CLASS TEST

Sl.: 01SK_EC_ABCDEFGHI_160625

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ELECTRONIC DEVICES

EC-EE

Date of Test : 16/06/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

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

2. (a)

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

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

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

α = common base current gain = $\gamma\beta^*$ = 0.98 × 0.98 = 0.9604

3. (b)

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

4. **(d)**

Hall effect is used to determine the following

* type of semiconductor
* carries concentration
* conductivity
* mobility

5. **(c)**

6. (b)

$$I'_{CBO} = 500 \times 10^{-9}\left[2^{\frac{90-25}{10}}\right] = 45.25\ \mu\text{A}$$

7. **(b)**

8. **(b)**

Given, optical power incident on photodiode is,

$$P_0 = 3\ \mu\text{W}$$

Photocurrent, $I_p = 4\ \mu\text{A}$

Responsivity, $R = \frac{I_P}{P_0} = \frac{4}{3}\ \text{A/W} = 1.33\ \text{A/W}$

9. **(c)**

Flat band voltage of MOS capacitor is,

$$V_{FB} = \phi_{ms} - \frac{Q_s}{C_{ox}}$$

Given,
$$V_{FB} = -1.5 \text{ V}$$
$$Q_s = 4.5 \times 10^{-8} \text{ C/cm}^2$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{4 \times 8.85 \times 10^{-14}}{400 \times 10^{-8}}$$

$\therefore$
$$C_{ox} = 8.85 \times 10^{-8} \text{ F/cm}^2$$

$$-1.5 = \phi_{ms} - \frac{4.5 \times 10^{-8}}{8.85 \times 10^{-8}}$$

$\therefore$
$$\phi_{ms} = -0.992 \text{ V}$$

10. (b)

Given, MOSFET is operated in saturation region and channel length modulation is present,

$\therefore$ Drain current,
$$I_D = \mu_n C_{ox} \frac{W}{2L}(V_{GS} - V_T)^2 [1 + \lambda V_{DS}] \quad \text{...(i)}$$

Drain to source conductance,
$$g_{ds} = \frac{\partial I_D}{\partial V_{DS}} = \mu_n C_{ox} \frac{W}{2L}(V_{GS} - V_T)^2 (\lambda) \quad \text{...(ii)}$$

From equation (i), we can write,
$$\frac{I_D}{1 + \lambda V_{DS}} = \mu_n C_{ox} \frac{W}{2L}(V_{GS} - V_T)^2$$

We can re-write equation (ii) as,
$$g_{ds} = \frac{I_D}{1 + \lambda V_{DS}} \cdot \lambda$$

or,
$$g_{ds} = \frac{I_D}{\frac{1}{\lambda} + V_{DS}}$$

11. (b)

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

12. (a)

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

Given,
$$\phi_s = 0.035 \text{ V}$$
$$V_{ox} = \frac{\sqrt{2qN_A \varepsilon_{si} \phi_s}}{C_{ox}}$$
$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 2 \times 10^{-9} \text{ F/cm}^2$$
$$V_{ox} = 1.91 \text{ V}$$
$$V_G = 1.945 \text{ V}$$

13. (c)

Force due to magnetic field,
$$\vec{F}_m = q\vec{v}_d \times \vec{B} = q\mu_p \vec{E}_{\text{applied}} \times \vec{B} = \frac{q\mu_p V_x}{L}\hat{x} \times (-10\hat{z})$$
$$= \frac{100 q\mu_p}{L}\hat{y}$$
$$\vec{F}_{ei} = \text{force due to induced Hall electric field} = -\vec{F}_m$$
$$= \frac{100 q\mu_p}{L}(-\hat{y}) = q\vec{E}_{\text{ind}}$$
$$\vec{E}_{\text{ind}} = \frac{100\mu_p}{L}(-\hat{y})$$

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

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

14. (c)

$$\rho_{max} = \frac{1}{\sigma_{min}} = \frac{1}{(2q\sqrt{\mu_n\mu_p})n_i}$$
$$\sigma_{min} = 2qn_i\sqrt{\mu_n\mu_p} = 2\times 1.6\times 10^{-19}\times n_i \times \sqrt{1600\times 400}$$
$$= 25.6\times 10^{-17}\times n_i$$
$$\rho_{max} = \frac{1}{25.6\times 10^{-17}\times n_i}$$
$$n_i = \frac{10^{17}}{25.6\times \rho_{max}} = \frac{10^{17}}{25.6\times 5\times 10^3}\text{ cm}^{-3}$$
$$n_i = \frac{1}{128}\times 10^{14} = \frac{1000}{128}\times 10^{11}\text{ cm}^{-3}$$
$$n_i = 7.8125\times 10^{11}\text{ cm}^{-3}$$

