Electronic Devices Test 4

Number of Questions: 25 **Time: 60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. Silicon dioxide (Sio_2) is used in ICs
(A) because it facilitates the penetration of diffusants.
(B) to control the location of diffusion and to protect and insulate the silicon surface.
(C) because of its high heat conduction
(D) to control the concentration of diffusants.

2. In an n channel MOSFET $I_{D(sat)} = 0.3$ mA
$V_{DS} = 0.9V$, $V_{Tn} = 0.8V$ and $V_{DS(sat)} = 4V$.
The gate voltage is
(A) 3.8 V (B) 4.2 V
(C) 4.8 V (D) 3.2 V

3. A MOS capacitor has oxide thickness t_{ox} of 70 nm. The capacitance is
(A) 0.49 mF/m² (B) 0.49 μF/m²
(C) 0.39 mF/m² (D) 0.39 μF/m²

4. In a n channel enhancement mode MOSFET, $V_{Tn} = 1.6V$, $K_n = 0.28$ mA/V².
If $V_{GS} = 5V$ and $V_{DS} = 6V$ then I_D is
(A) 2.34 mA (B) 1.36 μA
(C) 2.36 μA (D) 0.672 mA

5. Compared to junction isolation, oxide isolation is
(A) better because it causes less disruption in the Si crystalline structure.
(B) worse because it eliminates conducting paths needed for current flow into the substrate.
(C) better because it eliminates parasitic junction capacitances.
(D) None of these

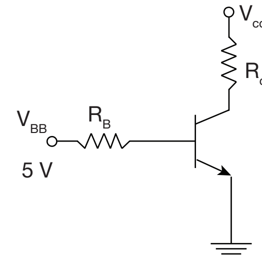
6. Silicon dioxide layer is used in IC chips for
(A) providing contacts
(B) diffusing elements
(C) providing mechanical strength to the chip
(D) providing mask against diffusion

7. A JFET has $I_{DSS} = 18$mA and $V_P = -6$ volts, $V_{GS} = -2$ V the value of drain current is
(A) 4 mA (B) 6 mA
(C) 7.9 mA (D) 8.3 mA

8. The threshold voltage of an n channel MOSFET can be increased by
(A) reducing channel dopant concentration
(B) reducing the channel length
(C) increasing the channel dopant concentration
(D) reducing the gate oxide thickness.

9. A JFET has $V_p = -8.5$ V, $I_{DSS} = 20$ mA and $I_D = 3.5$ mA determine its transonductence
(A) 2.22 mA/V (B) 1.99 mA/V
(C) 3.6 mA/V (D) 4.2 mA/V

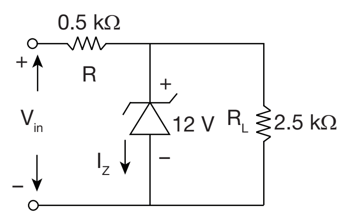
10. Consider the transistor circuit shown in figure



If the Base current $I_B = 3$ mA, then the value of R_B would be ________.
(Consider $V_{BE} = 0.7$ V and 'α' = 0.985)
(A) 1.7 kΩ (B) 1.66 kΩ
(C) 1.9 kΩ (D) 1.43 kΩ

11. Purpose of metallization in IC fabrication process is
(A) to act as a heat sink
(B) to supply a bonding surface for mounting the chip.
(C) to interconnect the various circuit elements
(D) to protect the chip from oxidation.

12. For the zener voltage regulator shown in the figure



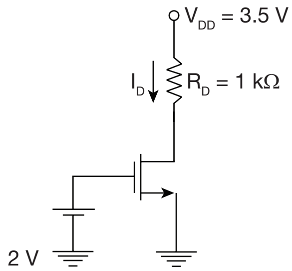
If the maximum zener current does not exceeds 25 mA. Then the ratio between the $V_{\text{in max}}$ to $V_{\text{in min}}$ is ________.
(A) 1.64 (B) 2
(C) 1.52 (D) 2.2

13. Calculate the resistance of a diffused resistor that is 45 μm long and 10 μm wide. A 80 μm thick *Si* wafer has been doped uniformly with boron of the concentration 10^{16} cm³.
(A) 7.3 Ω (B) 82 Ω
(C) 820 Ω (D) 703 Ω

