CLASS TEST

Sl.: 01DLSK_EC_ABCDEFG_030826

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ELECTRONIC DEVICES

ELECTRONICS ENGINEERING

Date of Test : 03/08/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

Given,
$$\alpha = 0.98$$
$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = 49$$
$$I_{CEO} = (1+\beta)I_{CBO}$$
$$= 50 \times 4 \times 10^{-6} = 0.2 \text{ mA}$$
$$I_{CQ} = \beta I_{BQ} + I_{CEO}$$
$$= 49 \times 100 \times 10^{-6} + 0.2 \times 10^{-3}$$
$$= (4.9 + 0.2) \times 10^{-3}$$
$$I_{CQ} = 5.1 \text{ mA}$$

2. (d)

$$C_j = \frac{\varepsilon_s A}{W_{dep}}$$
$$W_{dep} = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_a}+\frac{1}{N_d}\right)(V_{bi}+V_R)}$$

For p^+n diode, $N_a >> N_d$

So,
$$W_{dep} = \sqrt{\frac{2\varepsilon_s}{qN_d}(V_{bi}+V_R)}$$
$$W_{dep} \propto \frac{1}{\sqrt{N_d}}$$
$$C_j \propto \frac{1}{W_{dep}} \propto \sqrt{N_d}$$
$$\frac{1}{C_j^2} \propto \frac{1}{N_d}$$

3. (b)

Given for silicon P^+N junction diode,

Carrier lifetime, $\tau_p = 10\ \mu\text{sec}$

Mobility, $\mu_p = 3500 \text{ cm}^2/\text{V-sec}$

$$\frac{D_p}{L_p} = \frac{D_p}{\sqrt{D_p \tau_p}} = \sqrt{\frac{D_p}{\tau_p}} = \sqrt{\frac{\mu_p \cdot V_T}{\tau_p}}$$

$\therefore$
$$\frac{D_p}{L_p} = \sqrt{\frac{3500 \times 0.026}{10 \times 10^{-6}}} \approx 3016 \text{ cm/sec}$$

4. (b)

We know that,

Diffusion Current density, $J = qD_n \dfrac{dn}{dx}$

$$J = 1.6 \times 10^{-19} \times 225 \times \frac{10^{18} - 7 \times 10^{17}}{0.1}$$

$\therefore$
$$J = 108 \text{ A/cm}^2$$

5. (d)

Given, $V_{RB1} = 25\text{ V}\ ;\quad W_1 = 10\ \mu\text{m}$

In linearly graded diode, $W \propto (V_{bi} + V_{RB})^{1/3}$

Given, $|V_{bi}| << |V_{RB}|$

$\therefore\quad W \propto V_{RB}^{1/3}$

$$\frac{W_1}{W_2} = \left(\frac{V_{RB1}}{V_{RB2}}\right)^{1/3}$$

$$\frac{10\ \mu\text{m}}{W_2} = \left(\frac{25}{50}\right)^{1/3}$$

$$W_2 = 10(2)^{1/3}\ \mu\text{m} \approx 12.6\ \mu\text{m}$$

6. (c)

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

or $C_D = \dfrac{\tau}{r_d}$; where r_d = dynamic resistance

or $C_D = \tau g_d$; where g_d = dynamic conductance

$\therefore\quad 2 \times 10^{-7} = 5 \times 10^{-6} \times g_d$

$\therefore\quad g_d = \dfrac{2\times10^{-7}}{5\times10^{-6}} = 40\text{ m}\mho$

7. (a)

$$V_{\text{bi}} = \frac{1}{2}E_{\max}\,x_{\text{dep}}$$

$$= \frac{1}{2}\times1.80\times10^{6}\times0.50\times10^{-6} = \frac{1.80}{4} = 0.45\text{ V}$$

8. (b)

Given, two ideal p^+-n step junction diodes,
for p^+-n step junction diode,

the reverse saturation current, $I_0 \cong qA\dfrac{D_P}{L_P}\dfrac{n_i^2}{N_D}$

$\therefore\quad I_0 \propto \dfrac{1}{N_D}\dfrac{D_P}{L_P}\ ;\ I_0 \propto \dfrac{\sqrt{\mu_P}}{N_D}$

