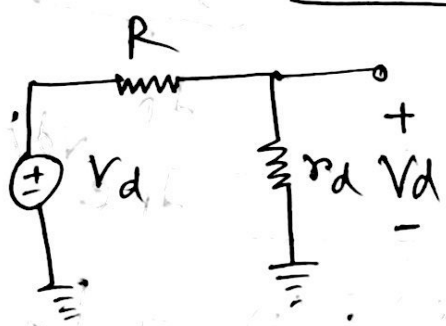
$r_d = \frac{26mV}{I_D}$

Diode Internal resistance

ⓐ







$I_D = \cancel{Dce}\ \frac{V_{DD} - V_D}{R}$

$= \frac{10 - 0.7}{10} = 0.93mA$

$V_T \approx (25 \sim 26)\,mV$

AC $\left\{ r_d = \frac{26mV}{I_D} = \frac{26mV}{0.93mA} = 27.9\,\Omega \right.$

Using VDR,

$$V_d = 1 \times \frac{r_d}{R + r_d} = 1 \times \frac{27.9\Omega}{10k + 27.9\Omega} = \cancel{0.73V}$$

$$= 2.78\,mV$$

$$I_D = \frac{V_d}{V_T}$$

AC+DC

$$\therefore i_D(t) = 0.93\,mA + I_D \frac{V_d}{V_T}$$

instanteneous current

$$= 0.93 + \left(0.93 \frac{2.78}{26}\right)$$

$$= 1.029\,mA$$

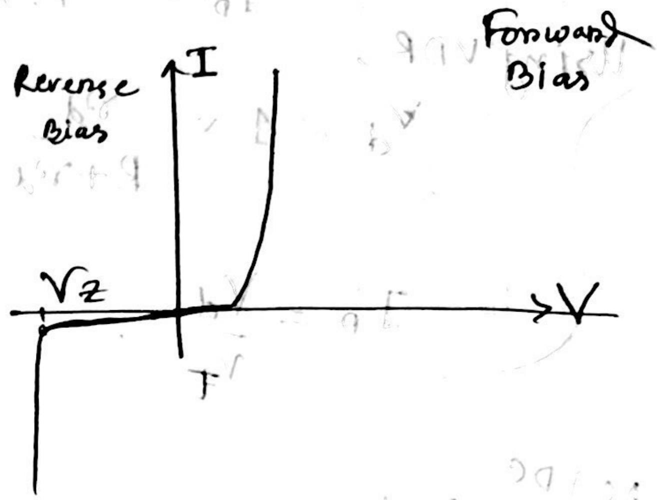
For the case ⓐ $R = 10k\Omega$. The power supply V^+ has a dc value of 10V on which is superimposed a 60Hz sinusoid of 1-V peak amplitude. calculate both the dc voltage of the diode and the amplitude of the sine-wave signal appearing accross it. Assume, the diode to have a 0.7V drop at 1-ma current.

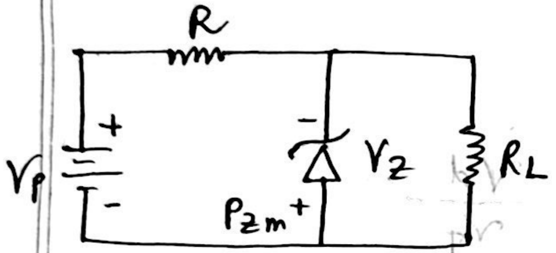
12/11/24

Zener diode

Reverse bias এ current pass হয়।

V_Z = Zener Voltage

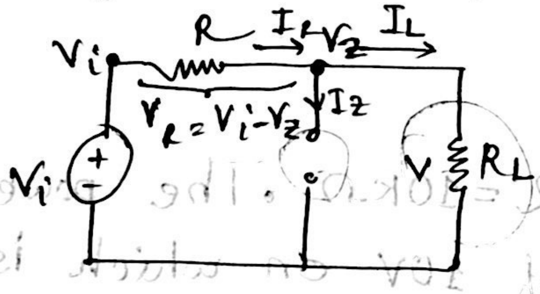




P_{zm} = maximum Zener power $= V_Z I_{zm}$

$$\therefore I_{zm} = \frac{P_{zm}}{V_Z}$$

① প্রথমে Zener কে open করবো।



Using VDR,

$$V = \frac{V_i R_L}{R + R_L}$$

$V > V_Z \rightarrow$ Zener ON (Reverse Bias এ current যাবে)

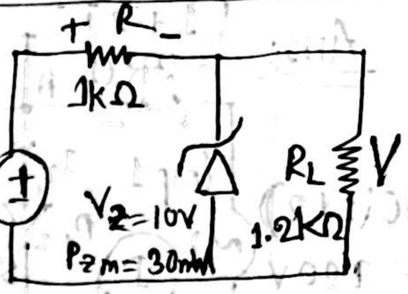
$V < V_Z \rightarrow$ Zener OFF

Using Ohm's law, $I_R = \frac{V_i - V_Z}{R}$ | $I_L = \frac{V_Z}{R_L}$

Applying KCL at node Z, $I_R = I_Z + I_L$

$$\Rightarrow I_L = I_R - I_Z$$

For the Zener diode of the following circuit., find V_L, V_R, I_Z, P_Z

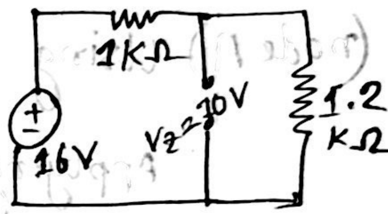


⇒ Repeat for $R_L = 3k\Omega$

$V < V_Z$, Zener 'OFF'

Using VDR, $V = \frac{V_i R_L}{R+R_L} = \frac{16 \times 1.2}{1+1.2} = 8.7V$

$I_R = I_L = \frac{V_i}{R+R_L} = \frac{16}{1+1.2} = 7.27\,mA$



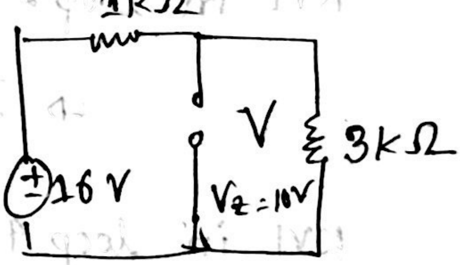
$V_R = I_R R$

$= 7.27mA \times 1K = 7.27V$

$V_L = I_L R_L = 7.27 \times 1.2K = 8.724V$

$I_Z = 0 \quad \therefore \quad P_Z = 0W$

for $3k\Omega$,



$V > V_Z$, Zener 'ON'

$V = \frac{V_i R_L}{R+R_L} = \frac{16 \times 3}{1+3} = 12V$

$I_R = \frac{V_R}{R} = \frac{6}{1k} = 6mA$

$I_L = \frac{V_Z}{R_L} = \frac{10}{3k} = 3.33\,mA$

$V_R = V_i - V_Z = 16 - 10 = 6V$

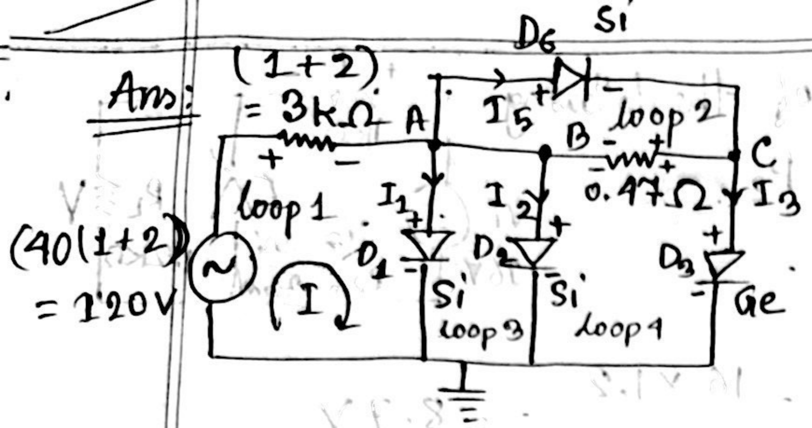
KCL $I_Z = I_R - I_L = 6 - 3.33$
$= 2.67\,mA$

$P_Z = V_Z I_Z = 10 \times 2.67$

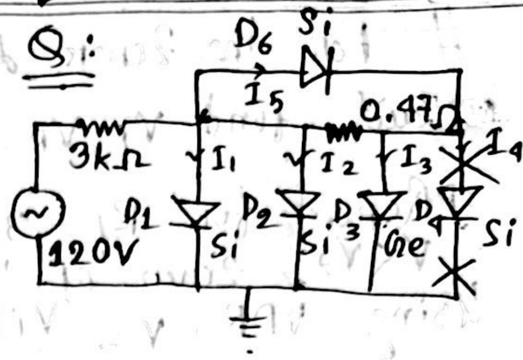
Quiz-1

Wrong Answer

Ans:



Q:



