CLASS TEST

Sl. 01 SK_EC_ABCD_22062023

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ANALOG ELECTRONICS

ELECTRONICS ENGINEERING

Date of Test : 22/06/2023

ANSWER KEY

1.	(d)	7.	(b)	13.	(c)	19.	(b)	25.	(a)
2.	(b)	8.	(d)	14.	(d)	20.	(a)	26.	(c)
3.	(d)	9.	(a)	15.	(a)	21.	(c)	27.	(c)
4.	(b)	10.	(c)	16.	(b)	22.	(c)	28.	(a)
5.	(c)	11.	(c)	17.	(a)	23.	(b)	29.	(a)
6.	(b)	12.	(b)	18.	(b)	24.	(b)	30.	(a)

DETAILED EXPLANATIONS

1. (d)

When D_2 is ON then the value of V_0 will be

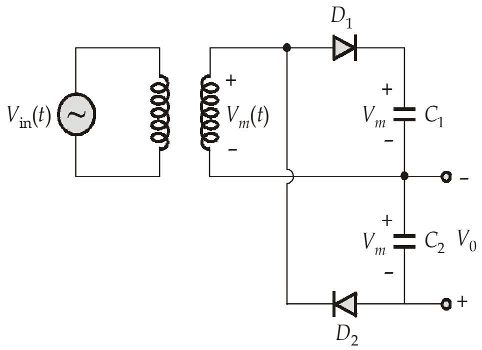
$$V_0 = 3 - 0.7 \text{ V} = 2.3 \text{ V}$$

Hence, D_1 will be OFF.

Thus, The current, $I = \dfrac{2.3-(-3)}{5} \times 10^{-3} = \dfrac{5.3}{5} \times 10^{-3} = 1.06 \text{ mA}$

3. (d)

The circuit can be redrawn as,



The circuit represents a voltage doubler circuit, if the voltage was taken by adding voltages of both the capacitors, but to calculate V_0 we have to find the voltage stored on a single capacitor. Thus, comparing from the above figure,

$$V_0 = -V_m$$

4. (b)

$$V_{GS} - V_t = 2 - 1.5 = 0.5 \text{ V}$$

and $\quad V_{DS} = 1 \text{ V}$

$\therefore \quad V_{DS} > V_{GS} - V_T$

Hence, MOSFET is in saturation region.

5. (c)

For a fixed biased circuit,

$$I_C = \beta I_B + (\beta + 1)I_{co}$$

$\therefore \quad \dfrac{\partial I_c}{\partial I_{co}} = (\beta + 1) \qquad \left[\because I_B = \dfrac{V_{CC} - V_{BE}}{R_B} = \text{constant}\right]$

$\therefore \quad S = \dfrac{\partial I_c}{\partial I_{co}} = 100 + 1 = 101$

6. (b)

The early voltage V_A can be calculated as

$$V_A = r_0 I_C$$

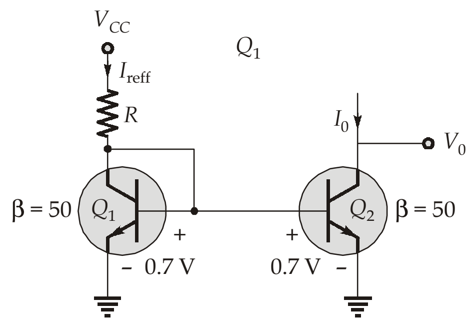
where r_0 = output resistance = $\dfrac{1}{\text{slope of } I_C - V_{CB} \text{ curve}}$

$$r_0 = \frac{1}{3 \times 10^{-5}}$$

thus, $\quad V_A = \dfrac{1}{3\times 10^{-5}} \times 3 \times 10^{-3} = 100 \text{ V} \qquad (\because I_C = 3 \times 10^{-3} \text{ A})$

8. (d)

The circuit can be redrawn as,



For current mirror circuit,

$$I_{reff} = \frac{V_{CC} - V_{BE}}{R} = \frac{10 - 0.7}{37 \times 10^3} = 0.251 \text{ mA}$$

now,
$$I_0 = \frac{I_{reff}}{\left(1 + \frac{2}{\beta}\right)} = \frac{0.251}{\left(1 + \frac{2}{50}\right)} = 0.241 \text{ mA}$$

9. (a)

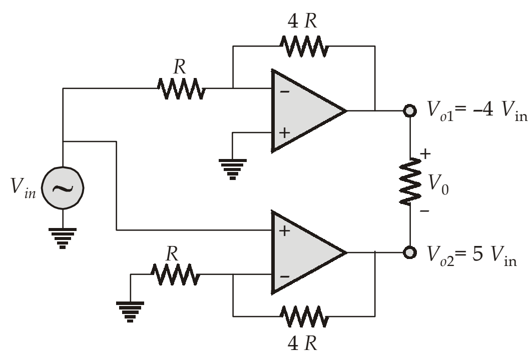
Since, the op-amp represents a closed loop unity gain amplifier.