$\therefore\quad \dfrac{I_{01}}{I_{02}} = \dfrac{N_{D2}}{N_{D1}}\sqrt{\dfrac{\mu_{P2}}{\mu_{P1}}}$

also given, $I_{01} = -1.0\text{ mA},\ I_{02} = -0.1\text{ mA}$

$\therefore\quad \dfrac{-1.0\text{ mA}}{-0.1\text{ mA}} = \dfrac{N_{D2}}{N_{D1}}\sqrt{\dfrac{\mu_{P1}}{\mu_{P2}}} = \dfrac{2\times N_{D2}}{N_{D1}}$

$$\frac{N_{D1}}{N_{D2}} = 0.2$$

$\therefore\quad N_{D1} = 0.2 \times N_{D2}$

9. (c)

Given, cross sectional area of copper wire,

$$A = 7.85 \times 10^{-7}\ \text{m}^2$$

$$\text{Conduction electron density, } n = 8.5 \times 10^{28}\ \text{m}^{-3}$$

$$\text{current, } I = 1.5\ \text{A}$$

We know that, $\quad$ current, $I = nAV_d e$

where V_d : drift velocity of electron,

$$V_d = \frac{I}{nAe} = \frac{1.5}{8.5\times10^{28}\times7.85\times10^{-7}\times1.6\times10^{-19}}$$

$$\therefore \quad V_d = 1.4 \times 10^{-4}\ \text{m/sec}$$

10. (c)

Given, $\quad$ Length of silicon bar, $L = 3\ \text{mm} = 3 \times 10^{-3}\ \text{m}$

Cross section area of bar, $A = 50\ \mu\text{m} \times 100\ \mu\text{m}$

Current through bar, $I = 1\ \mu\text{A}$

Intrinsic resistivity, $\rho_i = 2.3 \times 10^5\ \Omega\text{-cm} = 2.3 \times 10^3\ \Omega\text{-m}$

We know that,

$$\text{Electric field intensity, } E = \frac{J}{\sigma_i}$$

$$E = \frac{J}{\sigma_i} = \frac{I}{A}\times\frac{1}{\sigma_i} = \frac{I}{A}\cdot\rho_i\ \text{V/m}$$

$$\therefore \quad E = \frac{10^{-6}}{50\times10^{-6}\times100\times10^{-6}}\times2.3\times10^3$$

$$E = 4.6 \times 10^5\ \text{V/m}$$

The applied voltage across the bar is,

$$V_{\text{bar}} = E \times L = 4.6 \times 10^5 \times 3 \times 10^{-3}$$

$$\therefore \quad V_{\text{bar}} = 1380\ \text{V}$$

11. (c)

$$J_p(\text{diffusion}) = -qD_p\frac{dp}{dx}$$

$$J_p = -qD_p\frac{dp}{dx} = -qD_p\left(\frac{p_1-p_2}{x_1-x_2}\right)$$

$$\frac{J_p}{qD_p} = \frac{-(p_1-p_2)}{(0-0.01)}$$

$$p_1 - p_2 = (+0.01)\times\frac{20}{1.6\times10^{-19}\times10} = +0.0125\times10^{19}$$

$$p_2 = p_1 - 0.0125 \times 10^{19} = 4 \times 10^{17} - 1.25 \times 10^{17}$$

$$p_2 = 2.75 \times 10^{17}\ \text{cm}^{-3}$$

12. (a)

Given, $\quad$ Acceptor concentration, $N_a = 10^{17}\ \text{cm}^{-3}$

Cross sectional area of Si bar, $A = 0.5\ \text{cm}^2$

Steady state excess hole concentration at $x = 0$ is,

$$\Delta p = 5 \times 10^{16}\ \text{cm}^{-3}$$

We know that,
the hole current density at a distance 'x' in a Si bar by injection of excess carriers,

$$J_p = -qD_p \frac{dp}{dx}$$

where, $$p = p_0 + \Delta p e^{\frac{-x}{L_p}}$$

$\therefore$ $$J_p = -qD_p \frac{d}{dx}\left[p_0 + \Delta p e^{\frac{-x}{L_p}}\right]$$

$$= +q\frac{D_p}{L_p}\Delta p\, e^{\frac{-x}{L_p}}$$

We know that, hole current, $I_p = J_p \cdot A$

$\therefore$ $$I_p = qA\frac{D_p}{L_p}\Delta p e^{\frac{-x}{L_p}}$$

where, D_p : diffusion coefficient of holes
L_p : diffusion length of holes

We know that, $D_p = \mu_p V_T = 500 \times 0.026 = 13$ cm/s

$$L_p = \sqrt{D_p \tau_p} = \sqrt{13\times 10^{-10}} = 3.61\times 10^{-5}\,\text{cm}$$

$\therefore$ $$I_p = 1.6\times 10^{-19}\times 0.5\times \frac{13}{3.61\times 10^{-5}}(5\times 10^{16})e^{\frac{-1000\times 10^{-8}}{3.61\times 10^{-5}}}$$

$$I_p = 1.092 \times 10^3 \text{ A}$$

13. (b)

From the fermi probability distribution function,

$$f(E) = \frac{1}{1+e^{(E-E_F)/kT}}$$

where, 'E' is the allowed energy state.
and E_F is the fermi energy state.