$I_4 = 0A$

(node A) Using KCL, $I = I_1 + I_2 + I_5 = 0.3976$

Applying KVL in loop 1, $-120 + 3kI + 0.7 = 0$

$\Rightarrow 3kI = 119.3$

$\therefore I = \dfrac{119.3}{3000} = 0.3976\,A$

KVL in loop 2, $+0.7 + 0.47 I_3 = 0$

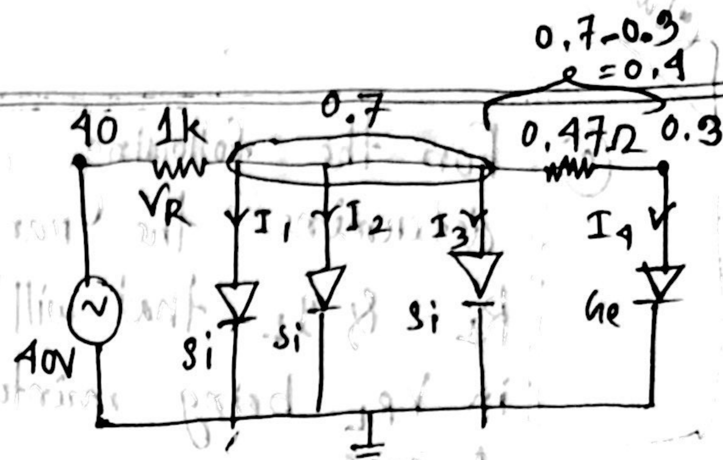
$\Rightarrow I_3 = \dfrac{-0.7}{0.47} = -1.489A.$

KVL in loop 4, $-0.7 - 0.47 I_3 + 0.3 = 0$

$\Rightarrow -0.47 I_3 = 0.4$

$\Rightarrow I_3 = -0.85\,A$

Solution



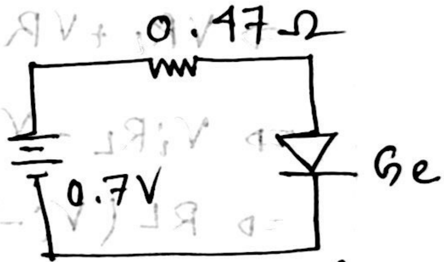
$V_R = (40 - 0.7)\ V = 39.3V$

$I_R = \dfrac{39.3}{1k} = 39.3mA$

$I_4 = \dfrac{0.4V}{0.47\Omega} = 0.85A$

$39.3 - 0.85A = -38.4mA$

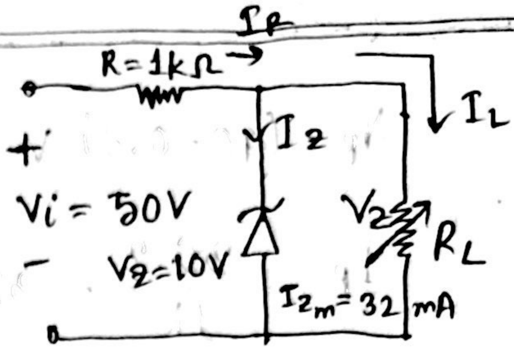
$I_1 = I_2 = I_3 = \dfrac{-38.4}{3} = -12.8$



load current = ?

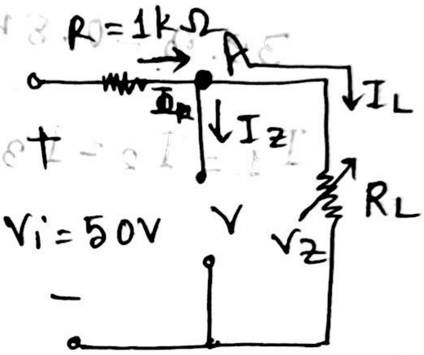
Classwork

(a) For the following circuit, determine the range of R_L & I_L that will result in V_{R_L} being maintained at 10V



(b) Determine the maximum wattage rating of the diode.

$$V = \frac{V_i R_L}{R_L + R}$$



$$\Rightarrow V R_L + V R = V_i R_L$$

$$\Rightarrow V_i R_L - V R_L = V R$$

$$\Rightarrow R_L (V_i - V) = V R$$

$$\Rightarrow R_{L_{min}} = \frac{V R}{V_i - V}$$

$$V_R = 50 - 10 = 40V$$

$V \geq V_Z$, for Zener "ON" ; $V = V_Z = 10V$

$$R_{L\,min} = \frac{10 \times 1k}{50 - 10} = 250\Omega$$

$\cancel{I_L = \frac{V_i}{R + R}}$

KVL in loop 1, $-50 + 1 I_R + V_Z = 0$

$$\Rightarrow I_R = 50 - 10$$

$$\therefore I_R = 40\,mA$$

$$I_{L_{max}} = \frac{V}{R_{L_{min}}} = \frac{V_Z}{R_{L_{min}}} = \frac{10}{250} = 0.04A = 40mA$$

$I = \frac{V}{R}$

$R = \frac{V}{I}$

$$\cancel{R_{L_{max}} = \frac{V_Z}{I_L}}$$

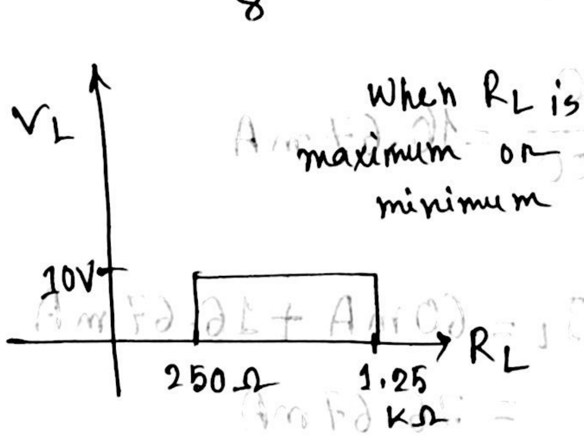
KCL at node A,

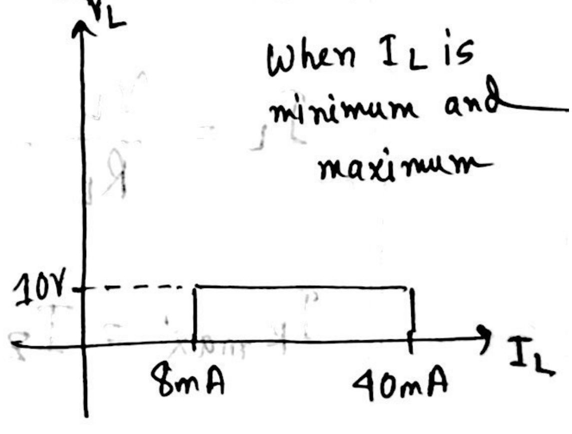
$$I_R = I_{Z_m} + I_L$$

$$\Rightarrow 40 = 32 + I_L$$

$$\Rightarrow I_L = 8mA$$

$$R_{max} = \frac{10}{8} = 1.25k\Omega$$



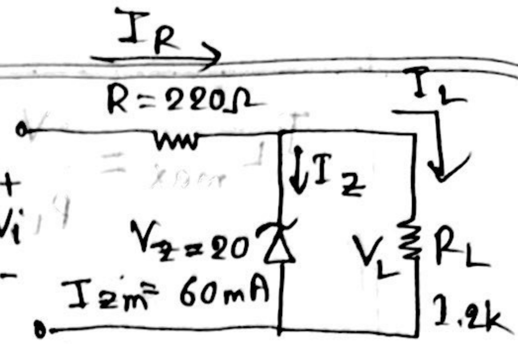


$$P_Z = V_Z I_{Zm} = 10 \times 32mA$$

$$= 320mW$$

$$= 0.32 W$$

Determine the range of V_i.



$$V = \frac{V_i R_L}{R_L + R}$$

$$\Rightarrow V R_L + V R = V_i R_L$$

$$\Rightarrow V_i = \frac{V(R_L + R)}{R_L}$$

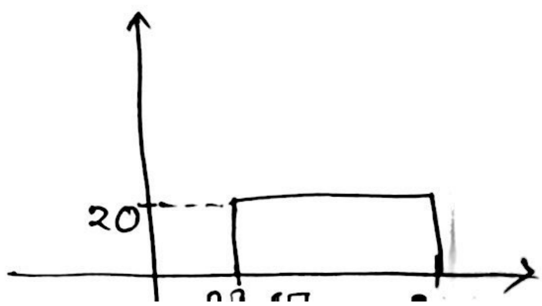
$$= \frac{20(1.2k + 220)}{1.2k}$$

$$\therefore V_{min} = 23.67 \text{ V}$$

$$I_L = \frac{V_L}{R_L} = \frac{20}{1200} = 16.67 \text{ mA}$$

$$I_{R\,max} = I_{Zm} + I_L = 60 \text{ mA} + 16.67 \text{ mA}$$
$$= 76.67 \text{ mA}$$

$$V_{i\,max} = (I_{R\,max} \times R) + V_Z$$
$$= (76.67 \text{mA} \times 220) + 20$$
$$= 36.87 \text{ V}$$



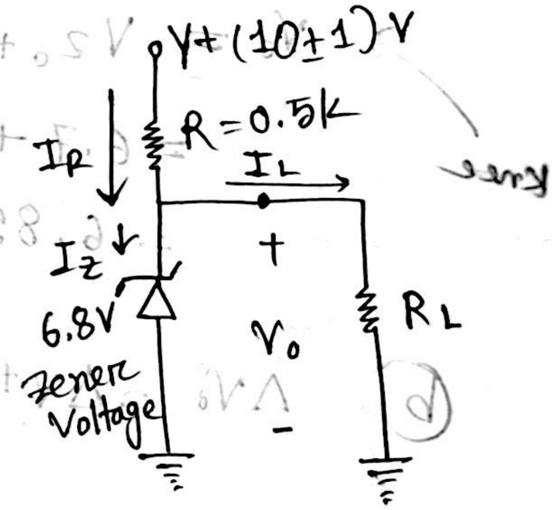
Example - 4.7 → Sedra (Page - 205)

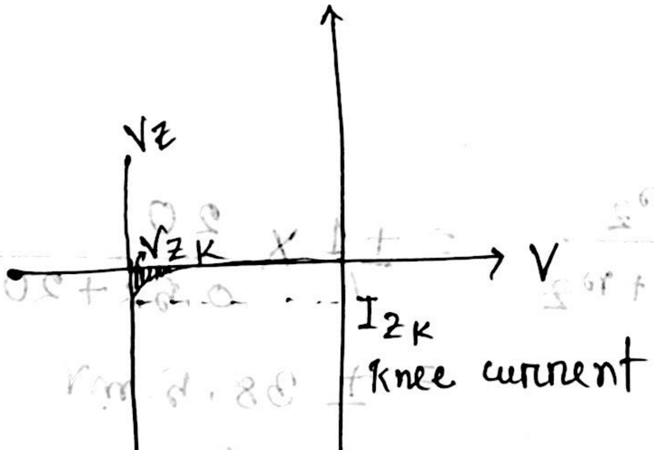
1. The 6.8 V Zener diode in the following circuit is specified to have $V_Z = 6.8V$ at $I_Z = 5mA$, $r_z = 20\Omega$ and $I_{ZK} = 0.2mA$. The supply voltage V^+ is nominally 10V but can vary by $\pm 1V$

ⓐ Find the V_o with no load and with V^+ at its nominal value.

