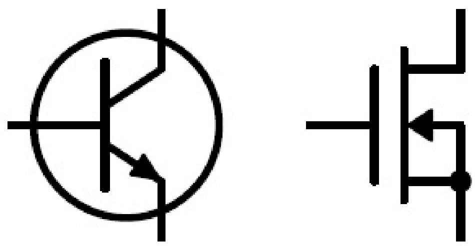
GATE | PSUs

ELECTRONICS & COMMUNICATION ENGINEERING

Analog Circuits

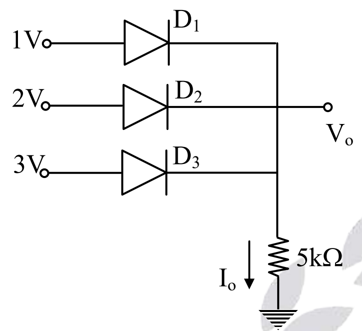
(**Text Book :** Theory with worked out Examples and Practice Questions)

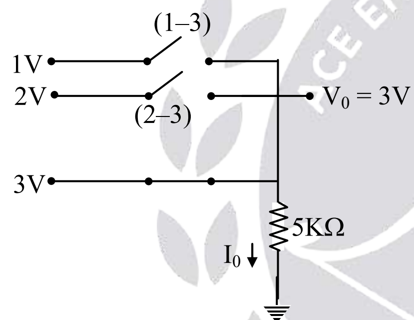


Analog Circuits

(Solutions for Text Book Practice Questions)

01.
Sol:



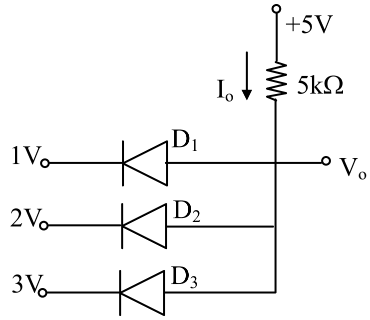


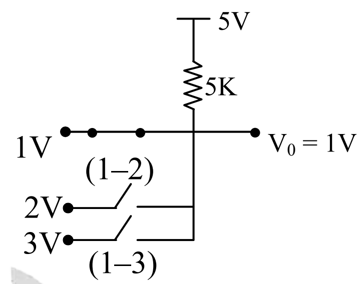
$\Rightarrow$ D_1, D_2 are reverse biased and D_3 is forward biased.

i.e., D_3 only conducts.

$\therefore$ $I_0 = 3/5K = 0.6mA$

02.
Sol:





$\Rightarrow$ D_2 & D_3 are reverse biased and 'D_1' is forward biased.
i.e., D_1 only conduct

$$\therefore\ I_0 = \frac{5-1}{5K} = 0.8mA$$

03.
Sol: Let diodes D_1 & D_2 are forward biased.

$\Rightarrow V_0 = 0$ volt

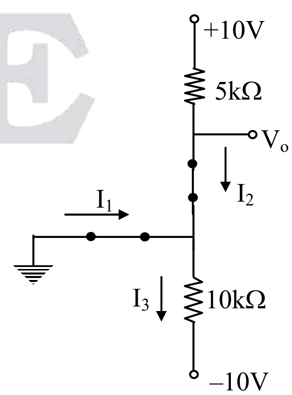
$$I_2 = \frac{10-0}{5K} = 2mA$$

$$I_3 = \frac{0-(-10)}{10K} = 1mA$$

Apply KVL at nodes 'V_0':

$-I_1 + I_3 - I_2 = 0$

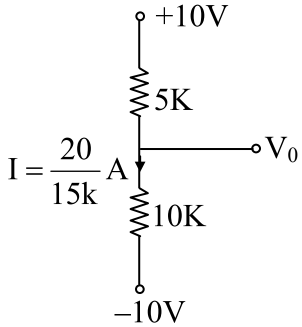
$\Rightarrow I_1 = -(I_2 - I_3) = -1mA$



So, D_1 is reverse biased & D_2 is forward biased

$\Rightarrow$ 'D_1' act as an open circuit & D_2 is act as short circuit.

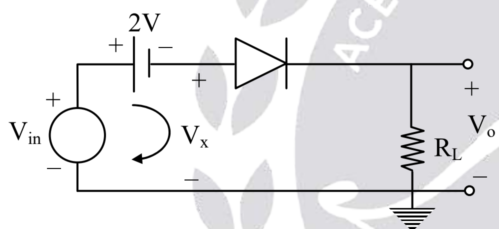
Then circuit becomes



$$\Rightarrow V_0 = 10k \times \left(\frac{20}{15k}\right) - 10$$

$\therefore\ V_0 = 3.33V$

04.
Sol:



Apply KVL to the loop:

$V_{in} – 2 – V_x = 0$

$\Rightarrow V_x = V_{in}–2$ ----- (1)

Given, V_{in} range = –5V to 5V

$\Rightarrow V_x$ range = –7V to 3V [$\because$ from eq (1)]

Diode ON for $V_x > 0V$

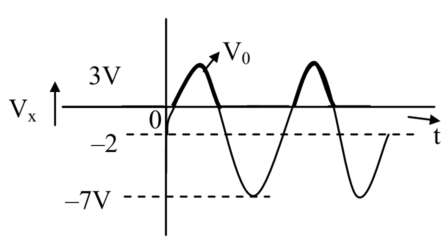
$\Rightarrow V_0 = V_x$

Diode OFF for $V_x < 0V$

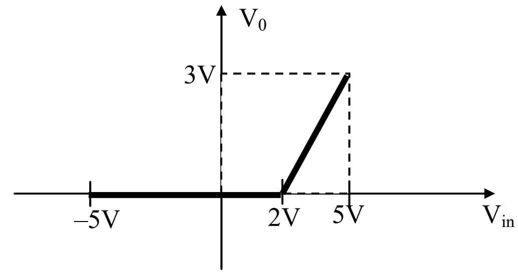
$\Rightarrow V_0 = 0$ V

$\therefore V_0$ range = 0 to 3V

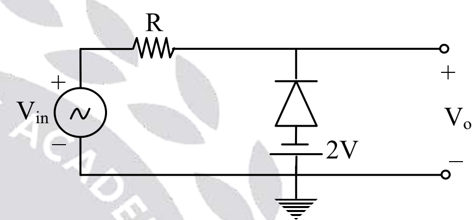
Output wave form:



Transfer characteristics:



05.
Sol:

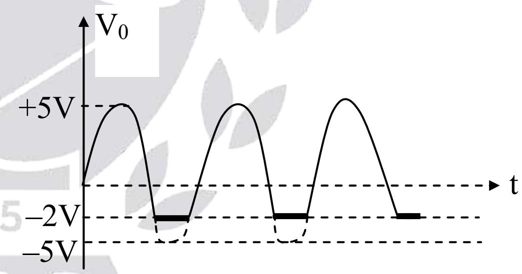


For $V_i < – 2$Volt, Diode ON

$\Rightarrow V_0 = – 2$Volt

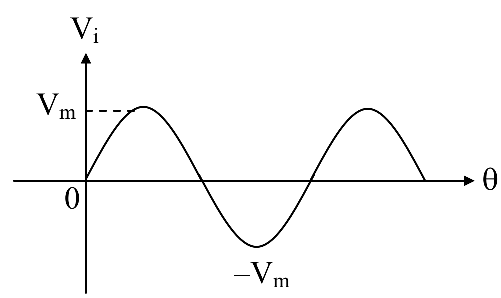
For $V_i > – 2$Volt, Diode OFF

$\Rightarrow V_0 = V_i$



06. Ans: (a & c)

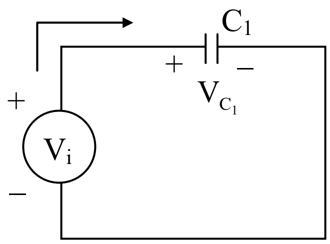
Sol: In positive half, of input →



Capacitor C_1 is charging so, $\underset{\text{Char}}{T} = R_{F_1} C_1 = 0$

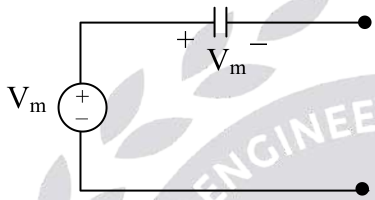
For $\theta \to$ Range from $0 \to \frac{\pi}{2}$,

$\left.\begin{array}{l} D_1 \to \text{Short} \\ D_2 \to \text{Open} \end{array}\right\} \to$



Now at $\theta = \frac{\pi}{2}$, $V_{C_1} = V_m$

D_1 & D_2 both are OFF



So, C_1 has no discharging path $\Rightarrow$ steady state,

So, at steady state $V_{C_1} = +V_m = +5V$.

Since in ANALOG circuit, for either clampers (or) for Ripple removal shunt capacitor filter,

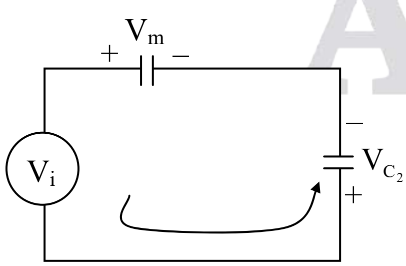
$T_{discharge} >>> T$, where $T \to$ Time period.

Now for $\theta > \frac{\pi}{2}, V_{C_1} = V_m > V_i$

$\Rightarrow$ Due to V_{C_1}, D_1 is OFF

D_2 is ON

Now circuit is $\to$



Now, $V_i = V_{C_1} - V_{C_2} \Rightarrow V_{C_2} = V_{C_1} - V_i$

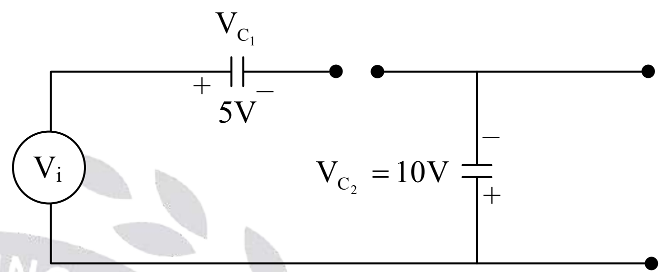
Now, at $\theta = \frac{3\pi}{2}$, $V_i = -V_m$

$\Rightarrow V_{C_2} = 2V_m = 10V$

Now, at $\theta = \frac{3\pi}{2}$, $V_{C_1} = 5V$ from the circuit such that, $V_{C_2} = 10V$

Due to V_{C_2}, D_2 act as open circuit

So, at $\theta = \frac{3\pi}{2}$, the circuit looks like $\to$



Now, as no discharge path for C_1 & C_2

$\Rightarrow$ Steady state

So, at steady state, $V_{C_2} = 10V$, but form circuit V_{C_2} polarity is opposite

$\Rightarrow V_{C_2} = -10V$

So, options (a) & (c) are correct.