Thus,
$$A_{CL} = \frac{A_{OL}}{1 + A_{OL}}$$

$$= \frac{999}{1 + 999} = 0.999$$

10. (c)

In the given circuit

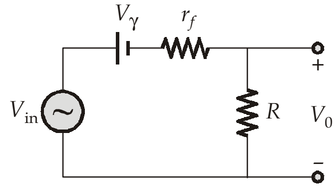


∴
$$V_o = V_{o_1} - V_{o_2}$$
$$= -4\ V_{in} - 5\ V_{in}$$
$$= -9\ V_{in}$$

∴
$$\frac{V_o}{V_{in}} = -9$$

11. (c)

The small signal equivalent model can be drawn as



∴ The output can be expressed as,

$$V_0 = \frac{R}{R+r_f}V_{in} - \frac{R}{R+r_f}V_\gamma \qquad \text{...(i)}$$

Thus, the slope of line in the graph of the input output curve can be written

$$\text{Slope} = \frac{R}{R+r_f} = \frac{1.2}{2-0.7} = \frac{1.2}{1.3} \qquad \text{...from equation (i)}$$

Thus, $r_f = 83.33\ \Omega$

12. (b)

In the transistor $V_{GS} = V_{DS}$

Since, the gate and drain terminals are shorted,

the transistor will always be in saturation mode.

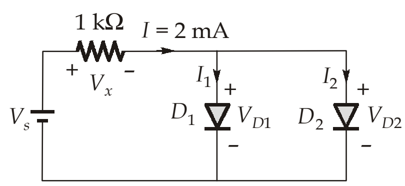
thus, $$I_D = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

now, $$I_D = \frac{V_0}{R} = \frac{3}{3}\times 10^{-3} = 1\text{ mA}$$

thus, $$1 \times 10^{-3} = \frac{50\times 10^{-3}}{2}\left(\frac{W}{L}\right)\times(2-1)^2$$

$$\left(\frac{W}{L}\right) = \frac{1}{25} = 0.04$$

13. (c)



$$V_s = V_x + V_{D1} \qquad (\because V_{D1} = V_{D2})$$

and $$I = I_1 + I_2$$

thus $$2 \times 10^{-3} = 10^{-12}\left[e^{\frac{V_{D1}}{26\times 10^{-3}}} - 1\right] + 10^{-10}\left[e^{\frac{V_{D1}}{26\times 10^{-3}}} - 1\right]$$

$$2 \times 10^{-3} \approx 10^{-10}(1.01)\cdot e^{\frac{V_{D1}}{26\times 10^{-3}}}$$

$$\frac{V_{D1}}{26\times 10^{-3}} = \ln(1.9801 \times 10^7) = 16.801$$

∴ $$V_{D1} = 0.437\text{ V}$$

Now, $V_x = 2 \times 10^{-3} \times 1 \times 10^{3} = 2\text{ V}$

$$V_s = V_x + V_{D1} = 2 + 0.437 = 2.437\text{ V}$$

14. (d)

Assuming the transistor to be in active region, we get,

$$I_C = \alpha I_E = \frac{\beta}{1+\beta}\cdot I_E = \frac{60}{61}\times 0.61\times 10^{-3} = 0.6\text{ mA}$$

Now, the voltage at $V_C = -10 + 4.7 \times 0.6 = -7.18\text{ V}$

Value of $I_B = \frac{I_C}{\beta} = \frac{0.6}{60}\times 10^{-3} = 1\times 10^{-5}\text{ A} = 10\,\mu\text{A}$,

now, $V_B = I_B R_B = 10 \times 10^{-6} \times 50 \times 10^{3} = 0.5\text{ V}$

$\therefore$ $V_E = V_B + V_{EB} = 0.5 + 0.7 = 1.2\text{ V}$

$V_{EC} = 1.2 - (-7.18) = 8.38\text{ V}$

$\therefore$ Power dissipated $= V_{EC} \times I_C = 8.38 \times 0.6 \times 10^{-3} \approx 5.028\text{ mW}$

15. (a)

The current of both the transistors are equal since they are perfectly matched.