ⓑ Find the change in voltage V_o resulting from the change $\pm 1V$ change in V^+

ⓒ Find the change in V_o resulting from connecting a load R_L that draws a current $I_L = 1mA$ and hence find the load regulation in mV/mA.





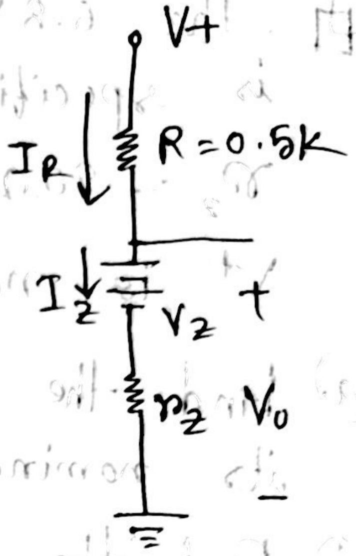
Theory.

$V_0 = V_Z + I_Z r_Z$

KCl, $I_R = I_Z + I_L$

$\Rightarrow 0.5\cancel{k \times 10} = I_Z + 0$

$\Rightarrow I_Z = \cancel{5A}\ 5mA$

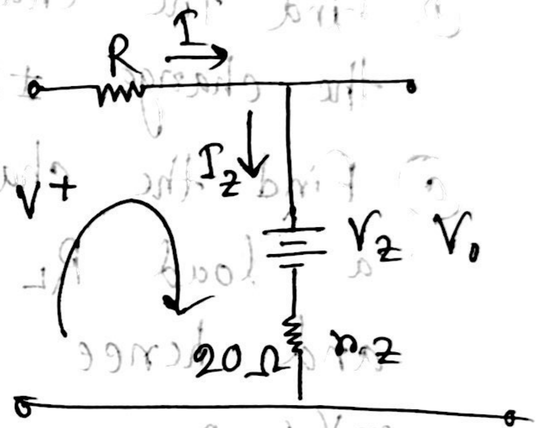


Ohms law,

$$I = I_Z = \frac{V^+ - V_{Z0}}{R + r_Z}$$

knee

$$= \frac{10 - 6.7}{0.5k + 20}$$



knee

$$V_0 = V_{Z0} + I_Z r_Z$$

$$= 6.7 + (6.35mA \times 20)$$

$$= 6.83V$$

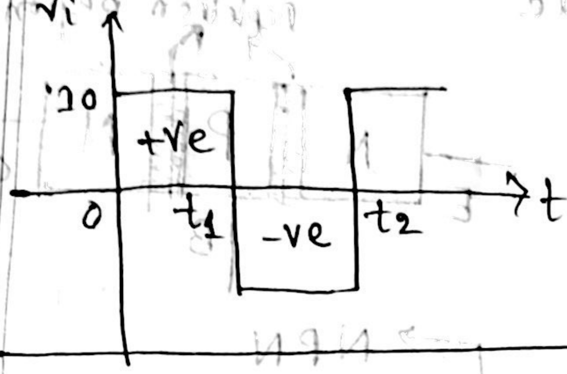
(b) $$\Delta V_0 = \Delta V^+ \times \frac{r_Z}{R + r_Z} = \pm 1 \times \frac{20}{0.5k + 20}$$