07.

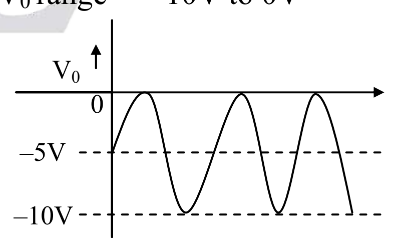
Sol: For positive half cycle diode Forward biased and Capacitor start charging towards peak value.

$\Rightarrow V_C = V_m = 5V$

$\Rightarrow V_0 = V_{in} - V_C = V_{in} - 5$

V_{in} range = – 5V to +5V

$\therefore$ V_0 range = – 10V to 0V



08.

Sol: For +ve cycle, diode 'ON', then capacitor starts charging

$\Rightarrow V_C = V_m - 7 = 10 - 7 = 3V$

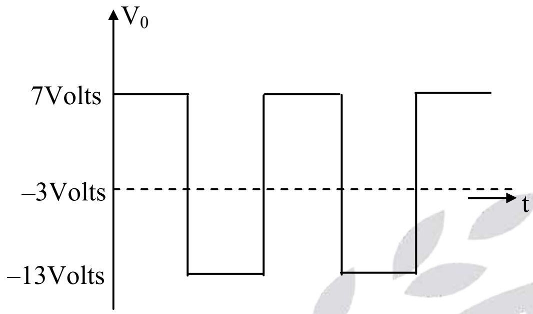
Now diode OFF for rest of cycle

$\Rightarrow V_0 = -V_C + V_{in}$

$= V_{in} - 3$

V_{in} range : –10V to +10V

$\therefore$ V_0 range: –13V to 7V



09.

Sol: Always start the analysis of clamping circuit with that part of the cycle that will forward bias the diodes this diode is forward bias during negative cycle.

For negative cycle diode ON, then capacitor starts charging

$\Rightarrow V_C = V_P + 9$

$= 12 + 9 = 21V$

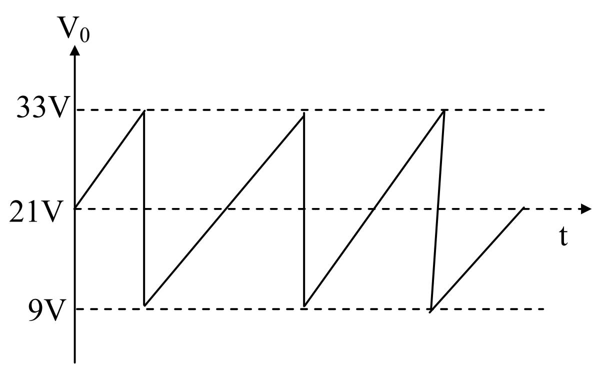
Now diode OFF for rest of cycle.

$\Rightarrow V_0 = V_C + V_{in}$

$= 21 + V_{in}$

V_{in} range: –12 to +12V

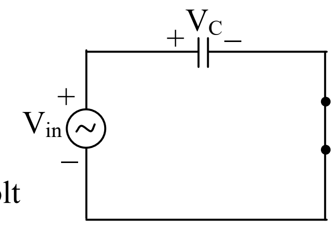
V_0 range: 9V to 33V



10.

Sol: During positive cycle,

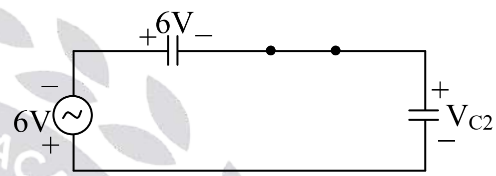
D_1 forward biased & D_2 Reverse biased.



$V_{C_1} = V_{in} = 6$volt

During negative cycle,

D_1 reverse biased & D_2 forward biased.

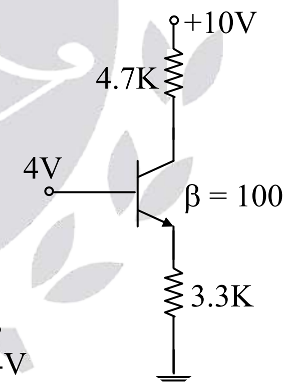


$V_{C2} = -6 - 6 = -12V$

Capacitor C_2 will charge to negative voltage of magnitude 12V

11.

Sol:



Given,

$V_B = 4V$

$V_{BE} = 0.7$

$V_B - V_E = 0.7$

$V_E = V_B - 7 = 3.3V$

$\Rightarrow I_E = \dfrac{3.3}{3.3K\Omega} = 1mA$

Let transisotr in active region

$\Rightarrow I_C = \beta/(\beta+1) \cdot I_E = 0.99mA$

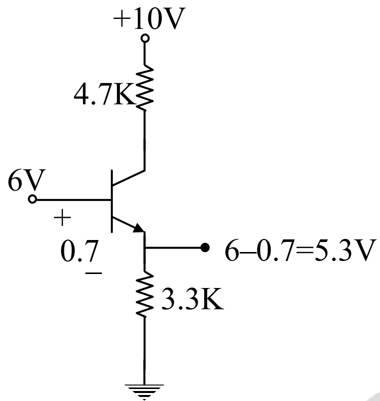
$I_B = I_C/\beta = 9.9\mu A$

$V_C = 10 - 4.7\times10^3\times0.99\times10^{-3} = 5.347V$

$\Rightarrow V_C > V_B$

$\therefore$ Transistor in the active region.

12.
Sol:



$V_E = V_B - V_{BE} = 6 - 0.7 = 5.3V$

$I_E = \dfrac{5.3}{3.3K} = 1.6mA$

Let transistor is active region

$\Rightarrow I_C = \dfrac{\beta}{(1+\beta)} I_E$

$I_C = 1.59mA$

$V_C = 2.55V$

$\Rightarrow V_C < V_B$

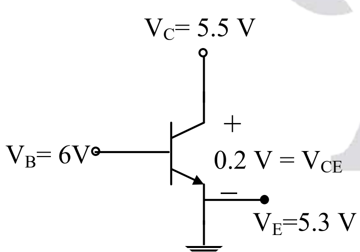
$\therefore$ Transistor in saturation region

$\Rightarrow V_{CE}(sat) = 0.2V$

$V_C - V_E = 0.2$

$V_C = 5.3 + 0.2$

$\Rightarrow V_C = 5.5V$



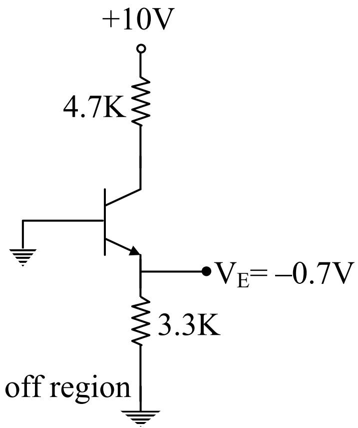
$\Rightarrow I_C = \dfrac{10-5.5}{4.7K} = 0.957mA$

$I_B = 1.6 - 0.957 = 0.643mA$

$\beta = \dfrac{I_C}{I_B} = \dfrac{0.957\ mA}{0.643 mA} = 1.483$

$\beta_{forced} < \beta_{active}$

13.
Sol:



$V_E = -0.7V$

Transistor in cut off region

$I_C = I_B = I_E = 0A$

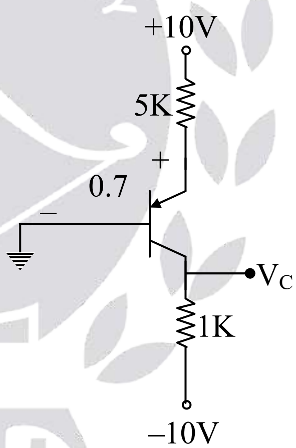
$V_{CE} = 10V$

$V_E = 0V$

$V_C = 10V$

$V_B = 0V$

14.
Sol:



$V_E = 0.7V\ [\because V_B = 0V]$

$\Rightarrow I_E = \dfrac{10-0.7}{5K} = 1.86mA$

Let transistor in active region.

$\Rightarrow I_C = \dfrac{\beta}{(\beta+1)} I_E = 1.84mA$

$\Rightarrow V_C = -10 + 1K \times 1.84m$

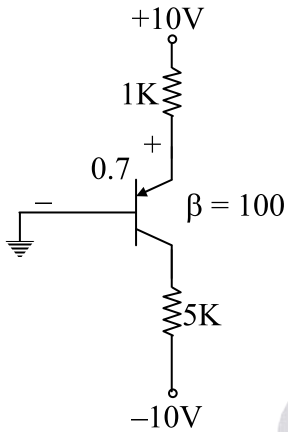
$V_C = -8.16V$

$V_{EC} = V_E - V_C = 8.86V$

$V_{EC} > V_{EB}$

$\therefore$ Transistor in active region

15.
Sol:



Let transistor in active region

$V_E = 0.7V \qquad [\because V_B = 0V]$

$$I_E = \frac{10-0.7}{1k} = 9.3mA$$

$$I_C = \frac{\beta}{\beta+1}.I_E = 9.2mA$$

$\Rightarrow V_C = -10 + 5K \times 9.2m$

$V_C = 36V$

$V_{EC} < V_{EB}$

Transistor in saturation region

$\Rightarrow V_{EC} = 0.2$

$V_E - V_C = 0.2 \Rightarrow V_C = 0.5V$

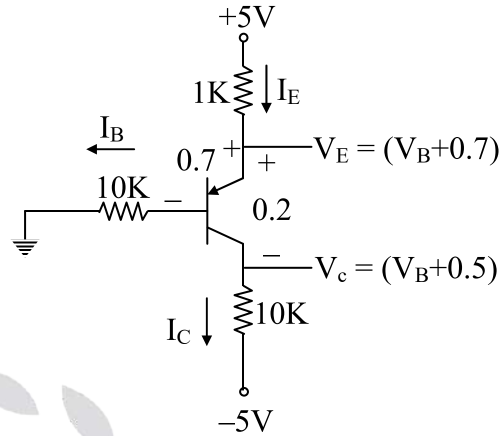
$$\Rightarrow I_C = \frac{0.5+10}{5K} = 2.1mA$$