14. A thin film capacitor has a silicon dioxide thickness of 18 A°. If the relative dielectric constant of Sio_2 is 3.9. Calculate the capacitance per unit Area in μF/cm².
(A) 1.73 (B) 1.91
(C) 0.78 (D) 2.32

15. For an *n*-channel silicon FET with $a = 3\times10^4$ cm and $N_D = 10^{17}$ electrons/cm³. The pinch off voltage V_P is ________.
(Consider $\varepsilon_s = \varepsilon_o\, \varepsilon_r = 12\, \varepsilon_o$).
(A) 6.77 V (B) 6.23 V
(C) 5.2 V (D) 4.7 V

16. Consider the MOSFET circuit shown in figure it has $V_T = 1V$, and $\mu_n \text{Cox}\left(\frac{W}{L}\right) = 1.5$ mA/V^2.



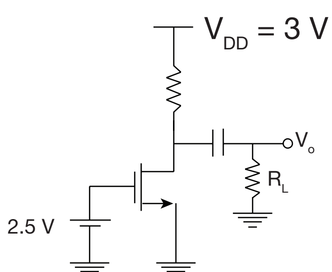
The drain current I_D will be ________

(A) 0.52 mA
(B) 1.25 mA
(C) 1.5 mA
(D) 0.75 mA

17. An NMOS transistor has $V_{to} = 1$ V, $2\Phi_f = 0.7$ V, and the fabrication process parameter $\gamma = 0.4$ V$^{1/2}$. The value of threshold voltage (V_t), when $V_B = 3.3$ V is ________.

(A) 1.46 V
(B) 1.32 V
(C) 1.21 V
(D) 0.782 V

18. Consider the n-channel MOSFET circuit shown in figure. It has $V_t = 1.5$V, $K_n^1 \frac{W}{L} = 0.25$ mA/V^2, and $V_A = 50$ V.



The output resistance r_o is _______

(A) 57 kΩ
(B) 400 kΩ
(C) 200 kΩ
(D) 125 kΩ

19. A 1.8 kΩ resistor has to be fabricated using an *n*-type silicon bar with 5 mm thick, 40 μm wide and 400 μm long, the required donor concentration is ________ atoms/m^3.
($\mu_n = 1300$ cm^2/V.sec)

(A) 5.34×10^{19}
(B) 6.5×10^{22}
(C) 1.6×10^{23}
(D) 5.3×10^{21}

20. A doped silicon semiconductor square bar with resistivity 250 kΩ –cm is placed in transverse magnetic field of 0.5 wb/m^2 and width = 8 mm. The hall voltage and current measured are 55 mV and 8 μA respectively. Find the mobility of carriers.

(A) 1400 cm^2/V.sec
(B) 1800 cm^2/V.sec
(C) 440 cm^2/V.sec
(D) 350 cm^2/V.sec

21. Silicon is doped with acceptor concentration of 5×10^{14} atom/cm^3. Assume the intrinsic carrier concentration of silicon to be 1.2×10^{10} cm^{-3} at $V_T = 28$ mV. Compared to intrinsic silicon, the shift in position Fermi level of extrinsic silicon is

(A) 0.325 eV
(B) 0.297 eV
(C) 0.423 eV
(D) 0.79 eV

22. For a silicon *P-N* junction diode, the doping concentrations are $N_A = 10^{18}$ cm^{-3}, $N_D = 10^{19}$ cm^{-3}, $n_i = 1.5 \times 10^{15}$ cm^{-3}. If the cross sectional area of junction is 10 mm^2, and junction is reverse biased at 6.5V, find the transition capacitance.
($\varepsilon_r = 12$, $\varepsilon_o = 8.85 \times 10^{12}$ F/m)

(A) 0.2 nF
(B) 0.1 pF
(C) 0.1 nF
(D) 0.2 pF

23. A silicon diode operates at forward bias voltage of 0.7V, ($\eta = 2$ for silicon) calculate the factor by which the current get multiplied when the temperature is increased from 27° to 107°C.

(A) 19
(B) 17.2
(C) 715.4
(D) 256

24. A diode with forward bias voltage of 0.695 volts is carrying 1.95 mA of current at room temperature. If $\eta = 1$, for this diode, the dynamic resistance of the diode is?