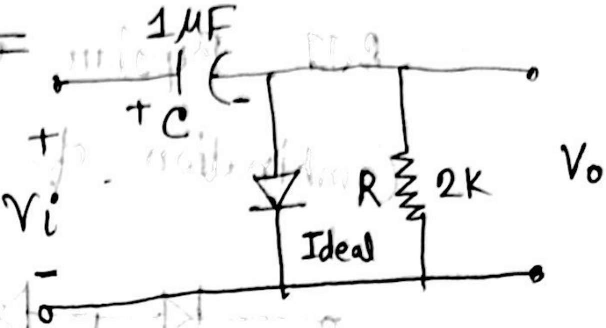
$$= \pm 38.5\ mV$$

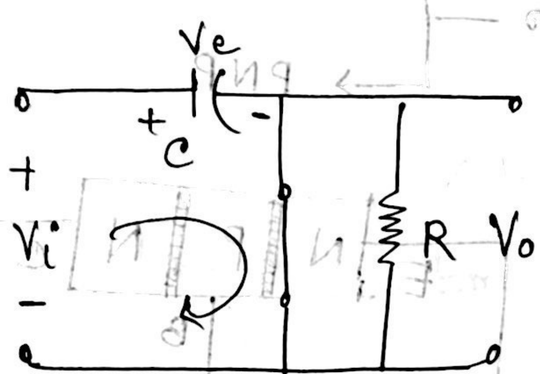
line regulation

C.W 19/11/2024

Clamper circuit







From $(0-t_1) \rightarrow$ +ve half cycle

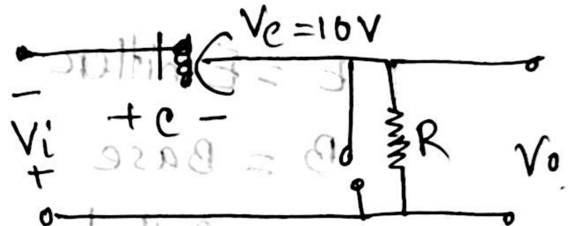
D → Forward Bias

KVL, $-V_i + V_c = 0$

$\therefore V_c = V_i = 10V$

From $(t_1 - t_2) \rightarrow$

-ve half cycle



$V_i + V_c + V_o = 0$

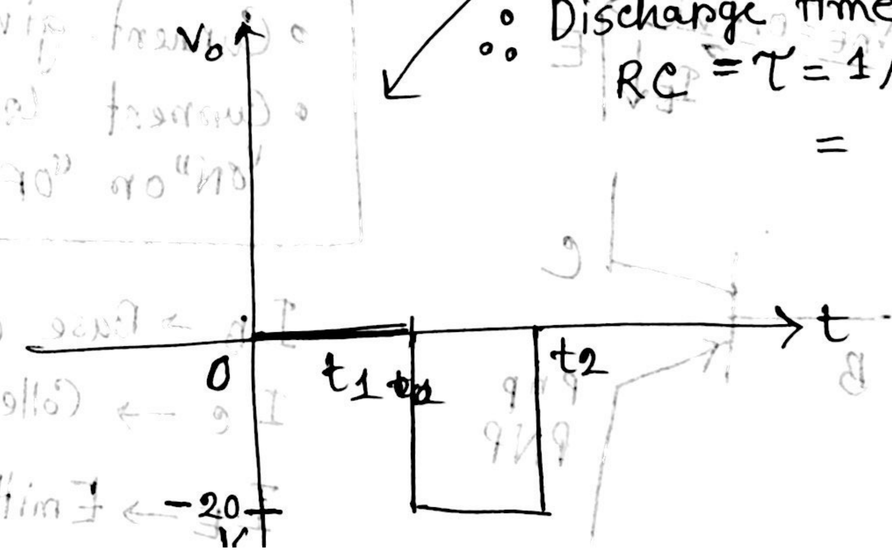
$\Rightarrow 10 + 10 + V_o = 0$

$\therefore V_o = -20V$

$\therefore$ Discharge time

$RC = \tau = 1\mu F \times 2K$

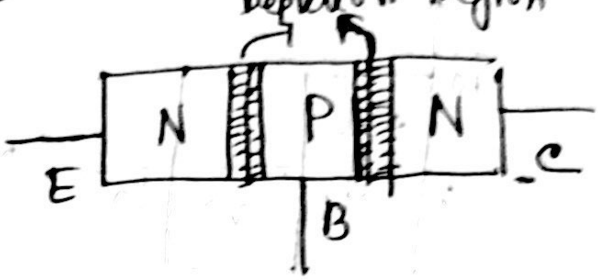
$=$ s



Transistor / BJT

BJT = Bipolar Junction Transister

Combination of 2 diode

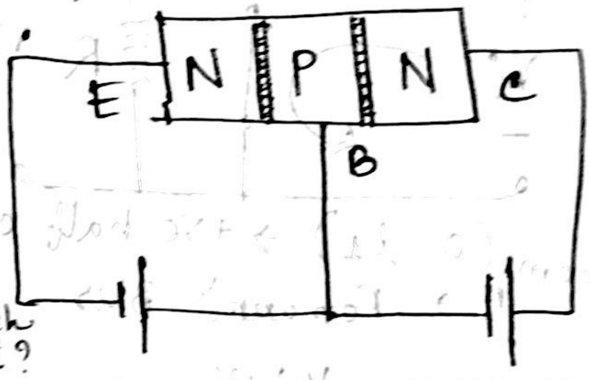


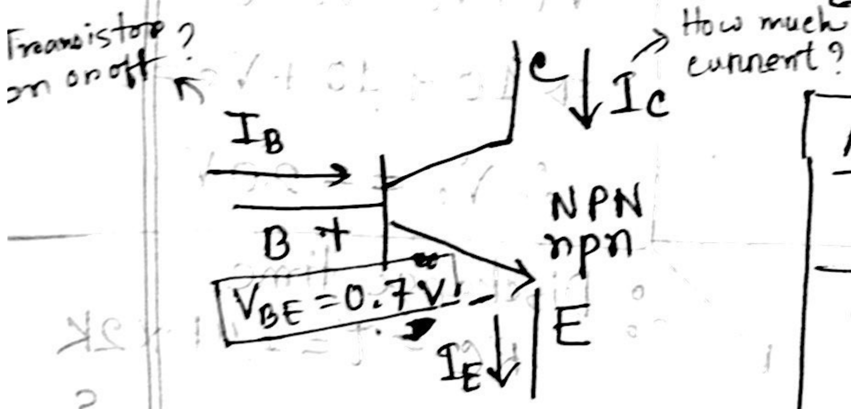
2 types of transistor → NPN, PNP

E = Emitter

B = Base

C = Collector

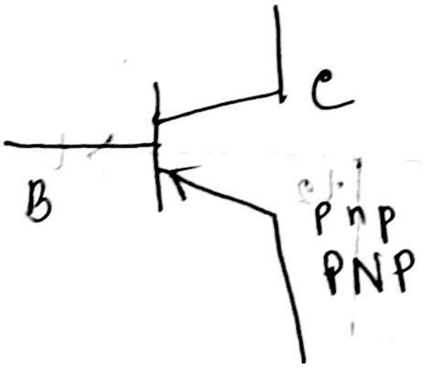




Application

- Amplify / ~~Swith~~ Switch

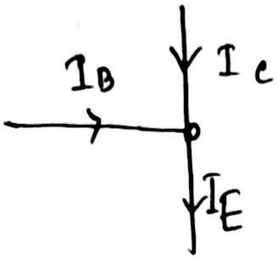
- Current given device
- Current এর depend করে "ON" or "OFF" হয়



I_B → Base current

I_C → Collector current

I_E → Emitter current



KCL, $I_E = I_B + I_C$

I_B is much less than I_C, I_E

Common Base = Base কে ground করবো

Common Collector = Collector " " "

Common Emitter = Emitter " " "

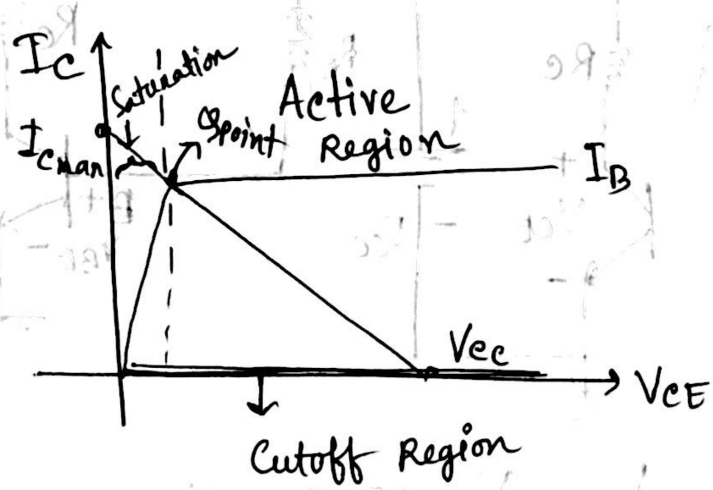
$\left.\begin{matrix}\alpha \\ \beta\end{matrix}\right\}$ current gain

$$\boxed{\alpha = \frac{I_C}{I_E} \approx 1}$$

$$I_C = \alpha I_E$$

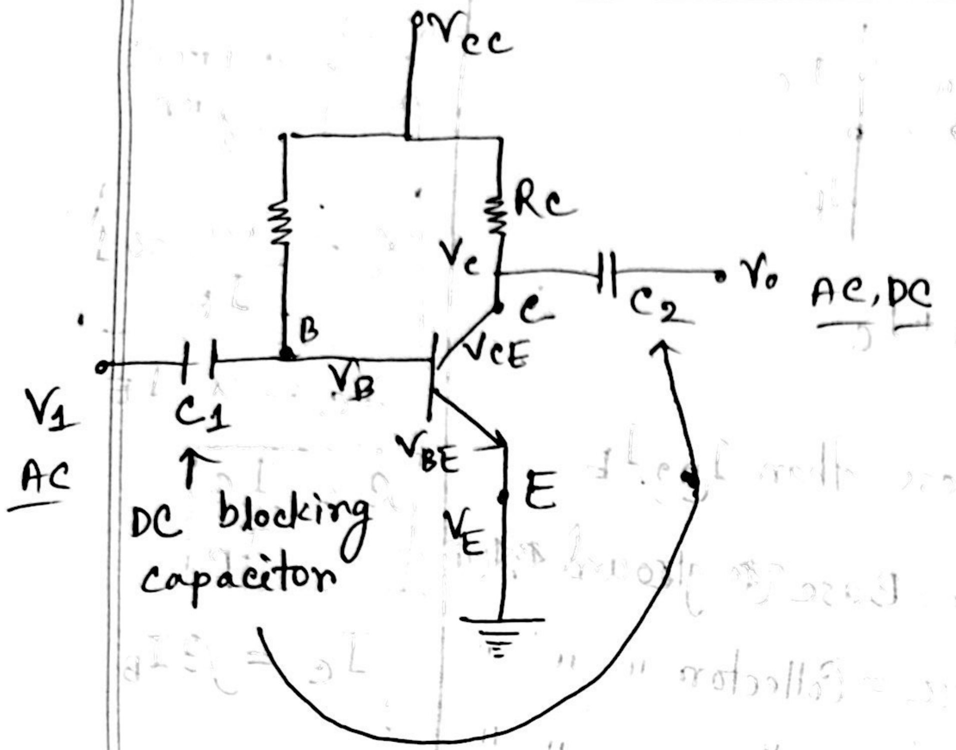
$$\boxed{\beta = \frac{I_C}{I_B}}$$

$$I_C = \beta I_B$$



Fixed Bias

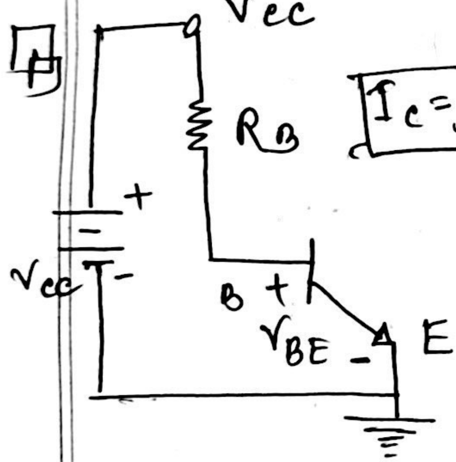
Boil State



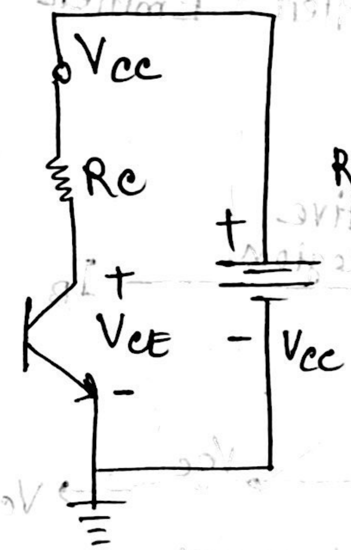
$V_{BE} = 0.7$

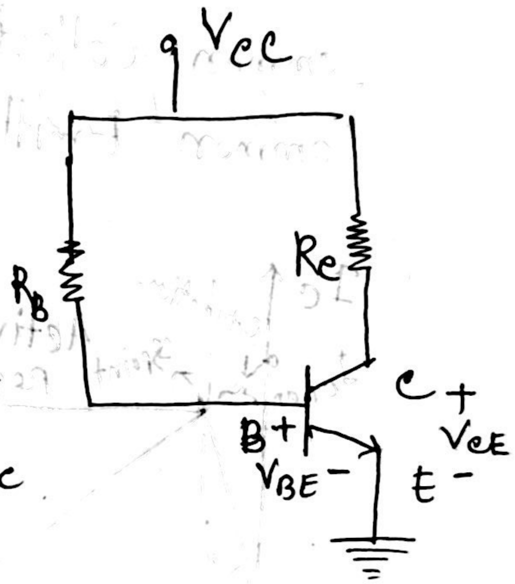
$V_c = V_{cc}$

$V_c = I_c R_c.$



$\boxed{I_c = \beta I_B}$





BE loop,

$$-V_{cc} + I_B R_B + V_{BE} = 0$$

$$\Rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B}$$

$$I_c = \beta I_B$$

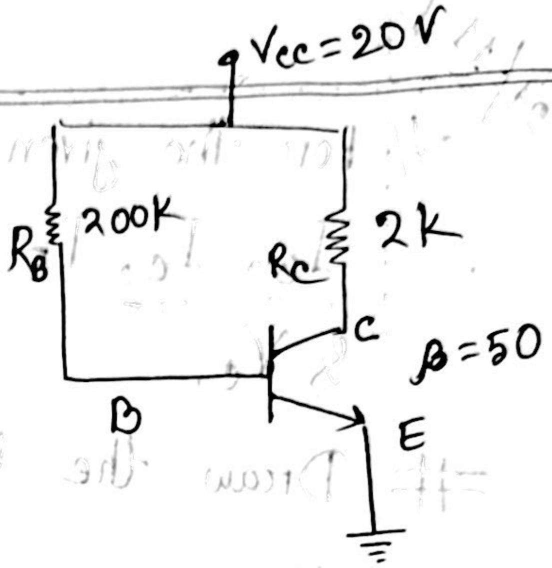
$$I_E = I_B + I_C$$

$$-V_{cc} + I_c R_c + V_{CE} = 0$$

$$\Rightarrow V_{CE} = V_{cc} - I_c R_c$$

Determine

I_B, I_C, I_E & V_{CE}



BE loop ?