$I_B = I_E - I_C = 7.2mA$

$$\beta_{forced} = \frac{I_{c(sat)}}{I_B} = \frac{2.1}{7.2} = 0.29$$

$\beta_{forced} < \beta_{active}$ i.e., saturation region

16.
Sol:



$I_E = I_C + I_B$

$$\Rightarrow \frac{5-(V_B+0.7)}{1k} = \frac{(V_B+0.5)+5}{10k} + \frac{V_B}{10k}$$

$10(5 - V_B - 0.7) = V_B + 0.5 + 5 + V_B$

$43 - 10V_B = 2V_B + 5.5$

$$V_B = \frac{43-5.5}{12} = 3.125V$$

$$I_B = \frac{3.125}{10K} = 0.3125mA$$

$V_C = V_B + 0.5 = 3.625V$

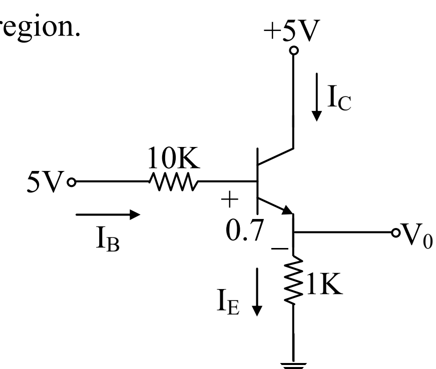
$V_E = 3.825V$

$\therefore I_E = 1.175mA$

$\therefore I_C = 0.862mA$

17.

Sol: Here the lower transistor (PNP) is in cut off region.



Apply KVL to the base emitter loop:

$5 - 10K.\ I_B - 0.7 - 1K.\ (1+\beta)I_B = 0$

$\Rightarrow I_B = \dfrac{4.3}{(101)K + 10K}$

$= 38.73\mu A$

$I_C = 3.87mA$

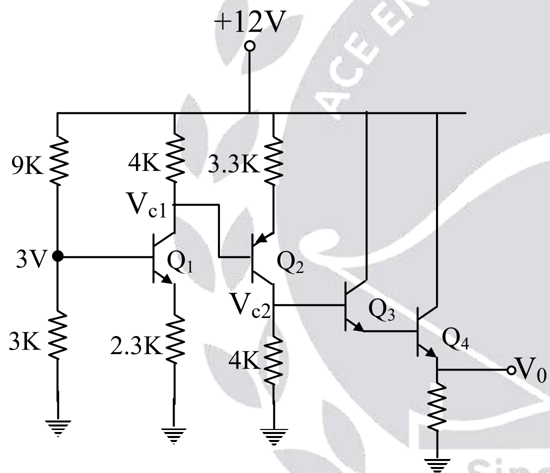
$I_E = 3.91mA$

$\Rightarrow V_E = V_0 = I_E(1k) = 3.91\ V$

$V_C = 5V$

$V_B = 5 - 10\ k\ (I_B) = 4.61\ V$

18.
Sol:



$$I_{C_1} = I_{\varepsilon_1} = \frac{2.3V}{2.3k} = 1m\,Amp$$

$$V_{C_1} = 12V - 4\times10^3 \times 1\times10^{-3} = 8V$$

$$V_{\varepsilon_2} = 8 + 0.7V = 8.7V$$

$$I_{\varepsilon_2} = \frac{12V - V_{\varepsilon 2}}{3.3k} = \frac{12V - 8.7}{3.3k} = 1m\,Amp$$

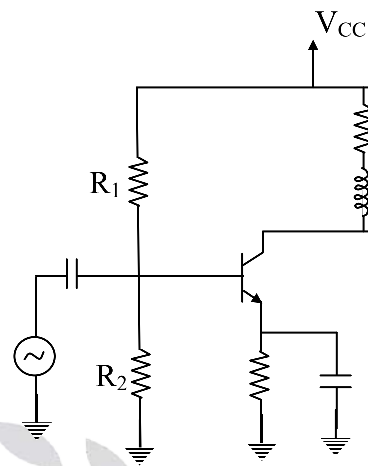
$$V_{C_2} = 4k \times 1mA = 4V$$

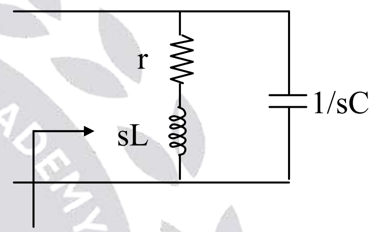
$$V_{\varepsilon 3} = 4V - 0.7 = 3.3V$$

$$V_{\varepsilon_4} = 3.3 - 0.7 = 2.6V$$

$V_0 = 2.6\ V$

19.
Sol:





$$Z_{eq} = \frac{1}{sC + \dfrac{1}{r + sL}}$$

$$= \frac{r + sL}{srC + s^2LC + 1}$$

$$= \frac{r + j\omega L}{(1 - \omega^2 LC) + j\omega rC}$$

$$Z_{eq} = \frac{(r + j\omega L)\left[1 - \omega^2 LC - j\omega rC\right]}{\left(1 - \omega^2 LC\right)^2 + \left(\omega rC\right)^2}$$

$$= \frac{\omega^2 rLC + r - \omega^2 rLC + j\omega L[1 - \omega^2 LC] - j\omega r^2 C}{\left(1 - \omega^2 LC\right)^2 + \left(\omega rC\right)^2}$$

Equate Imaginary terms:

$\omega L - \omega^3 L^2 C - \omega r^2 C = 0$

$L - \omega^2 L^2 C - r^2 C = 0$

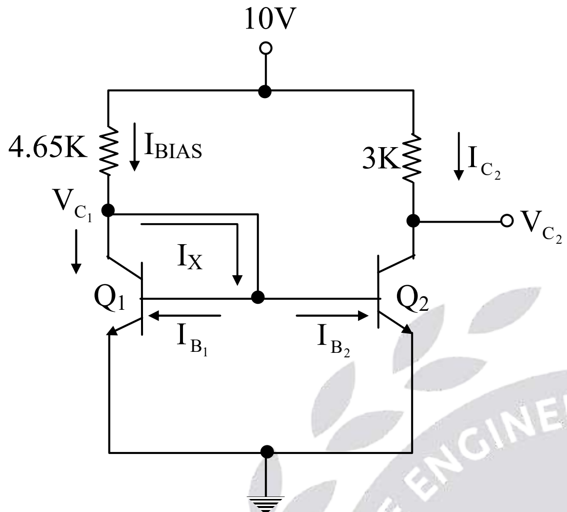
$\omega^2 L^2 C = L - r^2 C$

$$\omega = \sqrt{\frac{1}{L\,C} - \frac{r^2 C}{L^2 C}}$$

$$\omega = \sqrt{\frac{1}{LC} - \left(\frac{r}{L}\right)^2}$$

20. Ans: (a & b)

Sol: Step-1: KCL at collector node of Q_1 i.e., at C_1



$$I = I_{C_1} + I_x = I_{C_2} + 2I_{B_2} \;\ldots\ldots.(1)$$

$$= I_{C_2} + 2\frac{I_{C_2}}{\beta} \;\ldots\ldots.(2)$$

$$= I_{C_2}\left[1 + \frac{2}{100}\right] \ldots\ldots..(3)$$

$$\Rightarrow I_{C_2} = I\left[\frac{100}{102}\right] = 0.98I \ldots\ldots\ldots(4)$$

Step-2: KVL foe C-E loop of Q_1

$$I = \frac{10V - 0.7V}{4.65K\Omega} = 2mA \ldots\ldots\ldots(5)$$

$$\Rightarrow I_{C_2} = 1.96mA \ldots\ldots\ldots(6)$$

Step-3: KVL for loop of Q_2

$$V_{C_2} = 10V - 3K\Omega(1.96mA) = 4.12V \;\ldots.(7)$$

Step-4: KVL for C-loop of Q_1

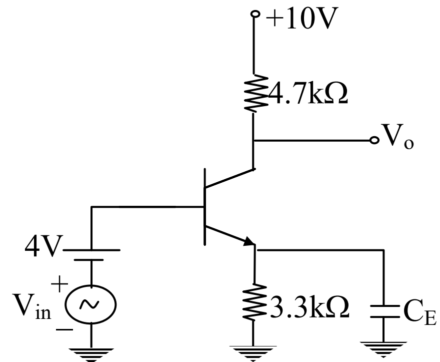
$$V_{C_1} = 10V - I_{BIAS} \times 4.65K \ldots\ldots..(8)$$

$$= 10V - 2mA \times 4.65K\Omega \ldots\ldots\ldots(9)$$

$$\therefore V_{C_1} = 0.7V \ldots\ldots.(10)$$

21.

Sol:



For D.C Analysis:

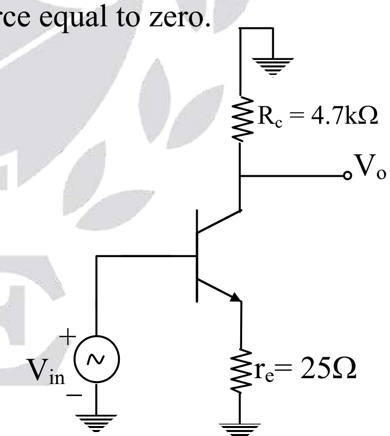
$V_B = 4$ V

$V_B - V_E = 0.7 \Rightarrow V_E = 4 - 0.7 = 3.3$ V

$$I_E = \frac{3.3}{3.3k} = 1mA$$

$$r_e = \frac{V_T}{I_E} = \frac{25\,mV}{1\,mA} = 25\,\Omega$$

To apply small signal analysis set D.C source equal to zero.