Given, $E = E_C + kT$,

$$f(E_C + kT) = \frac{1}{1+e^{(E_C+kT-E_F)/kT}} = e^{-10}$$

$$1+e^{(E_C+kT-E_F)/kT} = e^{10}$$

$$e^{(E_C+kT-E_F)/kT} = e^{10} - 1$$

$$\frac{E_C + kT - E_F}{kT} = \ln[e^{10} - 1]$$

$$E_C + kT - E_F = kT[\ln(e^{10} - 1)]$$

$$E_C - E_F + kT = kT[9.99]$$

$$E_C - E_F = 8.99\, kT \simeq 9\, kT$$

$\therefore$ $$E_F \simeq E_C - 9\, kT$$

14. (b)

We know that,

In thermal equilibrium no net current flows in a semiconductor,

i.e., $J_n(x) = 0$

$$J_n(x) = q\mu_n n(x)E(x) + qD_n \frac{dn(x)}{dx} = 0$$

$$\therefore \quad E(x) = -\frac{D_n}{\mu_n}\frac{1}{n(x)}\frac{dn(x)}{dx}$$

given, $n(x) = N_0 e^{-\alpha x}$

$$\frac{dn(x)}{dx} = -\alpha N_0 e^{-\alpha x}$$

$$\therefore \quad E(x) = -\frac{D_n}{\mu_n}\frac{1}{n(x)}\left[-\alpha N_0 e^{-\alpha x}\right]$$

$$E(x) = -\frac{D_n}{\mu_n}\frac{1}{N_0 e^{-\alpha x}}\left[-\alpha N_0 e^{-\alpha x}\right]$$

$$E(x) = \frac{D_n}{\mu_n}\cdot\alpha$$

where, $$\frac{D_n}{\mu_n} = \frac{kT}{q} = \frac{0.026\,eV}{1.6\times10^{-19}C} = \frac{0.026\times1.6\times10^{-19}J}{1.6\times10^{-19}C}$$

$$\therefore \quad \frac{D_n}{\mu_n} = 0.026\text{ V}$$

$$\therefore \quad E(x) = 0.026 \times \frac{1}{10^{-4}\text{cm}}$$

$$E(x) = 260\text{ V/cm}$$

15. (b)

Depletion charges are negative and metal voltage is positive hence it is P-substrate MOS capacitor in depletion mode.

16. (c)

For ideal MOS capacitor, flat band voltage $V_{FB} = 0$ V

and $V_{FB} = \phi_{MS} - \dfrac{Q'_{ox}}{C_{ox}}$ for Non-ideal MOS capacitor.

17. (c)

Given: $I_s = 20 \times 10^{-8}$ A, $T = 500°$ K

$V_{BE} = 0.88$ V, $\eta = 2$

We know that, Emitter current, $$I_E = I_s\left(e^{\frac{qV_{BE}}{\eta KT}} - 1\right)$$

$$I_E = 20\times10^{-8}\left(e^{\frac{1.6\times10^{-19}\times0.88}{500\times2\times1.38\times10^{-23}}} - 1\right)$$

$$= 20 \times 10^{-8}(26981.28 - 1)$$

$$= 5.396 \times 10^{-3}$$

$$I_E = 5.396 \text{ mA}$$

18. (d)

For a solar cell, figure of merit is also known as fill factor.

We know that, Fill factor $= \dfrac{V_m I_m}{I_{sc} V_{oc}}$

From the given graph, $V_m = 3$ V, $I_m = 2$ mA

$$I_{sc} = 4 \text{ mA}$$

$$\therefore \quad V_{oc} = \frac{V_m I_m}{I_{sc}(\text{fill factor})}$$

$$V_{oc} = \frac{3\times 2}{4\times 0.7}$$

$$V_{oc} = \frac{3}{1.4}$$

$$\therefore \quad V_{oc} = 2.14 \text{ volt}$$

19. (d)

Substrate doping concentration,

$$N_A = 1.6 \times 10^{15} \text{ cm}^{-3}$$

$$\in_{si} = 1.04 \times 10^{-12} \text{ F/cm}$$

$$\psi_s = 0.026 \text{ V}$$

As the MOS capacitor is ideal.