$$I_B = \frac{V_{CC}-V_{BE}}{R_B} = \frac{20-0.7}{200k}$$

$$= 0.0965 \text{ mA (Ans)}$$

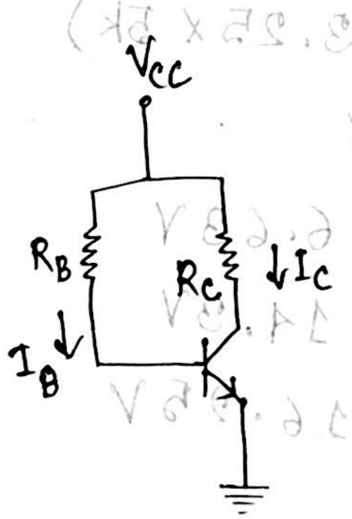
$$I_C = \beta I_B = 50 \times 0.0965 = 4.825 \text{ mA (Ans)}$$

$$V_{CE} = V_{CC} - I_C R_C = 20 - (4.825 \times 2)$$

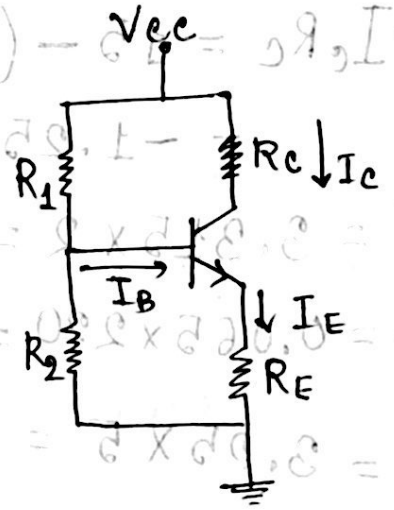
$$= 10.35 \text{ V}$$

$$I_E = I_B + I_C = 4.9215 \text{ mA (Ans)}$$

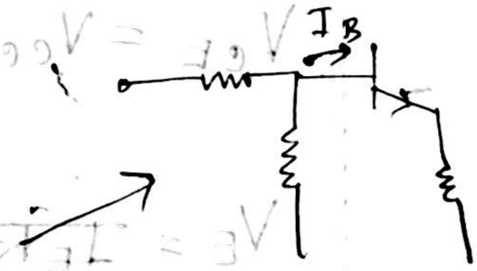
#



Fixed Bias



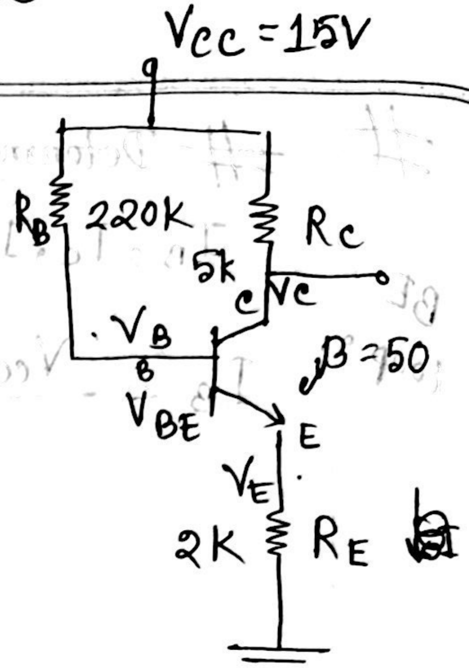
Voltage divider bias



21/11/2024

Wrong

For the given circuit determine I_B, I_C, I_E, V_{BE}, V_B, V_E, V_{CE} & V_C.



Draw the load line.

$V_{BE} = 0.7\,V$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{15 - 0.7}{220} = 0.065\,mA$$

$$I_C = \beta I_B = 50 \times 0.065 = 3.25\,mA$$

$$I_E = I_B + I_C = 0.065 + 3.25$$
$$= 3.315\,mA$$

$$V_{CE} = V_{CC} - I_C R_C = 15 - (3.25 \times 5k)$$
$$= -1.25\,V$$

$$V_E = I_E R_E = 3.315 \times 2 = 6.63\,V$$

$$V_B = I_B R_B = 0.065 \times 220 = 14.3\,V$$

$$V_C = I_C R_C = 3.25 \times 5 = 16.25\,V$$

Gain $= \beta$

$\therefore I_E = I_C + I_B$

$\Rightarrow I_E = \beta I_B + I_B$

$\Rightarrow I_E = I_B(\beta+1) = 0.044(50+1) = 2.2mA$

Soln:

$\therefore$ Applying KVL in B-E loop,

$-V_{cc} + I_B R_B + V_{BE} + I_E R_E = 0$

$\Rightarrow -V_{cc} + I_B R_B + V_{BE} + (\beta+1) I_B R_E = 0$

$\Rightarrow I_B(R_B + (\beta+1)R_E) = V_{cc} - V_{BE}$

$$\Rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B + (\beta+1)R_E}$$

$$= \frac{15 - 0.7}{220k + (50+1)2k} = 0.044mA$$

$\therefore I_C = \beta I_B = 50 \times 0.044 = 2.2mA$

$\therefore V_E = I_E R_E = 2.2mA \times 2k = 4.4V$

$\therefore V_{BE} = V_B - V_E \Rightarrow$

$V_B = V_{BE} + V_E = (0.7 + 4.4) = 5.1V$

$\therefore$ Applying KVL in C-E Loop,

$$-V_{cc} + I_c R_c + V_{CE} + I_E R_E = 0 \quad \text{——— (1)}$$

$$\Rightarrow V_{CE} = V_{cc} - I_c R_c - I_E R_E$$

$$= 15 - (2.2mA \times 5) - (2.2mA \times 2k)$$

$$= -1.1V$$

$$\therefore V_{CE} = V_C - V_E$$

$$\Rightarrow V_C = V_{CE} + V_E = -1.1V + 4.4V$$

$$= 3.3V \text{ (Ans)}$$

From equation (1)