$\Rightarrow V_0 = -i_cR_c$

$V_{in} = i_br_\pi = i_b\beta r_e = i_cr_e$

$$\therefore A_V = \frac{V_0}{V_i}$$

$$= \frac{-i_cR_c}{i_cr_e} = \frac{-R_c}{r_e} = \frac{-4.7\,k}{25}$$

$$= -188$$

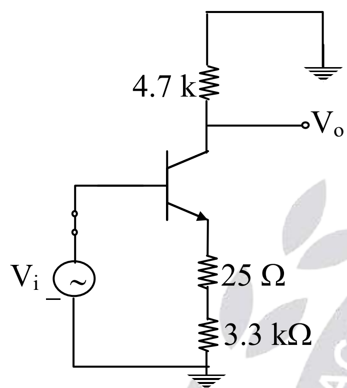
22.

Sol: D.C calculation is same as previous question

$I_E = 1$ mA

$r_e = 25\ \Omega$

Apply small signal analysis:



$$\frac{V_0}{V_i} = \frac{-R_c}{r_e + R_E} = \frac{-4700}{25+3300}$$

$$\therefore A_V = \frac{V_0}{V_i} = -1.413$$

23.

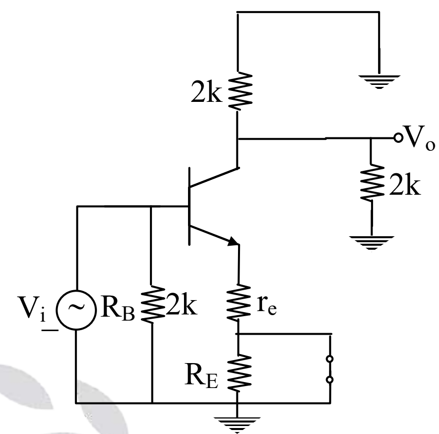
Sol: To calculate r_e value apply D.C analysis

$$I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}}$$

$$= \frac{3-0.7}{2.3k + \frac{2k}{101}} = 0.991\text{mA}$$

$$r_e = \frac{V_T}{I_E} = \frac{25}{0.991} = 25.22\Omega$$

Now apply small signal analysis:



$$A_V = \frac{V_0}{V_i} = \frac{-R_C}{r_e} = \frac{-(2k \parallel 2k)}{25.22} = -39.65$$

$R_i = R_B \parallel \beta r_e$

$R_i = 1.116\text{k}\Omega$

$$A_I = \frac{i_0}{i_i} = \frac{V_0}{R_L} \times \frac{R_i}{V_i} = A_V \times \frac{R_i}{R_L}$$

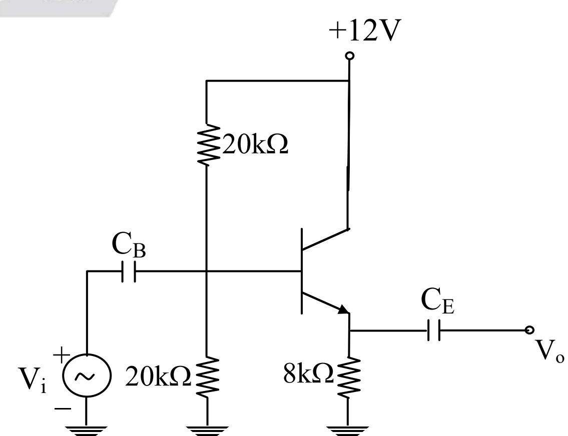
$$= \frac{-39.5 \times 1.116 \times 10^3}{2 \times 10^3}$$

$$= -22.322$$

$R_o = R_C = 2\text{k}\Omega$

24.

Sol:



Apply KVL at input Loop:

$6 - 10k\,(I_B) - 0.7 - 8\,k(1+\beta)I_B = 0$

$$I_B = \frac{6-0.7}{10k + 8k \times 101} = 6.47\ \mu A$$

$I_E = 0.65$ mA

$$r_e = \frac{V_T}{I_E} = \frac{25}{0.65} = 38.5\ \Omega$$

Apply small signal analysis

$$A_v = \frac{V_0}{V_i} = \frac{R_E}{r_e + R_E}$$

$$= 0.995$$

$R_i = R_B \parallel \beta R_{E_{Total}}$

$R_{E_{Total}} = (R_E + r_e)$

$R_i = 10\text{ k} \parallel 803.85\text{k}$

$= 9.87$ kΩ

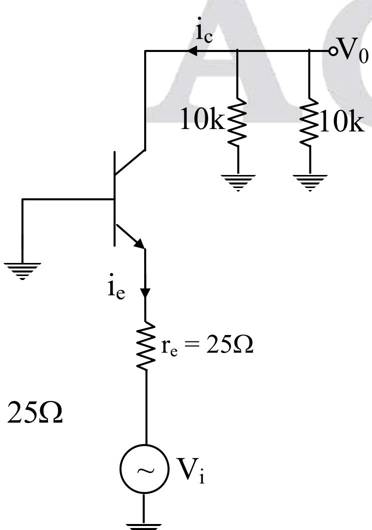
$R_0 = R_E \parallel r_e = 38.3\ \Omega$

25.
Sol: $V_0 = -i_c R_C$

$$i_e \approx i_c = \frac{-V_i}{r_e}$$

$$V_0 = \left(\frac{V_i}{r_e}\right) R_C$$

$$\frac{V_0}{V_i} = \frac{R_C}{r_e}$$



Given $I_E = 1$mA

$$\Rightarrow\ r_e = \frac{25\text{mV}}{1\text{mA}} = 25\Omega$$

$$A_V = \frac{R_C}{re}$$

$$A_V = \frac{10k // 10k}{25} = \frac{5000}{25} = 200$$

$R_0 = R_C = 10k\Omega$

$R_i = r_e = 25\Omega$

$$A_I = \frac{i_0}{i_i} = \frac{v_0}{R_L} \times \frac{R_i}{v_i}$$

$$= A_V \times \frac{R_i}{R_L} = \frac{200 \times 25}{10^4} = 0.5$$

26.
Sol: For the given differential amplifier,

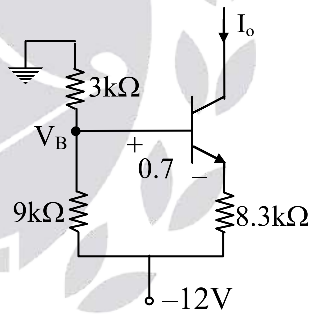
$I_E = 1$mA

$$r_e = \frac{V_T}{I_E} = 25\Omega$$

$$A_d = \frac{V_0}{V_i} = \frac{-R_c}{r_e} = \frac{-3000}{25}\ \text{(or)}\ -g_m R_c$$

$A_d = -120$

27.
Sol:



$$I_1 = \frac{0 - (-12)}{12k} = 1\text{mA}$$

$$I_1 = \frac{0 - V_B}{3K}$$

$V_B = -3$V

$V_B - V_E = 0.7$

$V_E = V_B - 0.7$

$V_E = -3.7$ Volt

$$I_0 = \frac{-3.7 + 12}{8.3k}$$

$I_o = 1$mA

$I_E = 0.5$mA

$$r_e = \frac{25mV}{0.5mA} = 50\Omega$$

$$A_d = \frac{-R_C}{r_e} = \frac{-2000}{50}$$

$$A_d = -40$$

28.

Sol: Voltage shunt feedback amplifier and

$$\frac{V_0}{V_{in}} = \frac{-R_f}{R_S} = \frac{-10k}{1k} \approx -10$$

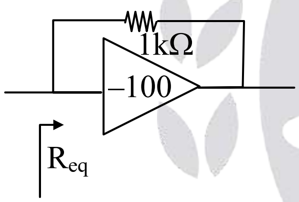
29.

Sol: Current - series feedback amplifier and

$$A_V \approx \frac{R_C}{R_E} = \frac{4.7k}{3.3k} = 1.4242$$

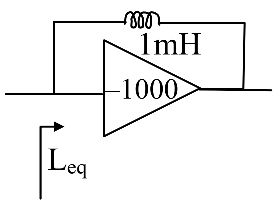
30.

Sol:



Using millers effect,

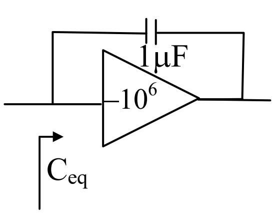
$$R_{eq} = \frac{1k}{1+100} = 9.9\Omega$$



$$L_{eq} = \frac{1mH}{1+1000} \approx 1\mu H$$

31.

Sol:



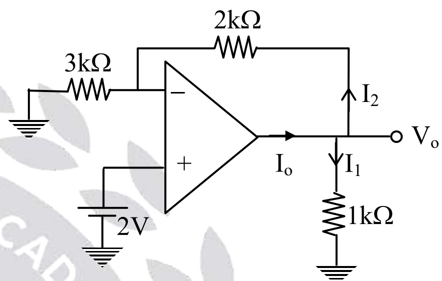
$$C_{eq} = 1\mu F\left(1+10^6\right) \approx 1F$$

32.

Sol: $V_0 = \left(1+\frac{R_f}{R_1}\right)V_i$

$$V_0 = \left(1+\frac{2k}{3k}\right)2$$

$$V_0 = \frac{10}{3}\text{volt} = 3.33\text{ V}$$



$$I_1 = \frac{V_0}{1k} = \frac{10}{3}\text{mA} \;\&$$

$$I_2 = \frac{V_0 - 2}{2k} = \frac{\frac{10}{3} - 2}{2k} = \frac{2}{3}\text{mA}$$

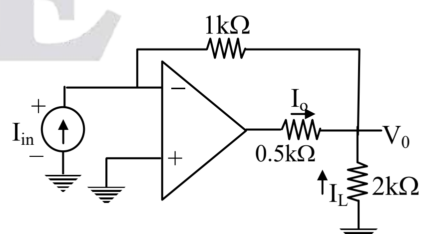
$$\therefore I_0 = I_1 + I_2 = 4\text{mA}$$

33.

Sol: $V_0 = \frac{-R_2}{R_1}V_{in}$

34.