(A) 356 Ω
(B) 13.3 Ω
(C) 26.6 Ω
(D) 712 Ω

25. In an asymmetrical silicon diode, the mean life time of holes is 12 ns at room temperature, and $\eta = 2$. If the forward current of 0.2 mA is flowing in the diode, find the diffusion capacitance.

(A) 38.5 pF
(B) 42.5 μF
(C) 46.15 μF
(D) 52.25 pF

Answer Keys

1. B	**2.** C	**3.** A	**4.** D	**5.** C	**6.** D	**7.** C	**8.** A	**9.** B	**10.** D
11. C	**12.** A	**13.** D	**14.** B	**15.** A	**16.** D	**17.** A	**18.** B	**19.** A	**20.** C
21. B	**22.** C	**23.** A	**24.** B	**25.** C					

Hints and Explanations

1. Choice (B)

2. $V_{DS(sat)} = V_{GS} - V_{Tn}$

$4 = V_{GS} - 0.8$

$V_{GS} = 4.8$ V. Choice (C)

3. $t_{ox} = \dfrac{\varepsilon_{ox}}{C_{ox}} = \varepsilon_{\sigma x} = 3.9\ \varepsilon_0$

$C_{ox} = \dfrac{3.9\times 8.85\times 10^{-12}}{70\times 10^{-9}} = 0.49$ mF/m^2. Choice (A)

4. $V_{DS(sat)} = V_{GS} - V_{Tn} = 5 - 1.6 = 3.4$V

$V_{DS} < V_{DS(sat)}$, biased in non saturation region.

$I_D = \dfrac{K_n}{2}\left[2\left(V_{GS} - V_{Tn}\right)V_{DS} - V_{DS}^2\right]$

$= [2(5 - 1.6)6 - 6^2] = 0.672$ mA. Choice (D)

5. Choice (C)

6. Choice (D)

7. $I_D = I_{DSS}\left[1 - \dfrac{V_{GS}}{V_P}\right]^2$

$= 18\times 10^{-3}\left[1 - \left(\dfrac{-2}{-6}\right)\right]^2$

$= 18\times 10^{-3}\left[1 - \left(\dfrac{1}{3}\right)\right]^2$

$= 18 \times 10^{-3} \times 0.44 = 7.9$ mA Choice (C)

8. Choice (A)

9. $g_m = \dfrac{-2I_{DSS}}{V_P}\left[1 - \dfrac{V_{GS}}{V_P}\right]$

$V_{GS} = V_p\left[1 - \sqrt{\dfrac{I_D}{I_{DSS}}}\right]$

$= -8.5\left[1 - \sqrt{\dfrac{3.5}{20}}\right] = -4.911$

$g_m = \dfrac{-2\times 20mA}{-8.5}\left[1 - \dfrac{-4.9}{-8.5}\right]$

$= \dfrac{40\text{mA}}{8.5} = 1.99\text{mA}/\text{V}$ Choice (B)

10. Applying KVL to the input loop:

$V_{BB} - R_B . I_B - V_{BE} = 0$

$R_B = \dfrac{V_{BB} - V_{BE}}{I_B} = \dfrac{5 - 0.7}{3}$ kΩ

$R_B = 1.433$ kΩ Choice (D)

11. Choice (C)

12. $V = V_L = 12$

$I_L = \dfrac{12}{2.5}$ mA $= 4.8$ mA

$\therefore\ V_{\text{in min}} = 0.5 \times 10^3 \times 4.8 \times 10^{-3} + 12$

$= 2.4 + 12 = 16.4$V

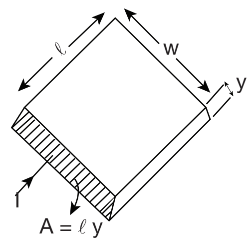
When zener diode curent max $I_R = I_{zm} + I_L$

$= 25$ mA $+ 4.8$ mA $= 29.8$ mA

$V_{\text{in max}} = 500 \times 29.8 \times 10^{-3} + 12 = 26.9$ V

$\dfrac{V_{in\,max}}{V_{in\,min}} = \dfrac{26.9}{16.4} = 1.64$ Choice (A)

