S.No. : 01 LS1_EC_A_300519

Electrtronic Devices & Circuits

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# CLASS TEST 2019-2020

## ELECTRONICS ENGINEERING

## Electrtronic Devices & Circuits

Date of Test : 30/05/2019

### *Answer Key*

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

## DETAILED EXPLANATIONS

1. (c)

$$p = \text{steady state minority concentration}$$
$$p_0 = \text{thermal equilibrium concentration of holes}$$
$$p = p_0 + G_L \tau_p$$
$$p_0 = \frac{n_i^2}{N_D} = \frac{2.25\times10^{20}}{10^{16}} = 2.25 \times 10^4 \text{ cm}^{-3}$$
$$p = (2.25 \times 10^4) + (10^{10} \times 10^{-6}) = 3.25 \times 10^4 \text{ cm}^{-3}$$

2. (b)

$$\frac{I_{02}}{I_{01}} = 2^{\frac{T_2-T_1}{10}}$$
$$\frac{I_{02}-I_{01}}{I_{01}}\times100 = 300$$
$$\frac{I_{02}}{I_{01}} = 4 = 2^{\frac{T_2-T_1}{10}}$$
$$2^2 = 2^{\frac{T_2-T_1}{10}}$$
$$T_2 - T_1 = 20°\text{C}$$
$$T_2 - 25°\text{C} = 20°\text{C}$$
$$T_2 = 20°\text{C} + 25°\text{C} = 45°\text{C}$$

4. (a)

$$I_{CEO} = I_{CBO}(1+\beta)$$
$$10^{-1} \times 10^{-3} = (1+\beta)\times 10^{-6}$$
$$\beta = 99$$

5. (b)

$$np = n_i^2$$
$$\Rightarrow \quad 4.5 \times 10^{15} \times n = 2.25 \times 10^{20}$$
$$n = 0.5 \times 10^5 = 5 \times 10^4 \text{ cm}^{-3}$$

6. (c)

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T \quad \text{(Eienstein's equation)}$$
$$\Rightarrow \quad \frac{48}{\mu_n} = \frac{12}{\mu_p}$$
$$\Rightarrow \quad 4 = \frac{\mu_n}{\mu_p}$$
$$\mu_p + \mu_n = 100 \qquad \text{(given)}$$
$$5\mu_p = 100$$
$$\mu_p = 20$$
$$\mu_n = 80 \text{ cm}^2/\text{V-sec}$$

7. (b)

$$I_s = I_Z + I_L$$
$$\frac{25\text{V} - 12\text{ V}}{1\text{k}\Omega} = I_Z + I_L$$

$$13 \text{ mA} = I_Z + I_L$$
$$13 \text{ mA} = I_{Z(\max)} + I_{L(\min)}$$
$$I_{Z(\max)} = 13 - 5 = 8 \text{ mA}$$

9. (a)

$$\alpha = \beta^* \gamma$$

$\gamma$ = emitter injection efficiency, $\gamma = \dfrac{98}{100} = 0.98$

$\beta^*$ = base transport factor, $\beta^* = \dfrac{99 - 1.98}{99} = 1 - \dfrac{2}{100} = 0.98$

$$\alpha = \text{common base current gain} = \gamma\beta^* = 0.98 \times 0.98 = 0.9604$$

10. (b)

$$\lambda \le \frac{1.24}{E_g(\text{in eV})} \mu\text{m}$$
$$\lambda_{(\max)} = \frac{1.24}{2.5} \mu\text{m} = 0.496 \mu\text{m} = 4960 \text{ Å}$$

11. (c)

$$n \times p = n_i^2$$
$$n = p + N_D$$
$$(p + N_D)p = n_i^2$$
$$p^2 + N_D p - n_i^2 = 0$$
$$p = -\frac{N_D}{2} + \sqrt{\frac{N_D^2 + 4n_i^2}{4}}$$
$$p = -\frac{N_D}{2} + \sqrt{\left(\frac{N_D}{2}\right)^2 + n_i^2}$$
$$p = -10^{10} + \sqrt{2 \times 10^{20}} \text{ cm}^{-3} = \left(\sqrt{2} - 1\right) \times 10^{10} \simeq 41.42 \times 10^8 \text{ cm}^{-3}$$