$$-V_{cc} + I_c R_c + V_{CE} + I_E R_E = 0$$

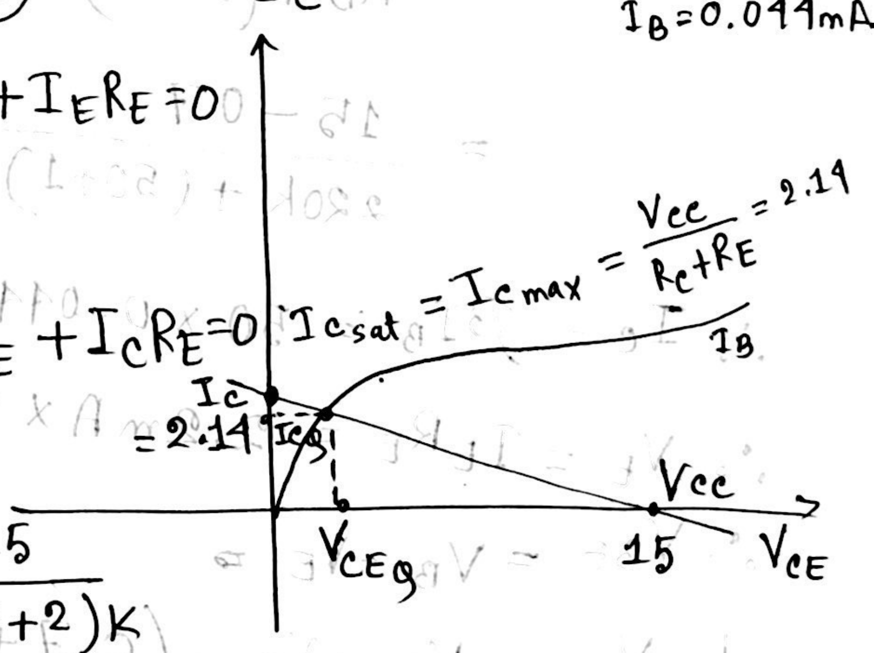
$$\boxed{\because I_c \approx I_E}$$

$$-V_{cc} + I_c R_c + V_{CE} + I_c R_E = 0$$

Let, $V_{CE} = 0$

$$I_c = \frac{V_{cc}}{R_c + R_E} = \frac{15}{(5+2)K}$$

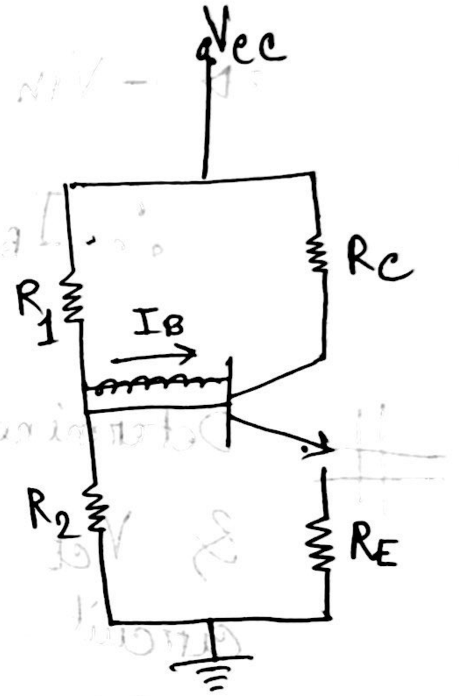
$$I_c = 2.14 \text{ mA}$$

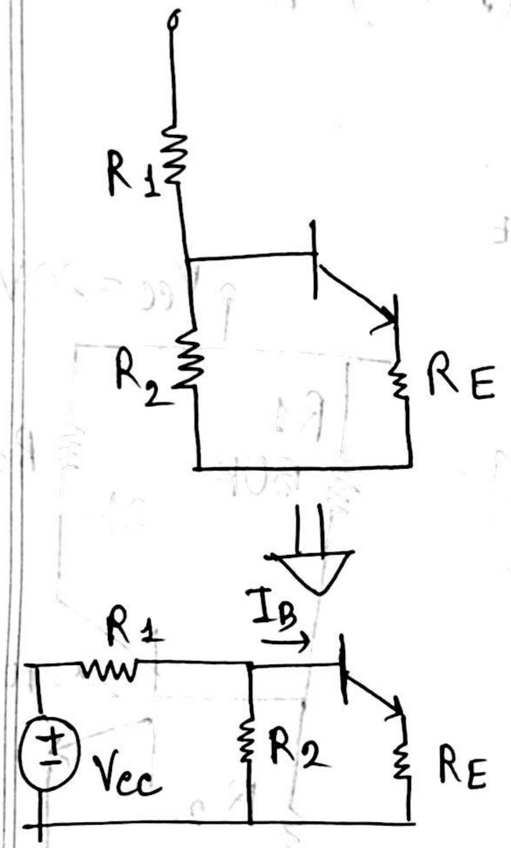


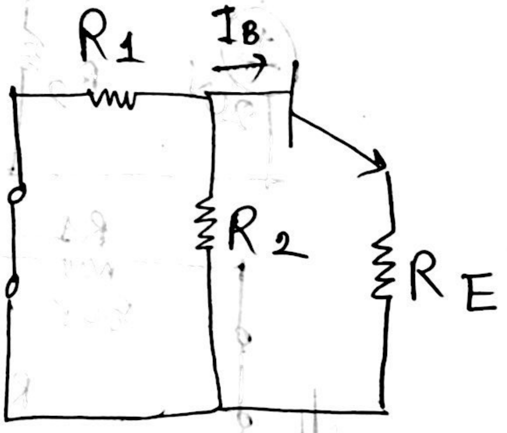
Let, $I_C = 0$

$V_{CE} = V_{CC} = 15V$

Voltage Divider Bias





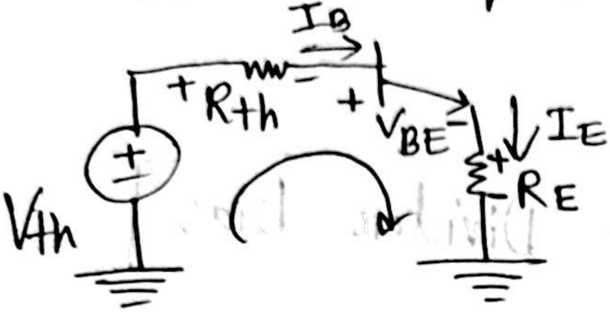


Using Thevenin's Theorem,

$$R_{th} : R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_{th} : \frac{V_{CC} R_2}{R_1 + R_2} \quad [VDR]$$

Thevenin's eqv circuit;



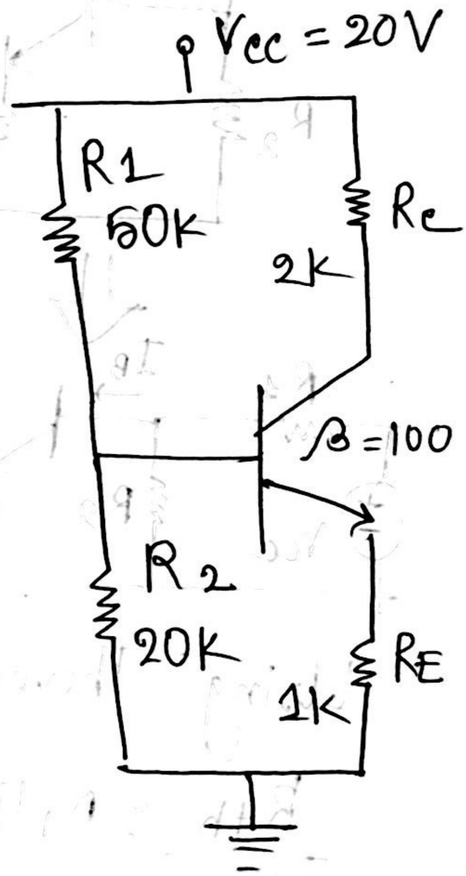
Applying KVL,

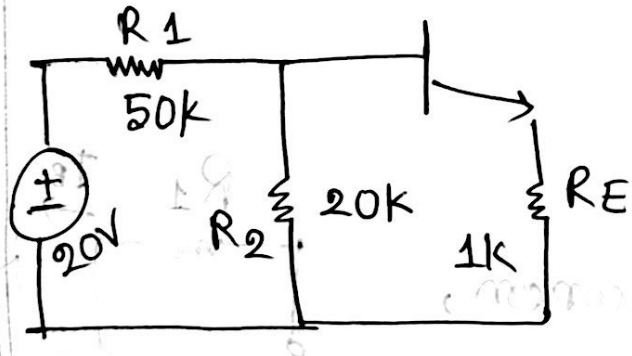
$-V_{th} + I_B R_{th} + V_{BE} + I_E R_E = 0$

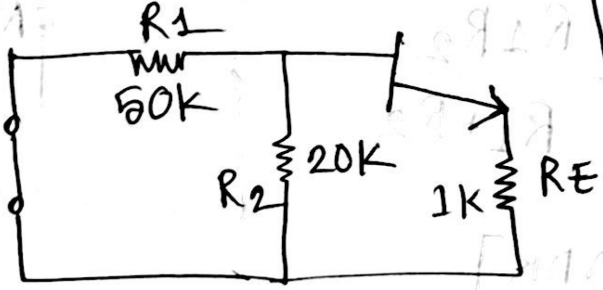
$\Rightarrow -V_{th} + I_B R_{th} + V_{BE} + (\beta+1) I_B R_E = 0$

$$\therefore I_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E}$$

Determine I_B, I_C, I_E & V_{CE} for the following circuit.



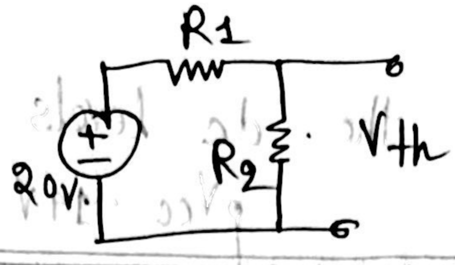


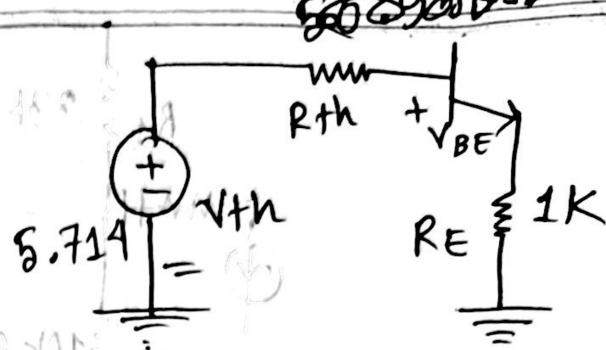


R_{th}:

$\cancel{50+}\ \frac{20 \times 50}{20 + 50} = 14.28\ k\Omega$

$\cancel{= 50.95 k\Omega}$





$$V_{th} = \frac{20 \times 20}{20+50} = 5.714$$

Applying KVL,

$$-5.714 + I_B R_{th} + V_{BE} + I_E R_E = 0$$

$$\Rightarrow \cancel{5.714 =} \; I_B = \frac{5.714 - 0.7}{14.28 + (100+1)\,1K}$$

$$= \frac{5.014}{115.28} = 0.043 \text{ mA}$$

$$I_c = \beta I_B = 4.35 \text{ mA}$$

$$I_E = I_B + I_c = 4.39 \text{ mA}$$

KVL,

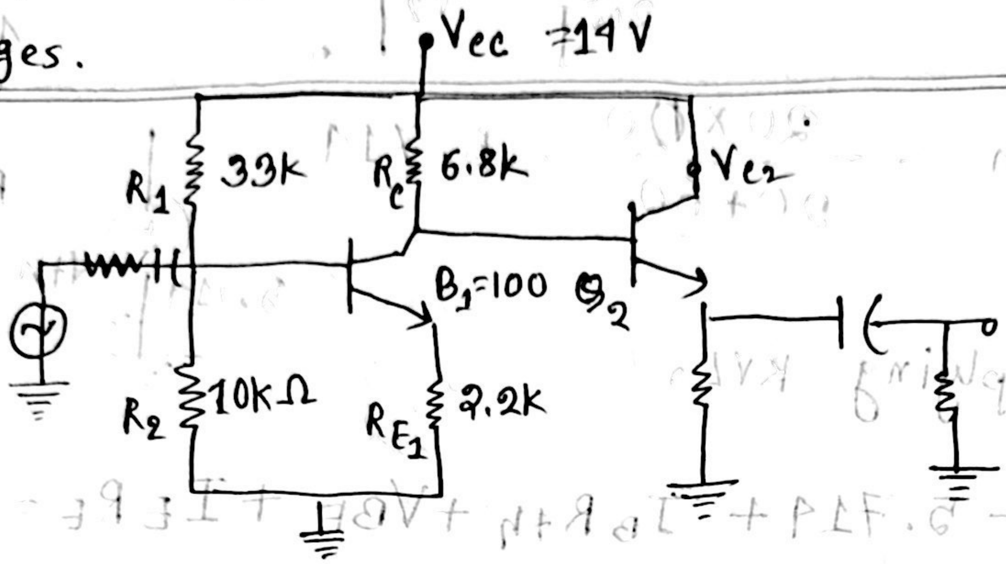
$\underline{V_{CE}}$: $-V_{cc} + I_c R_c + V_{CE} + V_{BE} + I_E R_E = 0$