Sol:



$$V_0 = -I_{in} \times 1K$$

$$I_L = \frac{I_i \times 1K}{2K} = \frac{I_{in}}{2}$$

$$I_0 + I_{in} + I_L = 0$$

$$I_0 + I_{in} + \frac{I_{in}}{2} = 0$$

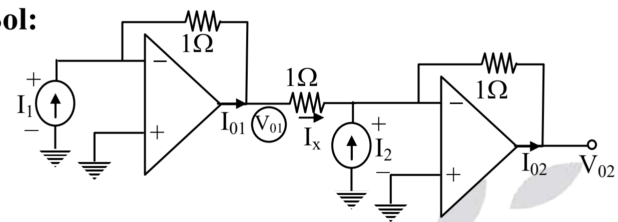
$$2I_0 + 2I_{in} + I_{in} = 0$$

$$2I_0 = -3I_{in}$$

$$\frac{I_0}{I_{in}} = \frac{-3}{2} = -1.5$$

35.

Sol:



$$V_{01} = -I_1$$

Apply KCL:

$$I_x + I_2 = \frac{0 - V_{0_2}}{1}$$

$$\frac{V_{01}}{1} + I_2 = -V_{02}$$

$$V_{01} + I_2 = -V_{02}$$

$$-I_1 + I_2 = -V_{02}$$

$$V_{02} = (I_1 - I_2)\text{volt}$$

$$I_{01} + I_1 = I_x$$

$$I_{01} + I_1 = V_{01} \qquad \left[\because I_x = \frac{V_{01}}{1}\right]$$

$$I_{01} = V_{01} - I_1$$

$$I_{01} = -2I_1 \qquad [\because V_{01} = -I_1]$$

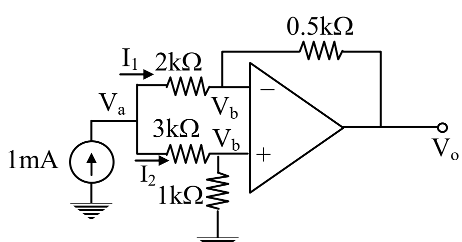
$$I_{02} = -(I_2 + I_x)$$

$$I_{02} = -(I_2 + V_{01})$$

$$I_{02} = (I_1 - I_2)\text{A}$$

36.

Sol:



Apply KCL at V_a:

$$1m = \frac{V_a - V_b}{2k} + \frac{V_a - V_b}{3K}$$

$$1m = \frac{3V_a - 3V_b + 2V_a - 2V_b}{6k}$$

$$6 = 5V_a - 5V_b$$

$$V_a - V_b = \frac{6}{5}$$

$$V_a - V_b = 1.2\text{Volt}$$

$$I_1 = \frac{V_a - V_b}{2k} = \frac{1.2}{2k} = 0.6\text{mA}$$

$$I_2 = \frac{1.2}{3k} = 0.4\text{mA}$$

$$V_b = 0.4m \times 1k = 0.4 \text{ Volt}$$

$$I_1 = \frac{V_b - V_0}{0.5k}$$

$$0.6m = \frac{0.4 - V_0}{0.5k}$$

$$0.3 = 0.4 - V_0$$

$$\therefore V_0 = 0.1 \text{ Volt}$$

37.

Sol: $V_C = \frac{-I}{C}.t = \frac{-10\times10^{-3}}{10^{-6}}\times0.5\times10^{-3}$

$$V_C = -5\text{Volt}$$

38.

Sol: Given open loop gain = 10

$$\frac{V_0}{V_i} = \frac{\left(1+\frac{R_f}{R_1}\right)}{1+\left(1+\frac{R_f}{R_1}\right)\times\frac{1}{A_{0L}}}$$

$$\frac{V_0}{V_i} = \frac{(1+3)}{1+\frac{4}{10}}$$

$$V_0 = V_i \times \frac{4}{1+\frac{4}{10}}$$

$$V_0 = \frac{2\times4}{1+\frac{4}{10}} = 5.715\text{Volt}$$

39.

Sol: $$\frac{V_0}{V_i} = \frac{-R_f/R_1}{1+\frac{(1+R_f/R_1)}{A_{OL}}}$$

$$\frac{V_0}{V_i} = \frac{-9}{1+\frac{10}{10}}$$

$$\frac{V_0}{V_i} = \frac{-9}{2}$$

$V_0 = -4.5V$

40.

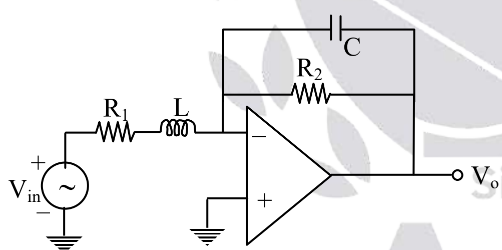
Sol: $SR = 2\pi f_{max} V_{0max}$

$$V_{0\,max} = \frac{SR}{2\pi f_{max}} = \frac{10^6}{2\pi\times 20\times 10^3} = 7.95\text{Volt}$$

$$V_0 = A\times V_i \Rightarrow V_i = \frac{V_0}{A} = 79.5\text{mV}$$

41.

Sol:



$$z_2 = R_2 \| \frac{1}{sC} = \frac{R_2}{sCR_2+1}$$

$z_1 = R_1 + sL$

$$\left|\frac{V_0}{V_i}\right| = \frac{\frac{R_2}{sCR_2+1}}{R_1+sL}$$

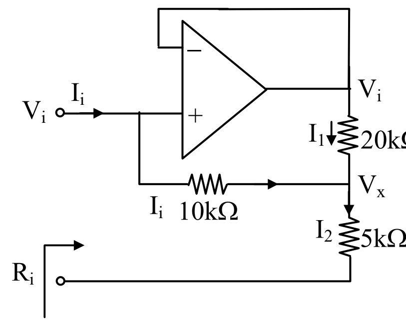
$$\left|\frac{V_0}{V_i}\right| = \frac{R_2}{(sCR_2+1)(R_1+sL)}$$

It represent low pass filter with

D.C gain $= \frac{R_2}{R_1}$

42.

Sol: (i)



Apply KCL at V_x:

$$\frac{V_x}{5k} = I_i + I_1$$

$$\frac{V_x}{5k} = \frac{V_i - V_x}{10k} + \frac{V_i - V_x}{20k}$$

$$\frac{V_x}{5} = \frac{3V_i - 3V_x}{20}$$

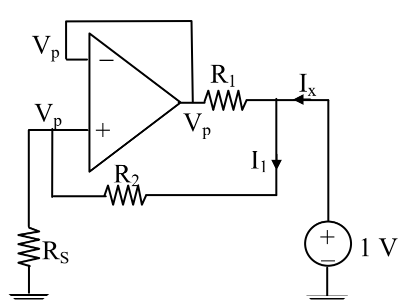
$$V_x = \frac{3}{7}V_i$$

$$I_i = \frac{V_i - V_x}{10k}$$

$$I_i = \frac{V_i - \frac{3}{7}V_i}{10k}$$

$$R_i = \frac{V_i}{I_i} = 17.5\,k\Omega$$

(ii)



$$R_0 = \frac{1}{I_x}$$

$$V_p = \frac{R_s}{R_2 + R_s}$$

$$I_x = \frac{1-V_p}{R_2} + \frac{1-V_p}{R_1}$$

$$I_x = (1-V_p)\left(\frac{1}{R_2} + \frac{1}{R_1}\right)$$

$$I_x = \left(1 - \frac{R_s}{R_2 + R_s}\right)\left(\frac{R_1 + R_2}{R_1 R_2}\right)$$

$$I_x = \frac{R_2}{R_2 + R_s}\left(\frac{R_1 + R_2}{R_1 R_2}\right)$$

$$\therefore R_0 = \frac{1}{I_x} = \left(\frac{R_s + R_2}{R_1 + R_2}\right) R_1$$

43.

Sol: $V_E = V_{in}$

$V_{CE} = V_C - V_E$

$V_{CE} = 15 - V_{in}$

given V_{in} 0 to 5 Volt

$\Rightarrow$Transistor is in active region

$$I_E = I_0 = \frac{V_{in} + 15}{10} = \frac{17}{10} = 1.7\,A \quad [\because V_{in} = 2V]$$

$$I_B = \frac{I_0}{1+\beta} = \frac{1.7}{100}\ A$$

$V_B = V_{in} + 0.7 = 2.7V$

$$I_B = \frac{V_{op} - V_B}{100}$$

$$\frac{V_{op} - 2.7}{100} = \frac{1.7}{100}$$

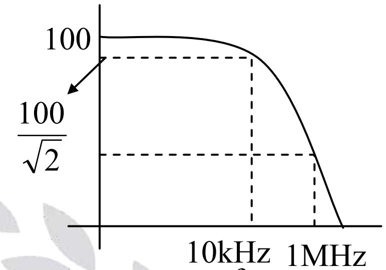
$V_{op} = 4.4$ Volt

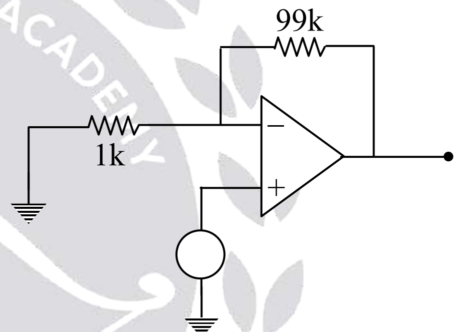
44.