Thus, $$\frac{I}{2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS1} - V_t)^2$$

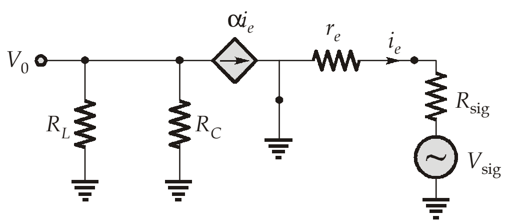
$$10 \times 10^{-3} = \frac{1}{2}\times 500\times 10^{-6}\times 100(V_{GS1} - 0.5)^2$$

$\therefore$ $V_{GS1} = V_{GS2} = 1.132\text{ V}$

Thus, $V_S = V_{cm} - V_{GS1} = 3 - 1.132 = 1.868\text{ V}$

16. (b)

The small signal r_e equivalent circuit can be drawn as



$$V_0 = -\alpha(R_C \parallel R_L)i_e \quad \text{...(i)}$$

and $$i_e = \frac{-V_{sig}}{R_{sig} + r_e} \quad \text{...(ii)}$$

Combining equation (i) and (ii), we get,

$$V_0 = \frac{\alpha(R_C \parallel R_L)}{R_{sig} + r_e}\cdot V_{sig}$$

thus, $$\frac{V_0}{V_{sig}} = \frac{\alpha(R_C \parallel R_L)}{R_{sig} + r_e}$$

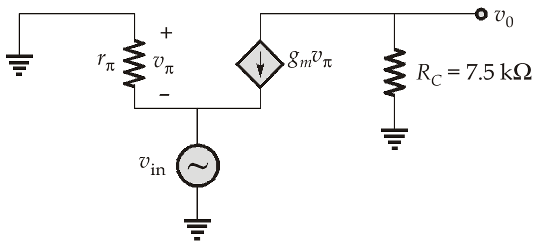
17. (a)

From the figure it can be seen that,

$$I_C = I_E = 0.5 \text{ mA} \qquad (\because \beta \text{ is very large})$$

now,
$$g_m = \frac{I_C}{V_T} \approx \frac{I_E}{V_T} = \frac{0.5\times10^{-3}}{25\times10^{-3}} \text{ A/V} = 20 \text{ mA/V}$$

Drawing the equivalent small signal circuit, we get,



Now, applying KVL, we get

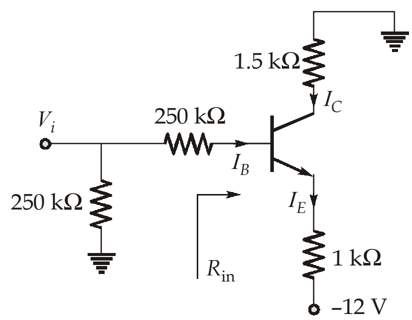
$$v_{in} + v_\pi = 0$$
$$v_{in} = -v_\pi$$

and
$$v_0 = -g_m v_\pi \times R_C$$
$$v_0 = g_m R_c v_{in}$$

$$\frac{v_0}{v_{in}} = g_m R_c = 20 \times 10^{-3} \times 7.5 \times 10^3 = 150$$

18. (b)

Base emitter loop



$$500\text{k } I_B + 0.7 + 1\text{k}(I_B + I_C) = 12$$
$$I_C = 100 I_B$$
$$I_E = 101\, I_B$$

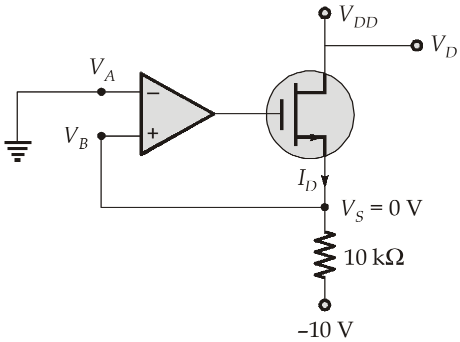
from here
$$I_B = 18.80\ \mu\text{A}$$

$$r_\pi = \beta\times\frac{V_T}{I_C} = \frac{V_T}{I_B} = \frac{26}{18.8} \text{ k}\Omega = 1.383 \text{ k}\Omega$$

$$R_{in} = r_\pi + (1+\beta)R_E$$
$$= 1.383\text{k} + 101 \times 1\text{k} = 102.383 \text{ k}\Omega$$

19. (b)