12. (b)

If $\beta I_B < I_{C\,\text{sat}}$ = BJT will be in active region and $I_C = \beta I_B$

If $\beta I_B \ge I_{C\,\text{sat}}$ = BJT will be in saturation region and $I_C = I_{C\,\text{sat}}$

In the given circuit, $I_B = \dfrac{12 - 0.7}{100} \text{ mA} = 0.113 \text{ mA}$

$$\beta I_B = 11.3 \text{ mA}$$
$$I_{C\,\text{sat}} = \frac{12 - 0.2}{4} \text{ mA} = 2.95 \text{ mA}$$

So, the BJT in the given circuit is working in saturation region.

13. (d)

$$\eta = \frac{I_L / q}{P_{\text{in}} / h\nu}$$

Units : $I_L \to$ A, $q \to$ C, $P_{\text{in}} \to$ W, $h\nu \to$ J

$$h\nu = 2 \text{ eV} = 2 \times 1.6 \times 10^{-19} \text{ J}$$
$$q = 1.6 \times 10^{-19} \text{ C}$$
$$\eta = \frac{I_L(2)}{P_{\text{in}}}$$
$$I_L = \frac{0.8 \times 10}{2} \text{ mA} = 4 \text{ mA}$$

14. (b)

Fill factor, $$FF = \frac{P_{L\,max}}{V_{oc}I_{sc}}$$

$$P_{L\,max} = (FF)\,(V_{oc}\,I_{sc}) = 58.22 \text{ mW}$$

15. (a)

$$P_n = P_{n0}\,e^{0.5/V_t}$$

$$P_{n0} = \frac{n_i^2}{n_{n0}} = \frac{10^{20}}{5\times10^{15}} = 2\times10^4 \text{ cm}^{-3}$$

$$P_n = 2\times10^4\,e^{20} \approx 10\times10^{12} \text{ cm}^{-3}$$

16. (d)

Voltage across forward biased diodes in both the circuits is same and is independent of source voltage.
$V_{D_1} = V_t\ ln(2)$ in both the circuits.

17. (a)

$$q\phi(x) = E_F - E_i(x)$$

$$q\phi(0) = E_F - E_i(0) = kT\,ln\left(\frac{N_D(0)}{n_i}\right)$$

$$\phi(0) = \frac{kT}{q}ln\left(\frac{N_D(0)}{n_i}\right)$$

$$\phi(x = 5\mu m) = \frac{kT}{q}ln\left(\frac{N_D(5\mu m)}{n_i}\right)$$

$$V_0 = \phi(0) - \phi(x = 5\mu m) = \frac{kT}{q}ln\left(\frac{N_D(0)}{N_D(5\mu m)}\right)$$

$$= 0.026\,ln\left(\frac{10^{20}}{10^{15}}\right)\text{V} \simeq 0.3 \text{ V}$$

18. (d)

$$3\times10^{15} = \frac{n_i^2}{N_A}e^{\frac{\phi_s}{V_t}}$$

$$\phi_s = \text{surface potential}$$

$$\phi_s = V_t\,ln\left(\frac{3\times10^{15}}{1.8\times10^{5}}\right)$$

$$\phi_s = 0.026\,ln\left(\frac{3\times10^{10}}{1.8}\right) \simeq 0.612 \text{ V}$$

