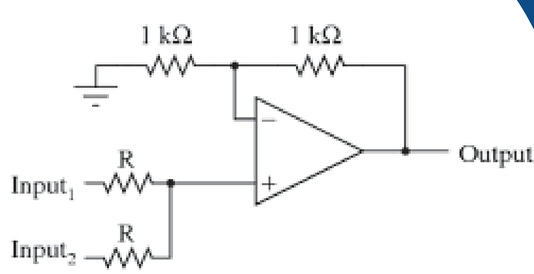
ESE | GATE | PSUs

ELECTRONICS & TELECOMMUNICATION ENGINEERING

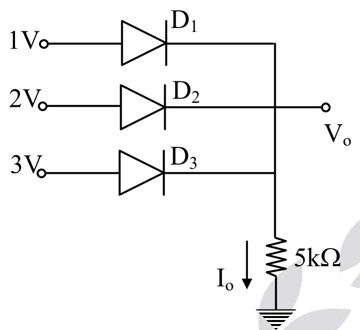
ANALOG CIRCUITS

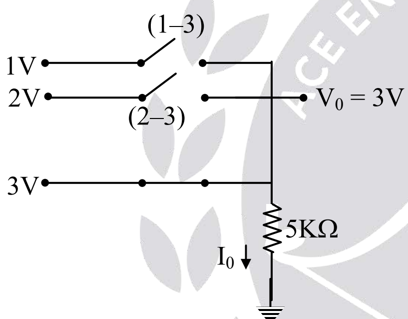
Volume - 1 : Study Material with Classroom Practice Questions



Chapter 1 Diode Circuits
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (d)
Sol:



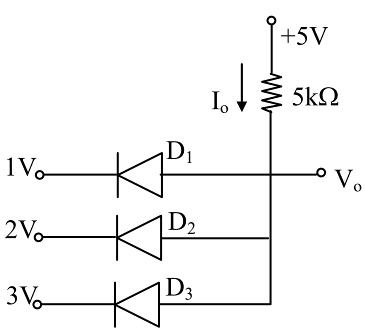


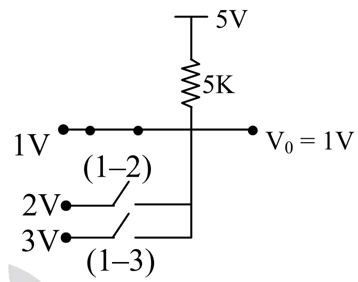
⇒ D_1,D_2 are reverse biased and D_3 is forward biased.

i.e., D_3 only conducts.

∴ $I_0 = 3/5K = 0.6mA$

02. Ans: (b)
Sol:





⇒ D_2 & D_3 are reverse biased and 'D_1' is forward biased.

i.e., D_1 only conduct

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

03. Ans: (d)

Sol: Let diodes D_1 & D_2 are forward biased.

⇒ $V_0 = 0$ volt

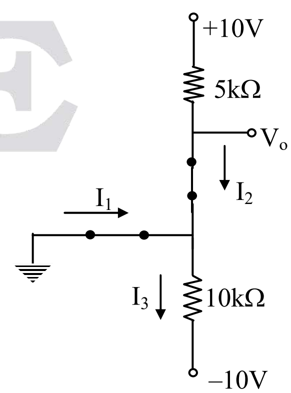
$I_2 = \dfrac{10-0}{5K} = 2mA$

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

Apply KVL at nodes 'V_0':

$-I_1 + I_3 - I_2 = 0$

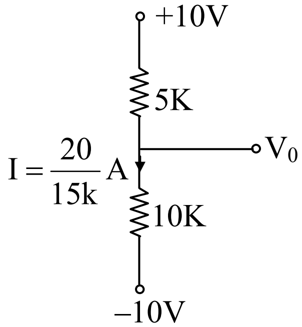
$\Rightarrow I_1 = -(I_2 - I_3) = -1mA$



So, D_1 is reverse biased & D_2 is forward biased

⇒ 'D_1' act as an open circuit & D_2 is act as short circuit.

Then circuit becomes

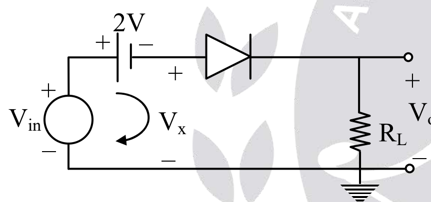


$$\Rightarrow V_0 = 10k \times \left(\frac{20}{15k}\right) - 10$$

$\therefore$ $V_0 = 3.33V$

04. Ans: (c)

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 $V_x > 0V$

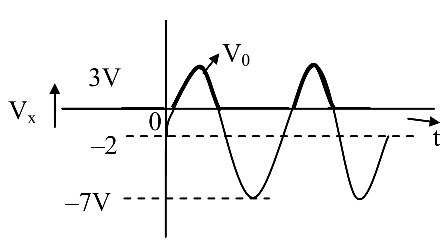
$\Rightarrow V_0 = V_x$

Diode OFF for $V_x < 0V$

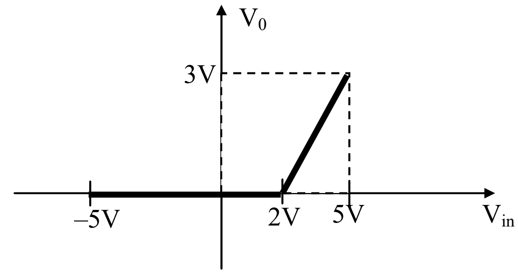
$\Rightarrow V_0 = 0$ V

$\therefore V_0$ range = 0 to 3V

Output wave form:

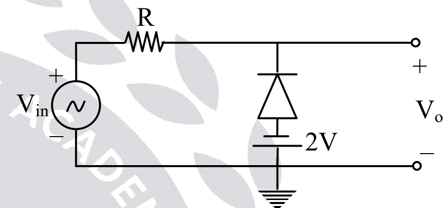


Transfer characteristics:



05. Ans: (b)

Sol:

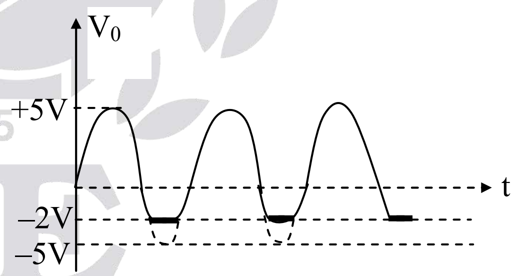


For $V_i < -2$Volt, Diode ON

$\Rightarrow V_0 = -2$Volt

For $V_i > -2$Volt, Diode OFF

$\Rightarrow V_0 = V_i$



06. Ans: (c)

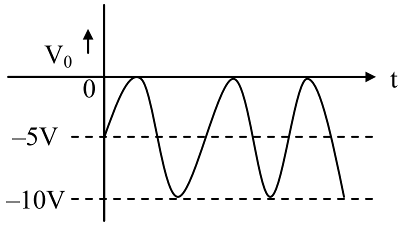
Sol: For positive half cycle diode Forward biased and Capacitor start charging towards peak value.