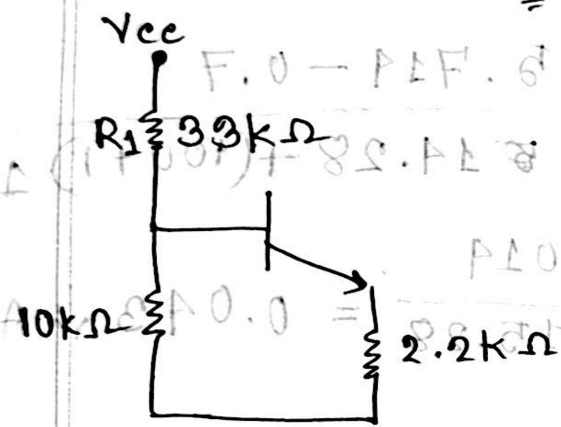
$$\Rightarrow V_{CE} = V_{cc} - V_{BE} - I_c R_c - I_E R_E$$

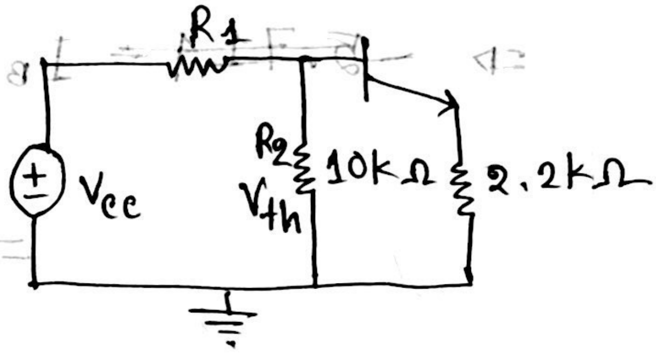
$$= 6.8 \text{ V}$$

26/11/2021

Determine the dc levels for the currents and Voltages.

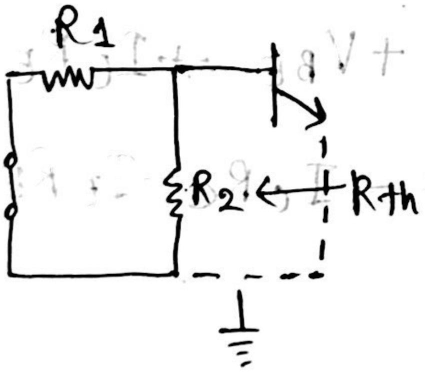






Applying Theverin's equivalent,

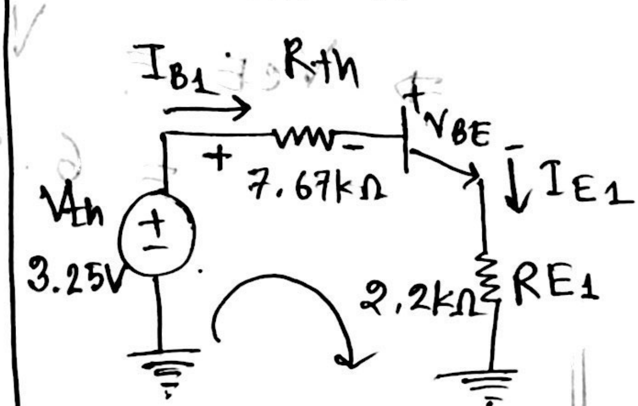
$$V_{th} = \frac{V_{cc} R_L}{R_1 + R_2} = \frac{14 \times 10k}{33k + 10k} = 3.25V$$



$R_{th} = R_1 \| R_2$

$= 7.67 k\Omega$

Theverin's eqv circuit



Scanned with CamScanner

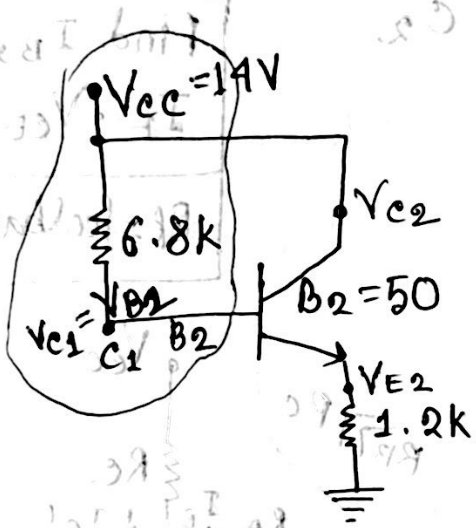
Applying KVL, $-V_{th} + I_{B1}R_{th} + V_{BE_1} + I_{E1}R_{E1} = 0$

$$\Rightarrow -V_{th} + I_{B1}R_{th} + V_{BE_1} + (\beta_1+1) I_{B_1}R_{E1} = 0$$

$$\therefore I_{B_1} = \frac{V_{th} - V_{BE1}}{R_{th} + (\beta_1+1)R_{E1}} = \frac{3.25 - 0.7}{7.67k + (100+1)\,2.2k}$$

$$= 0.011\,mA = 11\,\mu A$$

Again,



$$\therefore V_{c1} = V_{B2} = V_{cc} - I_{c1}R_c$$

$$= 14 - (1.1\,mA \times 6.8k)$$

$$= 6.52V$$

$$\therefore I_{E1} = I_{C1} + I_{B1} = 1.1\,mA + 0.011\,mA = 1.11\,mA$$

$$\therefore V_{E1} = I_{E1}R_{E1} = 1.11\,mA \times 2.2k = 2.44\,V$$

$$\therefore V_{BE2} = V_{B2} - V_{E2}$$

$$\Rightarrow V_{E2} = V_{B2} - V_{BE2} = (6.52 - 0.7)\,V = 5.82V$$

$$\therefore I_{E2} = \frac{V_{E2}}{R_{E_2}} = \frac{5.82}{1.2k} = 4.85\,mA$$

$$\therefore V_{c_2} = V_{cc} = 14V$$

$I_{c}' \gg I_B$

$I_c' = I_c$

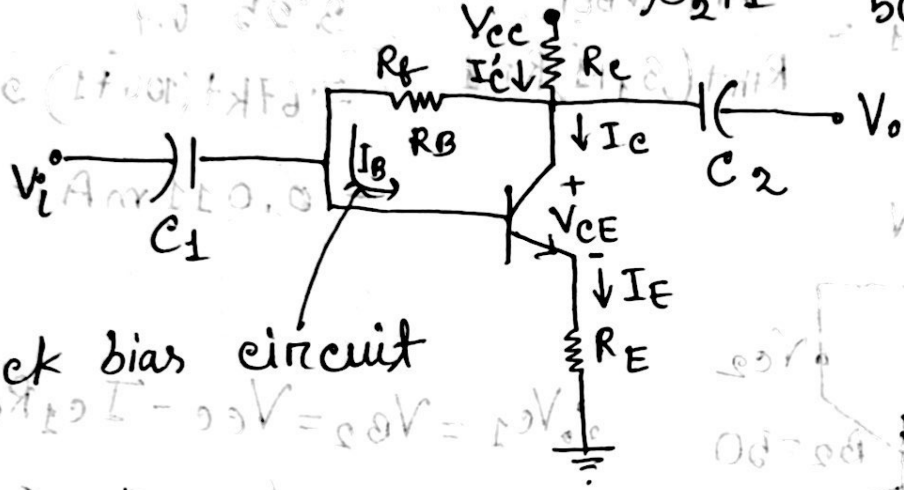
$I_{C_2} \approx I_{E_2}$

$\cancel{\boxed{I_{B_2} = I_{E_1} - I_C}}$

$$I_{E_2} = (\beta_2 + 1) I_{B_2}$$

$$\therefore I_{B_2} = \frac{I_{E_2}}{\beta_2 + 1} = \frac{4.85}{50+1} = 0.095\text{ mA}$$

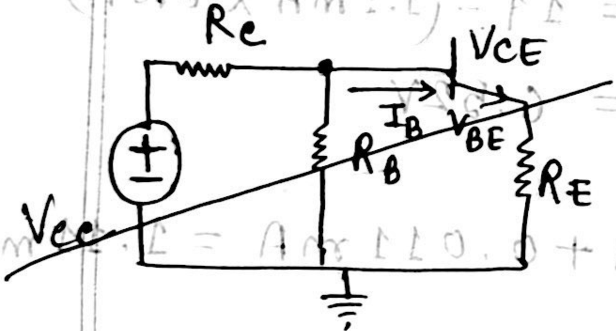
#

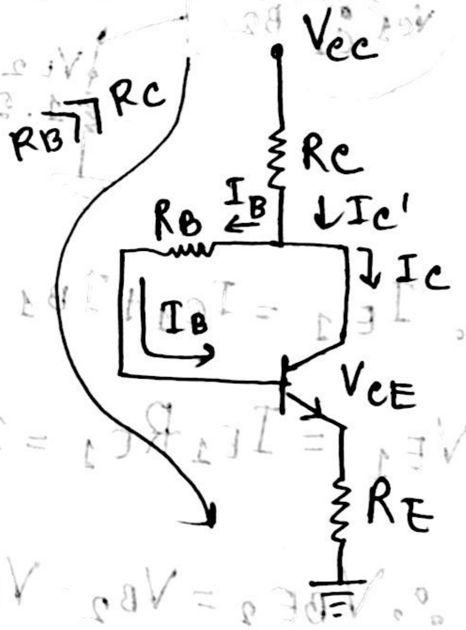


Feedback bias circuit

Find $I_B, I_C, I_E, V_{CE} = ?$

R_f = feedback R.