19. (a)

$$V_G = V_{ox} + \phi_s$$

Given, $$\phi_s = 0.035 \text{ V}$$

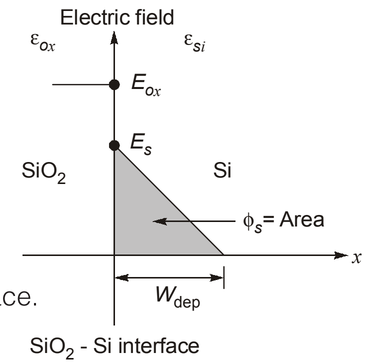
$$V_{ox} = \frac{\sqrt{2qN_A\varepsilon_{si}\phi_s}}{C_{ox}}$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 2\times10^{-9} \text{ F/cm}^2$$

$$V_{ox} = 1.91 \text{ V}$$

$$V_G = 1.945 \text{ V}$$

20. (a)




$$\phi_s = \text{surface potential} = \frac{1}{2}E_s W_{dep}$$

$$E_s = \frac{2\phi_s}{W_{dep}} = \frac{2 \times 0.035}{0.4} \text{ V/}\mu\text{m}$$

$$E_s = 0.175 \text{ V/}\mu\text{m}$$

Boundary condition of electrostatic field should be satisfied at the interface.

So, $$\varepsilon_{ox}E_{ox} = \varepsilon_{si}E_s$$

$$E_{ox} = \frac{\varepsilon_{si}E_s}{\varepsilon_{ox}} = 3E_s$$

$$E_{ox} = 0.525 \text{ V/}\mu\text{m}$$

$$E_{ox} = \frac{V_{ox}}{t_{ox}}$$

$$V_{ox} = E_{ox}t_{ox} = 0.525 \times 1.8 \text{ V} = 0.945 \text{ V}$$

$$V_G = V_{ox} + \phi_s = 0.98 \text{ V}$$

21. (c)

Force due to magnetic field, $$\vec{F}_m = q\vec{v}_d \times \vec{B} = q\mu_p \vec{E}_{\text{applied}} \times \vec{B} = \frac{q\mu_p V_x}{L}\hat{x} \times (-10\hat{z})$$

$$= \frac{100q\mu_p}{L}\hat{y}$$

$$\vec{F}_{ei} = \text{force due to induced Hall electric field} = -\vec{F}_m$$

$$= \frac{100q\mu_p}{L}(-\hat{y}) = q\vec{E}_{\text{ind}}$$

$$\vec{E}_{\text{ind}} = \frac{100\mu_p}{L}(-\hat{y})$$

As $\vec{E}_{\text{ind}}$ in $(-\hat{y})$ direction, $V_H$ is +ve

$$V_H = W|\vec{E}_{\text{ind}}| = \frac{W(100)\mu_p}{L} = \frac{W(100)(500 \times 10^{-4})}{2W} = 2.5 \text{ V}$$

22. (c)

$$\rho_{max} = \frac{1}{\sigma_{min}} = \frac{1}{(2q\sqrt{\mu_n\mu_p})n_i}$$

$$\sigma_{min} = 2qn_i\sqrt{\mu_n\mu_p} = 2 \times 1.6 \times 10^{-19} \times n_i \times \sqrt{1600 \times 400}$$

$$= 25.6 \times 10^{-17} \times n_i$$

$$\rho_{max} = \frac{1}{25.6 \times 10^{-17} \times n_i}$$

$$n_i = \frac{10^{17}}{25.6 \times \rho_{max}} = \frac{10^{17}}{25.6 \times 5 \times 10^3} \text{ cm}^{-3}$$

$$n_i = \frac{1}{128} \times 10^{14} = \frac{1000}{128} \times 10^{11} \text{ cm}^{-3}$$

$$n_i = 7.8125 \times 10^{11} \text{ cm}^{-3}$$

23. (a)

$$\beta = \frac{\alpha}{1-\alpha} = 99$$

$$I_C = \beta I_B + (1+\beta)I_{CBO}$$
$$= 2.495 \text{ mA}$$

By neglecting leakage current,

$$I_C = \beta I_B = 2.475 \text{ mA}$$

Percentage error in the collector current calculation $= \frac{2.495 - 2.475}{2.495} \times 100 = 0.8\%$