13. $R = \dfrac{\rho\ell}{y.w} = R_s\,\dfrac{\ell}{w}\,\Omega$



$R = \dfrac{\ell}{\sigma.y.w} = \dfrac{\ell}{N_A\,\mu_p.q.y.w}$

$R = \dfrac{45\times 10^{-4}}{10^{16}\times 500\times 1.6\times 10^{-19}\times 10\times 10^{-4}\times 80\times 10^{-4}}$

$R = 7.03 \times 10^{-5} \times 10^{7} = 703\ \Omega$ Choice (D)

14. The capacitance $C = \dfrac{\varepsilon A}{d}$

$\dfrac{C}{A}$ = Capacitance per unit area $= \dfrac{\varepsilon}{d} = \dfrac{\varepsilon_o\,\varepsilon_r}{d}$

$= \dfrac{3.9\times 8.85\times 10^{-14}}{18\times 10^{-8}}\text{F}/\text{cm}^2$

$= 1.91 \times 10^{-6}$ F/cm^2 $= 1.91$ μF/cm^2 Choice (B)

15. $|V_p| = \dfrac{q.N_D.a^2}{2\varepsilon_s}$

$|V_p| = \dfrac{1.6\times 10^{-19}\times 10^{17}\times\left(3\times 10^{-4}\right)^2}{2\times 12\times 8.85\times 10^{-12}}$

$= 0.0677 \times 10^2 = 6.77$ V Choice (A)

16. From the given data

$V_G = 2$V at $V_S = 0$

$\therefore\ V_{GS} = 2$V

$V_{DD} = 3.5$V, $V_T = 1$V

$V_{GS} - V_T = 1$V $\{\therefore V_{GS} > V_T\}$

So Transistor is in ON state

Let it is in saturation.

$I_D = \dfrac{\mu_n C_{ox}\,w}{2L}(V_{GS} - V_T)^2$

$= \dfrac{1}{2} \times 1.5 \times 1 \times 10^{-3} = 0.75$ mA

Apply KVL at o/p loop:
$3.5 - I_D R_D - V_{DS} = 0$
$3.5 - 0.75 = V_{DS}$
$V_{DS} = 2.75$ V
$\therefore$ $V_{DS} > V_{GS} - V_T$
So transistor is in saturation mode, so assumption is correct. Choice (D)

17. $V_t = V_{to} + \gamma\left[\sqrt{2\varphi_f + V_{SB}} - \sqrt{2\varphi_f}\right]$

$= 1 + 0.4\left[\sqrt{0.7+3.3} - \sqrt{0.7}\right] = 1 + 0.4[2 - 0.8366]$

$V_t = 1.465$ volts Choice (A)

18. We know $r_o = \dfrac{V_A}{I_D}$

From the given data

$V_t = 1.5\text{V}, \mu_n C_{ox} \dfrac{W}{L} = 0.25 \text{ mA/V}^2$

$V_{GS} = 2.5\text{V}$
Let us assume transistor is in saturation mode
$V_{GS} > V_T \rightarrow \text{ON}$

$I_{Dsat} = \dfrac{1}{2} k_n^1 \dfrac{W}{L} [V_{GS} - V_T]^2$

$= \dfrac{1}{2} \times 0.25 \times 10^{-3} \times 1 = 0.125 \text{ mA}$

Check:- Saturation mode
Apply KVL in o/p loop.
$3 - 1.5 \times 0.125 - V_{DS} = 0$
$V_{DS} = 2.81825V$
$V_{DS} \geq V_{GS} - V_T$
So it is in saturation mode

$\therefore$ O/p resistance $r_o = \dfrac{50}{0.125} \text{k}\Omega$

$r_o = 400 \text{ k}\Omega$ Choice (B)

19. $R = \dfrac{\rho\ell}{A} = \dfrac{\ell}{\sigma A}$

For n type $\sigma = N_D.q.\mu_n$

$R = \dfrac{\ell}{(N_D.q.\mu_n) \times A} \Rightarrow N_D = \dfrac{\ell}{R.q.\mu_n \times A}$

$= \dfrac{400 \times 10^{-6}}{1.8 \times 10^3 \times 1.6 \times 10^{-19} \times 0.13 \times 5 \times 10^{-3} \times 40 \times 10^{-6}}$