For the transistor



$$V_S = V_B = V_A$$

due to virtual ground,

thus, $$V_S = 0 \text{ V}$$

Hence, $$I_D = \frac{0-(-10)}{10\times10^3} = 1 \text{ mA}$$

$$I_D = \frac{\mu_n C_{ox} W}{2L}(V_{GS}-V_T)^2$$

$\therefore$ $$V_{GS} - V_T = \sqrt{\frac{I_D}{\frac{\mu_n C_{ox} W}{2L}}}$$

$$V_{GS} - V_T = \sqrt{\frac{1\times10^{-3}}{\frac{0.5\times10^{-3}}{2}}}$$

$$V_{GS} - V_T = 2 \text{ V}$$

For the MOSFET to be in saturation region

$$V_{DS} \geq V_{GS} - V_T$$

$\therefore$ at the edge of saturation

$$V_{DS} = V_{GS} - V_T = 2 \text{ V}$$

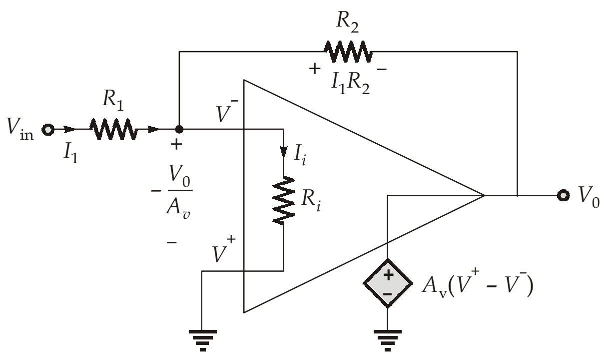
$\because$ $$V_S = 0$$

$\therefore$ $$V_D = V_G - V_T$$

$\Rightarrow$ $$V_{DD} = 2 \text{ V}$$

20. (a)

$\because R_i \neq \infty$ thus concept of virtual ground is not applicable for this circuit.



$$V_0 = -\frac{R_2}{R_1}\left[V_{in} + \frac{V_0}{A_v}\right] - \frac{V_0}{A_v}$$

$$V_0 = -\frac{R_2}{R_1}V_{in} - \frac{1}{A_v}\left[1+\frac{R_2}{R_1}\right]V_0$$

$\therefore$ $$\frac{V_0}{V_{in}} = \frac{-\frac{R_2}{R_1}}{1+\frac{1}{A_v}\left(1+\frac{R_2}{R_1}\right)}$$

Thus, $$\frac{V_0}{V_{in}} = \frac{-100/1}{1+\frac{1}{10^3}\left(1+\frac{100}{1}\right)} = \frac{-100}{1.1} = -90.83 \text{ V/V}$$

21. (c)

$$\text{Slew rate} = \left.\frac{dV_0}{dt}\right|_{max}$$

$$\therefore \quad \text{Slew rate} = A\cdot\frac{dV_0}{dt} = A\cdot\frac{d}{dt}A_m\sin(\omega t)$$

$$\text{Slew rate} = AA_m\omega$$

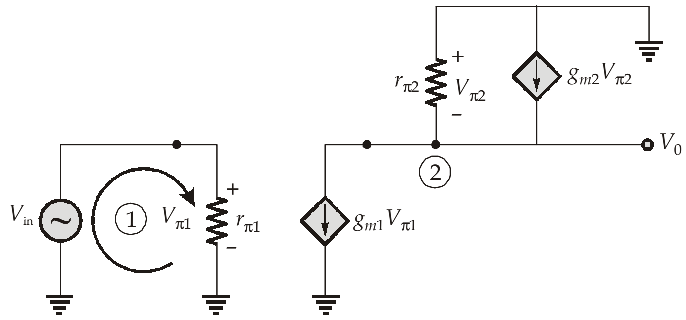
now, $$A = 10^{\frac{66.0206}{20}} \approx 2000$$

$$\therefore \quad 10\times10^6 = 2\times10^3\times A_m\times 2\pi\times10\times10^3$$

$$\therefore \quad A_m = 79.57 \text{ mV}$$

22. (c)

Drawing the small signal equivalent model of the transistor, we get,



Now, $$V_{in} = V_{\pi1}$$

and $$V_0 = -V_{\pi2}$$

Applying KCL at node-2 we get

$$g_{m1}V_{\pi1} + \frac{V_0}{r_{\pi2}} = g_{m2}V_{\pi2}$$

$$\Rightarrow \quad g_{m1}V_{in} + \frac{V_0}{r_{\pi2}} = -g_{m2}V_0$$

$$V_0\left[\frac{1}{r_{\pi2}} + g_{m2}\right] = -g_{m1}V_{in}$$

$$|A_v| = \left|\frac{V_0}{V_{in}}\right| = \frac{g_{m1}r_{\pi2}}{1+g_{m2}r_{\pi2}}$$