24. (b)

$$W = K\sqrt{V_{bi} + V_R}\,; \quad K \text{ is constant}$$

$$\therefore \quad \frac{W_2}{W_1} = \sqrt{\frac{V_{bi} + V_{R2}}{V_{bi} + V_{R1}}}$$

$$\frac{W_2}{2\ \mu\text{m}} = \frac{\sqrt{0.8 + 7.2}}{\sqrt{0.8 + 1.2}} = \frac{\sqrt{8}}{\sqrt{2}} = 2$$

$$W_2 = 4\ \mu\text{m}$$

25. (d)

$$\text{Recombination rate } (R) = \frac{P_n}{\tau_p}$$

$$P_n = P_{n0} + \delta P_n = \frac{10^{20}}{10^{15}} + (4\times10^5)\text{ cm}^{-3} = 5 \times 10^5 \text{ cm}^{-3}$$

$$R = \frac{P_n}{\tau_p} = \frac{5\times10^5}{10^{-6}} = 5\times10^{11}\text{ cm}^{-3}\text{ s}^{-1}$$

26. (b)

$$I_{Z(\max)} = \frac{P_{D(\max)}}{V_Z} = \frac{260\times10^{-3}}{5.2} = 50 \text{ mA}$$

By KVL,

$$V_S = R_{S(\min)} I_{Z(\max)} + V_Z$$

$$R_{S(\min)} = \frac{V_S - V_Z}{I_{Z(\max)}}$$

$$R_{S(\min)} = \frac{15 - 5.2}{50\times10^{-3}} = 196\ \Omega$$

27. (a)

As per mass-action law, $np = n_i^2$

$$p + N_D = n + N_A$$
$$p = n + N_A \qquad (\text{as } N_D = 0)$$
$$n(n + N_A) = n_i^2$$
$$n^2 + N_A \cdot n = n_i^2$$
$$n^2 + N_A \cdot n - n_i^2 = 0$$

$$n = \frac{-N_A \pm \sqrt{N_A^2 + 4n_i^2}}{2}$$

$$n = \frac{1}{2}\left(-N_A + \sqrt{N_A^2 + 4n_i^2}\right)$$

$$p = \frac{1}{2}\left(N_A + \sqrt{N_A^2 + 4n_i^2}\right)$$

28. (c)

$$J = -eD_p \cdot \frac{dp}{dx} = -eD_p \frac{d}{dx}\left(10^{16}\left(1 - \frac{x}{L}\right)\right)$$

$$= \frac{e10^{16} \cdot D_p}{L} = \frac{1.6 \times 10^{-19} \times 10^{16} \times 10}{10 \times 10^{-4}}$$

$$J = 16 \text{ A/cm}^2$$

29. (b)

$$x_p = 0.2\,(x_p + x_n)$$

$$0.8\,x_p = 0.2\,x_n$$

$$\frac{x_p}{x_n} = \frac{1}{4}$$

$$N_a x_p = N_d x_n$$

$$\frac{x_p}{x_n} = \frac{N_d}{N_a} = \frac{1}{4} = 0.25$$

30. (d)

$$I_D = K_N(V_{GS} - V_{TN})^2(1 + \lambda V_{DS}) \qquad \text{... as transistor is in saturation}$$

$$V_{GS} = V_{DS}$$

So, $$I_D = K_N(V_{DS} - V_{TN})^2(1 + \lambda V_{DS})$$

Let, $V_{DS1} = 5$ V, $V_{DS2} = 3$ V, $I_{D1} = 2$ mA and $I_{D2} = 1$ mA.

Given that, $$V_{TN} = 0.5 \text{ V}$$

So, $$\frac{I_{D1}}{I_{D2}} = \frac{(V_{DS1} - 0.5)(1 + \lambda V_{DS1})}{(V_{DS2} - 0.5)(1 + \lambda V_{DS2})}$$

$$\frac{4.5(1 + 5\lambda)}{2.5(1 + 3\lambda)} = 2$$

$$1.8 + 9\lambda = 2$$

$$3\lambda = 0.20$$

$$\lambda = \frac{0.20}{3} = 0.067 \text{ V}^{-1}$$

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