Sol: Single stage:

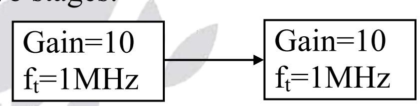
Gain = 40dB = 100, f_T = 1MHz = Gain BW

$$BW \to f_{3dB} = \frac{f_T}{Gain} = \frac{10^6}{100} = 10kHz$$



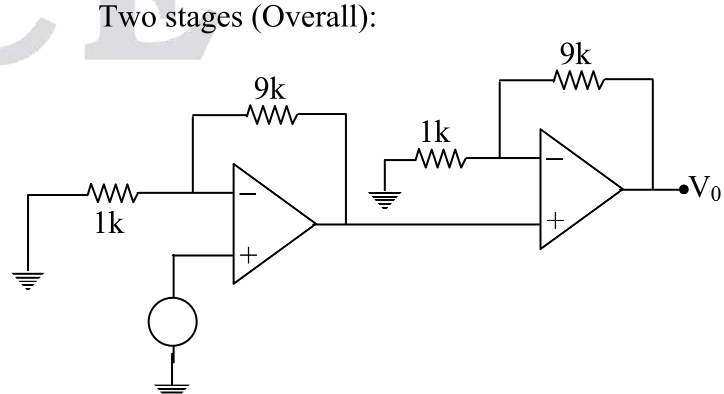


Two stages:



$f_{3dB} = \frac{1M}{10} = 100kHz$, f_{3dB} = 100kHz(for single stage)

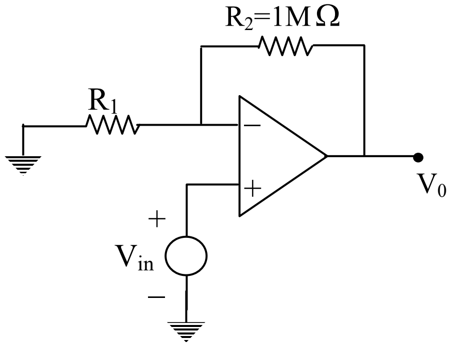
Two stages (Overall):



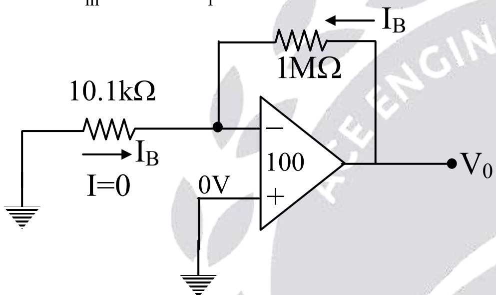
Overall BW = $f_{3dB}\sqrt{2^{1/2} - 1}$ = 100k (0.65)
= 65 kHz

45.

Sol: (a)



$$\text{Gain} = \frac{V_0}{V_{in}} = 1 + \frac{1M}{R_1} = 100 \Rightarrow R_1 = 10.1k\Omega$$



$V_0 = I_B(1M)$

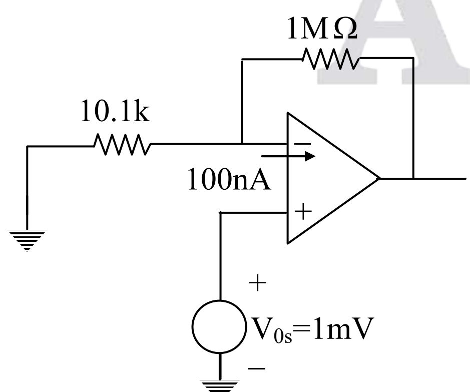
$= 100nA(1M)$

$= 0.1V$

(b)

→ op-amp draws current

→ op-amp CKT the curve doesn't pass through '0' (transfer characteristics)



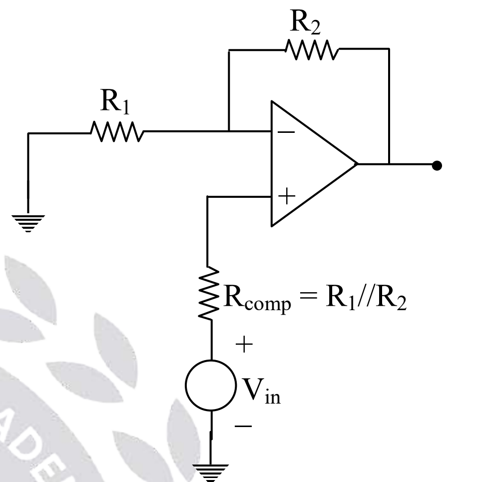
$$V_0 = \left|V_{0_{\text{Bios current}}}\right| + \left|V_{0_{\text{Offset Voltage}}}\right|$$

$$= 1M(I_B) + \left(1 + \frac{R_2}{R_1}\right)V_{os}$$

$= 1M\ (100nA) + 100(1mV)$

$= 0.2V$

(c)



→ $R_{comp} = R_1//R_2$, then $V_0 = (I_{B1} - I_{B2})\ R_2$

$= I_{os}\ R_2$

$V_0 = (I_{B1} - I_{B2})\ R_2$

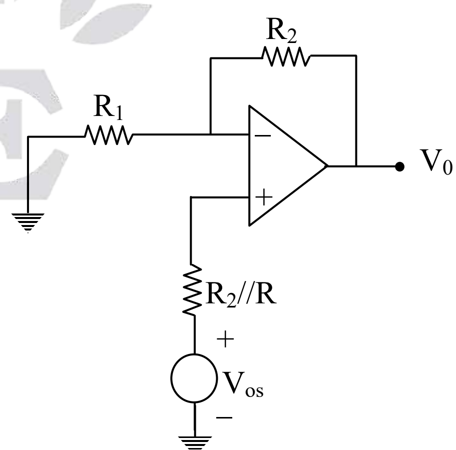
$= I_{os}\ R_2$

$= 1/10\ (I_B R_2)$

$$= \frac{1}{10} 100nA(1M)$$

$= 0.01V = 10mV$

(d)



$$V_0 = \left|V_{0_{\text{Offset Voltage}}}\right| + \left|V_{0_{\text{Bios current}}}\right|$$

$= 0.1 + 0.01$

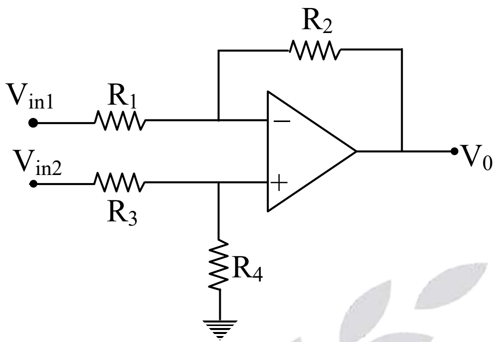
$= 0.11 = 110mV$

46.

Sol: Given

$R_1 = R_3 = 10k\Omega$

$R_2 = R_4 = 1M\Omega$



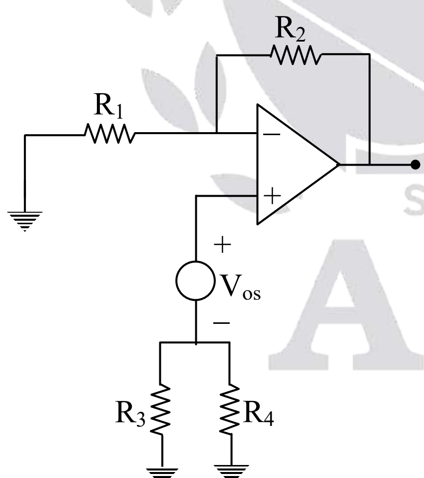
$$V_0 = \frac{R_2}{R_1}\left(V_{in2} - V_{in1}\right)$$

$$= \frac{1M}{10k}\left(V_{in2} - V_{in1}\right)$$

Given $V_{os} = 4mV$

$I_B = 0.3\ \mu A$

$I_{os} = 50\ nA$



$$V_0 = \left[1 + \frac{R_2}{R_1}\right]V_{os} + I_{os}R_2$$

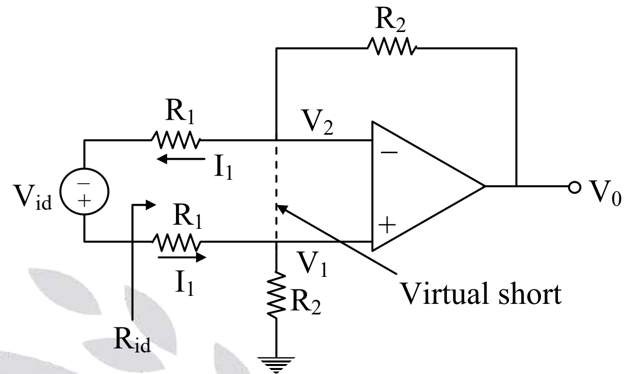
$$= \left[1 + \frac{1M}{10k}\right]4mV + 50nA[1M]$$

$= 454mV$

47. Ans: (b & d)

Sol: Step-1: Differential input resistance,

$$R_{id} = \frac{V_{id}}{I_1} \text{........(1)}$$



Consider virtual short circuit between V_1 & V_2 and writing a loop equation,

$V_{id} = R_1 I_1 + 0 + R_1 I_1$........(2)

$= 2R_1 I_1$........(3)

$$\therefore \frac{V_{id}}{I_1} = R_{id} = 2R_1 \text{......(4)}$$

But $R_{id} = 20K = 2R_1$........(5) [Given]

$\Rightarrow R_1 = 10K$.......(6)

Step-2: $\because$ The given circuit is a differential amplifier,

$$V_0 = \frac{R_2}{R_1}\left(V_A - V_B\right) \text{........(7)}$$

$$\Rightarrow A_d = \frac{V_0}{V_A - V_B} = \frac{R_2}{R_1} = 100 \text{........(8)}$$

[Given]

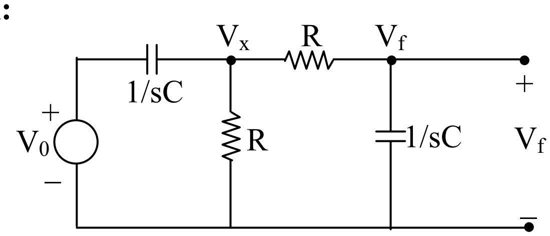
$\Rightarrow R_2 = 100\ R_1$........(9)

$= 100 \times 10K$.......(10)

$\therefore R_2 = 1000K = 1M\Omega$.......(11)

48.