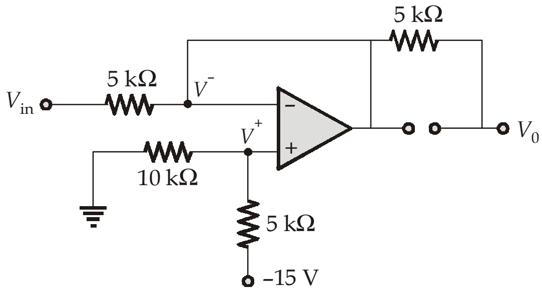
Since β >> 1 for both the transistors.

Thus, the above expression can be approximated as

$$|A_v| \approx \frac{g_{m1}}{g_{m2}}$$

23. (b)

Case -I : When $V_{in} > -10$ V, then the voltage across diode D_1 is positive so diode D_1 is in ON state, and therefore the equivalent circuit can be drawn as



$$V^+ = -15 \times \frac{10}{15} = -10 \text{ V}$$

Due to virtual ground, $V^+ = V^- = -10$ V

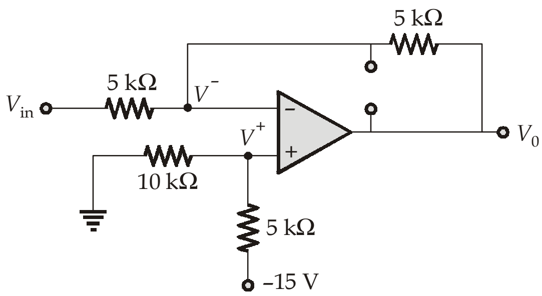
and $V_0 = V^- = -10$ V

$\therefore$ $V_0 = -10$ V

Case -II : When $V_{in} < -10$ V

$V_0 = +V_{sat}$

Thus,



$$\therefore \quad V_0 = -\frac{5}{5} \times V_{in} = -V_{in} \quad (\text{for } V_{in} < -10 \text{ V})$$

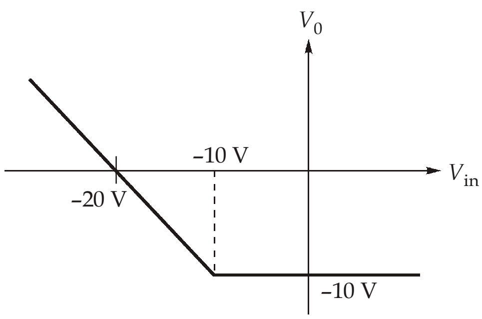
Alternately, we can write the equation of the graph by applying KCL at node V⁻

$\because$ $V^- = V^+ = -10$ V

$$\frac{-10 - V_{in}}{5\text{ k}\Omega} + \frac{-10 - V_0}{5\text{ k}\Omega} = 0$$

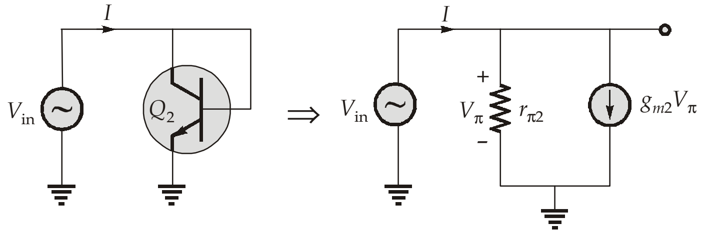
$$-20 - V_{in} - V_0 = 0$$

$$V_0 = -V_{in} - 20$$



24. (b)

For transistor Q_2, we can calculate the equivalent resistance as



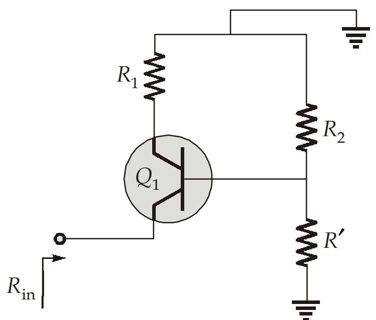
$$\therefore \quad I = \frac{V_\pi}{r_{\pi 2}} + g_{m2}V_\pi$$