$\Rightarrow V_C = V_m = 5V$

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

V_{in} range = – 5V to +5V

$\therefore$ V_0 range = – 10V to 0V



07. Ans: (d)

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

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

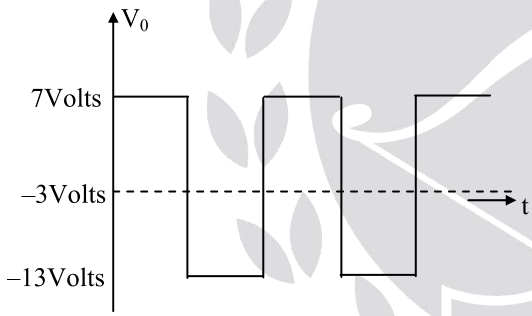
Now diode OFF for rest of cycle

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

$= V_{in} - 3$

V_{in} range : –10V to +10V

$\therefore$ V_0 range: –13V to 7V



08. Ans: (a)

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

$\Rightarrow V_C = V_P + 9$

$= 12 + 9$

$= 21V$

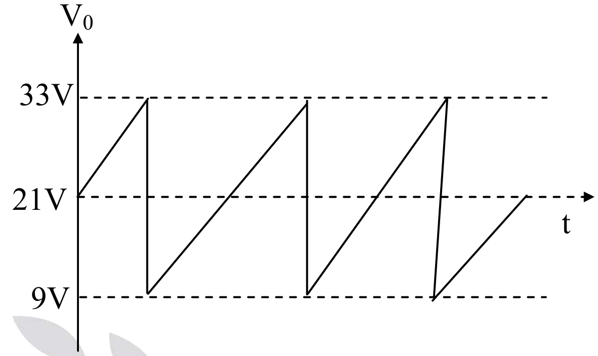
Now diode OFF for rest of cycle.

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

$= 21 + V_{in}$

V_{in} range: –12 to +12V

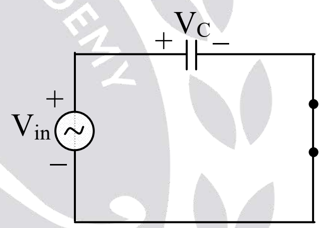
V_0 range: 9V to 33V



09. Ans: (b)

Sol: During positive cycle,

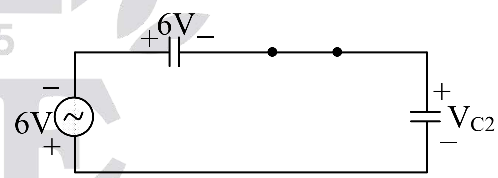
D_1 forward biased & D_2 Reverse biased.



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

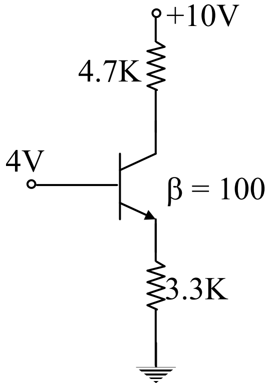
Chapter **2**

Bipolar Amplifiers

(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (c)

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

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

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

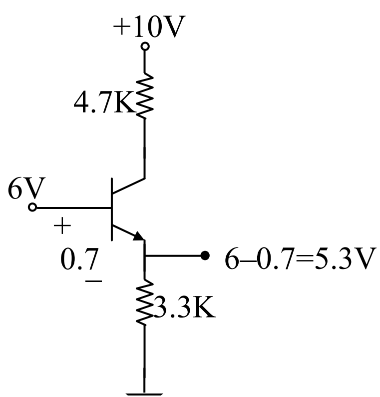
$V_C = 10 - 4.7\times10^3\times0.99\times10^{-3} = 5.347V$

$\Rightarrow V_C > V_B$

$\therefore$ Transistor in the active region.

02. Ans: (b)

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

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

$I_C = 1.59mA$

$V_C = 2.55V$

$\Rightarrow V_C < V_B$

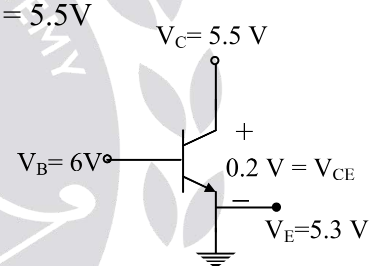
$\therefore$ Transistor in saturation region

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

$V_C - V_E = 0.2$

$V_C = 5.3+0.2$

$\Rightarrow V_C = 5.5V$



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

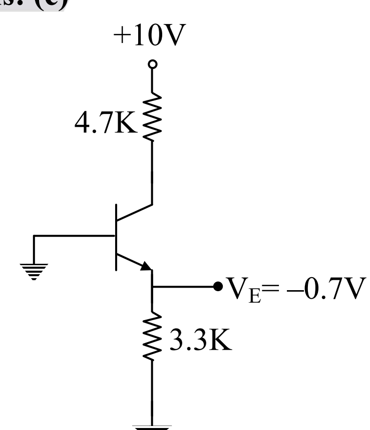
$I_B = 1.6 - 0.957 = 0.643mA$

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

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

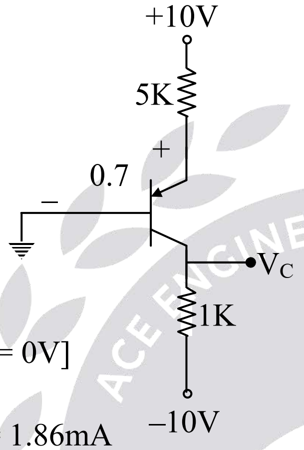
03. Ans: (c)

Sol:



$V_E = -0.7V$
Transistor in cut off region
$I_C = I_B = I_E = 0A$
$V_{CE} = 10V$
$V_E = 0V$
$V_C = 10V$
$V_B = 0V$

04. Ans: (c)
Sol:



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

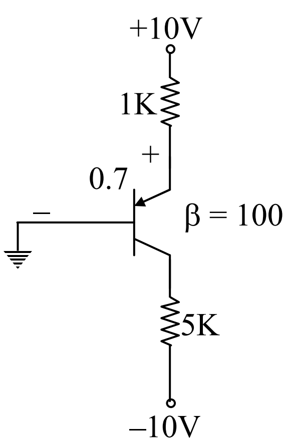
$\Rightarrow I_E = \dfrac{10-0.7}{5K} = 1.86mA$

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

05. Ans: (d)
Sol:



Let transistor in active region

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

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

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

$\Rightarrow V_C = -10 + 5K \times 9.2m$
$V_C = 36V$
$V_{EC} < V_{EB}$

Transistor in saturation region
$\Rightarrow V_{EC} = 0.2$
$V_E - V_C = 0.2 \Rightarrow V_C = 0.5V$

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

$I_B = I_E - I_C = 7.2mA$

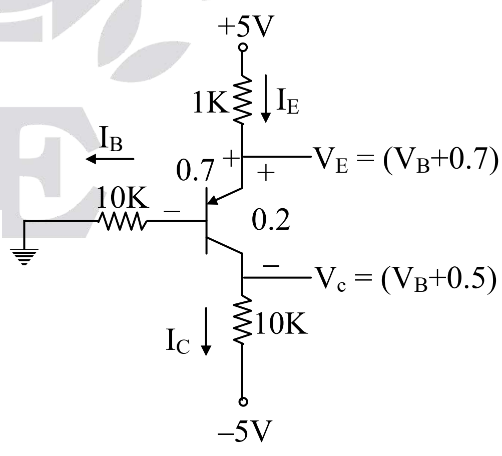
$\beta_{forced} = \dfrac{I_{c(sat)}}{I_B}$

$= \dfrac{2.1}{7.2}$

$= 0.29$

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

06. Ans: (c)
Sol:



$I_E = I_C + I_B$

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

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

$43 - 10V_B = 2V_B + 5.5$

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

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

$V_C = V_B + 0.5 = 3.625V$

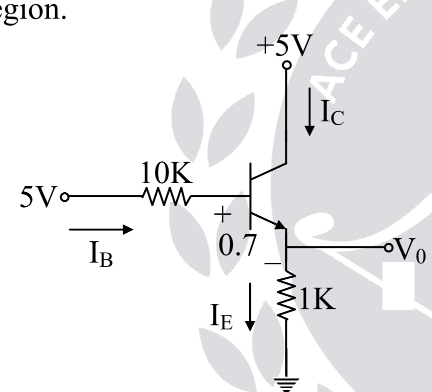
$V_E = 3.825V$

$\therefore\ I_E = 1.175mA$

$\therefore\ I_C = 0.862mA$

07. Ans: (b)

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



Apply KVL to the base emitter loop:

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

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

$= 38.73\mu A$

$I_C = 3.87mA$

$I_E = 3.91mA$

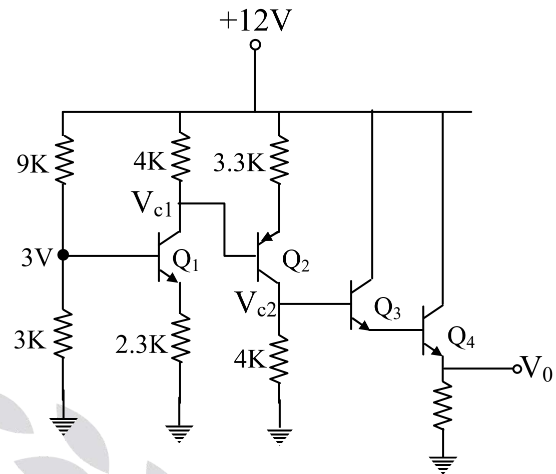
$\Rightarrow V_E = V_0 = I_E(1k) = 3.91\ V$

$V_C = 5V$

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

08. Ans: (a)

Sol:



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

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

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

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

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

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

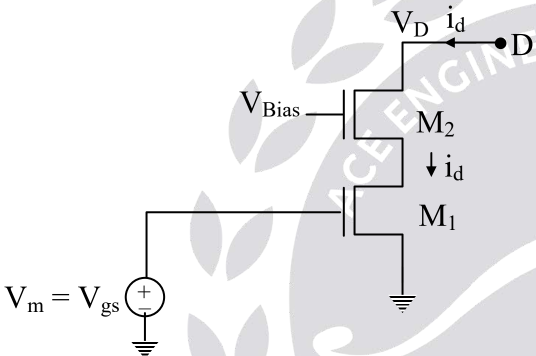
$V_{\varepsilon_4} = 3.3 - 0.7 = 2.6V$

$V_0 = 2.6\ V$

Chapter 3 MOSFET Amplifiers
(Solutions for Vol-1_Classroom Practice Questions)

01. 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.



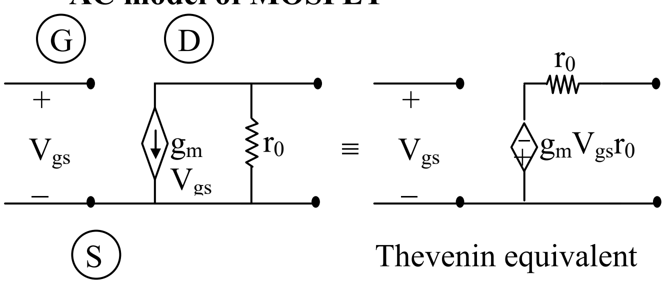
Overall transconductance

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

$$= g_{m_1}$$

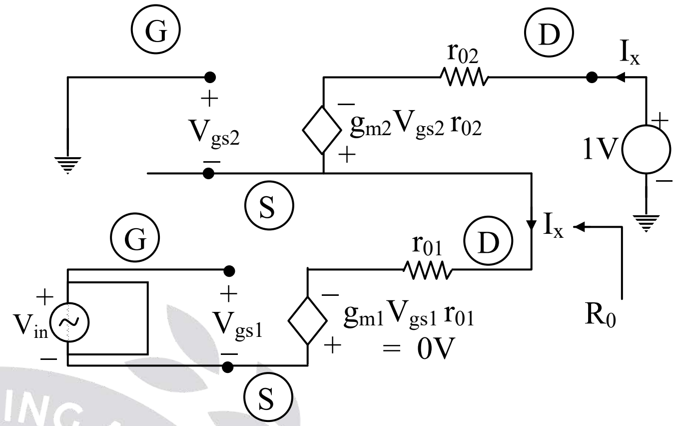
The overall (approximate) transconductance of the cascode amplifier is equal to the transconductance of common source amplifier g_{m_1}

AC model of MOSFET



Thevenin equivalent

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



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

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

By KVL

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

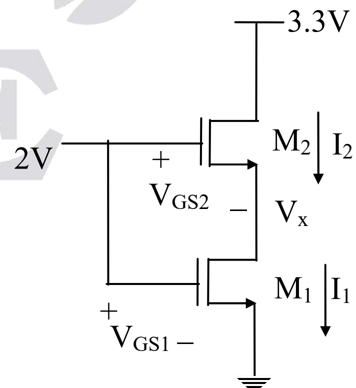
$-1 + I_x r_{02} + g_{m2} r_{02} I_x r_{01} + I_x r_{01} = 0$

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

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

02. Ans: (d)

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, $I_1 = I_2$

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

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

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

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

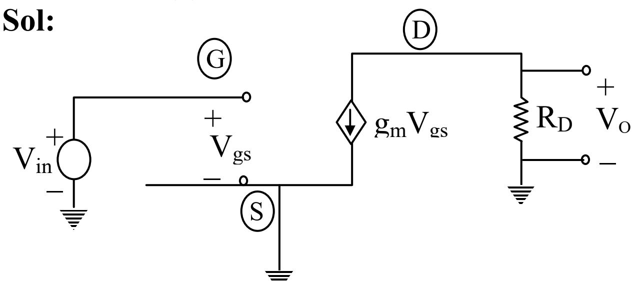
$V_x = 0.42V, \; -1.58V$

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

So, $V_x = 0.42$ V

03. Ans: (a)

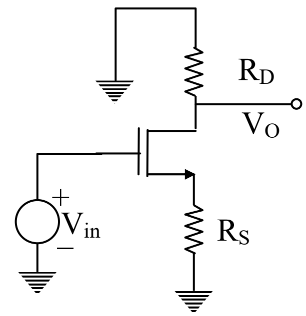
Sol:



$$\left.\begin{aligned} V_o &= -g_m V_{gs} R_D \\ V_{in} &= V_{gs} \end{aligned}\right\} \quad \frac{V_o}{V_{in}} = -g_m R_D$$

04. Ans: (b)

Sol:

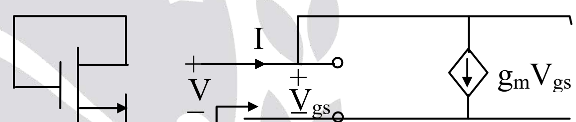


$$\frac{V_o}{V_{in}} = \frac{-\text{Drain resistance}}{\text{Source resistance}}$$

$$= \frac{-R_D}{R_S}$$

05. Ans: (c)

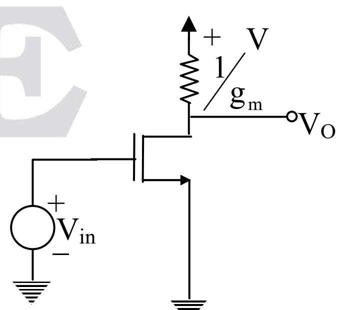
Sol:



$$R_{in} = \frac{V}{I} = 1/g_m$$

$I = g_m V_{gs}$

$V = V_{gs}$



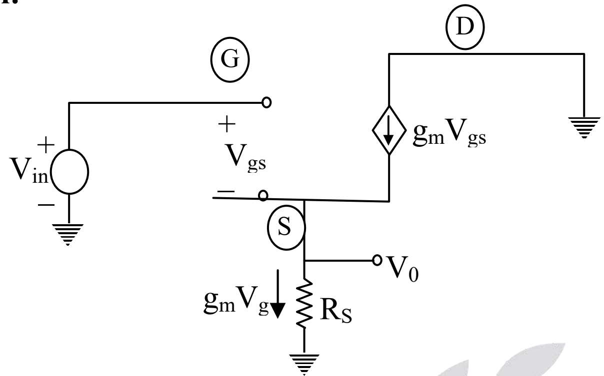
$$\frac{V_o}{V_{in}} = -g_m R_D$$

$= -g_m(1/g_m)$

$= -1$

06. Ans: (b)

Sol:



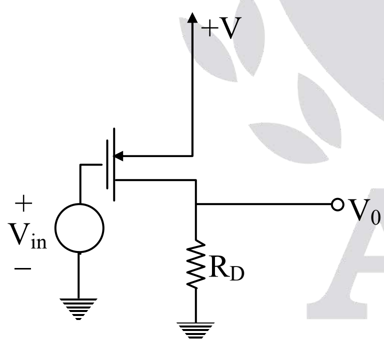
$V_o = g_m V_{gs} R_s$

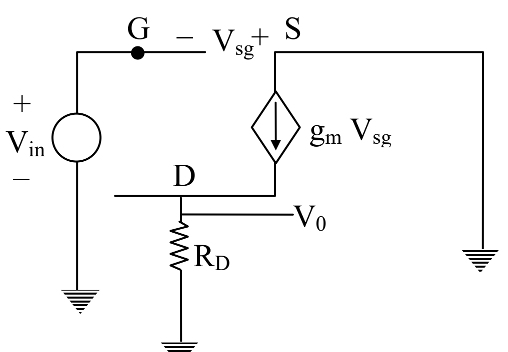
$V_{in} = V_{gs} + g_m V_{gs} R_s$

$$\boxed{\frac{V_o}{V_{in}} = \frac{g_m R_S}{1 + g_m R_S} = \frac{R_S}{R_S + \frac{1}{g_m}}}$$

07. Ans: (c)

Sol: In volume-I book, the diagram is wrong. The correct circuit diagram is





Common source

$V_{sg} = -V_{in}$

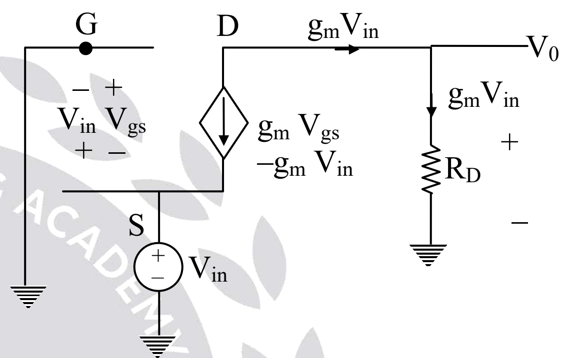
$V_0 = g_m V_{sg} R_D$

$= g_m(-V_{in})R_D$

$$\frac{V_0}{V_{in}} = -g_m R_D$$

08. Ans: (a)

Sol:



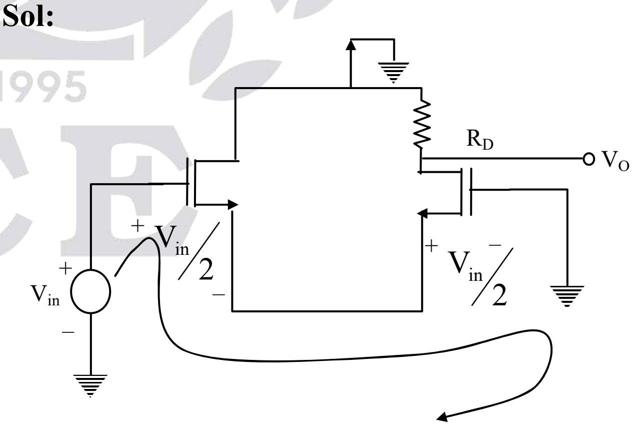
$V_{gs} = -V_{in}$

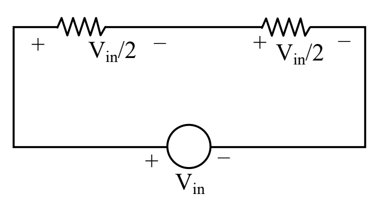
$V_0 = g_m V_{in} \times R_D$

$$\frac{V_0}{V_{in}} = g_m R_D$$

09. Ans: (d)

Sol:





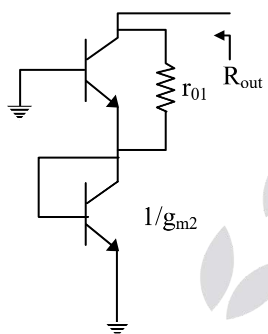
$V_o = -I_D R_D$

$V_{GS} = \frac{V_{in}}{2} \rightarrow V_{in} = 2V_{gs}$

$$\frac{V_o}{V_{in}} = \frac{I_D R_D}{2V_{GS}} = \frac{R_D}{2\left(\frac{1}{g_m}\right)} = \frac{g_m R_D}{2}$$

10. Ans: (c)

Sol:



$$R_{out} = r_{01} + (1+g_{m1}\, r_{01})\ \frac{1}{g_{m2}}$$

$$= r_{01} + \frac{1}{g_{m2}} + r_{01}$$

$$= 2\, r_{01}$$

Chapter 4 Cascode Amplifiers, Current Mirrors & Differential Amplifiers

(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (d)

Sol: For the given differential amplifier,

$I_E = 1mA$

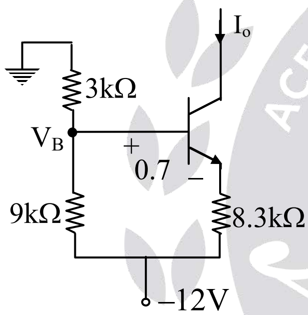
$$r_e = \frac{V_T}{I_E} = 25\Omega$$

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

$A_d = -120$

02. Ans: (a)

Sol:



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

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

$V_B = -3V$

$V_B - V_E = 0.7$

$V_E = V_B - 0.7$

$V_E = -3.7$ Volt

$$I_0 = \frac{-3.7+12}{8.3k} = 1mA$$

$I_E = 0.5mA$

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

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

$A_d = -40$

03. Ans: (a)

Sol: Since,

$$V_B = V_{BE_1} + I_1R_1 = V_{BE_2} + I_2R_2$$

Since in current mirror,

Transistor default must be perfectly matched

$\therefore\ I_{B_1} = I_{B_2}$

$\&\ I_{BE_1} = V_{BE_2}$

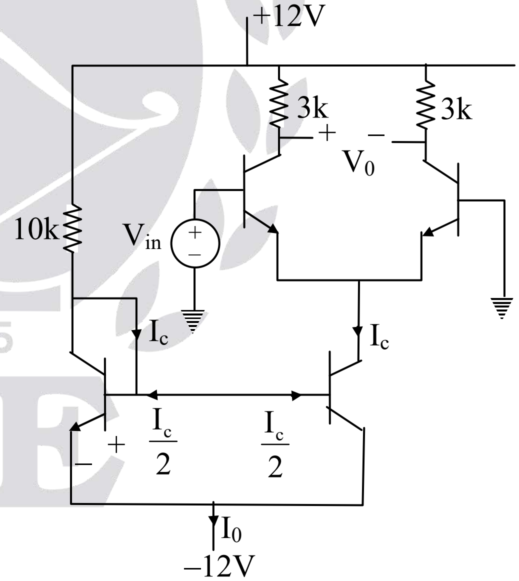
$\therefore\ I_1R_1 = I_2R_2$

$\therefore I_{ref}\ R_1 = I_{copy}\ R_2$

$$\therefore I_{copy} = I_{ref}\frac{R_1}{R_2}$$

04. Ans: (c)

Sol:



$$\frac{V_0}{V_i} = -g_m RC$$

$= -\ g_m\ (3k)$

$$g_m = \frac{I_c}{V_T}$$

$$I_0 = \frac{12-0.7+12}{10k} = \frac{23.3}{10k} = 2.33mA$$

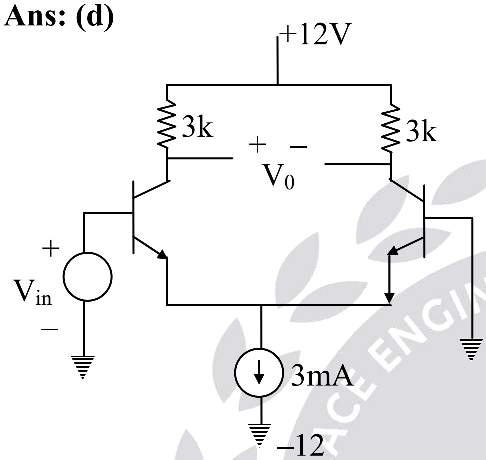
$$I_{c(Dc)} = \frac{I_0}{2} = \frac{2.33}{2}\text{mA} = 1.16\text{mA}$$

$$Ad = -\frac{1.16\mu A}{25\mu V} \times (3A) = -\frac{1.16}{25} \times 3(k)$$

$$= -139.5$$

05. Ans: (d)

Sol:



$$I_{c(DC)} = \frac{3mA}{2} = 1.5mA$$

$$g_m = \frac{I_{c(DC)}}{V_T} = \frac{1.5}{25}$$

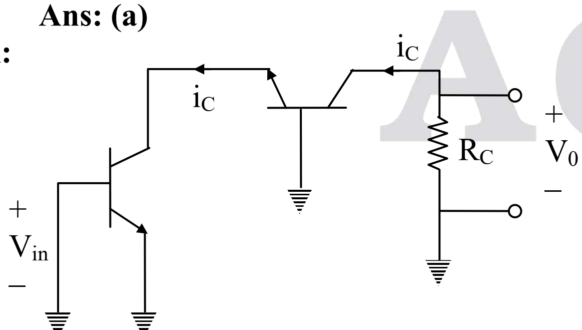
$$Ad = -g_m R_c$$

$$= -\frac{1.5}{25} \times 3k$$

$$= -180$$

06. Ans: (a)

Sol:



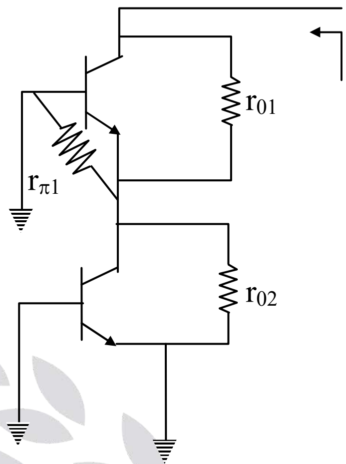
$$V_0 = i_c R_C$$

$$g_m = \frac{i_C}{V_{be}} = \frac{i_C}{V_{in}}$$

$$\frac{V_0}{V_{in}} = \frac{-I_c R_c}{V_{in}} = -g_m R_c$$

07. Ans: (b)

Sol:



$$R_{out} = r_{01} + (+g_{m1} r_{01})(r_{02} // r_{\pi 2})$$

$$= r_{01} + r_{\pi 2} + g_{m1}\, r_{01}\, r_{\pi 2}$$

$$= r_{01} + \beta\, r_{01}$$

$$= (\beta + 1)\, r_{01}$$

$$\approx \beta r_{01}$$

08. Ans: (a)

Sol: $Q_1 \rightarrow 1(V_{01} \text{ gain})$

$$Q_2 \rightarrow \frac{-R_c}{re_2} = -g_{m2} R_c$$

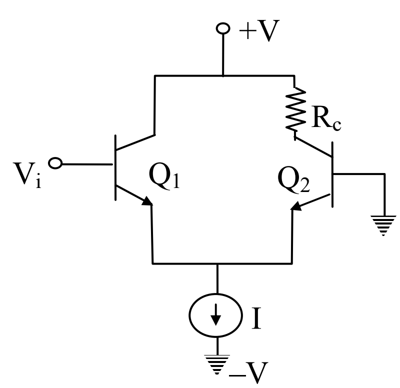
$$\therefore A_{V_T} = 1 \times (-g_{m_2} R_c) = -g_{m_2} R_c$$

$$\therefore A_{V_T} = -g_{m_2} R_c$$

09. Ans: (d)

Sol: $Q_1 \rightarrow$ Act as CC [Ac circuit $\rightarrow I \rightarrow$ open]

$Q_1 \rightarrow$ Act as CB



Since for CC $\rightarrow$V01.gain = 1

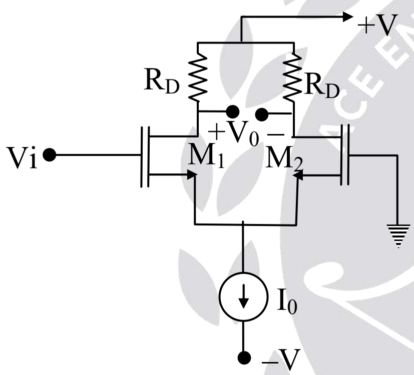
For CB $\rightarrow$ V01.gain$=\frac{R_c}{r_e}$

$$\therefore Av = 1\frac{R_c}{r_e} = \frac{R_c}{\frac{V_T}{\frac{I_E}{2}}} = \frac{R_c}{2y_e} = \frac{g_m R_c}{2}$$

$$\therefore Av = \frac{g_m R_c}{2}$$

10. Ans: (b)

Sol:



For $M_1 \rightarrow V_{01}$.gain$= -g_{m_1}\frac{R_0}{2} \Rightarrow g_{m_1}\frac{R_0}{2}V_i$

For M_1–M_2 $\rightarrow V_{01}$.gain$= +1\times+\frac{g_m R_0}{2}$

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

$$\Rightarrow V_{D_2} = \frac{g_m R_D}{2}V_i$$

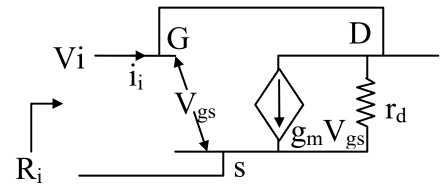
$$\therefore V_0 = V_{D_1} - V_{D_2} = \left[-g_{m_1}\frac{R_D}{2} - g_{m_2}\frac{R_D}{2}\right]V_i$$

$$\Rightarrow \frac{V_0}{V_i} = -g_m R_D$$

$\therefore V_{01}$.gain = – $g_m R_D$

11. Ans: (d)

Sol:



$$R_i = \frac{V_i}{i_i}, \text{ where } i_i = g_m V_{gs} + \frac{V_i}{r_d}$$

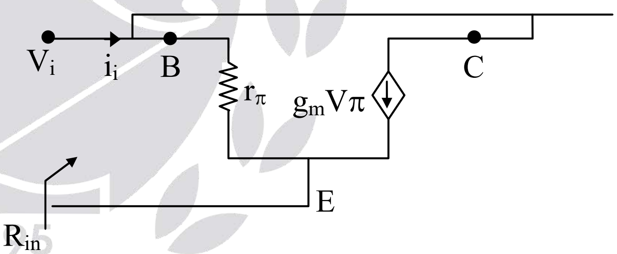
$$i_i = g_m V_i + \frac{V_i}{r_d}$$

$$\therefore R_i = \frac{V_i}{i_i} = \frac{1}{\frac{g_m r_d + 1}{r_d}} = \frac{r_d}{g_m r_d + 1} = \frac{1}{g_m}$$

$$\therefore R_i \frac{r_d}{g_m r_d + 1} = \frac{1}{g_m}$$

12. Ans: (b)

Sol:



$$R_{in} = \frac{V_i}{i_i}$$

Where,

$$i_i = g_m V_\pi + \frac{V_\pi}{r_\pi}$$

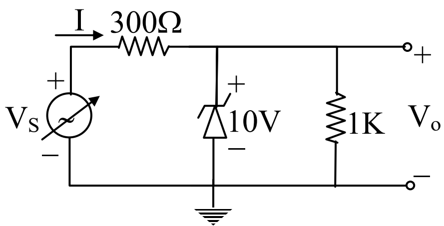
$$\therefore R_{in} = \frac{V_i}{i_i} = \frac{V_i}{V_i\left[g_m + \frac{1}{r\pi}\right]}$$

$$\therefore R_{in} = \frac{1}{g_m + \frac{1}{r_\pi}}$$

$$\therefore R_{in} = r_\pi // \frac{1}{g_m}$$

Chapter 5 Operational Amplifiers
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (d)
Sol:



I_z = 1mA to 60mA

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

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

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

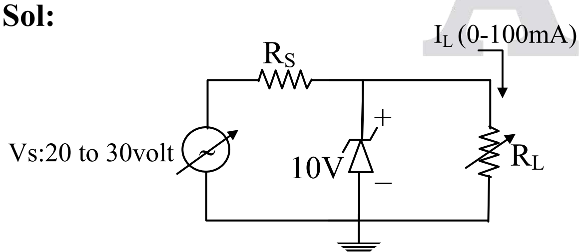
$$I_{min} = I_{zmin} + I_L \left[\because I_L + \frac{V_z}{1k} = 10mA\right]$$

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.

