CLASS TEST

Sl. : 01SK_EC_ABCD_300623

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ELECTRONIC DEVICES

ELECTRONICS ENGINEERING

Date of Test : 30/06/2023

ANSWER KEY

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

Detailed Explanations

1. (b)

Given, $\mu_n = 3900\text{ cm}^2\text{ V}^{-1}\text{ sec}^{-1} = 0.39\text{ m}^2\text{ V}^{-1}\text{ sec}$

$m_e = 0.16m_o = 0.16 \times 9.1 \times 10^{-31}$

We know that mean free time,

$$\tau_c = \frac{\mu_n m_e}{q} = \frac{0.39 \times 0.16 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19}}$$

$\therefore$ $\tau_c = 0.3549 \times 10^{-12}$ sec

$\tau_c = 3.549 \times 10^{-13}$ sec

2. (d)

Given, radiative lifetime τ_r

Non-radiative lifetime τ_{nr}

Efficiency of radiative recombination,

$$\%\eta = \frac{\tau_{nr} \times 100}{\tau_r + \tau_{nr}} = \frac{100}{20} = 5\%$$

3. (c)

4. (b)

Given, $I_{D-n} = I_{D-p}$

$$\frac{K'_n}{2} \times \frac{W_n}{L} \times (V_{0\text{V}})^2 = \frac{K'_p}{2} \times \frac{W_p}{L} \times (V_{0\text{V}})^2$$

$$K'_n \times W_n = K'_p \times W_p$$

But, $K'_n = \mu_n C_{ox}$; $K'_p = \mu_p C_{ox}$

$\Rightarrow$ $\mu_n C_{ox} W_n = \mu_p C_{ox} W_p$

$$\therefore \quad \frac{W_p}{W_n} = \frac{\mu_n}{\mu_p} = \frac{\mu_n}{0.4\mu_n} = 2.5$$

5. (d)

Given: $I_{CBO} = 0.5\ \mu A$; $I_{CEO} = 27\ \mu A$

We know that, $I_{CEO} = (1 + \beta)I_{CBO}$

$27 = \gamma \times 0.5$

$$\therefore \quad \gamma = \frac{27}{0.5} = 54$$

7. (c)

Since, NMOS transistor is in saturation region,

$$I_{DS} = \frac{1}{2}(\mu_n C_{ox})\left(\frac{W}{L}\right)V_{o\text{V}}^2 \text{ where, } V_{o\text{V}} = V_{GS} - V_t$$

$$100 \times 10^{-6} = \frac{1}{2} \times 387 \times 10^{-6} \times 10 \times V_{o\text{V}}^2$$

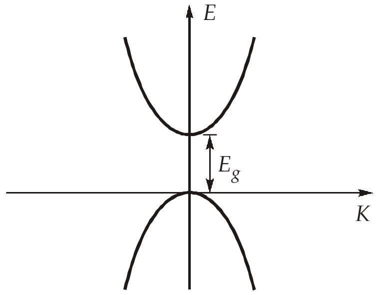
$\therefore$ $V_{o\text{V}} = 0.23$ V

Thus, $V_{GS} = V_t + V_{o\text{V}} = 0.5 + 0.23$

$V_{GS} = 0.73$ V

9. (b)

Energy change = $\Delta E = E_g$.



Momentum remains the same.

10. (c)

E_i has gone below E_f, thus indicating concentration of electrons exceeds concentration of holes near semiconductor oxide junction and the event is called as surface inversion.