Sol:



KCL

$$\frac{V_x - V_0}{(1/SC)} + \frac{V_x}{R} + \frac{V_x - V_f}{R} = 0 \text{ -------(1)}$$

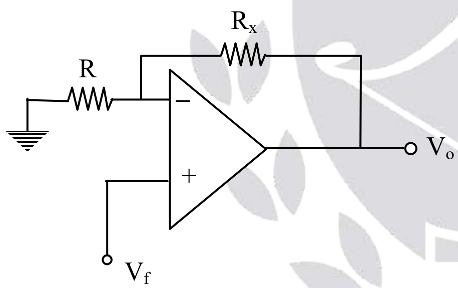
$$\frac{V_f - V_x}{R} + \frac{V_f}{(1/SC)} = 0 \text{ -------(2)}$$

From (1) and (2) eliminate V_x

$$\beta = \frac{V_f}{V_0} = \frac{SCR}{[S^2C^2R^2 + 3SCR + 1]}$$

$$\beta = \frac{1}{[3 + SCR + \frac{1}{SCR}]}$$

$$\beta = \frac{1}{3 + j\left(\omega RC - \frac{1}{\omega RC}\right)} \quad (S = j\omega)$$



$$A = \frac{V_0}{V_f} = 1 + \frac{R_x}{R}$$

Loop gain =1 → A = 1/β

Aβ = 1

$$1 + \frac{R_x}{R} = 3 + j\left(\omega RC - \frac{1}{\omega RC}\right)$$

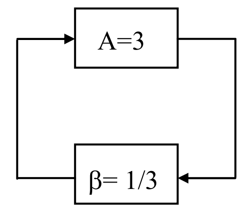
Equate imaginary parts

$$0 = \omega RC - \frac{1}{\omega RC}$$

$$\omega^2 = \frac{1}{R^2C^2}$$

$$f = \frac{1}{2\pi RC} \text{ frequency of oscillation}$$

Equate



$$1 + \frac{R_x}{R} = 3$$

$R_x = 2R$

49.

Sol: $\omega_0 = \frac{1}{\sqrt{LC}}$

$$\frac{V_F}{V_0} = \beta = \frac{0.5k}{R_x + 0.5}$$

$$A = 1 + \frac{9k}{1k} = 10$$

Aβ = 1 for sustained oscillations

$$\frac{0.5k}{R_x + 0.5k} \times 10 = 1$$

∴ $R_x = 4.5\ k\Omega$

50.

Sol: Given $\beta = \frac{1}{6}$

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

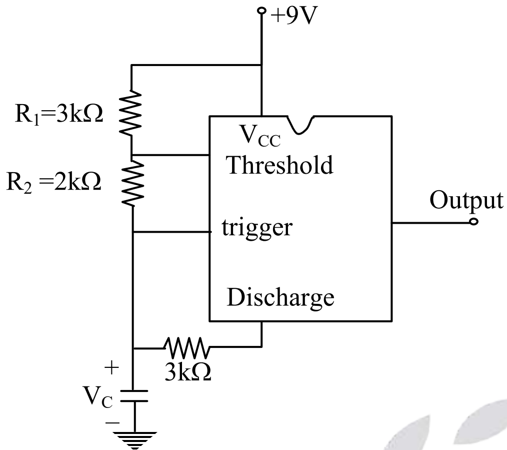
Aβ = 1 for sustained oscillations

$$\left(1 + \frac{R_2}{R_1}\right) . \frac{1}{6} = 1$$

$$\frac{R_2}{R_1} = 5$$

$R_2 = 5\ R_1$

51.
Sol:



$$V_{th} = \frac{2}{3}V_{CC} = \frac{2}{3}\times 9 = 6\ V$$

$$V_{th} - V_C = 2\times10^3\times I \qquad \left(I = \frac{9-6}{3k}\right)$$

$$V_{th} - V_C = 2\ V$$
$$V_C = V_{th} - 2 = 4\ V$$
$$V_{trigger} = \frac{1}{3}V_{CC} = 3\ V$$
$$V_C = 3\ V \text{ to } 4\ V$$

52. Ans: (a & d)

Sol: Case-(i): Consider

f_S = Series resonant frequency

$$= \frac{1}{2\pi\sqrt{L_SC_S}} \text{ …….(1)}$$

f_P = Parallel resonant frequency

$$= \frac{1}{2\pi\sqrt{L_SC_{eq}}} \text{ ……..(2)}$$

$$\Rightarrow \frac{Eq(2)}{Eq(1)} = \frac{f_P}{f_S} = \frac{1.0025}{1} = \frac{\frac{1}{2\pi\sqrt{L_SC_{eq}}}}{\frac{1}{2\pi\sqrt{L_SC_S}}} \text{ …..(3)}$$

$$\Rightarrow (1.0025)^2 = \frac{L_SC_S}{L_SC_{eq}} \text{ ……..(4)}$$

$$= \frac{C_S}{\left[\frac{C_SC_P}{C_S+C_P}\right]} \text{ ………(5)}$$

$$\Rightarrow \frac{C_P}{C_S+C_P} = \frac{1}{1.005} = 0.995 \text{ ……..(6)}$$

$$\Rightarrow C_S + C_P = \frac{C_P}{0.995} = \frac{5PF}{0.995} = 5.025pF \text{ ....(7)}$$

$$\therefore C_S = 5.025pF - 5pF = 0.25pF \text{…..(8)}$$

Case-(ii): Consider $f_S = \frac{1}{2\pi\sqrt{L_SC_S}}$ …….(9)

$$\Rightarrow \sqrt{L_SC_S} = \frac{1}{2\pi f_S} = \frac{1}{2\pi\times 1MHz} \text{ ………(10)}$$

$$\Rightarrow L_SC_S = \left(\frac{1}{2\pi\times 1MHz}\right)^2$$

$$\Rightarrow L_S = \frac{1}{C_S}\times\frac{1}{(2\pi\times 1MHz)^2} \text{ ……..(12)}$$

$$= \frac{1}{0.25pF}\times\frac{1}{4\pi^2\times1\times10^{12}\,Hz} \text{ ………(13)}$$

$$= \frac{1}{0.25\times10^{-12}F\times4\pi^2\times10^{12}\,Hz} \text{ ………(14)}$$

$$\therefore L_S = 0.10142399H \text{……..(15)}$$

Case-(iii): Quality factor,

$$Q_S = \frac{\omega_SL_S}{R_S} \text{ ……….(16)}$$

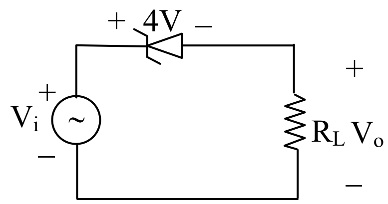
$$= \frac{2\pi f_SL_S}{R_S} \text{ ……..(17)}$$

$$= \frac{2\pi\times 1MHz\times 0.10142399H}{20\Omega} \text{ …….(18)}$$

$$= 0.111464965\times10^6 \text{……..(19)}$$

$$\therefore Q_S = 111464.965 = 1{,}11{,}465 \text{…….(20)}$$

53.
Sol:



$V_i = 8\sin t$ V

During –Ve cycle, Zener is Forward biased and act as short circuit.

$\Rightarrow V_0 = V_i$

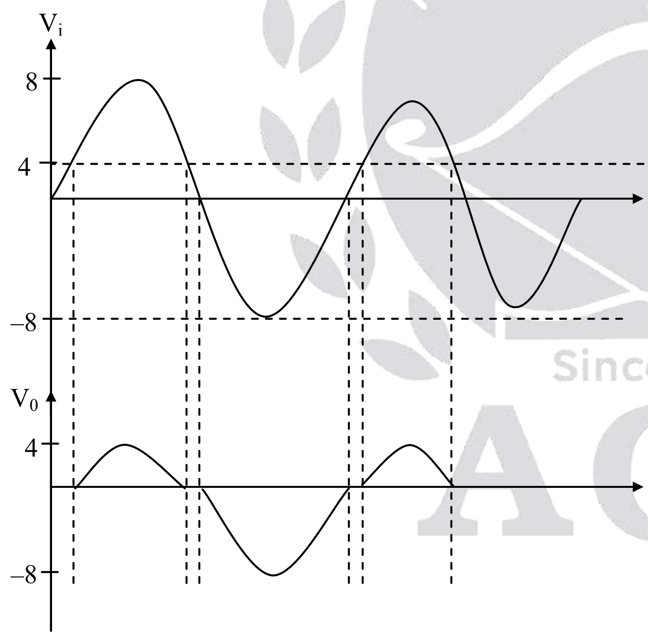
During + Ve cycle,

For $0 < V_i < 4$, Zener OFF Since Zener is not in break down

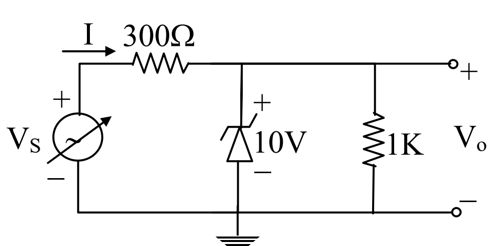
$\Rightarrow V_0 = 0$

For $V_i > 4$, Zener is in break down.

$\Rightarrow V_0 = V_i - 4$



54.
Sol:



I_z = 1mA to 60mA

$$I = \frac{V_s - V_z}{300}$$

$$I_{min} = \frac{V_{s\,min} - 10}{300} \text{ \_\_\_\_\_\_\_\_(I)}$$

$$I_{max} = \frac{V_{smax} - 10}{300} \text{ \_\_\_\_\_\_(II)}$$

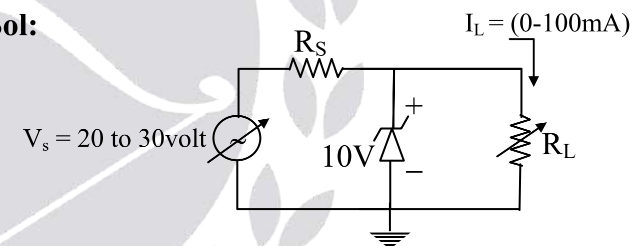
$$I_{min} = I_{zmin} + I_L \left[\because I_L + \frac{V_z}{1k} = 10mA\right]$$

I_{min} = 1mA + 10mA = 11mA

I_{max} = 60mA + 10mA = 70mA

From equation (1) and (2) required range of V_S is 13.3 to 31 volt.