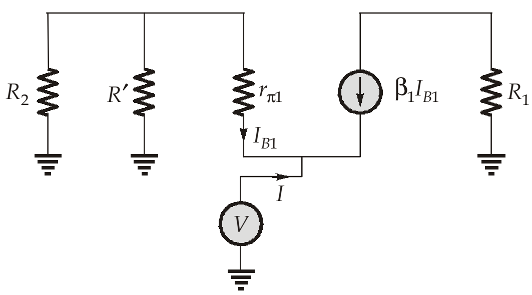
Now, $$V_{in} = V_\pi$$

$$\therefore \quad \frac{I}{V_{in}} = \frac{1}{r_{\pi 2}} + g_{m2}$$

or $$R' = r_{\pi 2} \,||\, \frac{1}{g_{m2}}$$

Now, the circuit can be redrawn as





$$I = -I_{B1} - \beta_1 I_{B1}$$
$$I = -(1 + \beta_1)\, I_{B1}$$

Now, $$I_{B1} = \frac{-V}{r_{\pi 1} + R' \,||\, R_2}$$

$$\therefore \quad \frac{V}{I} = \frac{r_{\pi 1} + R' || R_2}{\beta_1 + 1}$$

$$\therefore \quad R_{in} = \frac{1}{\beta_1 + 1}\left(r_{\pi 1} + \frac{1}{g_{m2}} \,||\, r_{\pi 2} \,||\, R_2\right)$$

$\because$ where, $\beta_1 = 99$

$$\therefore \quad R_{in} = \frac{1}{100}\left(r_{\pi 1} + \frac{1}{g_{m2}} \,||\, r_{\pi 2} \,||\, R_2\right)$$

25. (a)

In the circuit, the capacitor starts charging from 0 V (as the switch was initially closed) towards the steady state value of 20 V.

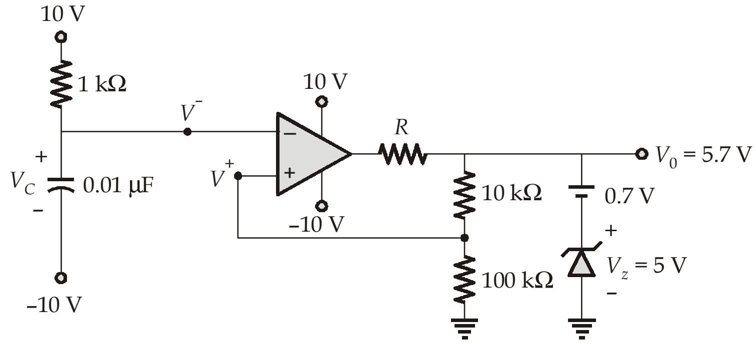
Now, when the switch is flipped open, the capacitor will charge upto 20 V.

$$\therefore \quad V_c(t) = V_c(\infty) - [V_c(0) - V_c(\infty)]e^{-t/RC}$$

$$RC = 1 \times 10^3 \times 0.01 \times 10^{-6} = 10\ \mu\text{sec}$$

$$\therefore \quad V_c(t) = 20\,(1 - e^{-t/RC})$$

Voltage at non-inverting amplifier is obtained as



$$V^+ = V_0 \times \frac{100\ \text{k}\Omega}{(10+100)\ \text{k}\Omega}$$

$$V^+ = V_0 \times \frac{100}{110} = \frac{V_0 \times 10}{11}$$

$\because$ Initially V^- was equal to –10 V, thus V_0 = +5.7 V.

Thus, now capacitor will start charging as soon as the switch is opened.

Thus, $\quad V^- = V_C - 10\ \text{V}$

or, $\quad V_C = V^- + 10\ \text{V}$

now, $\quad V^- = V^+ = \dfrac{5.7\ \text{V} \times 10}{11} \quad$ [$\because$ the op-amp will switch]

thus, $\quad V_C = \dfrac{10 \times 5.7}{11} + 10$

now, $\quad V_C = 20(1 - e^{-t/RC})$

$$\therefore \quad 20(1 - e^{-t/RC}) = 10 + \frac{57}{11}$$

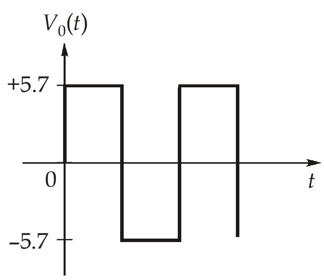
$$1 - e^{-t/RC} = \frac{1}{2} + \frac{57}{220}$$