02. Ans: (a)
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 = 90.9Ω

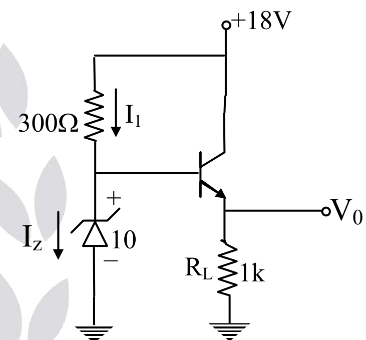
$$I_{z\,max} = \frac{30 - 10}{90.9} = 0.22A\left[\because I_{L\,min} = 0A\right]$$

$P_z = V_z\, I_{zmax}$

$P_z = 10 \times 0.22$

P_z = 2.2W

03. Ans: (d)
Sol:



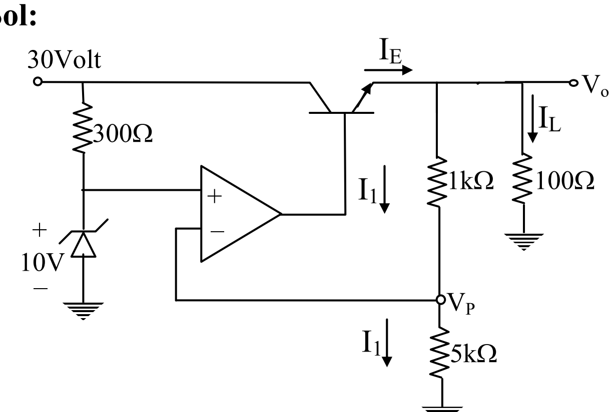
V_B = 10volt
V_E = 10 – 0.7 = 9.3volt
I_E = 9.3mA

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

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

$$I_z = I_1 - I_B = 26.57mA$$

04. Ans: (b)
Sol:



$V_p = 10\text{volt}$

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

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

$V_C = 30\text{volt}$

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

$I_E = I_1 + I_L$

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

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

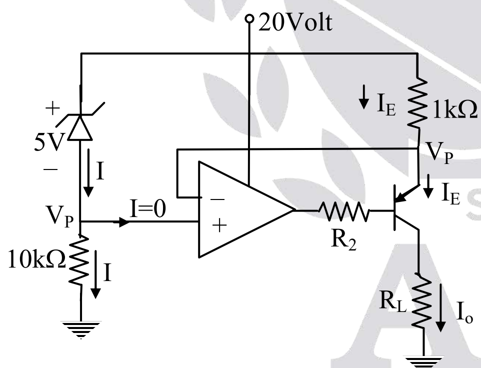
$\Rightarrow I_C = 0.120\text{Amp}$

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

$\therefore P_T = 2.17W$

05. Ans: (c)

Sol:



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

$V_P = 10k \times I = 15\text{volt}$

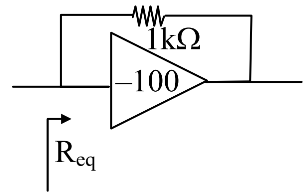
$$I_C = \frac{20 - V_P}{1k} = \frac{20-15}{1k} = 5mA$$

β large $\Rightarrow I_B \approx 0A$

$\therefore I_C = I_0 = 5mA$

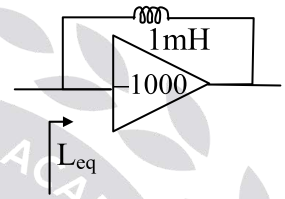
06. Ans: (b)

Sol:



using millers effect,

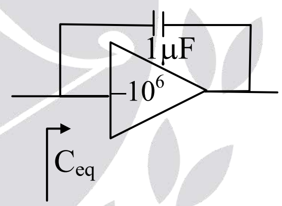
$$R_{eq} = \frac{1k}{1+100} = 9.9\Omega$$



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

07. Ans: (b)

Sol:



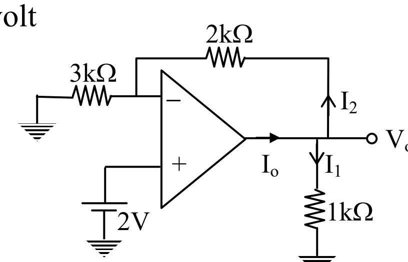
$$C_{eq} = 1\mu F\left(1+10^6\right) \approx 1F$$

08. Ans: (d)

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

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

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



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

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

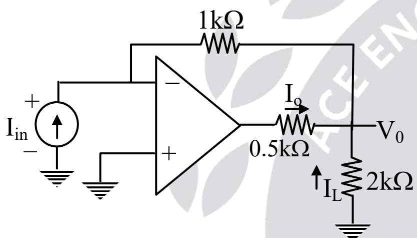
$$\therefore I_0 = I_1 + I_2 = 4\text{mA}$$

09. Ans: (c)

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

10. Ans: (c)

Sol:



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

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

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

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

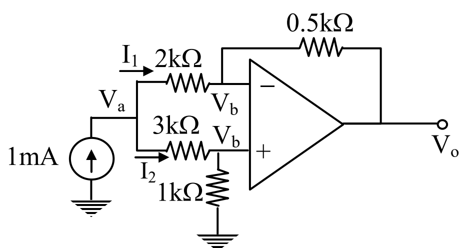
$2I_0 + 2I_{in} + I_{in} = 0$

$2I_0 = -3I_{in}$

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

11. Ans: (a)

Sol:



Apply KCL at V_a:

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

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

$6 = 5V_a - 5V_b$

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

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

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

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

$V_b = 0.4m \times 1k = 0.4$ Volt

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

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

$0.3 = 0.4 - V_0$

$\therefore V_0 = 0.1$ Volt

12. Ans: (c)

Sol: $V_C = \frac{-I}{C}.t = \frac{-10\times10^{-3}}{10^{-6}} \times 0.5\times10^{-3}$

$V_C = -5\text{Volt}$

13. Ans: (d)

Sol: Given open loop gain = 10

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

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

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

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

14. Ans: (c)

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

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

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

$$V_0 = -4.5\text{Volt}$$

15. Ans: (c)

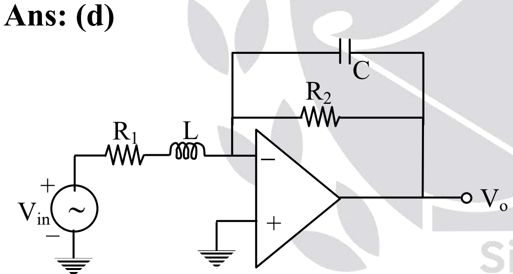
Sol: $SR = 2\pi f_{max} V_{0max}$

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

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

16. Ans: (d)

Sol:



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

$$z_1 = R_1 + sL$$

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

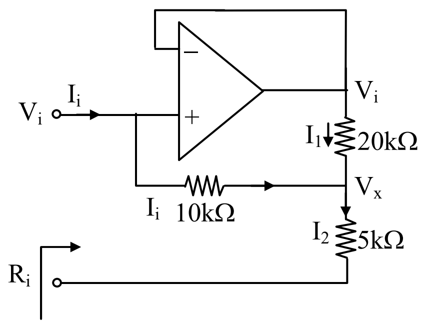
$$\left|\frac{V_0}{V_i}\right| = \frac{R_2}{(sCR_2+1)(R_1+sL)}$$

It represent low pass filter with

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

17. Ans: (b)

Sol:



Apply KCL at V_x :

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

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

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

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

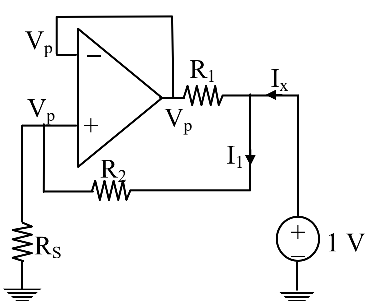
$$I_i = \frac{V_i - V_x}{10k}$$

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

$$\frac{V_i}{I_i} = 17.5\text{k}\Omega$$

18. Ans: (d)

Sol:



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

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

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

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

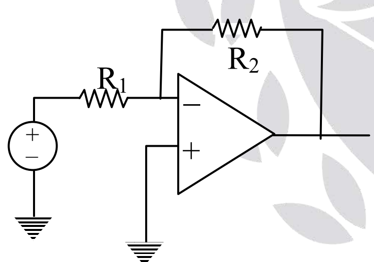
$$I_x = \left(1-\frac{R_s}{R_2+R_s}\right)\left(\frac{R_1+R_2}{R_1R_2}\right)$$

$$I_x = \frac{R_2}{R_2+R_s}\left(\frac{R_1+R_2}{R_1R_2}\right)$$

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

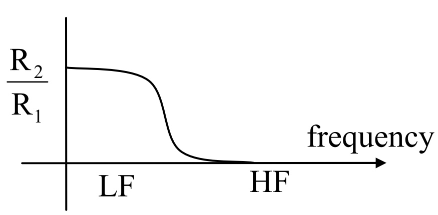
19. Ans: (b)

Sol: At Low frequency capacitor is open



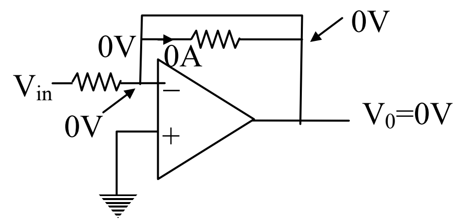
$$V_0 = -\frac{R_2}{R_1}\times V_{in}$$

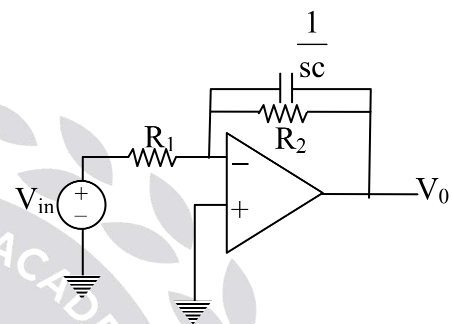
$$\left|\frac{V_0}{V_{in}}\right| = \frac{R_2}{R_1}$$



Low pass filter

At high frequency capacitor is short





$$\frac{R_2\times\frac{1}{sc}}{R_2+\frac{1}{sc}} = \frac{R_2}{1+scR_2} = Z_2 \;\ldots\ldots(1)$$

$$V_0 = -\frac{Z_2}{Z_1}\times V_{in} \;\ldots\ldots(2)$$

$$V_0 = -\frac{\frac{R_2}{1+sCR_2}}{R_1}\times V_{in} \;\ldots\ldots(3)$$

$$\left|\frac{V_0}{V_{in}}\right| = \frac{R_2}{R_1}\times\frac{1}{1+sCR_2} \;\ldots..(4)$$

$$\left|\frac{V_0}{V_{in}}\right| = \frac{\frac{R_2}{R_1}}{\sqrt{1+\omega^2C^2R_2^2}} = \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1+1}} \;\ldots..(5)$$

$$\omega CR_2 = 1$$

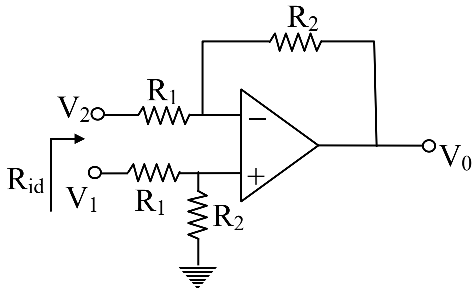
$$\omega = \frac{1}{CR_2}$$

$$\left|\frac{V_0}{V_{in}}\right| = \frac{1}{1+\frac{s}{\omega_{3dB}}}$$

$$\omega_{3dB} = \frac{1}{R_2C}$$

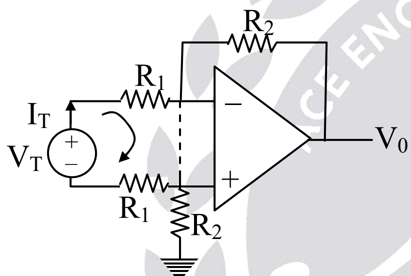
20. Ans: (c)

Sol:



To find input resistance R_{id} (differential input resistance) look from input port.

Connect a voltage source V_T &indicate current I_T from positive terminal of V_T as shown



Op amp in negative feedback virtual short valid

Writing KVL $\Rightarrow V_T = I_T R_1 + I_T R_1$

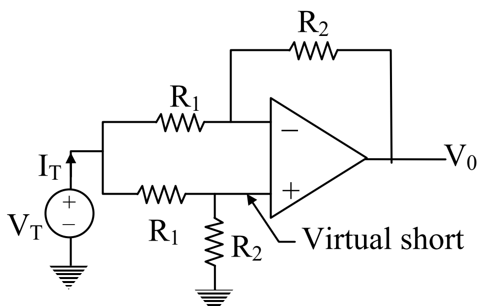
in loop $\qquad = 2I_T R_1$

$$\frac{V_T}{I_T} = 2R_1$$

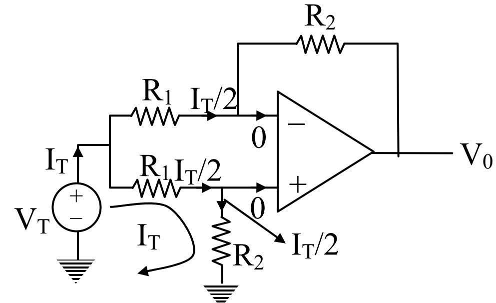
$R_{id} = 2R_1$

21. Ans: (d)

Sol: To find common input resistance (R_{cm}) connect a know voltage source V_T as shown.



