CLASS TEST

Sl. : 01SK_EC_ABCD_060822

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ELECTRONIC DEVICES

ELECTRONICS ENGINEERING

Date of Test : 06/08/2022

ANSWER KEY ➤

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

Detailed Explanations

1. (d)

Given,

Semiconductor bar length, $L = 3$ cm

DC voltage, $V = 8$ V

Electron mobility, $\mu_n = 1200\ \text{cm}^2/\text{V-sec}$

∴ drift velocity, $v_d = \mu_n \cdot E$

$$= \mu_n \cdot \frac{V}{L} = 1200 \times \frac{8}{3}$$

$$v_d = 3200\ \text{cm/sec}$$

$$v_d = 3.2 \times 10^3\ \text{cm/sec}$$

2. (b)

The Lattice scattering is related to the thermal motion of atoms.

∴ mobility varies as $T^{-3/2}$.

$$\therefore \qquad \mu \propto T^{-3/2}$$

Given, at $T_1 = 300$ K; $\mu_{n_1} = 1300\ \text{cm}^2/\text{V-s}$

at $T_2 = 400$ K; $\mu_{n_2} = ?$

$$\frac{\mu_{n_1}}{\mu_{n_2}} = \left(\frac{T_1}{T_2}\right)^{-\frac{3}{2}}$$

$$\frac{1300}{\mu_{n_2}} = \left(\frac{300}{400}\right)^{-\frac{3}{2}}$$

$$\mu_{n_2} = \frac{1300}{1.5396}$$

$$\mu_{n_2} = 844.375$$

$$\mu_{n_2} \approx 844\ \text{cm}^2/\text{V-sec}$$

3. (b)

Given, optical power incident on photodiode is,

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

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

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

4. (c)

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

but $\beta = \dfrac{\alpha}{1-\alpha}$

$$\therefore \qquad I_C = \beta I_B + \left(1 + \frac{\alpha}{1-\alpha}\right) I_{CO} = \beta I_B + \frac{1-\alpha+\alpha}{1-\alpha} I_{CO}$$

$$I_C = \beta I_B + \frac{1}{1-\alpha} I_{CO}$$

5. (b)

Maximum efficiency of solar panel is,

$$\eta_{\max} = \frac{P_{\max}}{P_R}$$

where, Power received, $P_R = P_D \times \text{area} = 1000 \times 3 = 3000$ W

$$\therefore \quad \eta = \frac{400}{3000} = \frac{4}{30} \times 100 = 13.33\ \%$$

6. (c)

Flat band voltage of MOS capacitor is,

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

Given, $V_{FB} = -1.5$ V

$Q_s = 4.5 \times 10^{-8}$ C/cm^2

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

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

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

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

7. (a)

Zener breakdown voltage is less because in higher doping region, depletion layer width is small and a small reverse voltage is able to break the covalent bond and gives sudden increase in current.

Hence, zener breakdown voltage V_1 corresponds to point A.

8. (c)

We know that,

$$P = p_0 + G_L \tau_p$$

where, P = Steady state minority concentration

p_0 = Thermal equilibrium concentration of holes

τ_p = Carrier life time

G_L = Generation rate of EHPs

but $$p_0 = \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{10^{16}} = 2.25 \times 10^4\ \text{cm}^{-3}$$

$$\therefore \quad G_L = \frac{P - p_0}{\tau_p} = \frac{(4 \times 10^4) - (2.25 \times 10^4)}{10^{-6}}$$

$\therefore \quad G_L = 1.75 \times 10^{10}$ cm^{-3}/s

9. **(c)**

Given, resistivity, $\rho = 1.5\ \Omega\text{-cm}$

Hall coefficient, $R_H = -1250\ \text{cm}^3/\text{C}$

Since, R_H is negative, the charge carriers are electrons.