55.
Sol:



The current in the diode is minimum when the load current is maximum and v_s is minimum.

$$R_s = \frac{V_{s\,min} - V_z}{I_{z\,min} + I_{L\,max}}$$

$$R_s = \frac{20-10}{(10+100)mA}$$

$R_s = 90.9\Omega$

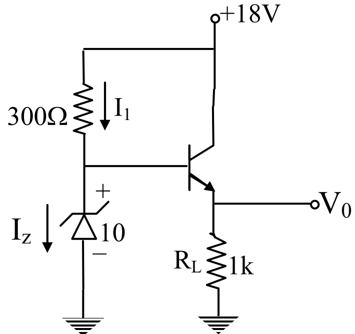
$$I_{z\,max} = \frac{30-10}{90.9} = 0.22A\left[\because I_{L\,min} = 0A\right]$$

$P_z = V_z I_{zmax}$

$P_z = 10 \times 0.22$

$P_z = 2.2W$

56.
Sol:



$V_B = 10$volt

$V_E = 10 - 0.7 = 9.3$volt

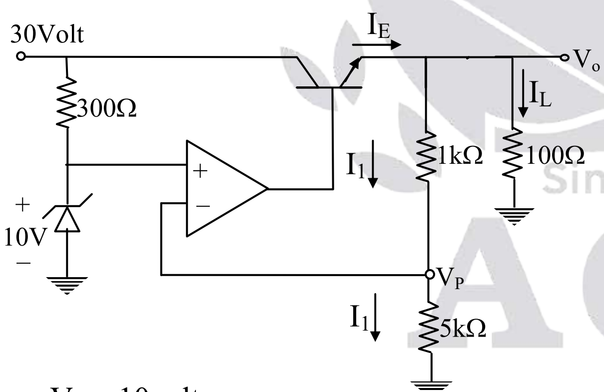
$I_E = 9.3$mA

$$I_B = \frac{I_E}{1+\beta} = \frac{9.3\text{mA}}{101} = 92.07\mu A$$

$$I_1 = \frac{18-10}{300} = 26.67\text{mA}$$

$$I_z = I_1 - I_B = 26.57\text{mA}$$

57.
Sol:



$V_p = 10$volt

$$I_1 = \frac{10}{5k} = 2\text{mA}$$

$\Rightarrow V_0 = (6k)\ I_1 = 12V = V_E$

$V_C = 30$volt

$\Rightarrow V_{CE} = V_C - V_E = 18$ volt.

$I_E = I_1 + I_L$

$$I_E = 2m + \frac{12}{100} = 122\text{mA}$$

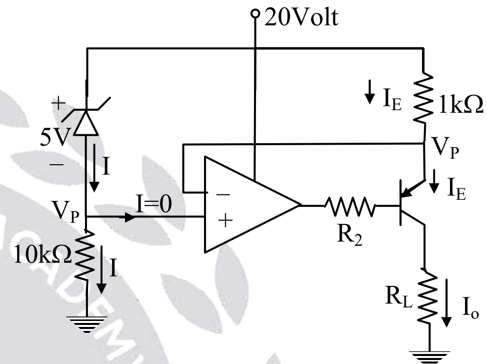
$$\Rightarrow I_C = \frac{\beta}{1+\beta} I_E$$

$\Rightarrow I_C = 0.120$Amp

$\Rightarrow P_T = I_C \times V_{CE}$

$\therefore\ P_T = 2.17$W

58.
Sol:



$$I = \frac{20-5}{10k} = \frac{15}{10}\text{mA}$$

$V_P = 10k \times I = 15$volt

$$I_C = \frac{20 - V_P}{1k} = \frac{20-15}{1k} = 5\text{mA}$$

β large $\Rightarrow I_B \approx 0A$

$\therefore\ I_C = I_0 = 5$mA

59. Ans: (a, b & d)

Sol: Step-1: KCL at node (A)

$I_S = I_Z + I_L$………(1)

$\Rightarrow I_Z = I_S - I_L$ …..(2)

$\Rightarrow\ I_{Z_{min}} = I_S - I_{L_{max}}$ ……..(3)

$\because$ Zener diode is ideal, $I_{Z_{min}} = 0$ ……..(4)

$\therefore\ I_S = I_{L_{max}} = 200\text{mA}$ …….(5)

Step-2: KVL for input loop

$$R_S = \frac{16V - 12V}{200\text{mA}} = 20\Omega \text{ …….(6)}$$

Step-3: From equation (2),

$$I_{Z_{max}} = I_S - I_{L_{min}} = 200\text{mA} \ldots\ldots..(7)$$

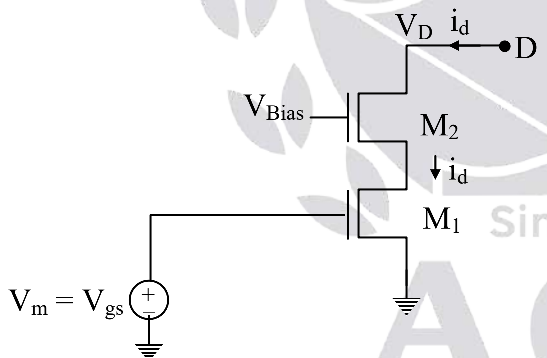
$$\Rightarrow P_{Z_{max}} = V_Z\ I_{Z_{max}} = 12 \times 200\text{mA}$$

$$= 2.4 \text{ Watts}$$

$\therefore$ For satisfactory voltage regulation in the circuit, the power rating of zener diode should be more than 2.4 Watts.

60. Ans: (c)

Sol: The circuit given is the MOS cascode amplifier, Transistor M_1 is connected in common source configuration and provides its output to the input terminals (i.e., source) of transistor M_2. Transistor M_2 has a constant dc voltage , V_{bias} applied at its gate. Thus the signal voltage at the gate of M_2 is zero and M_2 is operating as a CG amplifier. Which is current Buffer.



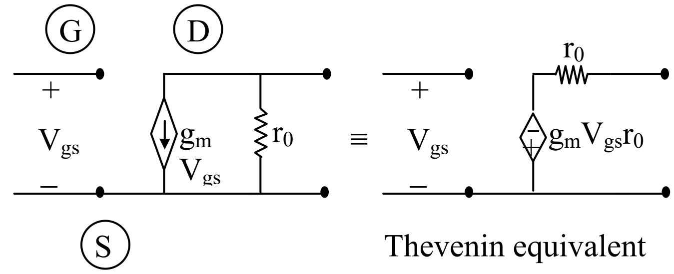
Overall transconductance

$$g_m = \frac{i_d}{V_{gs}} = \left[\frac{\partial i_D}{\partial V_{GS}}\right] = \frac{i_{d_1}}{V_{gs_1}}$$

$$= g_{m_1}$$

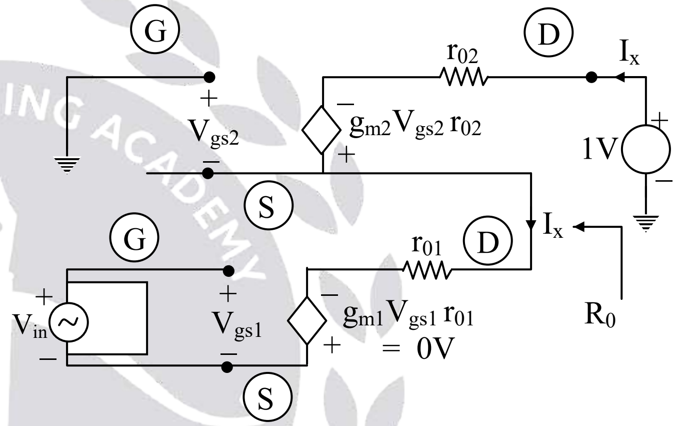
The overall (approximate) transconductance of the cascode amplifier is equal to the transconductance of common source amplifier g_{m_1}

AC model of MOSFET



Thevenin equivalent

Let us find the output resistance $R_0 = \frac{1V}{I_x}$



By KVL $V_{gs2} + I_x r_{01} = 0$

$V_{gs2} = -I_x r_{01}$ ------(1)

By KVL

$-1 + I_x r_{02} - g_m r_{02} V_{gs2} + I_x r_{01} = 0$

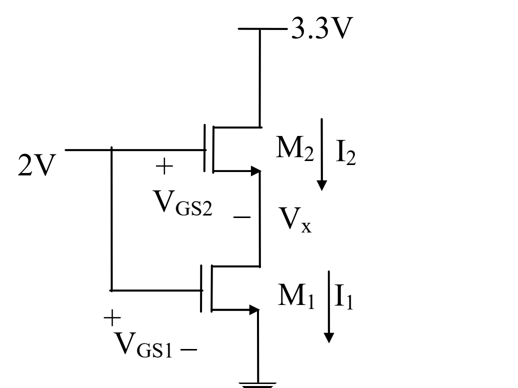
$-1 + I_x r_{02} + g_{m2} r_{02}\, I_x r_{01} + I_x\, r_{01} = 0$

$$\therefore I_x = \frac{1}{r_{01} + r_{02} + g_{m2} r_{02} r_{01}} \approx \frac{1}{g_{m2} r_{01} r_{02}}$$

$$R_0 = \frac{1}{I_x} = g_{m2} r_{01} r_{02}$$

61.

Sol:



$$\left(\frac{W}{L}\right)_2 = 2\left(\frac{W}{L}\right)_1$$

V_{TH} = 1V for both M_1 and M_2

For M_2 to be in saturation:

$V_D > V_G - V_{TH}$

3.3 > 2–1

3.3 > 1

So M_2 will be in saturation if it is ON.

For M_1 to be in saturation:

$V_D > V_G - V_{TH}$

$V_X > 2-1$

V_X >1V but if V_X is more than 1V, V_{GS2} becomes less than 1V, Which means M_2 will be off so M_1 can not be in saturation.

Now, We can conclude that M_1 is in triode and M_2 is in saturation

V_{GS1}=2V

V_{DS1}= V_X

$V_{GS2} = 2 - V_X$

Now, $I_1 = I_2$

$$\mu_n C_{ox}\left(\frac{W}{L}\right)_1\left[(V_{GS1} - V_{TH})V_{DS1} - \frac{1}{2}V_{DS1}^2\right]$$

$$= \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TH})^2$$

$$V_x - \frac{1}{2}V_x^2 = (1 - V_x)^2$$

$$3V_x^2 - 6V_x + 2 = 0$$

V_x = 0.42V, – 1.58V

V_x cannot be more than 1V, since M_2 will become off

So, V_x = 0.42 V

62. Ans: (a, b, d)

Sol: The given device is

- N-channel MOSFET with V_T = 2.5V
- Current due to only $\bar{e}$s and E-MOSFET does not have physical channel.

63. Ans: (a & c)