15. (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 = $\frac{2.495-2.475}{2.495}\times 100 = 0.8\%$

16. (b)

$$W = K\sqrt{V_{bi}+V_R}\,; \quad K \text{ is constant}$$
$$\therefore \quad \frac{W_2}{W_1} = \sqrt{\frac{V_{bi}+V_{R2}}{V_{bi}+V_{R1}}}$$
$$\frac{W_2}{2\ \mu\text{m}} = \frac{\sqrt{0.8+7.2}}{\sqrt{0.8+1.2}} = \frac{\sqrt{8}}{\sqrt{2}} = 2$$
$$W_2 = 4\ \mu\text{m}$$

17. (c)

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

$$= \frac{e10^{16} \cdot D_p}{L} = \frac{1.6\times10^{-19}\times10^{16}\times10}{10\times10^{-4}}$$

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

18. (d)

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

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

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

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

$$1.8 + 9\lambda = 2$$

$$3\lambda = 0.20$$

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

19. (d)

$$\text{Photocurrent} = 0.65 \times 10 \times 10^{-6} = 6.5 \text{ μA}$$

20. (d)

As doping increases, Fermi level moves closer to the conduction band.

21. (b)

For n-type substrate, inversion occurs for higher negative voltage. So, point 1 corresponds to inversion.

For low negative voltages, first the substrate becomes depleted of charge carriers and then inversion starts. The point at which inversion starts is threshold point i.e. point 2.

Point 3 corresponds to depletion region.

For positive voltage accumulation of electrons occurs in n-type substrate. Hence point 4 corresponds to accumulation.

22. (d)

n = new concentration of electrons at the surface

n_0 = equilibrium concentration of electrons

$$n_0 = \frac{n_i^2}{p_0} \approx \frac{n_i^2}{N_A} = 1.8\times10^5 \text{ cm}^{-3}$$

$$n = n_0 e^{\Psi/V_t}; \quad V_t = \frac{kT}{q}, \qquad \Psi = \text{surface potential}$$

$$\Psi = \frac{kT}{q} ln\left(\frac{n}{n_0}\right) = 0.026\, ln\left(\frac{3\times10^{10}}{1.8}\right) \approx 0.612 \text{ V}$$

23. (c)

In linear region

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

$$\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{linear}} = k'_n V_{DS} \qquad ...(1)$$

$$\left[\begin{array}{l}(\text{here } k_n = \mu_n C_{ox})\\ k'_n = k_n\left(\frac{W}{L}\right)\\ k = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\\ k = \frac{1}{2}k'_n\\ k'_n = 2k\end{array}\right]$$

In saturation region

$$I_D = k(V_{GS}-V_T)^2$$

$$\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{saturation}} = 2k(V_{GS}-V_T) \qquad ...(2)$$

$$\frac{\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{linear}}}{\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{saturation}}} = \frac{k'_n V_{DS}}{2k(V_{GS}-V_T)}$$

$$\frac{\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{linear}}}{\left(\frac{\partial I_D}{\partial V_{GS}}\right)_{\text{saturation}}} = \frac{2k V_{DS}}{2k(V_{GS}-V_T)} = \frac{V_{DS}}{(V_{GS}-V_T)}$$

24. (c)

$$C \propto \frac{1}{\sqrt{V_{bi}+V_{RB}}}$$

$$\frac{C_1}{C_2} = \frac{\sqrt{V_{bi}+V_{RB2}}}{\sqrt{V_{bi}+V_{RB1}}}$$

at $V_{RB1} = 0$ V, $C_1 = 1\ \mu$F.

at $V_{RB2} = 6$ V, $C_2 = 0.5\ \mu$F.

$$\frac{1}{0.5} = \frac{\sqrt{V_{bi}+6}}{\sqrt{V_{bi}+0}}$$

$$2 = \frac{\sqrt{V_{bi}+6}}{\sqrt{V_{bi}}}$$

$$4V_{bi} = V_{bi}+6$$

$$3V_{bi} = 6$$

$$V_{bi} = 2\text{ V}$$

25. (b)