$$\therefore \quad V_G = \psi_s - \frac{Q_d'}{C_{ox}}$$

where, $Q_d' = -\sqrt{2\in_{si} eN_A \psi_s}$

$$\therefore \quad V_G = \psi_s + \frac{\sqrt{2\in_{si} eN_A \psi_s}}{C_{ox}}$$

$$1.64 = 0.026 + \frac{\sqrt{2\times 1.04\times 10^{-12}\times 1.6\times 10^{-19}\times 1.6\times 10^{15}\times 0.026}}{C_{ox}}$$

$$1.614 = \frac{3.7208\times 10^{-9}}{C_{ox}}$$

$$C_{ox} = 2.305\times 10^{-9} = \frac{\in_{ox}}{t_{ox}}$$

$$t_{ox} = \frac{\in_{ox}}{2.305\times 10^{-9}}$$

$$= \frac{4\times 8.85\times 10^{-14}}{2.305\times 10^{-9}}$$

$$t_{ox} = 1.53 \times 10^{-4} \text{ cm}$$

$$t_{ox} = 1.53\ \mu\text{m}$$

20. (d)

The given curve is a high frequency C-V_G characteristics curve for p-type.

The gate oxide thickness for the two capacitors are same since they have same value of maximum capacitance ($C_{max} = C_{ox}$).

The minimum capacitance corresponds to the series combination of the oxide capacitance and the minimum depletion capacitance

$$C_{\min} = \frac{C_{ox} \cdot C_{s(\min)}}{C_{ox} + C_{s(\min)}}$$

For the same C_{ox}, larger $C_{s(\min)}$ results in larger $C_{\min}$. Since, capacitor 'a' has larger $C_{\min}$, it has higher doping in the semiconductor. (For a higher doped semiconductor, depletion width W_T is smaller and hence, $C_{s(\min)}$ is larger).

21. (c)

Responsivity is given as,

$$R = \frac{\eta e\lambda}{hc}$$

$$E_g = \frac{1.24}{\lambda(\mu m)}$$

$$\lambda(\mu\text{m}) = \frac{1.24}{1.1} = 1.127$$

$$\therefore \quad \lambda = 1.127\ \mu\text{m}$$

For detection, $\lambda < 1.127\ \mu$m. The minimum energy signal that can be detected has $\lambda = 1.127\ \mu$m.
For maximum responsivity,

$$\eta = 1$$

$$R_{\max} = \frac{e\lambda}{hc} = \frac{1.6 \times 10^{-19} \times 1.127 \times 10^{-6}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$$

$$R_{\max} = 0.091 \times 10^{-25} \times 10^{26}$$

$$= 0.91\ \text{A/W}$$

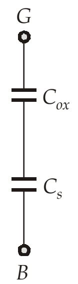
22. (d)

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

From the given characteristics, $C_{ox}A = C_{\max} = 10$ pF

$$\therefore \quad \text{Channel area,} \quad A = \frac{10 \times 10^{-12}}{2 \times 10^{-9}}\ \text{cm}^2 = 5 \times 10^{-3}\ \text{cm}^2$$

From the given characteristics,



$$A\left(\frac{C_{ox}\, C_{s(\min)}}{C_{ox} + C_{s(\min)}}\right) = 2\ \text{pF}$$

By solving, we get,

$$AC_{s\,(\min)} = 2.5\ \text{pF}$$

$$C_{s\,(\min)} = \frac{\varepsilon_{si}}{W_{d(\max)}} = \frac{2.5 \times 10^{-12}}{5 \times 10^{-3}}\ \text{F/cm}^2$$

$$W_{d\,(\max)} = \frac{1.04 \times 10^{-12}}{2.5 \times 10^{-12}} \times 5 \times 10^{-3}\ \text{cm} = 20.8\ \mu\text{m}$$

23. (a)

For p^+n junction,

$$\frac{1}{C_{dep}^2} = \frac{W_{dep}^2}{A^2 \in_s^2} = \frac{2(\phi_{bi} + V_r)}{qN_d \in_s A^2}$$

$\therefore$
$$\text{slope} = \frac{2}{qN_d \in_s A^2} = 2\times 10^{23} F^{-2}V^{-1}$$

$\therefore$
$$N_d = \frac{2}{2\times 10^{23}\times 1.6\times 10^{-19}\times 12\times 8.85\times 10^{-14}\times 10^{-8}}$$

$\therefore$
$$N_d = 5.88 \times 10^{15}\ \text{cm}^{-3}$$

24. (d)

According to space charge neutrality, the total negative space charge per unit area in p-side is equal to total positive space charge per unit area in n-side.