$$1 - e^{-t/RC} = 0.7590$$

$$e^{-t/RC} = 0.2409$$

$$T = 14.23\ \mu\text{sec}$$

Hence, the output voltage wave will be,

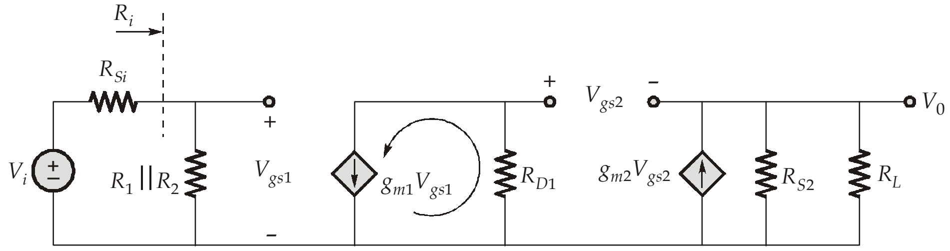


26. (c)

Now, $\quad g_{m1} = 2\sqrt{k_{n1} I_{D_1}} = 2\sqrt{0.5 \times 0.2 \times 10^{-6}} = 0.632\ \text{mA/V}$

and $\quad g_{m2} = 2\sqrt{k_{n2} I_{D_2}} = 2\sqrt{(0.2)(0.5) \times 10^{-6}} = 0.632\ \text{mA/V}$

Now, drawing the small signal equivalent circuit, we get,



Now, $V_0 = g_{m2}(R_{S2}||R_L).V_{gs2}$ . . . (i)

Also, $V_{gs2} + V_0 = -g_{m1}V_{gs1}R_{D1}$ . . . (ii)

and $V_{gs1} = \dfrac{R_1||R_2}{R_1||R_2 + R_{Si}} \times V_i$ . . . (iii)

Putting values of V_{gs1} and V_{gs2} from equation (i) and (iii) in equation (ii), we get

$$\frac{V_0}{g_{m_2}(R_{S2}||R_1)} + V_0 = -g_{m1}R_{D1}\left[\frac{R_1||R_2}{R_1||R_2 + R_{Si}}\right]\cdot V_i$$

$$\therefore \quad A_V = \frac{V_0}{V_i} = \frac{-g_{m1}\,g_{m2}R_{D1}(R_{S2}||R_L)}{1+g_{m2}(R_{S2}||R_L)} \times \left[\frac{R_1||R_2}{R_1||R_2 + R_{Si}}\right]$$

Now, $R_{S2}\ ||R_L = \dfrac{8}{3}\text{k}\Omega$

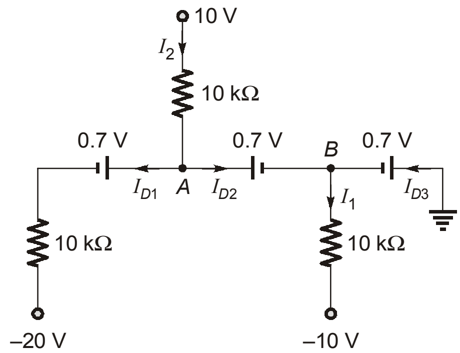
$R_1\ ||R_2 = 99.8\text{ k}\Omega \approx 100\text{ k}\Omega$

$$\therefore \quad A_v = \frac{V_0}{V_i} = \frac{-(0.632)(0.632)(16.1)(8/3)}{1+(0.632)(8/3)} \times \left[\frac{100}{104}\right]$$

$$\approx -6.14$$

27. (c)

Assuming all the diodes are forward biased,



$V_B = -0.7$ V

$V_A = 0$ V

$\therefore \quad I_2 = \dfrac{10-0}{10\text{ k}} = 1$ mA

and $I_1 = \dfrac{-0.7-(-10)}{10\text{ k}} = 0.93$ mA

$\because \quad I_2 = I_{D_1} + I_{D_2}$

and $I_1 = I_{D_2} + I_{D_3}$

applying KVL in the outer loop, we get,

$$10\text{k}I_2 + 0.7 + 10\text{k}\,I_{D_1} - 20 = 10$$

$$10\text{ k}(I_{D_1} + I_{D_2}) + 10\text{ k}\,I_{D_1} = 30 - 0.7 = 29.3$$

$$20\text{ k}I_{D_1} + 10\text{k}\,I_{D_2} = 29.3$$

$$2I_{D_1} + I_{D_2} = 2.93 \text{ mA} \quad ...(i)$$

also, $$I_{D_1} + I_{D_2} = I_2 = 1 \text{ mA} \quad ...(ii)$$

from (i) and (ii)

$$I_{D_1} = 1.93 \text{ mA and } I_{D_2} = -0.93 \text{ mA}$$

$\because$ $$I_{D_2} + I_{D_3} = 0.93 \text{ mA}$$

$\Rightarrow$ $$I_{D_3} = -I_{D_2} + 0.93 \text{ mA} = 1.86 \text{ mA}$$

Here I_{D_2} is negative, Hence, our assumption is incorrect.