11. (a)

Given: $N_a = 10^{18}\ \text{cm}^{-3}$; $N_d = 10^{17}\ \text{cm}^{-3}$; $n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$

The maximum electric field in the depletion region of an abrupt pn junction is,

$$E_{\max} = \frac{-2V_{bi}}{W}$$

where, V_{bi} = Built in potential

$$= \frac{kT}{q}\ln\left[\frac{N_a N_d}{n_i^2}\right] = 26\times10^{-3}\ln\left[\frac{10^{18}\times10^{17}}{(1.5\times10^{10})^2}\right]$$

$$V_{bi} = 0.876\ \text{V}$$

The maximum electric field at abrupt pn junction (in magnitude)

$$|E_{\max}| = \frac{2V_{bi}}{W}$$

Width, $$W = \sqrt{\frac{2\epsilon_{Si}}{q}\left[\frac{1}{N_a}+\frac{1}{N_d}\right]V_{bi}} = \sqrt{\frac{2\times1.05\times10^{-12}}{1.6\times10^{-19}}\left[\frac{1}{10^{18}}+\frac{1}{10^{17}}\right]0.876} = 1.12\times10^{-5}\ \text{cm}$$

$$|E_{\max}| = \frac{2\times0.876}{1.12\times10^{-5}} = 1.56\times10^{5}\ \text{V/cm}$$

12. (b)

Diffusion capacitance, $$C_D = \frac{\tau I_f}{\eta V_T}$$

$$C_D \propto I_f$$

and $$C_D \propto \frac{1}{T}$$

13. (b)

Given, Acceptor doping, $N_a = 3 \times 10^{13}\ \text{cm}^{-3}$

$$n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$$

Fermi level, $$E_F = E_i - kT\ln\left(\frac{N_a}{n_i}\right)$$

$$E_F = E_i - 26\times10^{-3}\ln\left(\frac{3\times10^{13}}{1.5\times10^{10}}\right) = E_i - 0.197\ \text{eV}$$

14. (b)

The depletion capacitance of a PN junction diode,

$$C_{dp} = A\sqrt{\frac{q\in_{Si}}{2(\phi_{bi}-V_{RB})}\frac{N_A N_D}{N_A+N_D}}$$

$$\therefore \quad C_{dp} \propto \frac{1}{\sqrt{\phi_{bi}-V_{RB}}}$$

$$\frac{10\text{ pF}}{C'_{dp}} = \sqrt{\frac{0.7+20}{0.7+10}}$$

$$\therefore \quad C'_{dp} = 7.19\text{ pF}$$

15. (b)

We know that, $I_C = \beta I_B + I_{CEO}$

$$2 = 80 \times 0.02 + I_{CEO}$$

$$I_{CEO} = 2 - 80 \times 0.02 = 0.4\text{ mA}$$

$$\alpha = \frac{\beta}{\beta+1} = \frac{80}{80+1} = 0.988$$

$$\therefore \quad I_{CBO} = (1-\alpha)I_{CEO} = (1-0.988) \times 0.4 = 0.0048\text{ mA}$$

16. (a)

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

Given, $\phi_s = 0.035$ V

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

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{0.36\times10^{-12}}{1.8\times10^{-4}} = 2 \times 10^{-9}\text{ F/cm}^2$$

$$V_{ox} = \frac{\sqrt{2\times1.6\times10^{-19}\times1.25\times10^{15}\times1.04\times10^{-12}\times0.035}}{2\times10^{-9}} = 1.9078\text{ V}$$

$$V_G = V_{ox} + \phi_s = 1.9078 + 0.035 = 1.943\text{ V}$$

17. (c)

For an npn transistor the emitter injection efficiency is given as

$$\gamma \approx \frac{1}{1+\frac{N_B}{N_E}\cdot\frac{D_E}{D_B}\cdot\frac{x_B}{x_E}}$$

and the magnitude of Early voltage is inversely proportional to the doping concentration.

18. (b)

Both electrons and holes diffuse from higher concentration to lower concentration:

$$\longrightarrow \phi_{P(\text{diffusion})} \qquad \longrightarrow I_{P(\text{diffusion})}$$

$$\longrightarrow \phi_{n(\text{diffusion})} \qquad \longleftarrow I_{n(\text{diffusion})}$$

Also, the hole current direction is same in the direction of the hole movement and electron current direction is opposite to the electron movement.