$\therefore$
$$\frac{1}{2}\left[0.8\times 8\times 10^{14}\right] = x_n \times 3 \times 10^{14}$$

$\therefore$
$$x_n = 1.067\ \mu\text{m}$$

The depletion width, $W = x_n + x_p$

$\therefore$
$$W = 1.067 + 0.8 = 1.867\ \mu\text{m}$$

25. (c)

We know that,

$$\text{Resistance, } R = \frac{\rho l}{A}$$

$$R \propto \rho \propto \frac{1}{N_D q\mu_n + N_A q\mu_p}$$

$\therefore$
$$R_1 \propto \frac{1}{N_D q\mu_n}; 0.5R_1 \propto \frac{1}{N_A q\mu_p}$$

From Eienstein relation, $\frac{D}{\mu} = V_T$

$$D = \mu V_T$$

$\therefore$
$$D \propto \mu$$

$$\frac{D_p}{D_n} = \frac{\mu_p}{\mu_n} = \frac{1}{50}$$

$\therefore$
$$\frac{R_1}{0.5R_1} = \frac{N_A q\mu_p}{N_D q\mu_n}$$

$\Rightarrow$
$$2 = \frac{N_A}{N_D}\times\frac{1}{50}$$

$\therefore$
$$N_A = 100\ N_D$$

26. (c)

For a n-type MOSFET having p-type substrate, in the depletion mode for $V_{GS} > V_{FB}$, the holes will be depleted with the increase in electrons causing band bending in the downward direction. In the accumulation mode for $V_{GS} < V_{FB}$, more holes are moved toward the interface causing band bending in the upward direction. Hence, option(c) is correct.

27. (d)

Given,
$$D_p = 100 \text{ cm}^2/\text{s}$$
$$\tau_p = 3 \times 10^{-7} \text{ sec}$$
base width, $W = 2\ \mu\text{m}$

We know that, diffusion length, $L_p = \sqrt{D_p \tau_p}$

$$L_p = \sqrt{100 \times 3 \times 10^{-7}} = 54.77\ \mu\text{m}$$

The common emitter current gain,

$$\beta \cong \frac{2L_p^2}{W^2} = \frac{2 \times (54.77 \times 10^{-4})^2}{(2 \times 10^{-4})^2}$$

$\therefore$ $\beta = 1500$

28. (b)

Given,
$$G_L = 10^{16} \text{ cm}^{-3}\text{s}^{-1}$$
$$\tau_n = \tau_p = 10\ \mu\text{s}$$
$$N_D = 10^{15} \text{ cm}^{-3}$$

excess carrier concentration under illumination,

$$\Delta n = \Delta p = \tau_p G_L = \tau_n G_L = 10 \times 10^{-6} \times 10^{16}$$

$\therefore$ $\Delta n = \Delta p = 10^{11} \text{ cm}^{-3}$

electron concentration, $n = n_{n0} + \Delta n$
$$= N_D + \Delta n$$
$$= 10^{15} + 10^{11} \simeq 10^{15} \text{ cm}^{-3}$$

hole concentration, $p = \dfrac{n_i^2}{N_D} + \Delta p = \dfrac{(10 \times 10^{10})^2}{10^{15}} + 10^{11} = 10^{11} \text{ cm}^{-3}$

29. (d)

Given,
$$\tau_r = \frac{10^9}{N} = \frac{10^9}{10^{19}} \text{sec}$$
$$\tau_{nr} = 10^{-7} \text{ s}$$

We know that, cutoff frequency,

$$f_c = \frac{1}{2\pi\tau}$$

where,
$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}} = \frac{1}{10^{-7}} + \frac{10^{19}}{10^9} = 10^{10}$$

$\therefore$ $\tau = 10^{-10}$ sec

$\therefore$ $f = \dfrac{1}{2\pi \times 10^{-10}} = 1.6 \text{ GHz}$

30. (a)

We know that,

$$V_T = V_{FB} + 2\psi_B + \frac{\sqrt{2 \in_s qN_A (2\psi_B)}}{C_{ox}}$$

$$= -1.1 + 0.84 + \frac{\sqrt{2 \times 11.9 \times 8.85 \times 10^{-14} \times 1.6 \times 10^{-19} \times 10^{17} \times 0.84}}{6.9 \times 10^{-7}}$$

$$= -0.016 \text{ V} \approx -0.02 \text{ V}$$

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