Mobility, $\mu_e \approx \sigma|R_H|$

$$= \frac{1}{\rho}|R_H| = \frac{1}{1.5}\times 1250$$

$\therefore$ $= 833\ \text{cm}^2/\text{V-sec}$

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)**

Given,

Depletion layer width,

$$W_1 = 3\ \mu\text{m}$$

Reverse bias voltage, $|V_{R1}| = 1.5\ \text{V}$

But potential at the junction,

$$V_j = V_{bi} + V_R$$

For abrupt *pn* junction depletion width,

$$W \propto V_j^{1/2}$$

$\therefore$ $$W \propto \sqrt{V_{bi}+V_R}$$

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

It is also given that,

$$W_2 = 2W_1 = 6\ \mu\text{m}$$

$$|V_{R2}| = 7.5 \text{ V}$$

$$\therefore \quad \frac{3}{6} = \frac{\sqrt{V_{bi}+1.5}}{\sqrt{V_{bi}+7.5}}$$

$$\sqrt{V_{bi}+7.5} = 2\sqrt{V_{bi}+1.5}$$

$$V_{bi} + 7.5 = 4(V_{bi} + 1.5)$$

$$3V_{bi} = 1.5$$

$$\therefore \quad V_{bi} = 0.5 \text{ V}$$

12. **(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

$$|V_{bi}| = \left|\frac{1}{2}\times(W_P+W_N)\times(-E)\right|$$

$$= \frac{1}{2}\times 4\ \mu\text{m}\times 15\times 10^4 \text{ V/m}$$

$$|V_{bi}| = 0.3 \text{ V}$$

13. **(b)**

As drain is connected to gate for both MOSFETs, they will be in saturation mode of operation.

i.e., $I_{D1} = I_{D2}$

$$K_1(V_{GS1} - V_T)^2 = K_2(V_{GS2} - V_T)^2$$

Since, $K \propto W$; $K_2 = 2K_1$

$$K_1(V_{GS1} - V_T)^2 = 2K_1(V_{GS2} - V_T)^2$$

But $V_{GS1} = 5 - V_0$

$$V_{GS2} = V_0$$

$$(5 - V_0 - 1.5)^2 = 2(V_0 - 1.5)^2$$

$$3.5 - V_0 = \sqrt{2}(V_0 - 1.5)$$

$$3.5 - V_0 = \sqrt{2}\ V_0 - 2.12$$

$$2.414\,V_0 = 5.62$$

$$V_0 = 2.33 \text{ V}$$

14. **(b)**

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

$$\frac{C_{T1}}{C_{T2}} = \frac{\sqrt{V_{bi}+V_{RB2}}}{\sqrt{V_{bi}+V_{RB1}}}$$

at $V_{RB1} = 0$ V, $C_{T1} = 1\ \mu$F.

at $V_{RB2} = -6$ V, $C_{T2} = 0.5\ \mu$F.

$$\frac{C_{T1}}{C_{T2}} = \frac{\sqrt{V_{bi}+V_{RB2}}}{\sqrt{V_{bi}+V_{RB1}}}$$

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

$$\therefore \quad V_{bi} = -2\text{ V}$$

15. (a)

We know that,

the net hole density varying along 'x' is

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

but,

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

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

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

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

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

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

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

16. (c)

We know that, by mass action law, $np = n_i^2$ as per the charge neutrality,

$$N_D + p = N_A + n$$

for the addition of donor impurities,

$$N_A \approx 0$$

$$N_D + p = n$$

$$\Rightarrow \quad p = n - N_D$$

$$\therefore \quad (n - N_D)n = n_i^2$$

$$n^2 - nN_D - n_i^2 = 0$$

$$\therefore \quad n = \frac{N_D \pm \sqrt{N_D^2 + 4n_i^2}}{2}$$

$$n = \frac{N_D}{2} \pm \sqrt{n_i^2 + \left(\frac{N_D}{2}\right)^2}$$

The new concentration should be more than impurity concentration,

$$n = \frac{N_D}{2} + \sqrt{n_i^2 + \left(\frac{N_D}{2}\right)^2} = \frac{10^{18}}{2} + \sqrt{(1.5\times10^{10})^2 + \left(\frac{10^{18}}{2}\right)^2}$$

$$= 1 \times 10^{18}\ \text{cm}^{-3}$$

17. **(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, $$g_m = \frac{\partial I_D}{\partial V_{gs}}$$

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

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

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

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

$$\Rightarrow \qquad V_{gs} - V_{\text{th}} = \frac{2I_D}{g_m} = \frac{2\times1}{1} = 2\ \text{V}$$

18. **(d)**

We know that,

Diode voltage V_D decreases by 2.5 mV per 1°C rise in temperature.

Given, temperature, $T_1 = 20°\text{C}$

$$\frac{\Delta V_D}{\Delta T} = -2.5\ \text{mV/°C}$$

$$\frac{V_{D2} - V_{D1}}{(T_2 - 20)} = -2.5 \times 10^{-3}$$

$$\therefore \qquad \frac{(600 - 700)\times10^{-3}}{-2.5\times10^{-3}} = T_2 - 20$$

$$\therefore \qquad T_2 = 60°\text{C}$$

19. (a)