Diffusion potential (or) built in potential,

$$V_{bi} = \text{Area under the electric field distribution curve}$$
$$= \text{Area under given curve (which resembles triangle)}$$
$$V_{bi} = \frac{1}{2} \times \text{Base} \times \text{height} = \frac{1}{2} \times (W_P + W_N) \times (-E)$$

magnitude of diffusion potential

$$|V_{bi}| = \left|\frac{1}{2} \times (W_P + W_N) \times (-E)\right|$$
$$= \frac{1}{2} \times 4\ \mu\text{m} \times 15 \times 10^4\ \text{V/m}$$
$$|V_{bi}| = 0.3\ \text{V}$$

26. (a)

We know that,

the net hole density varying along 'x' is

$$P_n(x) = P_{no} + G_L \tau_P$$

but, $$G_L = G_{LO}\left[1 - \frac{x}{L}\right]$$

$\therefore$ $$P_n(x) = P_{no} + G_{LO}\,\tau_P\left[1 - \frac{x}{L}\right]$$

At the middle of the silicon bar, the hole density $\left(\text{i.e., at } x = \frac{L}{2}\right)$

$$P_0(x)\big|_{x=\frac{L}{2}} = P_{no} + G_{LO}\,\tau_P\left[1 - \frac{x}{L}\right]$$

Given $$P_0(x)\big|_{\text{At } x=\frac{L}{2}} = 10^9\ \text{cm}^{-3}$$

$$P_{no} = 10^8\ \text{cm}^{-3}$$

$\therefore$ $$10^9 = 10^8 + 10^{15}\,\tau_p\left[1 - \frac{1}{2}\right] \qquad \because x = \frac{1}{2}(L)$$

$$\tau_p = \frac{10^9 - 10^8}{\frac{1}{2} \times 10^{15}} = 1.8 \times 10^{-6}\ \text{sec}$$

27. (b)

Given, MOSFET operating in saturation region,

Drain current, $$I_D = \frac{\mu_n C_{ox} W}{2L}(V_{gs} - V_{th})^2 \qquad \text{...(i)}$$

Transconductance, $$g_m = \frac{\partial I_D}{\partial V_{gs}}$$

$\therefore \quad g_m = \dfrac{\partial}{\partial V_{gs}}\left[\dfrac{\mu_n C_{ox} W}{2L}(V_{gs} - V_{th})^2\right]$

$$g_m = \frac{\mu_n C_{ox} W}{L}(V_{gs} - V_{th}) \quad \text{...(ii)}$$

Now divide equation (i) by equation (ii),

$$\frac{I_D}{g_m} = \frac{V_{gs} - V_{th}}{2}$$

$\Rightarrow \quad V_{gs} - V_{th} = \dfrac{2I_D}{g_m} = \dfrac{2 \times 1}{1} = 2\text{ V}$

28. **(c)**

29. **(c)**

Fill factor of solar cell is,

$$\text{F.F.} = \frac{\text{Maximum power obtained}}{V_{oc} \times I_{sc}}$$

$$0.65 = \frac{65 \times 10^{-3}}{V_{oc} \times I_{sc}}$$

$\therefore \quad V_{oc} \times I_{sc} = \dfrac{65 \times 10^{-3}}{0.65} = 100\text{ mW}$

$\therefore$ Option (c) satisfies the result ($V_{oc} \times I_{sc}$ = 40 mA × 2.5 V = 100 mW)

30. **(c)**

Given, $\mu_n C_{ox}\dfrac{W}{L} = 1.5 \times 10^{-3}\text{ A/V}^2$

$$V_T = 0.65\text{ V}$$
$$V_{GS} = 4\text{ V}$$
$$V_{DS} = 6\text{ V}$$

Power dissipation in the MOSFET is,

$$P = V_{DS} \times I_{DS}$$

where, I_{DS} is drain to source saturation current.
Since the MOSFET is operating in saturation region,

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

$$= \frac{1}{2} \times 1.5 \times 10^{-3}(4 - 0.65)^2$$

$$I_{DS} = 8.42 \times 10^{-3}\text{ A}$$

Power dissipation, $P = 6 \times 8.42 \times 10^{-3}$

$\therefore \quad P = 50.50\text{ mW}$

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