$N_D = 5.34 \times 10^{19}$ atoms per m^3 Choice (A)

20. Mobility $\mu = \sigma.R_H = \dfrac{R_H}{\rho}$

$R_H = \dfrac{V_H.W}{B_Z.I_x} = \dfrac{55 \times 10^{-3} \times 8 \times 10^{-3}}{0.5 \times 8 \times 10^{-6}} = 110\left(\dfrac{A - \text{sec}}{\text{m}^3}\right)^{-1}$

$\mu = \dfrac{R_H}{\rho} = \dfrac{110}{2.5 \times 10^3} = 0.044 \text{ m}^2\text{/V.sec}$

$= 440 \text{ cm}^2\text{/V.sec}$ Choice (C)

21. Acceptor concentration = $5 \times 10^{14}/\text{cm}^2$, it is a p-type impurity. So Fermi level goes down

Shift in Femi level = $\Delta E_F = \dfrac{KT}{q}.\ln\left(\dfrac{N_A}{n_i}\right) \text{e}_\text{V}$

$\Delta E_F = 28 \times 10^{-3} \ln\left(\dfrac{5 \times 10^{14}}{1.2 \times 10^{10}}\right) \text{eV}$

$= 0.2978$ eV Choice (B)

22. $N_A = 10^{18} \text{ cm}^{-3}, N_D = 10^{19} \text{ cm}^{-3}, n_i = 1.5 \times 10^{15} \text{ cm}^{-3}$
$A = 10 \text{ mm}^2$ Reverse bias = 6.5V

$C_T = \dfrac{\varepsilon A}{W}$

$W = \left[\dfrac{2\varepsilon V_i}{q}\left(\dfrac{1}{N_a} + \dfrac{1}{N_d}\right)\right]^{\frac{1}{2}}$ $(\because V_j = V + V_o)$

Contact potential $V_O = V_T \ln\left[\dfrac{N_a N_D}{n_i^2}\right]$

$V_o = 26 \times 10^{-3} \ln\left[\dfrac{10^{18} \times 10^{19}}{(1.5 \times 10^{15})^2}\right] = 0.3979\text{V}$

$V_j = 6.5 + 0.3979 = 6.8979\text{V}$

$W = \left[\dfrac{2 \times \varepsilon_o \varepsilon_r \times 6.8979}{1.6 \times 10^{-19}}\left[\dfrac{1}{10^{18}} + \dfrac{1}{10^{19}}\right]\right]^{\frac{1}{2}} = 1 \times 10^{-5} \text{ cm}$

$C_T = \varepsilon_r \varepsilon_o A = 1.06 \times 10^{-10} = 0.106 \text{ nF}$ Choice (C)

23. $I = I_o \left(e^{V/\eta V_T} - 1\right)$

$V = 0.7, \eta = 2, V_T = \dfrac{T}{11{,}600}$

$V_T \text{ at } 27^o c = \dfrac{27 + 273}{11{,}600} = 0.02586 \text{ V}$

$V_T \text{ at } 107^o c = \dfrac{107 + 273}{11{,}600} = 0.032758 \text{ V}$

$\dfrac{I_{27}}{I_{107}} = \dfrac{I_{o(27)}}{I_{o(107)}}.\dfrac{\left(e^{0.7/2 \times 0.02586} - 1\right)}{\left(e^{0.7/2 \times 0.032} - 1\right)}$

$\dfrac{I_{o(27)}}{I_{o(107)}} = 2^{(27-107)/10} = 2^{-8}$

$I_{107} = 19.07\, I_{27}$ Choice (A)

24. Dynamic resistance of the diode

$r = \dfrac{\eta V_T}{I} = \dfrac{1 \times 26 \times 10^{-3}}{1.95 \times 10^{-3}} = 13.3\Omega$

$V_T = 26$ mV at room temperature Choice (B)

25. Diffusion capacitance $C_D = \dfrac{\tau I}{\eta V_T} = \dfrac{12 \times 10^{-9} \times 0.2 \times 10^{-3}}{2 \times 26 \times 10^{-3}}$

$= 46.15\ \mu\text{ F}$ Choice (C)