Given, resistance, $R_1 = 10\ \Omega$ at $T_1 = 364$ K

$R_2 = 100\ \Omega$ at $T_2 = 333$ K

but, $$R = \frac{\rho l}{A} \qquad \therefore R \propto \rho$$

but, resistivity $$\rho = \frac{1}{n_i q[\mu_n + \mu_p]}$$

where, n_i is intrinsic carrier concentration

$$n_i = A_0 T^{3/2} e^{\frac{-E_{go}}{2kT}}$$

$\therefore$ $R \propto \rho \propto \frac{1}{n_i}$ [$\because$ given change due to temperature variation in n_i]

$$\therefore \quad R \propto \frac{1}{n_i}$$

$$\frac{R_1}{R_2} = \frac{n_{i2}}{n_{i1}} = \frac{T_2^{3/2}}{T_1^{3/2}} e^{\frac{-E_{go}}{2}\left[\frac{1}{kT_2} - \frac{1}{kT_1}\right]}$$

$$\therefore \quad \frac{10}{100} = \left(\frac{333}{364}\right)^{3/2} e^{\frac{-Ego}{2}\left[\frac{1}{kT_2} - \frac{1}{kT_1}\right]}$$

by taking 'ln' on both sides, we get,

$$-\frac{E_{go}}{2}\left[\frac{1}{kT_2} - \frac{1}{kT_1}\right] = -2.17$$

$$\therefore \quad \frac{E_{go}}{2}[2.95] = 2.17$$

$$\therefore \quad E_{go} = 1.47 \text{ eV}$$

20. (a)

We know that,

Potential function, $$\phi_s = V_T \ln\left(\frac{n_0}{n_i}\right)$$

or, $$\phi_s = V_T \ln\left[\frac{N_D}{n_i}\right]$$

Let potential at 1 μm distance is ϕ_{s1},

$$\therefore \quad \phi_{s1} = V_T \ln\left[\frac{N_{D2}}{n_i}\right] \qquad \text{...(i)}$$

$$\phi_{s1} = V_T \ln\left[\frac{10^{16}}{n_i}\right]$$

Let potential at 2 μm distance is ϕ_{s2},

$$\therefore \qquad \phi_{s2} = V_T \ln\left[\frac{N_{D1}}{n_i}\right] \qquad \text{...(ii)}$$

It is given magnitude of potential difference,

i.e., $$|\phi_{s1} - \phi_{s2}| = 0.12 \text{ V}$$

$$V_T \ln\left[\frac{N_{D2}}{N_{D1}}\right] = 0.12 \text{ V}$$

$$\therefore \qquad \frac{N_{D2}}{N_{D1}} = e^{\frac{0.12}{0.026}}$$

$$\Rightarrow \qquad N_{D1} = 9.89 \times 10^{13} \text{ cm}^{-3}$$

21. **(c)**

Given, acceptor concentration, $N_a = 10^{15}$ cm^{-3}

Diffusion coefficient, $D_n = 35$ cm^2 sec^{-1}

Carrier life time, $\tau_n = 2.57$ μsec

By neglecting the contribution of n^+-layer, we get,

Short circuit current, $$I_s = \frac{qAD_n n_i^2}{L_n N_a}$$

where, $L_n = \sqrt{D_n \tau_n} = 9.48 \times 10^{-3}$ cm

$$I_s = \frac{1.6 \times 10^{-19} \times 35 \times (1.5 \times 10^{10})^2}{9.48 \times 10^{-3} \times 10^{15}} = 1.33 \times 10^{-10} \text{ A}$$

Light generated current, $I_L = qAG_L L_n$

$$\therefore \qquad I_L = 1.6 \times 10^{-19} \times 1 \times 2.7 \times 10^{19} \times 9.48 \times 10^{-3}$$

$$\therefore \qquad I_L = 40.95 \text{ mA}$$

Open circuit voltage, $$V_{OC} = V_T \ln\left[1 + \frac{I_L}{I_S}\right]$$

$$\therefore \qquad V_{OC} = 26 \times 10^{-3} \ln\left[1 + \frac{40.95 \times 10^{-3}}{1.33 \times 10^{-10}}\right]$$

$$V_{OC} = 0.51 \text{ V}$$

22. **(b)**

Since two MOSFETs are operated in saturation mode,

$$I_{DN} = \mu_n C_{ox} \frac{W_n}{2L}(V_{GSN} - V_{TN})^2$$

or, $$I_{DN} = \mu_n C_{ox} \frac{W_n}{2L}(V_{OV})^2$$

where, overdrive voltage $V_{OV} = V_{GSN} - V_{TN}$

Similarly, $$I_{DP} = \mu_p C_{ox} \frac{W_p}{2L}(V_{GSP} - V_{TP})^2$$

or, $$I_{DP} = \mu_p C_{ox}\frac{W_p}{2L}(V_{OV})^2$$

where, overdrive voltage $V_{OV} = V_{GSP} - V_{TP}$

given, $I_{DN} = I_{DP}$

$$\mu_n C_{ox}\frac{W_n}{2L}(V_{OV})^2 = \mu_p C_{ox}\frac{W_p}{2L}(V_{OV})^2$$

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

In the given question, it is asking that,

$$\frac{W_p}{W_n} = \frac{1}{0.4} = 2.5$$

23. (c)