Holes drift in the direction of electric field and electrons drift in the direction opposite to electric field.

$$\longrightarrow \phi_{P(\text{drift})} \qquad \longrightarrow I_{P(\text{drift})}$$

$$\longleftarrow \phi_{n\,(\text{drift})} \qquad \longrightarrow I_{n\,(\text{drift})}$$

19. **(b)**

$$n_i = \sqrt{N_c N_v} e^{-E_G/2kT} = \sqrt{10^{19} \times 5 \times 10^{18}} e^{\frac{-1.1}{2 \times 0.026}}$$

$$n_i = 4.6 \times 10^9 \text{ cm}^{-3}$$

Also, $N_D = 10^{17} \text{ cm}^{-3}$

$\Rightarrow$ $n = N_D = 10^{17} \text{ cm}^{-3}$ (fully ionisation)

$$E_f - E_{fi} = KT \ln\left(\frac{n}{n_i}\right) = KT \ln\left(\frac{N_D}{n_i}\right) = 0.026 \ln\left(\frac{10^{17}}{4.6 \times 10^9}\right) = 0.44 \text{ eV}$$

20. **(b)**

$$D_p = \frac{KT}{q} \mu_P = 0.0259 \times 500 = 12.95 \text{ cm}^2/\text{s}$$

$$L_p = \sqrt{D_P \tau_P} = \sqrt{12.95 \times 10^{-10}} = 3.6 \times 10^{-5} \text{ cm}$$

If, $P = P_0 + \Delta P e^{-x/L_P}$

$$I_p = -qAD_P \frac{d}{dx} P = q \frac{AD_P}{L_P} \Delta P e^{-x/L_P}$$

$$= 1.6 \times 10^{-19} \times 0.5 \times \frac{12.95}{3.6 \times 10^{-5}} \times 5 \times 10^{16} e^{\frac{-10^{-5}}{3.6 \times 10^{-5}}}$$

$$I_p = 1.09 \times 10^3 \text{ A}$$

21. **(a)**

Given, $I_D \simeq I_S e^{V_D/V_T}$

$$e^{V_D/V_T} = \frac{I_D}{I_S}$$

$$V_D = V_T \ln\left(\frac{I_D}{I_S}\right) \quad \text{...(i)}$$

Let I_1 be the required current corresponding to new voltage V_{D1}.

$\therefore$ $I_1 = nI_D$

from equation (i) $V_{D1} = V_T \ln\left(\frac{nI_D}{I_S}\right)$

We can write, $V_{D1} = V_T \ln\left(\frac{I_D}{I_S}\right) + V_T \ln(n)$

$$V_{D1} = V_D + V_T \ln(n)$$

23. **(c)**

Given, Responsivity, $R = 0.5$ A/W

$$\text{Efficiency, } \eta = \frac{I_{ph} \times hc}{P_{op} \times q\lambda}$$

$$= R \cdot \frac{hc}{q\lambda}$$

$$\eta = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.5 \times 1.6 \times 10^{-19} \times 850 \times 10^{-9}} = 0.73$$

$$\eta = 0.73$$

24. **(b)**

We know that, the electron current density in the *npn* transistor,

$$J_n = qD_n \frac{dn}{dx}$$

$$J_n = qD_n\left(-\frac{n_p(0)}{W}\right)$$

$$J_n = 1.6\times10^{-19}\times5\times\left(-\frac{1.2\times10^5}{0.6\times10^{-4}}\right)$$

$$\therefore \quad |J_n| = 16\times10^{-10}\ \text{A/cm}^2$$

25. **(a)**

Given, $I_{D1} = 1$ mA for $V_{DS1} = 0.5$ V

$I_{D2} = 1.8$ mA for $V_{DS2} = 2.5$ V

For drain current (I_D) in saturation region of operation when channel length modulation present is,