Due to virtual short Two R_1 resistors are looking as in parallel



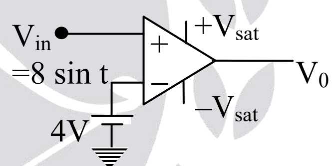
Writing KVL; $V_T = \frac{I_T}{2} \times R_1 + \frac{I_T}{2} \times R_2$

$$= \frac{I_T}{2}(R_1 + R_2)$$

$$\frac{V_T}{I_T} = \frac{R_1 + R_2}{2}$$

22. Ans: (c)

Sol:



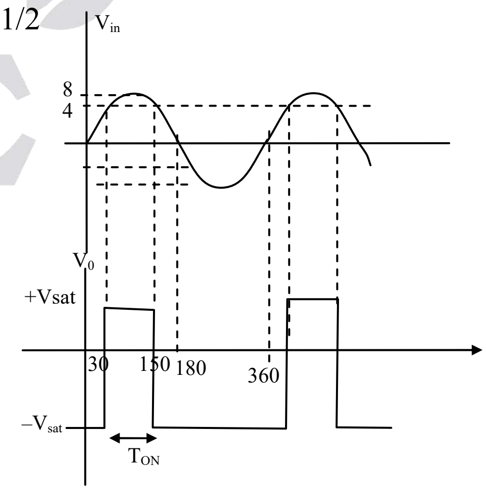
$V_{in} > 4 \Rightarrow V_0 = +V_{sat}$

$V_{in} < 4 \Rightarrow V_0 = -V_{sat}$

$V_{in} = 4 \Rightarrow 4 = 8\, \text{sint}$

sin t =1/2

t = 30

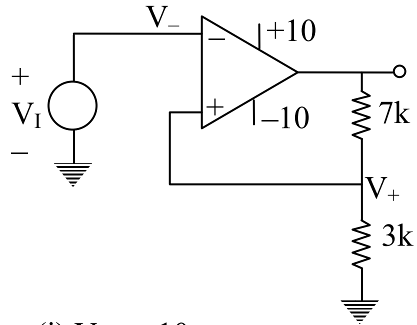


$T_{ON} = 120°$, $T = 360°$

$$\text{Duty cycle } \frac{T_{ON}}{T} = \frac{120}{360} = \frac{1}{3}$$

23. Ans: (c)

Sol:



Case (i) $V_0 = +10$

$V_- = V_I$

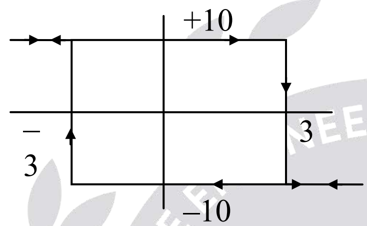
$V_+ = 10 \times \frac{3}{10}$

$= 3$

$V_+ > V_-$

$V_I < 3$

Upper trip point



Case (ii) $V_0 = -10$

$V_- = V_I$

$V_+ = -10 \times \frac{3}{10}$

$= -3$

$V_- > V_+$

$V_I > -3$

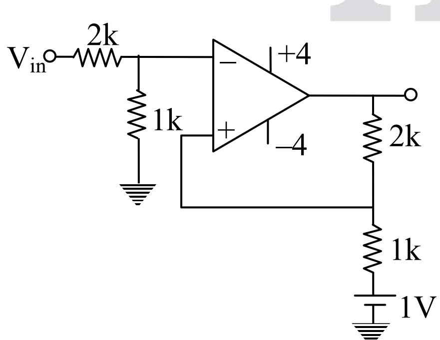
Lower Trip point

Hysterias is width = UTP – LTP

$= 3 - (-3) = 6V$

24. Ans: (d)

Sol:



$V_- = \frac{V_{in} \times 1}{1+2} = \frac{V_{in}}{3}$

Case(i) $V_0 = +4$

$V_- = \frac{V_{in}}{3}$

$V_+ = \frac{4 \times 1}{1+2} + \frac{1 \times 2}{1+2} = \frac{6}{3} = 2$

(super position)

$V_+ > V_-$

$2 > \frac{V_{in}}{3}$

$V_{in} < 6$

Case (ii) $V_0 = -4$

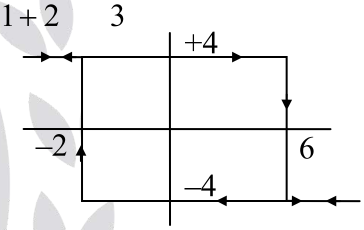
$V_- = \frac{V_{in}}{3}$

$V_+ = \frac{-4 \times 1}{1+2} + \frac{1 \times 2}{1+2} = \frac{-2}{3}$

$V_- > V_+$

$\frac{V_{in}}{3} > \frac{-2}{3}$

$V_{in} > -2$



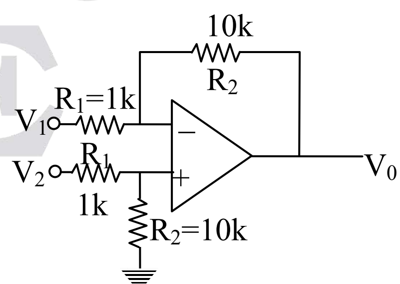
Hysteresis width =UTP–LTP

$= 6 - (-2) = 8V$

25. Ans: (d)

Sol: $V_1 = 10 \sin(2\pi \times 60t) - 0.1 \sin(2\pi \times 1000t)$

$V_2 = 10 \sin(2\pi \times 60t) + 0.1 \sin(2\pi \times 1000t)$



Given circuit is a difference amplifier

$V_0 = \frac{R_2}{R_1}(V_2 - V_1)$

$= 10(V_2 - V_1)$

$= 10 \times [2 \times 0.1 \sin(2\pi \times 1000t]$

$V_0 = 2 \sin(2\pi \times 1000t)$

Chapter **6**

Feedback Amplifiers & Oscillators

(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (b)

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

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

$A\beta = 1$ for sustained oscillations

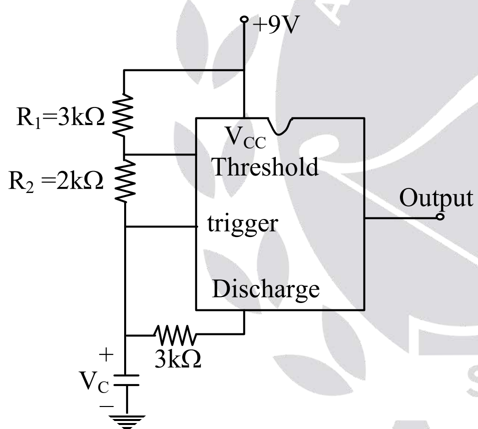
$$\left(1 + \frac{R_2}{R_1}\right).\frac{1}{6} = 1$$

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

$R_2 = 5\ R_1$

02. Ans: (c)

Sol:



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

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

$V_{th} - V_C = 2$ V

$V_C = V_{th} - 2 = 4$ V

$$V_{trigger} = \frac{1}{3}V_{CC} = 3\text{ V}$$

$V_C = 3$ V to 4 V

03. Ans: (b)

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

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

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

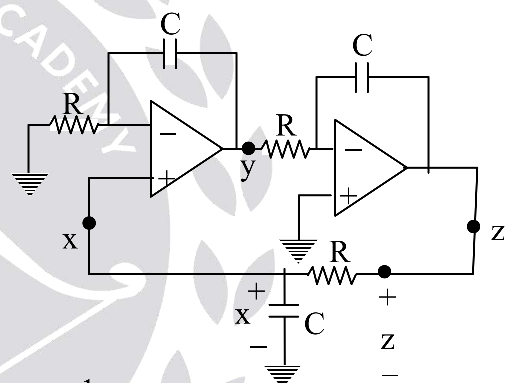
$A\beta = 1$ for sustained oscillations

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

$\therefore\ R_x = 4.5$ kΩ

04. Ans: (a)

Sol:



$$\frac{y}{x} = 1 + \frac{\frac{1}{sC}}{R} = 1 + \frac{1}{sCR} = \frac{sCR+1}{sCR} \quad \text{.......(1)}$$

$$\frac{z}{y} = \frac{-\frac{1}{sC}}{R} = \frac{-1}{sCR} \quad \text{.....(2)}$$

$$\frac{x}{z} = \frac{1}{1+sCR} \quad \text{......(3)}$$

For sustained oscillations

Loop Gain =1 $\Rightarrow \frac{y}{x}\times\frac{z}{y}\times\frac{x}{z} = 1$

$$\frac{sCR+1}{sCR}\times\left(\frac{-1}{sCR}\right)\times\frac{1}{1+sCR} = 1$$

$S^2C^2R^2 = -1$

$j^2\ \omega^2C^2R^2 = -1$

$\omega^2C^2R^2 = 1$

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