KVL,

$$\cancel{I_B =} -V_{cc} + I_c' R_c + I_B R_B + V_{BE} + I_E R_E = 0$$

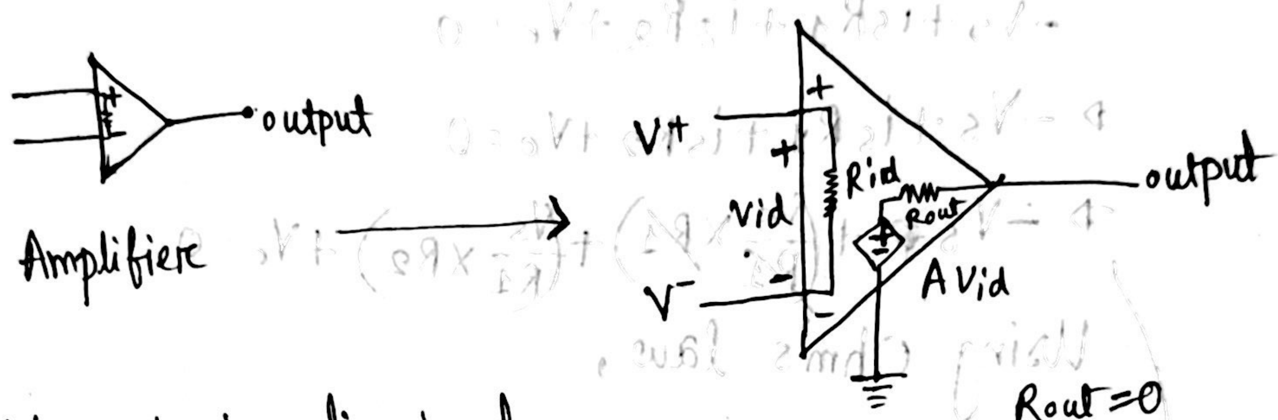
$$\Rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B + \beta R_c + (\beta+1) R_E}$$

$\boxed{\text{বইয়ে } (\beta+1) \approx \beta}$

gain = output এর respect এ input voltage ও হতে পারে, current ও হতে পারে

Operational Amplifiers & Application

অনেকগুলো Transistor এর cascade

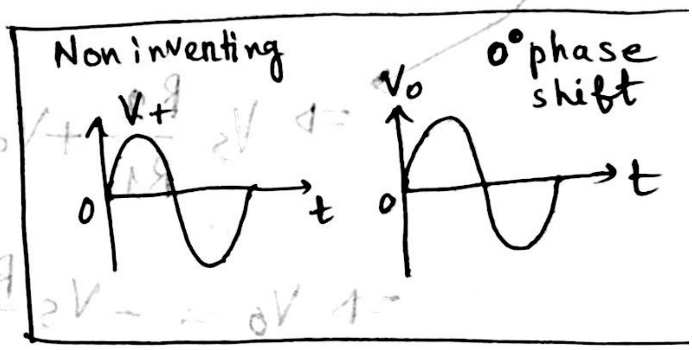


$R_{out} = 0$
$R_{id} = high$

$V^+ \rightarrow$ Non inverting input

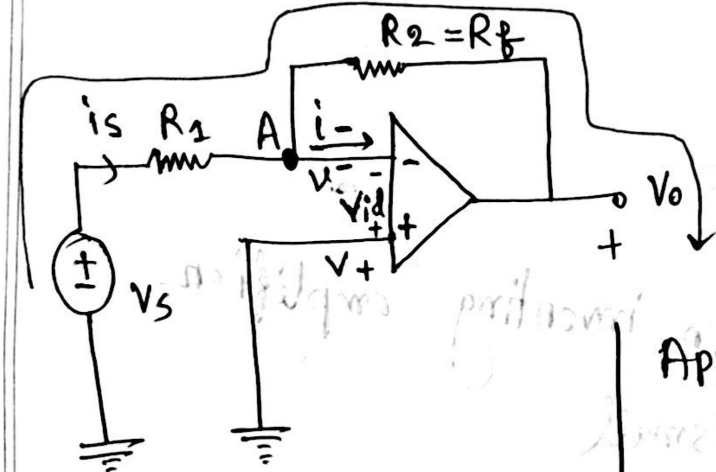
$V^- \rightarrow$ Inverting input

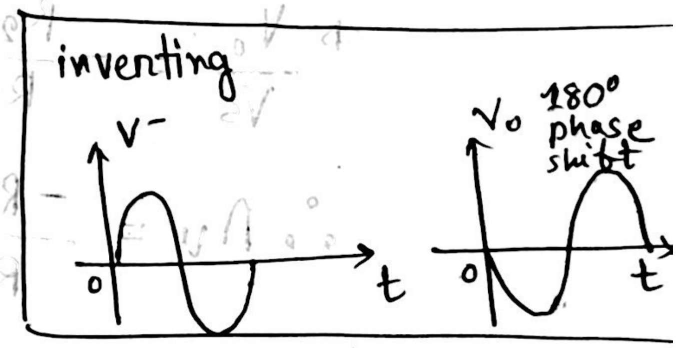
$A \rightarrow$ open circuit voltage gain



Inverting Amplifier :

Voltage gain : $A_v = \frac{V_o}{V_i}$





$\therefore V_{id} = V^+ - V^-$

$\therefore R_{id} = \text{infinity}, i_- = 0$

Apply KCL at node A,

$i_s = i_2 + i_-$

$\therefore i_s = i_2 + 0$

$\therefore i_s = i_2$

Applying KVL,

$$-V_s + i_s R_1 + i_2 R_2 + V_o = 0$$

$$\Rightarrow -V_s + i_s R_1 + i_s R_2 + V_o = 0$$

$$\Rightarrow -V_s + \left(\frac{V_s}{R_1} \times R_1\right) + \left(\frac{V_s}{R_1} \times R_2\right) + V_o = 0$$

Using Ohm's law,

$$i_s = \frac{V_s}{R_1}$$

$$\Rightarrow V_s \frac{R_2}{R_1} + V_o = 0$$

$$A_v = \frac{V_o}{V_s}$$

$$\Rightarrow V_o = A_v V_s$$

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

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

$$\therefore A_v = \frac{-R_2}{R_1}$$

Voltage gain for inventing amplifier

$R_1 > R_2$ = gain small

$R_2 > R_1$ = gain বড় হবে

output resistance বের করাতে Voltage add করলে, Thevenin

∞ = open circuit

~~To find output resistance, Thevenin's Theor~~

$$A_v = 20\,dB = (-10^{\frac{20}{10}}) = -100$$ [inverting amplifier]

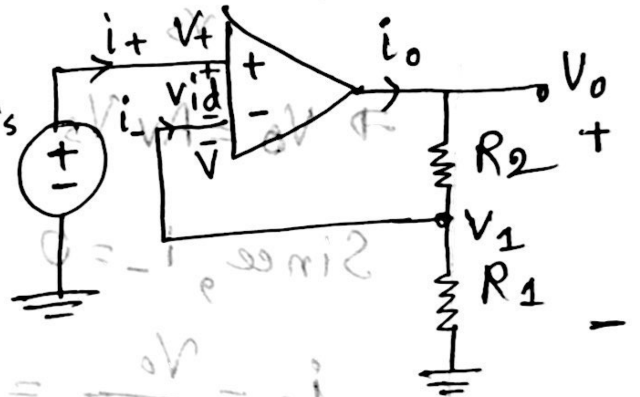
$R_1 = 20k\Omega$

$$\therefore A_v = -\frac{R_2}{R_1}$$

$$\Rightarrow -100 = -\frac{R_2}{20k}$$

$$\Rightarrow R_2 = 2M\Omega$$ (Ans)

Non-Inverting :-



Using VDR,

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

$$V_{id} = V_+ - V_- = V_s - V_1$$

As $i_- = 0$, $V_{id} = 0$

$$\therefore V_{id} = V_s - V_1$$

$$\Rightarrow 0 = V_s - V_1$$

$$\Rightarrow V_s = V_1$$

$$V_s = \frac{V_o R_1}{R_1+R_2}$$

$$\Rightarrow \frac{V_s}{V_o} = \frac{R_1}{R_1+R_2}$$

$$\Rightarrow \frac{V_o}{V_s} = \frac{R_1+R_2}{R_1}$$

$$\frac{V_o}{V_s} = 1 + \frac{R_2}{R_1}$$

$$\therefore A_v = 1 + \frac{R_2}{R_1}$$

Non inverting Example

$R_1 = 3k\Omega$

$R_2 = 43k\Omega$

$V_s = 0.1V$

$$A_v = 1 + \frac{R_2}{R_1}$$

$$= 1 + \frac{43k\Omega}{3k\Omega}$$

$$= 15.3$$

$$A_v = \frac{V_o}{V_s}$$

$$\Rightarrow V_o = A_v V_s = 15.3 \times 0.1 = 1.53V$$

Since, $i_- = 0$

$$i_o = \frac{V_o}{R_2 + R_1} = \frac{1.53}{43k\Omega + 3k\Omega} = 33.3\mu A$$