24. (a)

Now, $$V_{bi} = V_T\ln\left(\frac{N_A N_D}{n_i^2}\right) = (0.0259)\ln\left(\frac{2\times10^{16}\times2\times10^{15}}{(1.5\times10^{10})^2}\right) = 0.671\text{ V}$$

$$W = \left[\frac{2\varepsilon(V_{bi}+V_R)}{q}\left[\frac{1}{N_A}+\frac{1}{N_D}\right]\right]^{\frac{1}{2}}$$

$$= \left[\frac{2(11.7)\times(8.85\times10^{-14})(0.671)}{1.6\times10^{-19}}\cdot\left[\frac{1}{2\times10^{16}}+\frac{1}{2\times10^{15}}\right]\right]^{\frac{1}{2}}$$

$$W = 0.691\times10^{-4}\text{ cm}$$

now, $$E_{\max} = \frac{2(V_{bi})}{W} = \frac{2\times0.671}{0.691\times10^{-4}} = 1.94\times10^4\text{ V/cm}$$

25. (d)

$$\sigma = (\mu_n + \mu_p)q \times n_i$$

$$\therefore \quad n_i = \frac{10^{-6}}{1600\times1.6\times10^{-19}}$$

$$n_i = 3.91\times10^9\text{ atoms/cm}^3$$

now, $$n_i^2 = N_c N_v \exp\left(\frac{-E_g}{kT}\right)$$

$$E_g = kT\ln\left(\frac{N_c N_v}{n_i^2}\right)$$

$$= (0.0259)\ln\left(\frac{(10^{19})^2}{(3.91\times10^9)^2}\right)$$

$$E_g = 1.122\text{ eV}$$

26. **(c)**

Fill factor of solar cell is,

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

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

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

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

27. **(b)**

For compensated *n*-type semiconductor,

$$n_0 = N_D - N_A = N_C \, e^{-(E_C - E_{Fn})/kT}$$

Given,

$$N_D = 6.2 \times 10^{15} \text{ cm}^{-3}$$
$$N_A = 4.5 \times 10^{15} \text{ cm}^{-3}$$
$$N_C = 3 \times 10^{19} \text{ cm}^{-3}$$
$$1.7 \times 10^{15} = 3 \times 10^{19} \, e^{-(E_C - E_{Fn})/kT}$$
$$-(E_C - E_{Fn})/kT = -9.778$$
$$\therefore \quad E_C - E_{Fn} = kT \times 9.778 = 0.244 \text{ eV}$$
$$E_{Fn} = E_C - 0.244 \text{ eV}$$

The new position of fermi level is 0.244 eV below the conduction band.

28. **(c)**

Given,

$$\mu_n C_{ox} \frac{W}{L} = 1.5 \times 10^{-3} \text{ A/V}^2$$
$$V_T = 0.65 \text{ V}$$
$$V_{GS} = 4 \text{ V}$$
$$V_{DS} = 6 \text{ V}$$

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

$\therefore$ $P = 50.50$ mW

29. (b)

The steady state increase in conductivity,

$$\Delta\sigma = q(\mu_n + \mu_p)(\delta p)$$

In steady state, $\delta p = g' \tau_{po}$

where, g' is the uniform generation rate.

$$\therefore \quad \Delta\sigma = q(\mu_n + \mu_p)(g' \tau_{po})$$

$$2 = (1.6 \times 10^{-19})(8500 + 400)g' \times 10^{-7}$$

$$\therefore \quad g' = 1.404 \times 10^{22}\ \text{cm}^{-3}\ \text{s}^{-1}$$

30. (b)

The raised concentration,

$$N_D = \frac{n_i^2}{N_A} e^{\Psi_s/V_T}$$

where, Ψ_s = surface potential = 0.65 V

The raised concentration,

$$N_D = \frac{(1.5\times10^{10})^2}{1.3\times10^{15}}.\exp\left[\frac{0.65}{26\times10^{-3}}\right] = 1.246 \times 10^{16}\ \text{cm}^{-3} \approx 1.25 \times 10^{16}\ \text{cm}^{-3}$$

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