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_T)^2(1+\lambda V_{DS})$$

$$I_D \propto (1+\lambda V_{DS})$$

$$\frac{I_{D1}}{I_{D2}} = \frac{1+\lambda V_{DS1}}{1+\lambda V_{DS2}}$$

$$\frac{1}{1.8} = \frac{1+\lambda\times0.5}{1+\lambda\times2.5}$$

$$\Rightarrow \quad 1+2.5\lambda = 1.8+0.9\lambda$$

$$\Rightarrow \quad 1.6\lambda = 0.8$$

$$\lambda = \frac{0.8}{1.6} = 0.5\ \text{V}^{-1}$$

26. **(b)**

Clearly from the given graph,

Semiconductor potential, $\phi_s = V_G - V_{ox} = 1.8 - 1.2 = 0.6$ V

The width of depletion region, under the strong inversion,

$$W_{max} = \left[\frac{2\epsilon_{Si}(\phi_s)}{qN_a}\right]^{1/2}$$

$$W_{max} = \left[\frac{2\times1.04\times10^{-12}\times0.6}{1.6\times10^{-19}\times1.5\times10^{15}}\right]^{1/2}$$

$$W_{max} = 0.72\times10^{-4}\ \text{cm} = 0.72\ \mu\text{m}$$

27. **(c)**

At flatband voltage, hole concentration is equal to doping concentration.

$\therefore$ At the junction, $p = N_a = 10^{16}\ \text{cm}^{-3}$

At threshold voltage, e^- concentration is equal to doping concentration.

$\therefore$ At the junction, $n = N_a = 10^{16}\ \text{cm}^{-3}$

$$\therefore \quad p(x=0) = \frac{n_i^2}{n} = \frac{10^{20}}{10^{16}}$$

$$p = 10^4\ \text{cm}^{-3}$$

28. (a)

Under active mode biasing

Collector base junction is reverse bias. The punch through voltage,

$$V_{CB} \propto \left[\frac{N_C N_B}{N_C + N_B}\right]$$

Clearly $[V_{CB}]_{Tr\cdot A} < [V_{CB}]_{Tr\cdot B}$

and it is limited by Avalanche Breakdown.

29. (c)

Let us assume that D_I acceptor atoms per cm^2 are implanted into a p-type substrate directly adjacent to the oxide-semiconductor interface. The shift in threshold voltage due to the implant is

$$\Delta V_T = \frac{+qD_I}{C_{ox}}$$

No. of acceptor atoms per unit area = $\dfrac{C_{ox} \times \Delta V_T}{e}$

$$C_{ox} = \frac{\varepsilon_{ox}}{t} = \frac{3.9 \times 8.854 \times 10^{-14}}{22 \times 10^{-8}}$$

$$C_{ox} = 1.5695 \times 10^{-6}\ \text{F/cm}^2$$

No. of acceptor atoms per unit area

$$= \frac{1.5695 \times 10^{-6} \times 0.5}{1.6 \times 10^{-19}}$$

$$= 4.9 \times 10^{12}\ \text{atoms/cm}^2$$

$$\simeq 5 \times 10^{12}\ \text{atoms/cm}^2$$

30. (d)

$$P_i = \frac{1}{n_i q(\mu_n + \mu_p)} \Rightarrow \rho_i \propto \frac{1}{n_i}$$

$$\Rightarrow \quad \frac{\rho_{i_2}}{\rho_{i_1}} = \frac{n_{i_1}}{n_{i_2}} = \frac{T_1^{3/2} e^{-E_{G_o}/2KT_1}}{T_2^{3/2} e^{-E_{G_o}/2KT_2}}$$

$$\Rightarrow \quad 0.1 = \left(\frac{300}{330}\right)^{3/2} e^{\frac{E_{G_o}}{2K}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)}$$

$$\Rightarrow \quad -2.1596 = \frac{E_{G_o}}{2K}\left(\frac{1}{330} - \frac{1}{300}\right)$$

$$\Rightarrow \quad E_{G_o} = \frac{-2.1596 \times 2K}{-3.03 \times 10^{-4}} = \frac{2.1596 \times 2 \times 8.625 \times 10^{-5}}{3.03 \times 10^{-4}} = 1.229\ \text{eV} \simeq 1.3\ \text{eV}$$

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