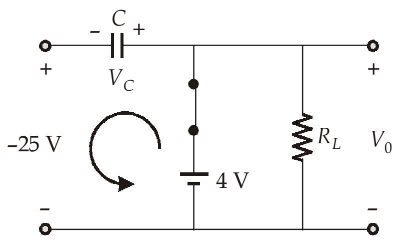
Therefore, D_2 is reverse biased

and $\because$ I_{D_1} and I_{D_3} are positive,

D_1, D_3 are forward biased.

28. (a)

The diode will get forward biased when the negative value of input wave will be applied at the input terminal.



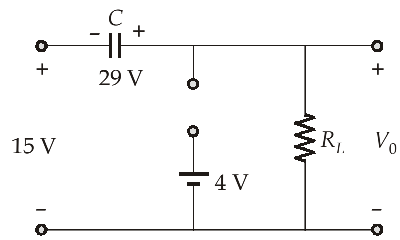
Applying KVL, we get,

$$-4 \text{ V} + V_C - 25 \text{ V} = 0$$

$$V_C = 29 \text{ V}$$

and $$V_0 = 4 \text{ V}$$

For positive cycle



$\therefore$ $$V_0 = 29 + 15 = 44 \text{ V}$$

29. (a)

$$I_z + I_B = I_1$$

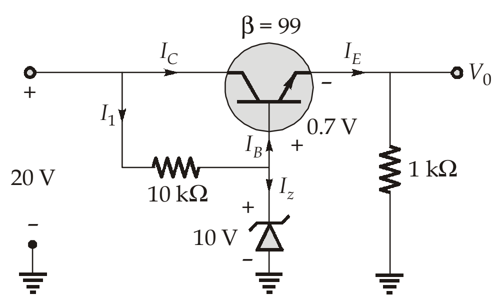
$$I_z = I_1 - I_B$$

$$V_0 = V_Z - V_{BE}$$

$$= 10 - 0.7 = 9.3 \text{ V}$$

and $$I_E = \frac{V_0}{1 \text{ k}\Omega} = \frac{9.3 \text{ V}}{1 \text{ k}\Omega} = 9.3 \text{ mA}$$

now, $$I_B = \frac{I_E}{\beta + 1} = \frac{9.3}{100} = 93 \text{ μA}$$

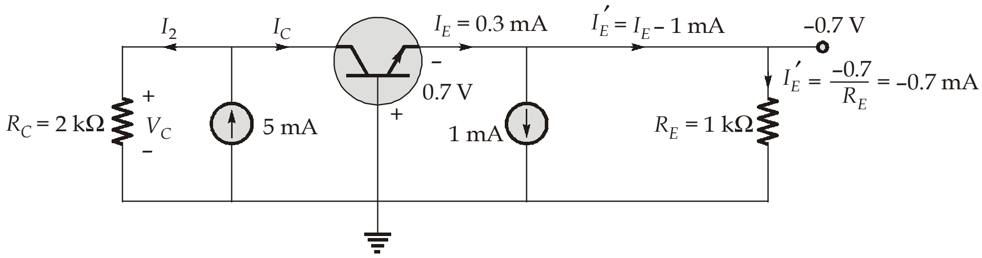


$$I_1 = \frac{20-10}{10\text{ k}} = 1\text{ mA}$$

$\therefore$ $I_z = (1000 - 93)\ \mu A$

$I_z = 907\ \mu A$

30. (a)



now, $I_E = I_E' + 1\text{ mA}$

$I_E = 1\text{ mA} - 0.7\text{ mA} = 0.3\text{ mA}$

now, $I_C = \alpha I_E$

$$\alpha = \frac{\beta}{1+\beta} = \frac{99}{1+99} = 0.99$$

$\therefore$ $I_C = 0.99 \times 0.3 = 0.297\text{ mA}$

$\therefore$ $I_2 + I_C = 5\text{ mA}$

$I_2 = 5\text{ mA} - I_C$

$= 4.703\text{ mA}$

$\therefore$ $V_C = I_2 \cdot R_C = 4.703 \times 2$

$V_C = 9.406$

$\therefore$ $V_{CE} = 9.406 + 0.7 = 10.1\text{ V}$

■■■■